Universal Serial Bus
Device Class Definition
for
Audio/Video Devices

(Developed pursuant to USB-IF IP agreement for Video Display and subsequently renamed as above)

AVFormat 3 – Uncompressed Full Frame Isochronous Video

Release 1.0

December 07, 2011

Scope of This Release

This document is the Release 1.0 of this AVFormat 3 – Uncompressed Full Frame Isochronous Video Definition.

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1. Introduction

1.1. Scope

This document describes in detail the Isochronous Video-Only AV Data Formats that are supported by the AV Device Class. This document is considered an integral part of the AV Device Class Definition, although subsequent revisions of this document are independent of the revision evolution of the main USB AV Device Class Definition. This is to easily accommodate the addition of new Video-Only Data Formats without requiring changes to other USB AV documents.

1.2. Purpose

The purpose of this document is to provide all necessary information a designer needs to build AVFunctions that use the Video Data Formats described here on at least one of its AVData Video Streaming Interfaces.

1.3. Related Documents

- [USB2.0] – Universal Serial Bus Specification, Revision 2.0, April 27, 2000 (referred to in this document as the USB 2.0 Specification) (available at: http://www.usb.org/developers/docs).
- [USB3.0] – Universal Serial Bus 3.0 Specification, Revision 1.0 (including errata and ECN's through May 1, 2011), June 6, 2011 (referred to in this document as the USB 3.0 Specification) (available at: http://www.usb.org/developers/docs.)
- [AUDIO1.0] – Universal Serial Bus Device Class Definition for Audio Devices, Release 1.0, March 18, 1998 (available at: http://www.usb.org/developers/devclass_docs).
- [FORMATS1.0] – Universal Serial Bus Device Class Definition for Audio Data Formats, Release 1.0, March 18, 1998 (available at: http://www.usb.org/developers/devclass_docs).
- [TERMTYPES1.0] – Universal Serial Bus Device Class Definition for Terminal Types, Release 1.0, March 18, 1998 (available at: http://www.usb.org/developers/devclass_docs).
- [AUDIO2.0] – Universal Serial Bus Device Class Definition for Audio Devices, Release 2.0, May 31, 2006 (available at: http://www.usb.org/developers/devclass_docs).
- [FORMATS2.0] – Universal Serial Bus Device Class Definition for Audio Data Formats, Release 2.0, May 31, 2006 (available at: http://www.usb.org/developers/devclass_docs).
- [TERMTYPES2.0] – Universal Serial Bus Device Class Definition for Terminal Types, Release 2.0, May 31, 2006 (available at: http://www.usb.org/developers/devclass_docs).
- [USBCS] – Universal Serial Bus Device Class Definition for Content Security Devices – Content Security Framework, Revision 2.0 (available at: http://www.usb.org/developers/devclass_docs).
- [USBCSM-5] – Universal Serial Bus Device Class Definition for Content Security Devices – Content Security Method 5 – High-bandwidth Digital Content Protection 2.1 (HDCP 2.1) Implementation, Revision 1.0 (available at: http://www.usb.org/developers/devclass_docs).
- USBECNIAD – USB Engineering Change Notice: Interface Association Descriptors (available at: http://www.usb.org/developers/docs).
- [USBIADDCC] – USB Interface Association Descriptor Device Class Code and Use Model, Revision 1.0, July 23, 2003 (available at: http://www.usb.org/developers/whitepapers).
- [USBLANGIDS] – Universal Serial Bus Language Identifiers (LANGIDs), Revision 1.0, March 29, 2000 (available at: http://www.usb.org/developers/docs).
- [AVFUNCTION] – Universal Serial Bus Device Class Definition for Audio/Video Devices – AV Device Class Overview & AVFunction Definition, Release 1.0, December 07, 2011 (available at: http://www.usb.org/developers/devclass_docs).
- [AVFORMAT_1] – Universal Serial Bus Device Class Definition for Audio/Video Devices – AVFormat 1 – Video over Bulk, Release 1.0, December 07, 2011 (available at: http://www.usb.org/developers/devclass_docs).
- [AVFORMAT_2] – Universal Serial Bus Device Class Definition for Audio/Video Devices – AVFormat 2 – Isochronous Audio, Release 1.0, December 07, 2011 (available at: http://www.usb.org/developers/devclass_docs).

- [AVFORMAT_3] – Universal Serial Bus Device Class Definition for Audio/Video Devices – AVFormat 3 – Uncompressed Full Frame Isochronous Video, Release 1.0, December 07, 2011 (available at: http://www.usb.org/developers/devclass_docs).
- [AVSCHEMA] – Available at: http://avschemas.usb.org/v1/avschema.xsd
- [BDP] – Universal Serial Bus Device Class Definition for Audio/Video Devices – Basic Device Profile, Release 1.0 (available at: http://www.usb.org/developers/whitepapers).
- [ANSIS1_11] – ANSI S1.11-2004 (R2009) standard (available at: http://www.ansi.org).
- [IEC11172_3] – MPEG-1 standard ISO/IEC 11172-3:1993 Information technology – Coding of moving pictures and associated audio for digital storage media at up to about 1.5 Mbit/s – Part 3: Audio (available at http://www.iec.ch).
- [IEC13818_1] – MPEG-2 standard ISO/IEC 13818:2000 Information technology – Generic coding of moving pictures and associated audio information – Part 1: Systems (available at http://www.iec.ch).
- [IEC13818_3] – MPEG-2 standard ISO/IEC 13818:1998 Information technology – Generic coding of moving pictures and associated audio information – Part 3: Audio" (available at http://www.iec.ch).
- [AC_3] – Digital Audio Compression Standard (AC-3, Enhanced AC-3), ETSI TS 102 366 (available at http://www.etsi.org).
- [IEEE_754] – ANSI/IEEE-754 floating-point standard (available at http://www.ieee.org).
- [IEC60958] – ISO/IEC 60958 International Standard: Digital Audio Interface and Annexes (available at: http://www.iec.ch).
- [IEC61937] – ISO/IEC 61937 standard (available at: http://www.iec.ch).
- [ETSI_TS_102_114] – ETSI Specification TS 102 114, "DTS Coherent Acoustics; Core and Extensions" (available at http://www.etsi.org).
- [HDCP2.1] – High-bandwidth Digital Content Protection System. Interface Independent Adaptation. Revision 2.1, July 18, 2011 (available from http://www.digital-cp.com).
- [MLP] – DVD Specifications for High Definition Video: MLP Reference Information.
- [IEC14496_3] – MPEG-4 Standard ISO/IEC 14496-3 – Information Technology – Coding of audio-visual objects – Part 3: Audio (available at http://www.iec.ch).
- [IEC14496_10] – MPEG-4 Standard ITU-T H.264 and ISO/IEC 14496-10:2004 – Information Technology – Coding of audio-visual objects – Part 10: Advanced Video Coding. Second Edition 2004-10-01 (available at http://www.iec.ch).
- [WMA] – Audio compression format from Microsoft. For technical and licensing information, contact Microsoft directly (http://www.microsoft.com/windows/windowsmedia/default.aspx).
- [HDMI] – The official High Definition Multimedia Interface website http://www.hdmi.org.
- [RFC5646] – Tags for Identifying Languages, September 2009 (available at http://www.rfc-editor.org/rfc/rfc5646.txt).
- [KHRONOS] – The Khronos Group, Open Standards for Media Authoring and Acceleration (available at http://www.khronos.org).
- [CEA-861-E] – A DTV Profile for Uncompressed High Speed Digital Interfaces, March 2008 (available at http://www.cea.org).
- [VESA] – Video Electronics Standards Association (available at http://www.vesa.org).
- [IEC10918_4] – JPEG Standard ISO/IEC 10918-4 – Information technology – Digital compression and coding of continuous-tone still images: Registration of JPEG profiles, SPIFF profiles, SPIFF tags, SPIFF colour spaces, APPn markers, SPIFF compression types and Registration Authorities (REGAUT). First Edition 1999-08-15 (available at http://www.iec.ch).

1.4. Terms and Abbreviations

This section defines terms used throughout this document. For additional terms that pertain to the Universal Serial Bus, see Chapter 2, "Terms and Abbreviations," in [USB2.0] and [USB3.0].

Table 1-1: Terms and Abbreviations

Term	Description
2D Video	A VideoStream consisting of a single VideoChannel, providing a monoscopic video experience.

Term	Description
3D2 Video	A VideoStream consisting of 2 separate VideoChannels, providing a stereoscopic 3-dimensional video experience. One VideoChannel is intended for the left eye, and the other VideoChannel is intended for the right eye.
3Dn Video	A VideoStream consisting of n separate VideoChannels, providing a multiscopic 3-dimensional video experience. This type of VideoStream usually requires a sophisticated lenticular system in front of the display to ensure that the viewer only sees 2 (one for the left eye, one for the right eye) out of the n channels at the same time. Depending on the position of the viewer with respect to the display, a different set of 2 VideoChannels is made visible to the viewer.
AAC	Advanced Audio Coding.
AC-3	Audio compression standard from Dolby Labs.
AudioBundle	AudioChannels are physically organized into AudioTracks, and AudioTracks are then organized into the AudioBundle where each AudioChannel has an AudioChannel Type associated with it. Very similar to the AudioCluster concept, but the physical characteristics of the audio stream, such as AudioFrame Rate and bit resolution, are retained in the AudioBundle.
(Logical) AudioChannel	A logical transport medium for a single audio channel. Makes abstraction of the physical Properties and formats of the connection. Is identified by AudioChannel Type.
AudioChannel Type	The spatial location of an AudioChannel. Uniquely identifies the AudioChannel. Examples are Front Left channel (FL), Back Right channel (BR), etc.
AudioCluster	The group of all the audio-only logical AudioChannels in an AVCluster.
AudioControl Property	A parameter of an AudioControl. Examples are Current, Next, Range Properties of a Volume Control.
AudioControl	A logical object that is used to manipulate a specific audio Property. Examples are Volume Control, Mute Control, etc.
AudioSample	The basic representation of an audio signal (one channel), sampled (digitized) at a specific moment in time.
AudioSlot	A collection of AudioSubSlots, each containing an AudioSample of a different physical audio channel, taken at the same moment in time.
AudioStream	A concatenation of a potentially very large number of AudioSlots ordered according to ascending time where the AudioSamples are formatted according to one of the Audio Formats described in this specification and where the AudioChannels are organized in an AudioBundle.
AudioStreamConfig (AudioStream Configuration)	An XML Description that provides all the information necessary to fully characterize an AudioStream. Includes an AudioBundle, AudioFrame, and AudioSample component.
AudioStreamConfigList	A list of AudioStreamConfig Descriptions used to indicate the different AudioStream Configurations an AVData Audio Streaming Interface supports.
AudioSubSlot	Holds a single AudioSample of a single audio channel.
AV Description Document (AVDD)	An XML-formatted document that provides a complete description of all the AV class-specific elements and features of the AVFunction.
AV Interface Association	A grouping of a single AVControl Interface, and zero or more AVData Streaming Interfaces that together constitute a complete interface to an AVFunction.
AV Profile	A set of limitations and restricting rules, bundled in a single document that applies to the AV Device Class Definition. A Profile defines a specific type of AVFunction that is guaranteed to interoperate with all Controllers that support that Profile.
AVBundle	A group of physical VideoChannels AudioChannels and MetadataChannels that carry tightly related (from a content perspective) synchronous video, audio, and metadata information over a USB pipe.
AVCluster	A group of logical VideoChannels AudioChannels and MetadataChannels that carry tightly related (from a content perspective) synchronous video, audio, and metadata information over an interconnect within the AVCore.
AVCore	That part of the AVFunction that contains most of the building blocks (Terminals, Units) that makes up most of the AVControl functionality of the AVFunction. Explicitly excludes the AVData Streaming Interfaces that are part of the AVFunction.
AVControl Interface	A USB interface used to access the AVControls inside an AVFunction.
AVData Entity	An addressable Entity representing a source of AV data flowing into or a sink for AV data flowing out of the AVCore (including AVData Streaming Interfaces).
AVData Streaming Interface	A USB interface used to transport AVStreams into or out of the AVFunction.

Term	Description
AVFunction	An independent part of a USB device that deals with AV-related functionality. Includes the AVCore and all AVData Entities.
AVHeader	The Header preceding the AudioPayload or VideoPayload in a Command or Notify Message. Also, the Header present in every SIP.
AVStream	A generic name for either a VideoStream or an AudioStream. See VideoStream and AudioStream.
AVStream Configuration	A generic name for either a VideoStream Configuration or an AudioStream Configuration. See VideoStream Configuration and AudioStream Configuration.
BDP	Basic Device Profile. See [BDP]
BIB	Bus Interval Boundary ([USB3.0]).
CBP	Control Bulk Pair. A pair of one Bulk IN and one Bulk OUT endpoint in the AVControl Interface that is used for AV class-specific messaging.
CBP Idle Condition	A condition when an AVFunction determines that it will not have data available on its CBP Bulk IN pipe for a certain amount of time (AV_CBP_IDLE_TIME) and informs the Host of this condition to avoid having the Host continually issue IN tokens for that pipe.
Channel	A logical channel in an AVCluster. Can be a VideoChannel, AudioChannel, or MetadataChannel.
Controllee	The entity that is controlled by the Controller. The AVFunction always assumes this role.
Controller	The entity that controls the AVFunction. In this version of the specification, the USB Host assumes this role.
Control Sequence	A sequence of a Command and Response Message that is used to convey or retrieve one or more control parameters to or from the AVFunction.
Converter Unit (CU)	Provides the means to transform an incoming VideoTrack and/or AudioTrack into another VideoTrack and/or AudioTrack with different characteristics.
CUD	Converter Unit Description.
Description	Section of the AVDD (AV Description Document) that provides a detailed XML description of a specific Entity or other building block of the AVFunction architecture. Replaces the concept of the class-specific USB Descriptor.
DTS	Digital Theater Systems.
DUD	Metadata Unit Description.
DVD	Digital Versatile Disc.
Effect Unit (EU)	Provides advanced AV manipulation on the incoming logical AudioChannels.
Encoded Audio Bit Stream	A concatenation of a potentially very large number of encoded audio frames, ordered according to ascending time.
Encoded AudioFrame	A sequence of bits that contains an encoded representation of AudioSamples from one or more physical audio channels taken over a fixed period of time.
Encoded VideoFrame	A sequence of bits that contains an encoded representation of VideoSamples from one VideoFrame.
Entity	An addressable logical object inside an AVFunction.
EUD	Effect Unit Description.
Feature Unit (FU)	Provides basic AV manipulation on the incoming logical AV channels.
FUD	Feature Unit Description.
GraphicsEngine Entity (GEE)	An addressable Entity inside the AVCore representing a graphics subsystem of the AVFunction.
H.264	ITU name of ISO MPEG4 part10 Advanced Video Coding standard. See [IEC14496_10].
HE_AAC	High Efficiency Advanced Audio Coding
Header	A collection of SubHeaders present in a SIP, containing Extended Audio Format data.
Input Pin	A logical input connection to an Entity. Carries a single AVCluster.
Input Terminal (IT)	A receptacle for AV information flowing into the AVFunction.
Inter-VideoFrame	A VideoFrame composed of Intra-coded and Inter-coded MacroBlocks.
Intra-VideoFrame	A VideoFrame composed of Intra-coded MacroBlocks only.

Term	Description
ITD	Input Terminal Description.
MacroBlock	An elementary group of VideoSamples considered by an H.264 encoder.
MetadataBundle	The group of all the metadata-only physical channels in an AVBundle.
(Logical) MetadataChannel	A logical transport medium for a single metadata channel. Makes abstraction of the physical Properties and formats of the connection. Is identified by MetadataChannel Type.
MetadataChannel Type	The metadata type of a MetadataChannel. Uniquely identifies the MetadataChannel. Examples are Subtitle (SUB), Commentary (COM), etc.
MetadataCluster	The group of all the metadata-only logical channels in an AVCluster.
MetadataControl	A logical object that is used to manipulate a specific metadata Property. Examples are Font Control, Color Control, etc.
MetadataControl Property	Parameter of a MetadataControl. Examples are Current, Next, Range Properties of a Font Control.
MetadataTrack	A group of MetadataChannels in a MetadataCluster that is associated with a single program.
MetadataTrack Selector	A Control that allows indicating or selecting one MetadataTrack from the MetadataCluster. The selected MetadataTrack is called the Active MetadataTrack.
Metadata Unit (DU)	Provides basic manipulation on the incoming logical MetadataChannels.
Mixer Unit (MU)	Mixes a number of logical input channels into a number of logical output channels.
MLP	Meridian Lossless Packing
MotionVector	A couple of coordinates (x,y) defining an offset from the current MacroBlock position in the current VideoFrame into the previous VideoFrame. The current MacroBlock position is defined by two coordinates (xMB, yMB) defining the position of the upper left pixel of that MacroBlock.
MPEG	Moving Pictures Expert Group.
MUD	Mixer Unit Description.
NAL	Network Abstraction Layer, See [IEC14496_10]
NAL Unit	An integer number of bytes, preceded by a ony-byte NAL Header indicating the type of data in the NAL Unit.
OTD	Output Terminal Description.
Output Pin	A logical output connection to an Entity. Carries a single AVCluster.
Output Terminal (OT)	An outlet for AV information flowing out of the AVCore.
Processing Unit (PU)	Applies a predefined process to a number of logical input channels.
PUD	Processing Unit Description.
Router Unit (RU)	Provides the means to assemble an outgoing AVCluster from multiple incoming AVClusters.
RUD	Router Unit Description.
Selector Unit (SU)	Selects from a number of input AVClusters.
ServiceInterval	A grouping of USB (micro)frames that are related.
ServiceIntervalPacket	A packet that contains all the VideoSamples that are transferred over the bus during a ServiceInterval.
SI	ServiceInterval.
SIP	ServiceIntervalPacket.
SIPDescriptor	A 4-byte field present at the beginning of every SIP, providing information about the layout of the SIP. Only present when transporting Extended Audio Format Type I data.
SOF	Start of Frame ([USB2.0]).
Stereo 3D Video	A video stream consisting of 2 separate video channels, providing a stereoscopic 3-dimensional video experience. One video channel is intended for the left eye, and the other video channel is intended for the right eye.
SubHeader	A header containing additional information, related to the data in the SIP.
SUD	Selector Unit Description.
Terminal	A logical object inside an AVCore that represents a connection to the AVCore's outside world.

Term	Description
Transfer Delimiter	A unique token that indicates an interruption in an isochronous data packet stream. Can be either a zero-length data packet or the absence of an isochronous transfer in a certain USB (micro)frame.
Unit	A logical object inside an AVCore that represents a certain AV functionality.
VideoBundle	VideoChannels are physically organized into VideoTracks, and VideoTracks are then organized into the VideoBundle where each VideoVhannel has a VideoChannel Type associated with it. Very similar to the VideoCluster concept, but the physical characteristics of the video stream, such as VideoFrame Rate are retained in the VideoBundle.
(Logical) VideoChannel	A logical transport medium for a single video channel. Makes abstraction of the physical Properties and formats of the connection. Is identified by VideoChannel Type: i.e. observation location. Examples are Channels for left eye, right eye.
VideoChannel Type	The observation location of a VideoChannel. Uniquely identifies the VideoChannel. Examples are Channels for left eye (OL001), right eye (OL002).
VideoCluster	The group of all the video-only logical channels in an AVCluster.
VideoControl	A logical object that is used to manipulate a specific video Property. Examples are Contrast Control, Zoom Control, etc.
VideoControl Property	A parameter of a VideoControl. Examples are Current, Minimum, Maximum and Resolution Properties of a Brightness Control.
VideoFrame	One of the many still images which compose a complete moving picture or VideoSequence.
VideoParticle	The basic structure used to send video data over USB. Can be one VideoSample, two VideoSamples that share Chrominance information, or individual Luminance and Chrominance components of one VideoSample.
VideoPayload	All data bytes related to one VideoFrame. Includes NAL Headers, InfoBlock Headers, etc. The AVHeader is not part of the VideoPayload.
VideoSample	The basic representation of a video signal, sampled (digitized) at a specific moment in time.
VideoSequence	A sequence of closely related VideoFrames that together make up a movie or video clip.
VideoSlot	A collection of VideoSubSlots, each containing a VideoSample of a different physical video channel, taken at the same moment in time.
VideoStream	A concatenation of a potentially very large number of VideoSlots ordered according to ascending time where the VideoSamples are formatted according to one of the VideoFrame and VideoSample Formats described in this specification and where the video channels are organized in a VideoBundle.
VideoStreamConfig (VideoStream Configuration)	An XML Description that provides all the information necessary to fully characterize a VideoStream. Includes a VideoBundle, VideoFrame, and VideoSample component.
VideoStreamConfigList	A list of VideoStreamConfig Descriptions used to indicate the different VideoStream Configurations an AVData Entity supports.
VideoSubSlot	Holds a single VideoParticle.
Viewpoint	A position from which an event (program) is observed.
WMA	Windows Media Audio.
XML Descriptions	See Descriptions.

2. Fundamentals

2.1. Transfer Delimiter

Isochronous data streams are continuous in nature, although the actual number of bytes sent per packet may vary throughout the lifetime of the stream. To indicate a temporary stop in the isochronous data stream without closing the pipe (and thus relinquishing the USB bandwidth), an in-band Transfer Delimiter needs to be defined. This specification considers two situations to be a Transfer Delimiter. The first is a zero-length data packet and the second is the absence of an isochronous transfer in a ServiceInterval (see below) that would normally have an isochronous transfer. Both situations are considered equivalent and the AVFunction is expected to behave the same. In both cases, this specification considers a Transfer Delimiter to be an entity that can be signaled over the USB.

2.2. ServiceInterval and ServiceIntervalPacket Definitions

To better describe packetization for video, the concept of a ServiceInterval (SI) is introduced. A ServiceInterval represents the number of USB (micro)frames or Bus Intervals within which an isochronous endpoint is serviced once.

For full-/high-speed isochronous endpoints, a ServiceInterval is defined as:

$$SI = (micro)frame * 2^{(bInterval-1)}$$

See the [USB2.0] specification for more information on the bInterval field, its allowed values and its use.

For SuperSpeed isochronous endpoints, a ServiceInterval is identical to the Service Interval as defined in the [USB3.0] specification:

$$SI = Service\ Interval = Bus\ Interval * 2^{(bInterval-1)}$$

In addition, a ServiceIntervalPacket (SIP) is introduced. A ServiceIntervalPacket is defined as a packet that contains all the samples that are transferred over the bus during a ServiceInterval. For full-/high-speed endpoints, the SIPs are exactly the same as the physical packets that are transferred over USB. For high-speed high-bandwidth endpoints, the SIP is the concatenation of the two or three physical packets that are transferred over the bus in a microframe. For SuperSpeed endpoints, the SIP is the concatenation of up to the 48 physical packets (3 burst opportunities of maximum 16 bursts) that are transferred over the bus in a ServiceInterval.

The above definitions provide a model of 'one ServiceInterval packet (SIP) per ServiceInterval', irrespective of the actual transactions on the USB.

2.3. Video Transport

When transported over USB, uncompressed VideoSamples are first segmented into VideoParticles and then packetized into an integer number of bytes, called the VideoSubSlot. Multiple VideoSlots are then packetized into SIPs.

The following Sections provide more details.

2.3.1.1. VideoParticle

The basic structure used to represent video data is the VideoParticle.

VideoSamples are packetized into VideoParticles depending on the VideoSample Format (see Section 2.5, "VideoSample Formats":

- For VideoSample Formats that do not involve color space compression, there is a one-to-one relationship between a VideoSample and a VideoParticle. One VideoSample equals one VideoParticle. All Type I VideoSample Formats (see Section 2.5.1) and the RGB565, RGB888, RGB8888, and IYU2 Type II VideoSample Formats (see Sections 2.5.2.2.1, 2.5.2.2.2, 2.5.2.2.3, and 2.5.2.2.4 respectively) use this (trivial) form of packetizing.
- For VideoSample Formats that involve a form of color space compression, some of the components that make up a VideoSample are shared among VideoSamples:
  - The YUY2, YVYU, and UYVY VideoSample Formats (see Sections 2.5.2.2.5, 2.5.2.2.6, and 2.5.2.2.7 respectively) share one U and V Chrominance sample between two Y Luminance samples; i.e. Y_i and Y_{i+1} share the same U_i

and V_i Chrominance samples. One VideoParticle contains all the information needed to describe two VideoSamples: the two Luminance values and the shared U and V Chrominance values for the two VideoSamples.

- The I420 and YV12 VideoSample Formats (see Sections 2.5.2.2.8 and 2.5.2.2.9 respectively) are planar formats (Luminance and Chrominance values are sent separately and chrominance values are shared among four VideoSamples) and therefore, Luminance and Chrominance values are packetized in separate VideoParticles (one VideoParticle contains one component of a VideoSample) so that multiple VideoParticles are required to describe one VideoSample.

In summary, a VideoParticle either contains one VideoSample, two VideoSamples or a Luminance or Chrominance component of a VideoSample.

2.3.2. VideoSubSlot

The basic structure used to transport VideoParticles over USB is the VideoSubSlot. All VideoSubSlots shall have the same VideoSubSlot size.

One VideoParticle always occupies one VideoSubSlot.

This specification limits the possible VideoSubSlot sizes ($subSlotSize$) to 1, 2, 3 or 4 bytes per VideoSubSlot. The VideoParticle that occupies the VideoSubSlot is represented using a number of bits ($bitResolution$) less than or equal to the total number of bits available in the VideoSubSlot:

$$bitResolution \leq subSlotSize * 8$$

In case $bitResolution < subSlotSize * 8$, the actual VideoParticle is always left-justified and padded with trailing zero bits to fill the entire VideoSubSlot.

2.3.3. VideoSlot

A VideoSlot consists of a collection of VideoSubSlots, arranged according to different interleaving schemes.

2.3.3.1. VideoParticle-interleaved VideoSlots

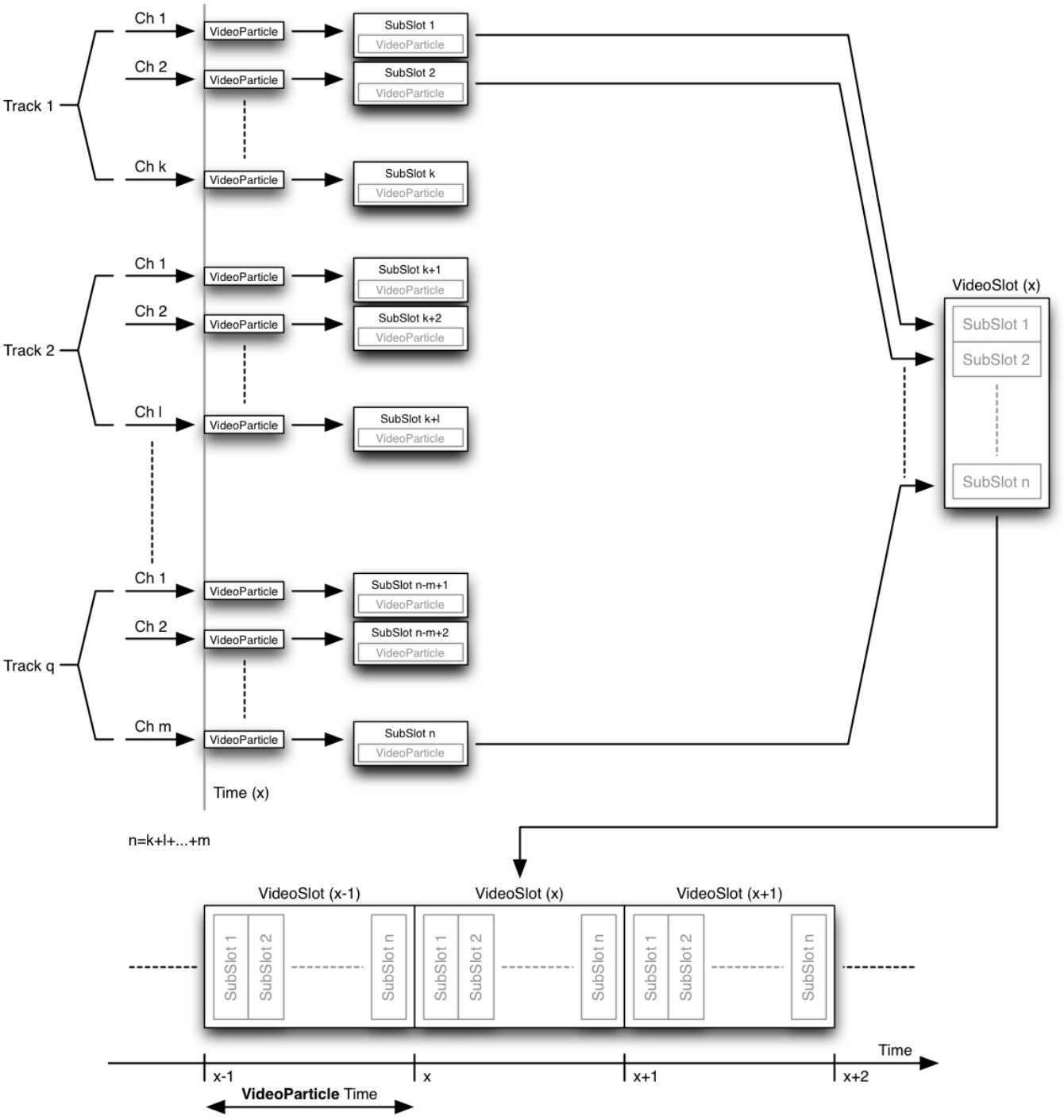


Figure 2-1: VideoParticle Stream

Each VideoSlot groups all the VideoSubslots containing the VideoParticle of a different physical video channel, taken at the same moment in time. The number of VideoSubSlots in a VideoSlot, n, equals the total number of video channels in the VideoBundle. The VideoSubSlots in the VideoSlot are ordered starting with the VideoSubslot of the first video channel in the first VideoTrack, followed by the VideoSubSlot of the second video channel in the first VideoTrack and so on until the VideoSubSlot of the last video channel of the last VideoTrack is reached.

There are currently no Frame Assemblies defined that use the VideoParticle-interleaved organization.

2.3.3.2. VideoLine-interleaved VideoSlots

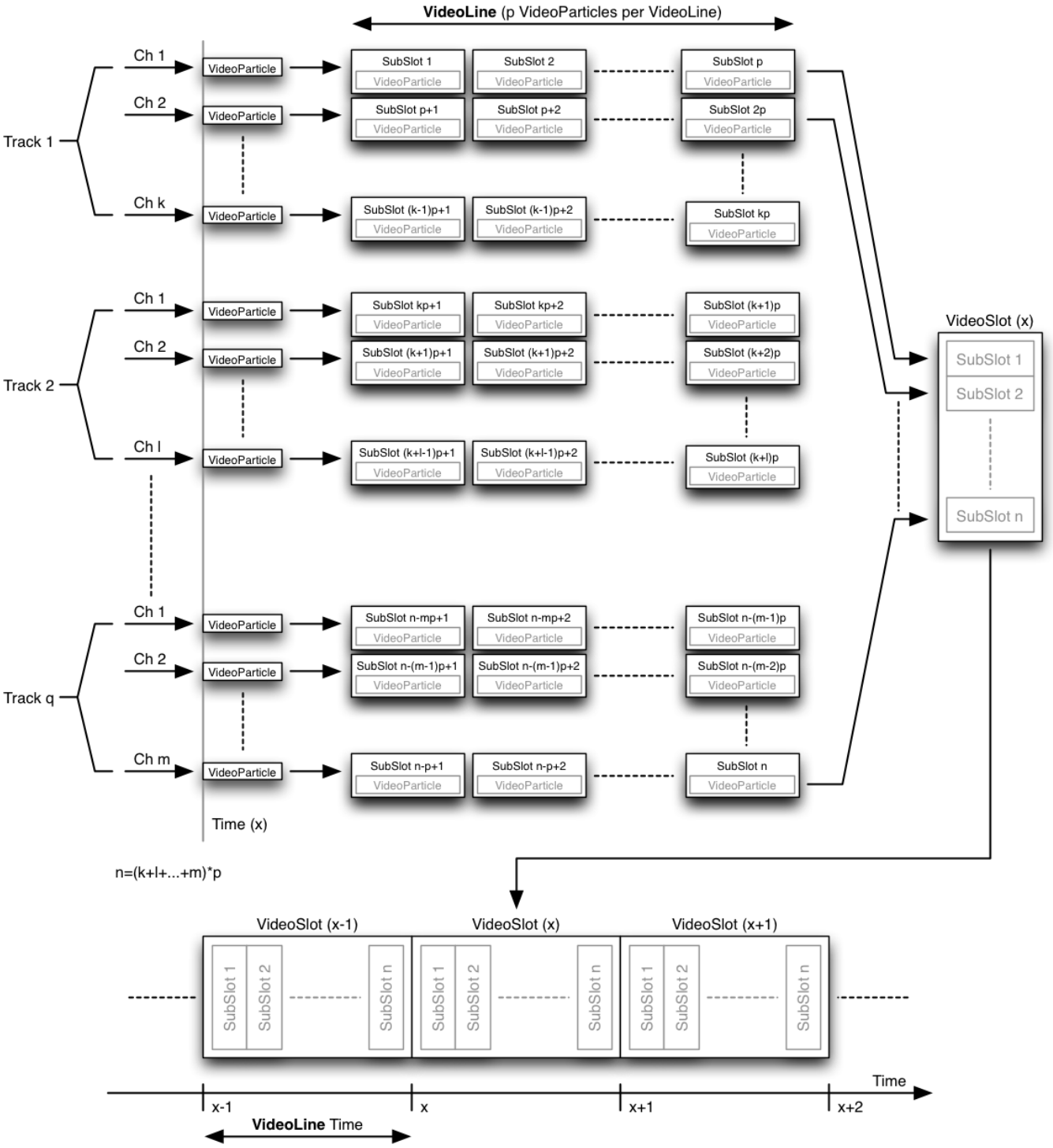


Figure 2-2: VideoLine Stream

Each VideoSlot groups all the VideoSubSlots containing all the VideoParticles that belong to the same VideoLine for all the different physical video channels present in the VideoBundle. The number of VideoSubSlots in a VideoSlot, *n*, equals the total number of video channels in the VideoBundle times the number of VideoParticles in a VideoLine. The VideoSubSlots in the VideoSlot are ordered starting with all the VideoSubslots of the VideoLine (in timed order) of the first video channel in the first VideoTrack, followed by all the VideoSubSlots of the same VideoLine of the second video

channel in the first VideoTrack and so on up to all the VideoSubSlots of the same VideoLine of the last video channel of the last VideoTrack.

All currently defined 3D2 Side-by-Side Frame Assemblies use the VideoLine-interleaved organization.

2.3.3.3. VideoFrame-interleaved VideoSlots

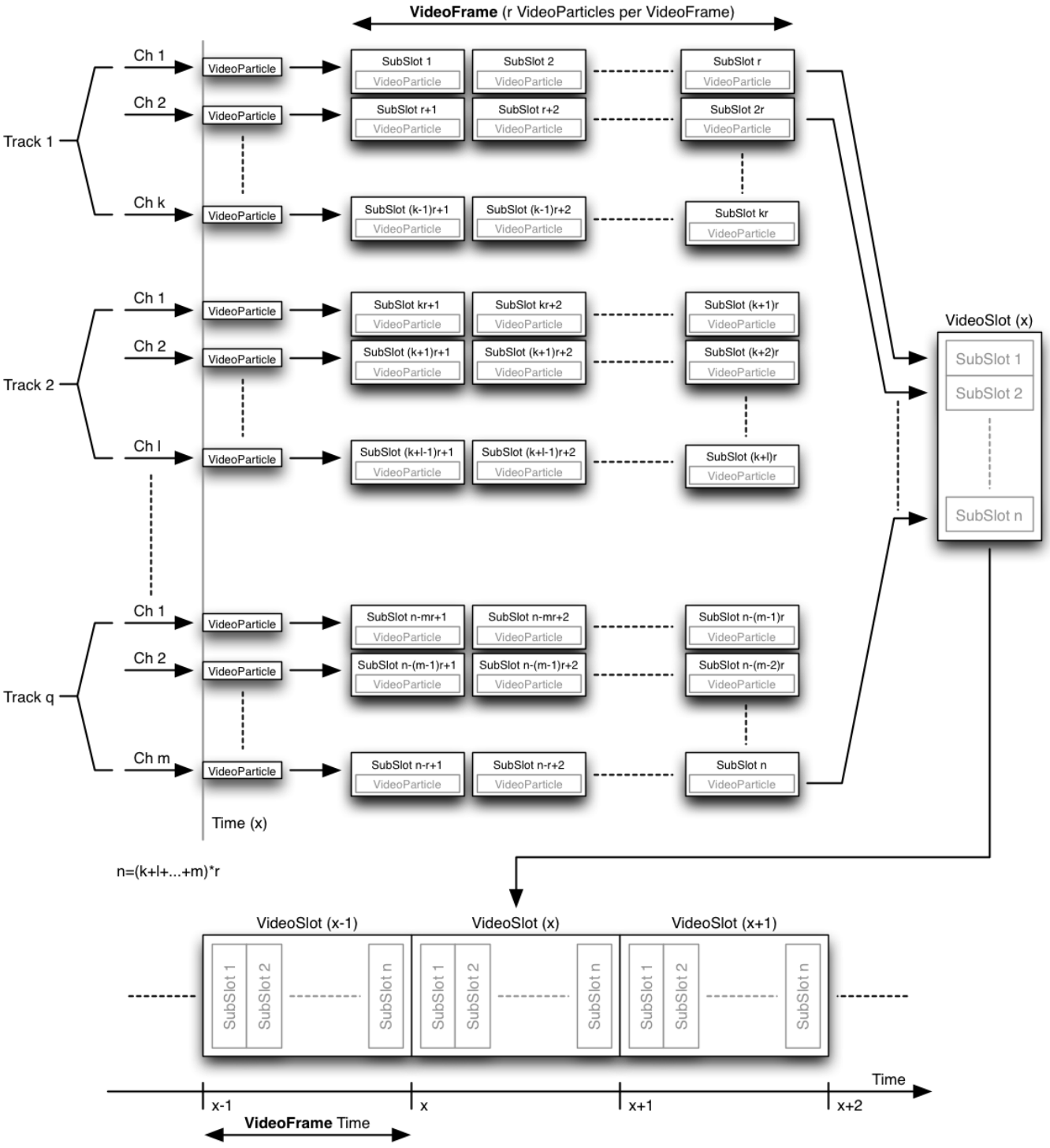


Figure 2-3: VideoFrame Stream

Each VideoSlot groups all the VideoSubSlots containing all the VideoParticles that belong to the same VideoFrame for all the different physical video channels present in the VideoBundle. The number of VideoSubSlots in a VideoSlot, n, equals the total number of video channels in the VideoBundle times the number of VideoParticles in a VideoFrame. The VideoSubSlots in the VideoSlot are ordered starting with all the VideoSubslots of the VideoFrame (in timed order) of the first video channel in the first VideoTrack, followed by all the VideoSubSlots of the same VideoFrame of the second video channel in the first VideoTrack and so on up to all the VideoSubSlots of the same VideoFrame of the last video channel of the last VideoTrack.

All currently defined 3D2 Top-and-Bottom Frame Assemblies and the 2D Frame Assembly use the VideoFrame-interleaved organization.

2.3.4. VideoBundle

Video channels are transmitted over USB in a VideoBundle. The VideoBundle concept is very similar to the VideoCluster concept as defined in the USB AVCore Definition, except that a VideoBundle retains all of the physical aspects of the video stream, such as VideoSample Rate, bits per VideoSample, etc. Like a VideoCluster, a VideoBundle consists of a number of VideoTracks and each VideoTrack in turn consists of a number of physical video channels. The following figure illustrates the concept.

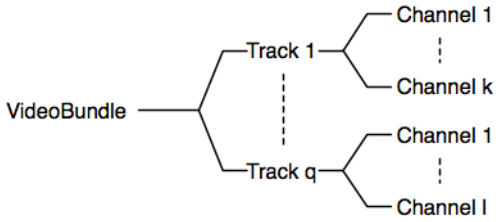


Figure 2-4: VideoBundle

A VideoBundle is a concatenation of a potentially very large number of VideoSlots, ordered according to ascending time. VideoBundles are packetized when transported over USB whereby SIPs can only contain an integer number of VideoSlots. Each SIP always starts with the same channel, and the channel order is respected throughout the entire transmission. If, for any reason, there are no VideoSlots available to construct a SIP, a Transfer Delimiter shall be sent instead.

2.3.4.1. VideoBundle Description

The VideoBundle Description is a hierarchical component of the VideoStreams Configuration Description. Refer to Section 2.7.1, “VideoStreamConfigList Description” for details.

2.4. VideoFrame

A VideoFrame is a single picture that is typically shown as part of a larger sequence. Many single VideoFrames are run in succession to produce what appears to be a seamless piece of film or movie. The following sections define a number of concepts related to the VideoFrame.

2.4.1. VideoFrame Rate

The VideoFrame Rate is the frequency (rate), expressed in Hertz (Hz), at which an imaging device produces unique consecutive images called VideoFrames. The term applies equally well to computer graphics, video cameras, film cameras, and motion capture systems.

All video-related frequency values shall tolerate at least ±5000 PPM inaccuracy to accommodate sampling clock inaccuracies.

2.4.2. VideoFrame Coordinates

The following VideoFrame Coordinate definitions are used in this document:

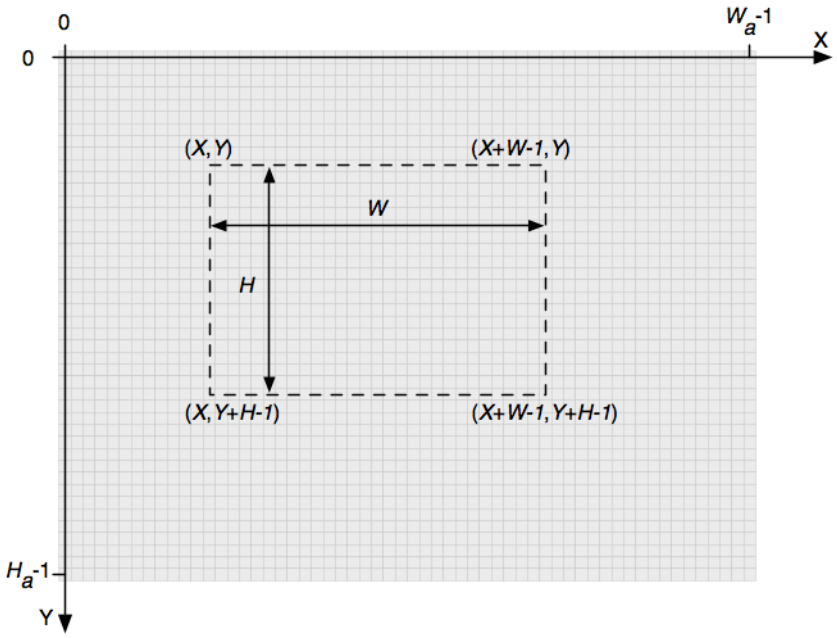


Figure 2-5: VideoFrame Coordinates

- The Width of the VideoFrame in VideoSamples (pixels): W_a
- The Height of the VideoFrame in VideoLines: H_a
- A particular VideoSample in the VideoFrame, indicated by:
  - Its horizontal coordinate: X
  - Its vertical coordinate: Y
- The Origin (0,0) (upper left VideoSample(0) of the VideoFrame) is on the intersection of the first VideoLine (VideoLine 1) and the first VideoColumn (VideoColumn 1) of a VideoSample coordinate system oriented as defined in the picture above.

  Note: VideoLine and VideoColumn numbers are one-based.

2.4.2.1. Subregions

Within this coordinate system, rectangular subregions may be defined as follows:

- Horizontal coordinate of the upper left VideoSample of the subregion in the system above, in VideoSamples: X
- Vertical coordinate of the upper left VideoSample of the subregion in the system above, in VideoLines: Y
- Width of a specific rectangular area within the VideoFrame, in VideoSamples: W
- Height of a specific rectangular area within the VideoFrame, in VideoLines: H

The values X, Y, W, H, W_a, and H_a shall always be multiples of two (even numbers).

Subregions shall never overlap.

2.4.3. VideoFrame Spatial Layout and Timing Aspects

The following sections describe the VideoFrame Spatial Layouts for both 2D and 3D2 Frame Organizations (see Section 2.4.4, “VideoFrame Organization” for more information).

2.4.3.1. 2D VideoFrame Spatial Layout

The following figure describes a typical VideoFrame Spatial Layout for the 2D (one video channel) case:

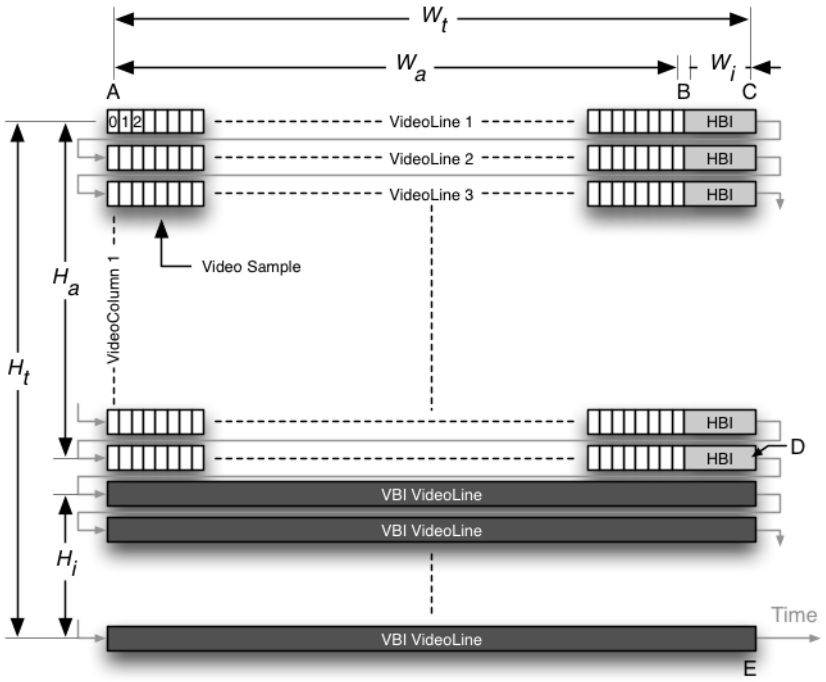


Figure 2-6: 2D VideoFrame Spatial Layout and Timings

A VideoFrame consists of a number of horizontal progressive scan lines where each VideoLine has an active part (for example, the segment between A and B in Figure 2-6), containing the actual VideoSamples (W_a) that make up the VideoLine, and an inactive part, (W_i) (for example, the segment between B and C in Figure 2-6), called the Horizontal Blanking Interval or HBI. The HBI does not contain any VideoSamples. Following the active part of the VideoFrame (H_a – the part that contains VideoLines with actual VideoSamples – the segment between A and D in Figure 2-6), there are a number of inactive VideoLines (H_i – the segment between D and E in Figure 2-6) that together constitute the Vertical Blanking Interval or VBI. The VBI does not contain any VideoSamples.

The time difference between B and A is called the Active Line Time, T_{La}, the time difference between C and B is called the Inactive Line Time, T_{Li}, and the time difference between C and A is called the Total Line Time, $T_{Lt} = T_{La} + T_{Li}$.

The time difference between D and A in Figure 2-6 is called the Active VideoFrame Time, T_a, the time difference between E and D is called the Inactive VideoFrame Time, T_i, and the time difference between E and A is called the VideoFrame Time, $T = T_a + T_i$.

VideoSamples are numbered sequentially starting at the top left with VideoSample (0) and ending at the bottom right with VideoSample $(N - 1)$. If W_a is the horizontal resolution (number of VideoSamples in the active part of a VideoLine) and $H_a$is the vertical resolution of the VideoFrame (number of active VideoLines in the VideoFrame) then the total number of VideoSamples in the VideoFrame is:

$$N = (W_a \times H_a)$$

Interlaced formats are not supported.

2.4.3.2. 3D2 VideoFrame Layout

When transporting 3D2 video data, consideration has been given to aligning the 3D2 Layouts, VideoFrame Organizations, and video timings so that they match as closely as possible the 2D Layout, VideoFrame Organization and video timings.

2.4.3.2.1. 3D2 Half Resolution VideoFrame Spatial Layout

All Half Resolution 3D2 VideoFrame Organizations (see Section 2.4.4, “VideoFrame Organization”) use a VideoFrame Spatial Layout that is identical to the Full Resolution 2D VideoFrame Spatial Layout. This is accomplished by subsampling the original Full Resolution Left and Right VideoFrame by a factor of 2, either by dropping every other

VideoLine or every other VideoColumn of the original Left and Right VideoFrames and then recombining the resulting half resolution VideoFrames back into a Full Resolution resulting VideoFrame that has the exact same Spatial Layout, VideoFrame Organization and video timings as one of the original (Left or Right) VideoFrame. See Figure 2-6, "2D VideoFrame Spatial Layout". All of the Half Resolution Frame Organizations use this Spatial Layout.

2.4.3.2.2. 3D2 Full Resolution VideoFrame Spatial Layout

This specification supports only one Full Resolution Frame Organization (3D2FP, 3D2 Frame Packing – See Section 2.4.4, "VideoFrame Organization").

In this case, the total amount of actual video data per 3D2 VideoFrame doubles since Full Resolution Left and Right VideoFrames are combined by packing them together and no subsampling is performed.

To keep the overall VideoFrame timing intact (3D2 VideoFrame Time = Left VideoFrame Time = Right VideoFrame Time), the VideoSample clock is doubled, compared to the 2D Full Resolution case. The area corresponding to the Vertical Blanking Interval of the Left VideoFrame is called the Active Space. The Active Space contains exactly the same amount of VideoLines as does the Vertical Blanking Interval. The active part of the VideoLines in the Active Space shall contain VideoSamples that all have a zero value.

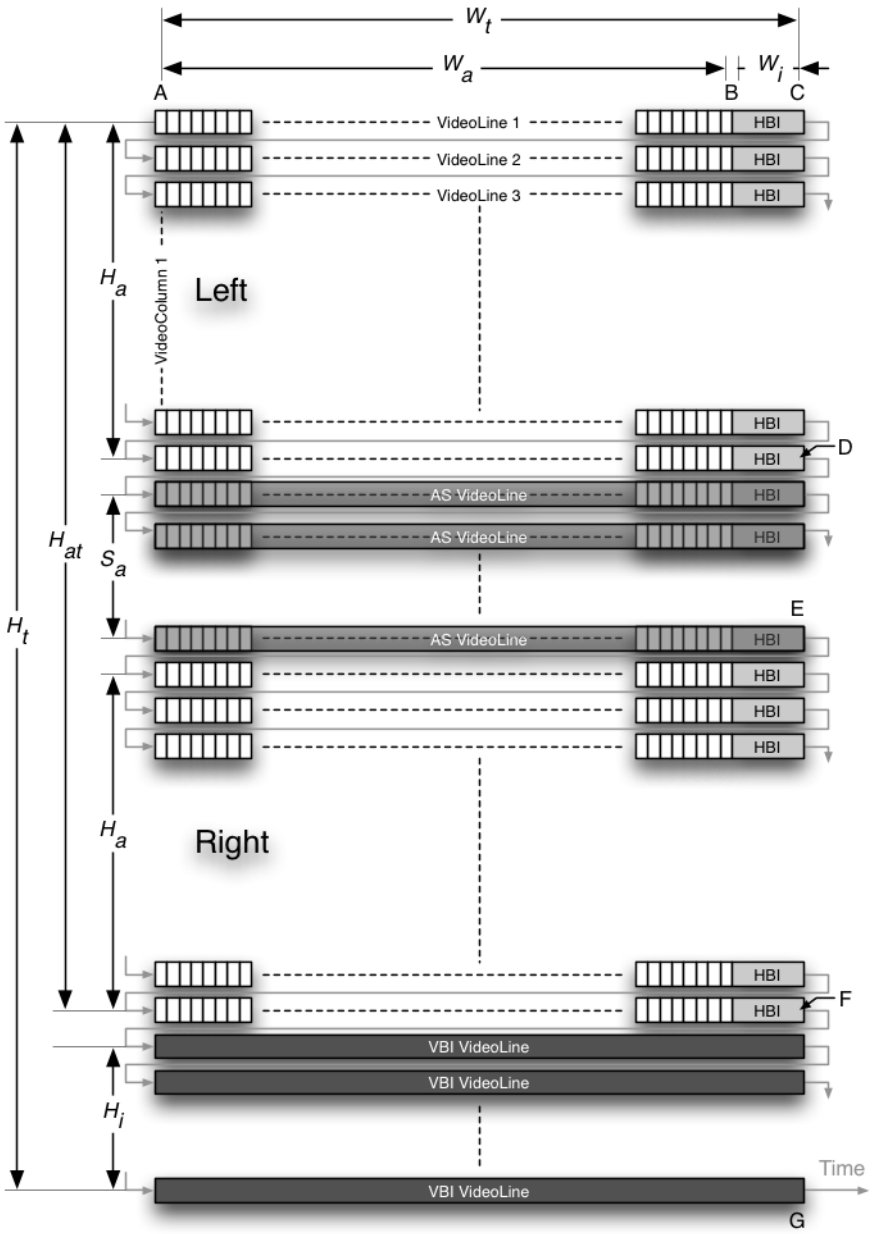


Figure 2-7: 3D2FP VideoFrame Spatial Layout and Timings

In this figure, the horizontal time scale is twice as large as it is in Figure 2-6 so that it takes exactly the same time in both cases from the beginning of the VideoFrame (A) to the end of the VideoFrame (G). As a consequence, all other time values are divided by a factor of 2. The following equations hold:

$$T_{La}^{3D2FP} = \frac{1}{2} * T_{La}^{2D}$$

$$T_{Li}^{3D2FP} = \frac{1}{2} * T_{Li}^{2D}$$

$$T_{Lt}^{3D2FP} = \frac{1}{2} * T_{Lt}^{2D}$$

$$T_{a}^{3D2FP} = \frac{1}{2} * T_{a}^{2D} + \frac{1}{2} * T_{i}^{2D} + \frac{1}{2} * T_{a}^{2D}$$

$$T_i^{3D2FP} = \frac{1}{2} * T_i^{2D}$$

$$T^{3D2FP} = T_a^{3D2FP} + T_i^{3D2FP} = T^{2D}$$

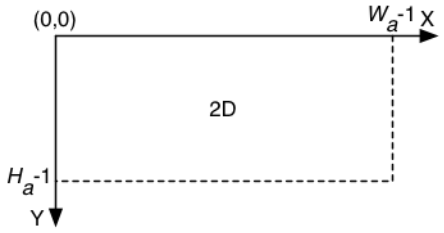
2.4.4. VideoFrame Organization

The AVFormat 3 Definition supports 2D VideoFrames (one video channel) as well as Stereoscopic 3D2 VideoFrames (two video channels) consisting of the assembly of a Left and a Right VideoFrame. The following tables define how the Left and Right VideoFrame can be assembled in different Frame Organizations. Each of the VideoFrame Organizations is assigned a unique VideoFrame Organization ID (FOID) and a unique VideoFrame Organization Legacy View Code (FOLVC) for use while in Legacy View as indicated in the tables. All VideoFrames are progressive scan. Interlaced formats are not supported.

2.4.4.1. 2D

The following table describes the 2D (one video channel) Full Resolution Frame Organization.

Table 2-1: 2D

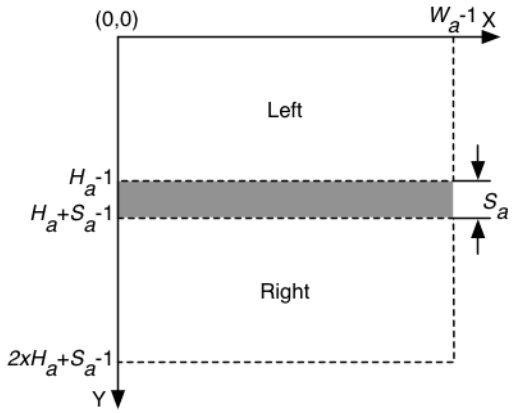


FOID	FOLVC	VideoFrame Organization
2D	0x0001	2D, Full Resolution.

2.4.4.2. 3D2FP

The following table describes the 3D2 (two video channels) Full Resolution Frame Organization. Left and Right VideoFrame are packed into a single resulting VideoFrame. When transported over USB, the VideoSamples in the Active Space (S_a) are either included in the VideoPayload or they are suppressed. When included, they shall all have zero values.

Table 2-2: 3D2FP

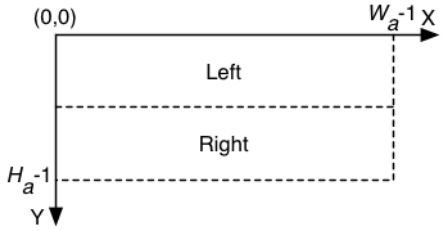


FOID	FOLVC	VideoFrame Organization
3D2FP	0x0002	3D, Full Resolution, Frame Packing. The Active Space (S_a) is either included or suppressed when the VideoFrame is transported over USB.

2.4.4.3. 3D2TAB

The following table describes the 3D2 (two video channels) Half Resolution Top and Bottom Frame Organization. Left and Right VideoFrames are subsampled by discarding every other VideoLine in both the Left and the Right VideoFrame and the subsampled VideoFrames are recombined into a single resulting VideoFrame.

Table 2-3: 3D2TAB

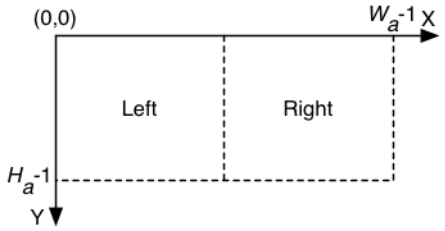


FOID	FOLVC	VideoFrame Organization
3D2TAB	0x0003	3D, Half Vertical Resolution, Odd Line Subsampling for Left and Right VideoFrame.

2.4.4.4. 3D2SHxx

The following table describes the 3D2 (two video channels) Half Resolution Side-by-Side Frame Organizations. Left and Right VideoFrames are subsampled by discarding every other Column in both the Left and the Right VideoFrame and the subsampled VideoFrames are recombined into a single resulting VideoFrame. Four combinations are possible as indicated in the table.

Table 2-4: 3D2SHxx



FOID	FOLVC	VideoFrame Organization
3D2SHOE	0x0004	3D, Half Horizontal Resolution. Odd Column Subsampling for Left and Even Column Subsampling for Right VideoFrame.
3D2SHOO	0x0005	3D, Half Horizontal Resolution. Odd Column Subsampling for Left and Odd Column Subsampling for Right VideoFrame.
3D2SHEO	0x0006	3D, Half Horizontal Resolution. Even Column Subsampling for Left and Odd Column Subsampling for Right VideoFrame.
3D2SHEE	0x0007	3D, Half Horizontal Resolution. Even Column Subsampling for Left and Even Column Subsampling for Right VideoFrame.

Note: "Odd" and "Even" in the tables above indicate the VideoLines or VideoColumns that are *retained* for creating the sub-sampled regions of the Left and Right views. Columns and Lines are numbered as indicated in Figure 2-6, "2D VideoFrame Spatial Layout and Timings", starting with VideoLine 1 (uppermost line) or VideoColumn 1 (leftmost column). For example, the 3D2SHOE Frame Organization retains the odd VideoColumns 1, 3, 5, etc. from the original Left VideoFrame, dropping the even VideoColumns 2, 4, 6, etc. to create the subsampled Left View and it retains the even VideoColumns 2, 4, 6, etc. from the original Right VideoFrame, dropping the odd VideoColumns 1, 3, 5, etc. to create the subsampled Right View as illustrated in the following figure.

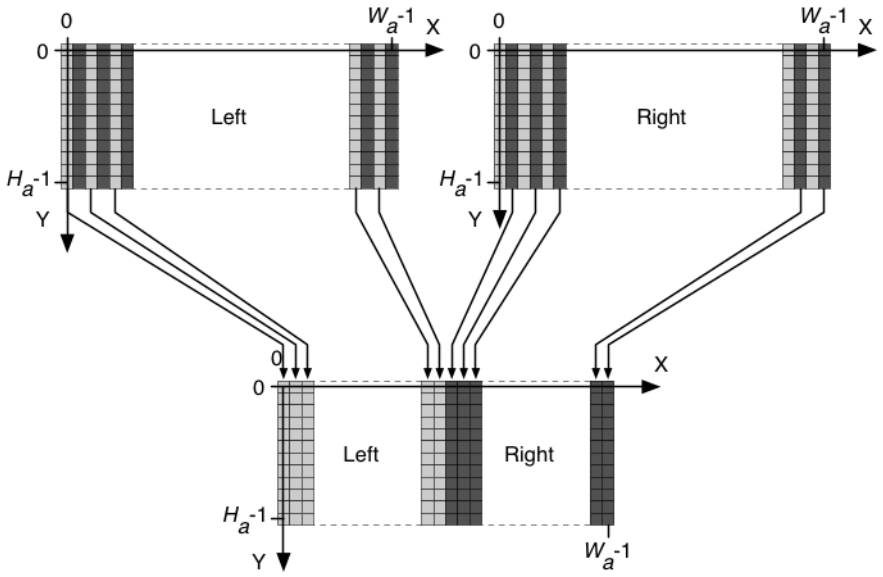


Figure 2-8: 3D2SHOE Frame Organization Subsampling

2.4.4.5. VideoFrame Organization Description

The VideoFrame Organization Description is a hierarchical component of the VideoStreams Configuration Description. Refer to Section 2.7.1, "VideoStreamConfigList Description" for details.

2.4.5. VideoFrame Formats

This specification supports a wide variety of VideoFrame formats, either predefined by this specification or vendor-defined. The VideoFrame Rate, together with the VideoFrame Format ID (VFID), fully identifies each VideoFrame format.

The following set of parameters fully defines the (2D or 3D2) VideoFrame:

- F: VideoFrame Rate (in Hz)
- A: The aspect ratio of the VideoFrame
- W_a: Active VideoFrame Width (in VideoSamples)
- H_a: Active VideoFrame Height (in VideoLines)

  Note: for the 3D2FP Frame Organization, H_a indicates the Active VideoFrame Height for each of the Left and Right (Full Resolution) VideoFrame.

- W_t: Total VideoFrame Width (in VideoSamples)
- H_t: Total VideoFrame Height (in VideoLines)
- F_{vs}: VideoSample Rate (pixelclock) (in MHz) – for informational purposes only

For the 3D2FP Full Resolution Frame Organization, the following secondary parameters can be calculated from the previous parameters:

- S_a: Indicates the size of the Active Space (in VideoLines): $S_a = \frac{1}{2} * H_t - H_a$
- H_{at}: Total Active VideoFrame Height (in VideoLines): $H_{at} = 2 * H_a + S_a$

Note that the VideoFrame Rate is an integral part of the VideoFrame Format definition. To fully identify one of the predefined VideoFrame Formats, both the VideoFrame Rate and the VideoFrame Format ID are required.

This specification defines a number of common predefined VideoFrame formats. Refer to Appendix A, "VideoFrame Format Dimensions and Timings" for a complete list.

2.4.5.1. VideoFrame Format Description

The VideoFrame Format Description is a hierarchical component of the VideoStreams Configuration Description. Refer to Section 2.7.1, "VideoStreamConfigList Description" for details.

2.5. VideoSample Formats

There are currently two VideoSample Format Types defined by this specification:

- VideoSample Format Type I
- VideoSample Format Type II

A unique VideoSample format ID (VSID) identifies each VideoSample Format. In addition, a unique VideoSample Format Legacy View Code (VSLVC) is defined for use while in Legacy View.

2.5.1. Type I Format

VideoSample format Type I groups the VideoSample formats that use one symbol per VideoSample. These formats are usually called RAW data formats. The following sections describe the VideoSample formats that belong to Type I.

2.5.1.1. Type I Format Type Description

The VideoSample Type I Description is a hierarchical component of the VideoStreams Configuration Description. Refer to Section 2.7.1, "VideoStreamConfigList Description" for details.

2.5.1.2. Type I Supported Formats

2.5.1.2.1. RAW Format

The RAW VideoSample format uses a single symbol to represent a VideoSample. To generate a color picture, the VideoSamples need to be further processed, starting from the Bayer pattern (Demosaicing, White Balance, Contrast, Color Saturation, Sharpening, …)

This specification supports a generic RAW format, ranging from 1 up to 32 bits per VideoSample. Each VideoSample is transported in a VideoSubSlot as described above.

The $bitResolution$ and $subSlotSize$ values shall always obey the following equation:

$$subSlotSize = \big((bitResolution - 1)\ DIV\ 8\big) + 1$$

The VSID for the RAW format shall be set to "RAW". The VSLVC shall be set to 0x0001.

2.5.2. Type II Format

VideoSample Type II groups the VideoSample formats that use multiple symbols per VideoSample. The Type II formats are also known as Color Spaces. Typical examples are the RGB formats and the YUV formats. The following sections describe the VideoSample Formats that belong to Type II.

2.5.2.1. Type II Format Type Description

The VideoSample Type II Description is a hierarchical component of the VideoStreams Configuration Description. Refer to Section 2.7.1, "VideoStreamConfigList Description" for details.

2.5.2.2. Type II Supported Formats

The Type II formats use multiple symbols to represent a VideoSample. For some of the Formats, the VideoSample concept does not really map well onto byte boundaries since Chrominance values may be shared among multiple VideoSamples and may even be arranged completely separate from the VideoSample Luminance values (planar arrangements). Therefore, the concept of the VideoParticle was introduced (see Section 2.3.1.1, "VideoParticle". In all cases there is never any padding involved when VideoSamples are first packetized into VideoParticles and then placed into VideoSubSlots since all Luminance and Chrominance values are always byte-aligned.

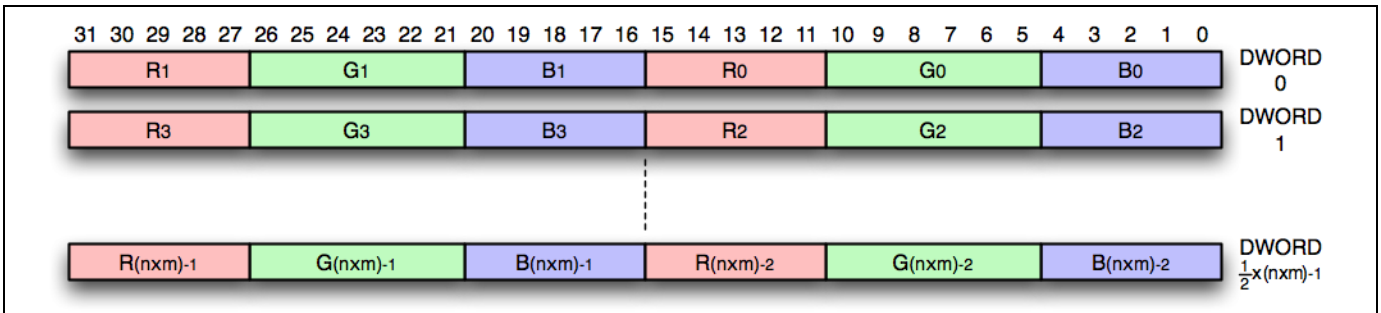
$bitResolution$ and $subSlotSize$ are implied by the VSID and are not reported in the AVDD.

The following Sections specify the VideoSample Formats allowed for use in this specification. The following notation is used in the tables:

- The **VSID** value is used to uniquely identify the VideoSample Format for the purposes of this specification.
- The **VSLVC** value is used to uniquely identify the VideoSample Format while in Legacy View.
- The **FourCC** field indicates the four-character code by which the VideoSample Format (Color Space) is registered at www.fourcc.org.
- The **Type** field specifies the type of the VideoSample Format: RGB, YCbCr, or YUV Planar.
- The **bitResolution** field indicates the number of bits per VideoParticle ($bitResolution$).
- The **subSlotSize** field indicates the number of bytes per VideoSubSlot ($subSlotSize$).
- The **bits/VideoSample** field indicates the (average) number of bits used for one VideoSample (informative).
- In the figures, n is the horizontal resolution W_s and m is the vertical resolution H_s of the VideoFrame.

2.5.2.2.1. RGB565

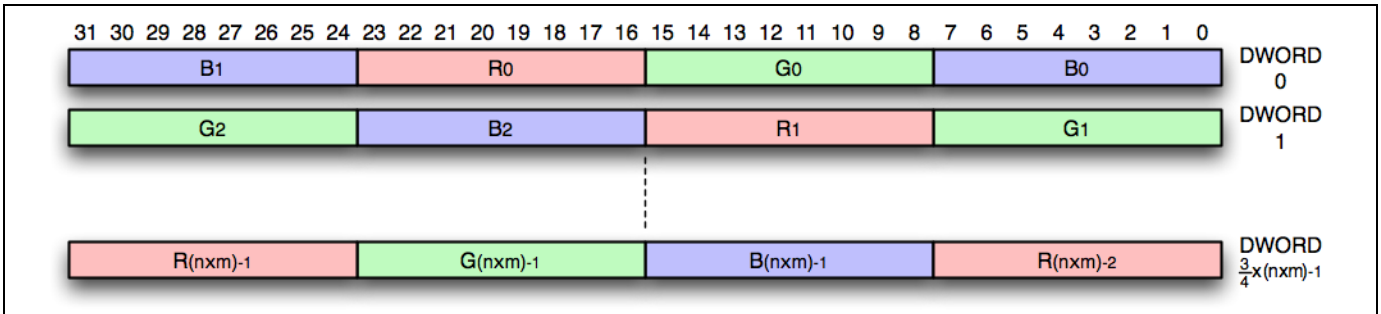
Table 2-5: RGB565 VideoSample Format



VSID	VSLVC	FourCC	Type	bitResolution	subSlotSize	bits/VS
RGB565	0x0002	BI_RGB	RGB	16	2	16

2.5.2.2.2. RGB888

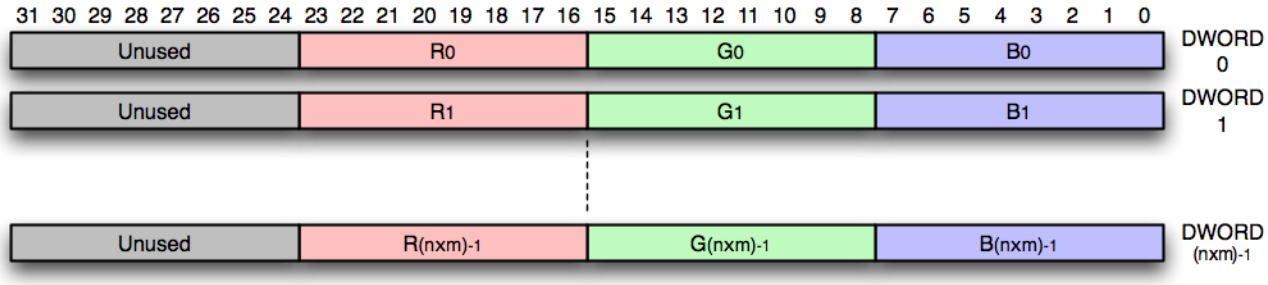
Table 2-6: RGB888 VideoSample Format



VSID	VSLVC	FourCC	Type	bitResolution	subSlotSize	bits/VS
RGB888	0x0003	BI_RGB	RGB	24	3	24

2.5.2.2.3. RGB8888

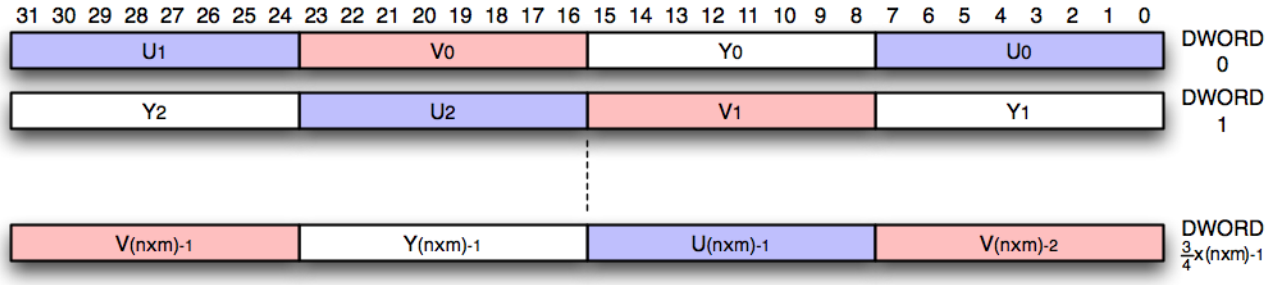
Table 2-7: RGB8888 VideoSample Format



VSID	VSLVC	FourCC	Type	bitResolution	subSlotSize	bits/VS
RGB8888	0x0004	BI_RGB	RGB	32	4	32

2.5.2.2.4. IYU2

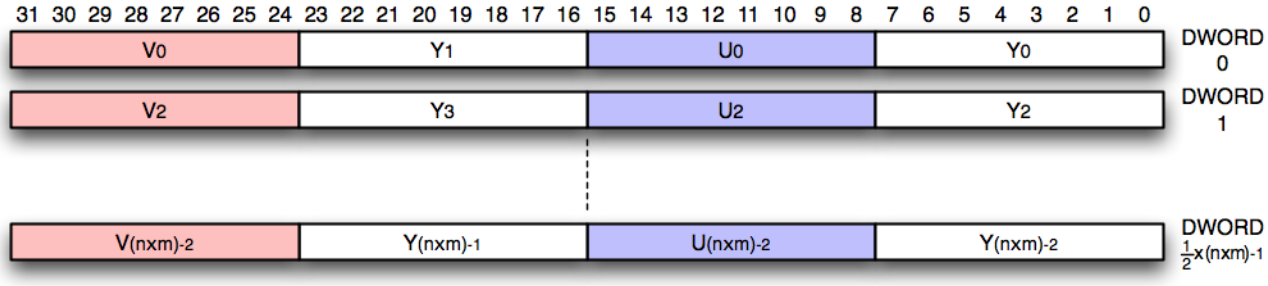
Table 2-8: IYU2 VideoSample Format



VSID	VSLVC	FourCC	Type	bitResolution	subSlotSize	bits/VS
IYU2	0x0005	IYU2	YCbCr444	24	3	24

2.5.2.2.5. YUY2

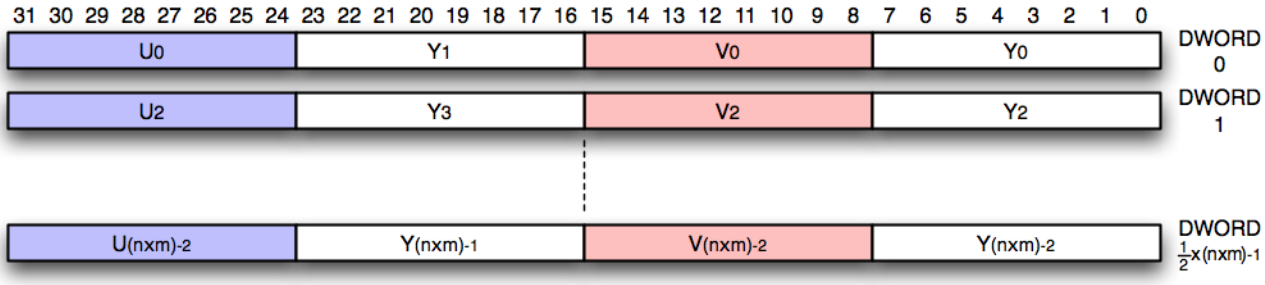
Table 2-9: YUY2 VideoSample Format



VSID	VSLVC	FourCC	Type	bitResolution	subSlotSize	bits/VS
YUY2	0x0006	YUY2	YCbCr422	32	4	16

2.5.2.2.6. YVYU

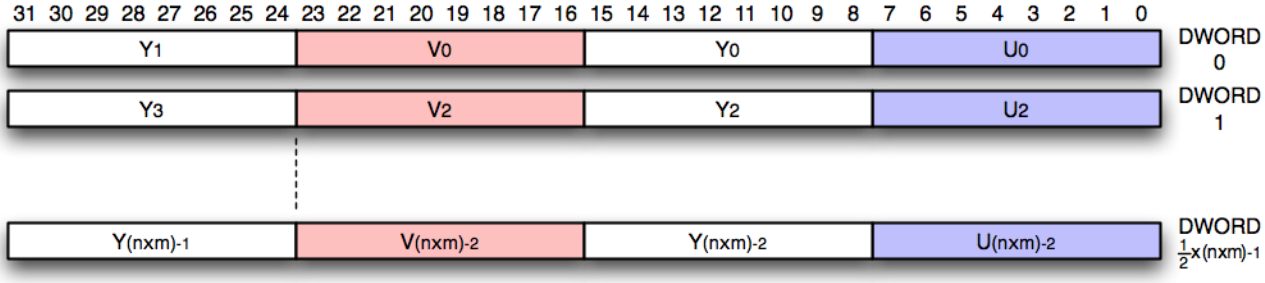
Table 2-10: YVYU VideoSample Format



VSID	VSLVC	FourCC	Type	bitResolution	subSlotSize	bits/VS
YVYU	0x0007	YVYU	YCbCr422	32	4	16

2.5.2.2.7. UYVY

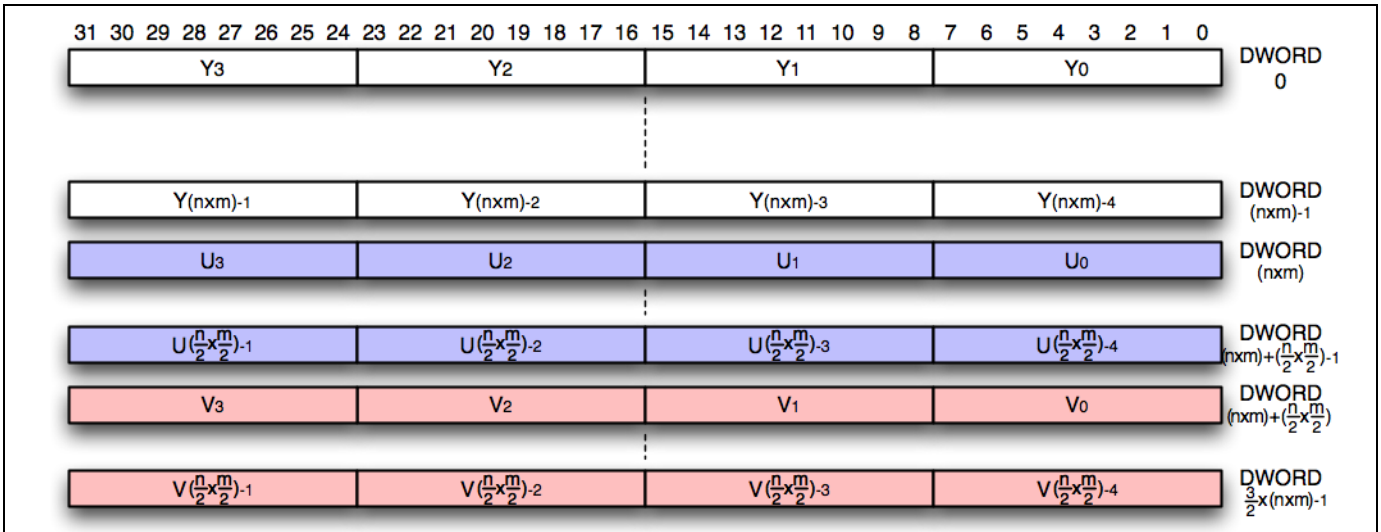
Table 2-11: UYVY VideoSample Format



VSID	VSLVC	FourCC	Type	bitResolution	subSlotSize	bits/VS
UYVY	0x0008	UYVY	YCbCr422	32	4	16

2.5.2.2.8. I420

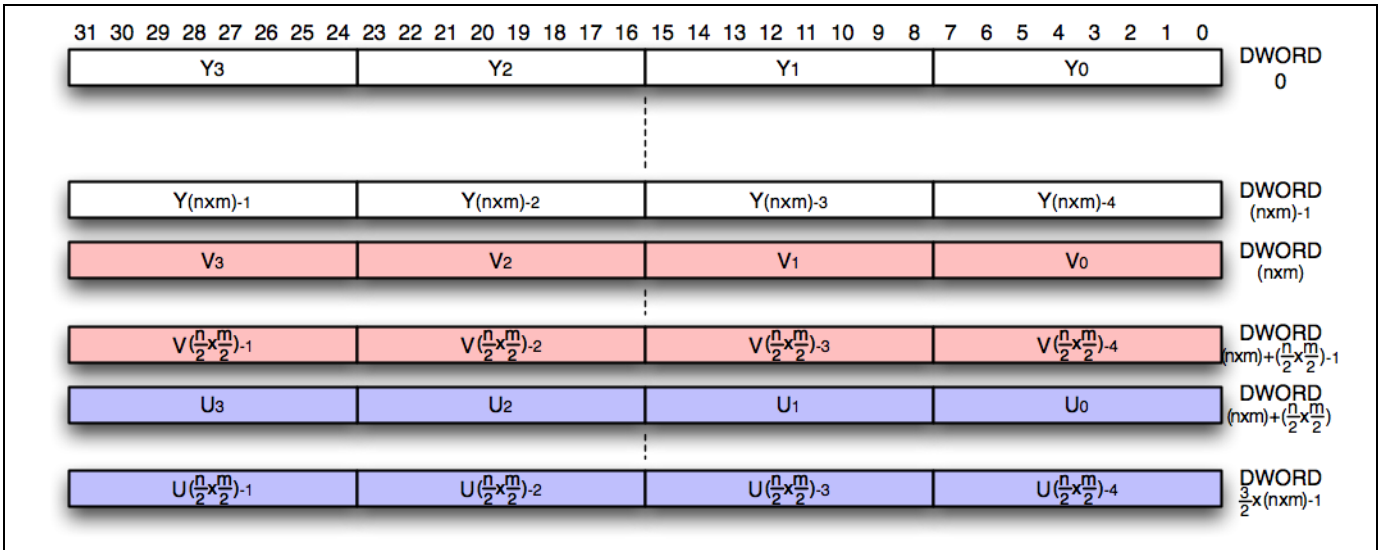
Table 2-12: I420 VideoSample Format



VSID	VSLVC	FourCC	Type	bitResolution	subSlotSize	bits/VS
I420	0x0009	I420/IYUV	YUV420 Planar	8	1	12

2.5.2.2.9. YV12

Table 2-13: YV12 VideoSample Format



VSID	VSLVC	FourCC	Type	bitResolution	subSlotSize	bits/VS
YV12	0x000A	YV12	YUV420 Planar	8	1	12

2.5.3. VideoCompression

This specification defines several methods for compressing video content. A unique Video Compression ID (VCID) identifies each Method. There is also a unique Video Compression Legacy View Code (VCLVC) defined as follows:

Table 2-14: Video Compression Methods

VCID	VCLVC	Method	Description
FULL	0x0001	Uncompressed Full Frame	All the VideoSamples that together constitute a full VideoFrame are transported uncompressed from the video source to the video sink.
PARTIAL	0x0002	Uncompressed Partial Frame	One or more subregions of a VideoFrame (see Section 2.4.2.1, “Subregions”) contain VideoSamples that have changed with respect to the previous VideoFrame. Only these subregions (containing the changed VideoSamples) are transported uncompressed from the video source to the video sink. To reconstruct the full VideoFrame, all VideoSamples outside the changed subregions from the previous VideoFrame are reused.
H264BASEINTRA	0x0003	H.264 Baseline Intra	Full VideoFrames are compressed using H.264 Baseline Profile codec tools and only Intra-coded MacroBlocks. The resulting VideoFrame is called an Intra-VideoFrame.
H264BASEPRED	0x0004	H.264 Baseline Predictive	Full VideoFrames are compressed using H.264 Baseline Profile codec tools and a combination of Intra-coded and Inter-coded MacroBlocks. I-frames are coded using intra-coded MacroBlocks. P-frames use Intra-coded Macroblocks for all areas in the VideoFrame that have changed with respect to the previous VideoFrame. Inter-coded MacroBlocks with Zero-MotionVector Predictor are used for all areas that have not changed (skip mode). The resulting VideoFrame is called an Inter-VideoFrame.
H264HiQINTRA	0x0005	H.264 High Quality Intra	Full VideoFrames are compressed using H.264 High Profile Profile codec tools and only Intra-coded MacroBlocks. The resulting VideoFrame is called an Intra-VideoFrame.
H264HiQPRED	0x0006	H.264 High Quality Predictive	Full VideoFrames are compressed using H.264 High Profile Profile codec tools and a combination of Intra-coded and Inter-coded MacroBlocks. I-frames are coded using intra-coded MacroBlocks. P-frames use Intra-coded Macroblocks for all areas in the VideoFrame that have changed with respect to the previous VideoFrame. Inter-coded MacroBlocks with Zero-MotionVector Predictor are used for all areas that have not changed (skip mode). The resulting VideoFrame is called an Inter-VideoFrame.
VENDOR	0xFFFF	Vendor-defined	Vendor-defined Compression Method. Further details should be provided via the AVDD.

The AVFormat 3 specification currently only supports the Uncompressed Full Frame Video Compression Method (FULL). All currently defined Video Compression Methods are supported by [AVFORMAT_1].

2.5.3.1. VideoCompression Description

The VideoCompression Description is a hierarchical component of the VideoStreams Configuration Description. Refer to Section 2.7.1, “VideoStreamConfigList Description” for details.

2.6. VideoStreamConfig

A VideoStream Configuration (VideoStreamConfig) in an AVData Video Streaming Interface is fully characterized by the following components:

- The VideoBundle (Section 2.3.4)
- The VideoFrame component, consisting of
  - The VideoFrame Rate (Section 2.4.1)
  - The VideoFrameOrganization (Section 2.4.4)
  - The VideoFrame format (Section 2.4.5)
- The VideoSample component, consisting of
  - The VideoSample Format (Section 2.5)
  - The VideoCompression (Section 2.5.3)
- The VideoSIPSize (Section 4)

2.6.1. VideoStreamConfig Description

The VideoStreamConfig Description is a hierarchical component of the VideoStreamConfigList Description. Refer to Section 2.7.1, “VideoStreamConfigList Description” for details.

2.7. VideoStreamConfigList

A VideoStreamConfigList is a construct that consists of a list of VideoStreamConfig Descriptions that are supported by a particular AVData Video Streaming Interface in which the VideoStreamConfigList is advertised.

2.7.1. VideoStreamConfigList Description

The VideoStreamConfigList Description can be found at: VideoIsoStreamConfigList.

2.8. Current Limitations

At this time, the AVFormat 3 specification only supports VideoBundles consisting of one VideoTrack. The single VideoTrack may contain either one video channel (2D) or 2 video channels (3D2). The video data is always uncompressed (except for color space compression) and is always full Frame (no partial update support). VideoSlots are either VideoLine-interleaved (Side-by-Side frame organization) or VideoFrame-interleaved (Top-and-Bottom frame organization). VideoParticle-interleaved Streams are not used at this time.

3. Video Synchronization

This specification describes how VideoStreams are transported over an isochronous pipe.

To keep the video source and the video sink synchronized in time, it is important that the average VideoFrame Rate (or VideoFrame Time) on both sides remain synchronized on average. Indeed, if the video sink consumes the VideoFrames at an average rate that is higher than the rate at which the video source provides the VideoFrames, then the video sink will inevitably run out of video data to display and buffer underruns will occur. Likewise, if the video sink consumes the VideoFrames at an average rate that is lower than the rate at which the video source provides the VideoFrames, then the video sink will inevitably run out of buffer space to store the incoming video data and buffer overruns will occur.

To avoid any of the scenarios described above, the *average* VideoFrame Rate on both sides (video source and sink) *must* match. Instantaneous VideoFrame Rate may vary (drift) between video source and sink and the accumulated variation is limited by the amount of buffer that is available at the video sink.

This specification defines the sequence of StartofVideoFrame(i) events. Each element of this sequence represents the exact moment in time (event) when a video Producer (such as a camera sensor or the VideoPlayer in a Controller) produces the first bit of the first VideoSample of VideoFrame(i). Therefore the duration of VideoFrame(i) at the Producer, T_P^i, is given by:

$$T_P^i = StartofVideoFrame(i+1) - StartofVideoFrame(i)$$

and the rate of VideoFrame(i) at the Producer, F_P^i, is given by:

$$F_P^i = 1/T_P^i$$

The average VideoFrame Time T_P can be obtained by averaging the instantaneous VideoFrame Time T_P^i during a sufficiently large time window v:

$$T_P = \frac{1}{v}\sum_{i=0}^{v-1} T_P^i = 1/F_P$$

Note: Other, more sophisticated averaging algorithms may be used to obtain a better estimate for T_P.

It is expected that the difference between T_P^i and T_P at the Producer is very small (mostly determined by the stability of the local clock from which T_P^i is derived).

The StartofVideoFrame events are transported over USB by setting the VideoFrameStart flag in the AVHeader of each SIP that contains the first Video Data of a VideoFrame. Therefore, the StartofVideoFrame events can be regarded as a continuous signal with an amplitude of either 0 or 1 and a frequency equal to the VideoFrame Rate that is sampled with a clock running with a time base equal to the ServiceInterval period.

As an example, consider a VideoFrame Rate $F_P = 60\ Hz$ ($T_P = 16.667\ ms$) and a ServiceInterval period $T_{SI} = 125\ \mu s$ ($F_{SI} = 8\ kHz$). Thus, the StartofVideoFrame signal of 60 Hz is sampled with a clock of 8 kHz. There will be on average $T_P/T_{SI} = 16.667\ ms/125\ \mu s = 133.3333$ ServiceIntervals per VideoFrame. However, due to the sampling process running at 8 kHz, the spacing between StartofVideoFrame events as observed at the video Consumer after transport over USB will be either 133 ServiceIntervals or 134 Intervals. In other words, for all i, the instantaneous VideoFrame Time(i), T_C^i, at the video Consumer is always $T_C^i = 133|134 * T_{SI}$. However, by averaging over a sufficiently large (sliding) time window w, the video Consumer can obtain an accurate estimate for T_C and use that as its local VideoFrame Time:

$$T_C = \frac{1}{w}\sum_{i=0}^{w-1} T_C^i = 1/F_C$$

Note: Other, more sophisticated averaging algorithms may be used to obtain a better estimate for T_C.

3.1. Video Synchronization Types

An isochronous endpoint (In or Out) always belongs to one of the three synchronization types as defined in Section 5.12 of [USB2.0]:

- Asynchronous Source or Sink
- Synchronous Source or Sink
- Adaptive Source or Sink

However, when used in an AVData Video Streaming Interface, this specification limits the synchronization types that may be used for its isochronous data endpoint to the following three cases:

- Asynchronous Source
- Synchronous Source
- Adaptive Sink

By limiting the possible variations in synchronization type to the cases above, maximum interoperability is guaranteed since an Adaptive Sink is always able to communicate with either an Asynchronous or a Synchronous Source.

The following sections provide more details about the supported synchronization cases.

3.1.1. Asynchronous Video Source

An asynchronous isochronous Video Source endpoint produces VideoFrames at a rate that is locked either to a clock external to the USB or to a free-running clock internal to the AVFunction. An asynchronous isochronous Video Source endpoint cannot be synchronized to a start of frame (SOF), Bus Interval Boundary (BIB), or to any other clock in the USB domain.

When an AVFunction (Provider) is sending video data to the Controller over an asynchronous isochronous endpoint, T_P is implied in the arrival time T_C^i of subsequent StartofVideoFrame events at the Controller. As explained above, these StartofVideoFrame events are quantized by the ServiceInterval period ($T_C^i = m * T_{SI}$, where m is an integer value). However, by averaging the arrival times over a sufficiently large (sliding) time window, an accurate VideoFrame Time T_C and therefore VideoFrame Rate F_C can be derived at the Controller (Consumer).

3.1.2. Synchronous Video Source

When an AVFunction (Provider) is sending video data to the Controller over a synchronous isochronous endpoint, T_P is tightly synchronized to the USB SOF or BIB. Therefore, the arrival time T_C^i of subsequent StartofVideoFrames at the Controller (Consumer), quantized again by the ServiceInterval period, will follow a distinct repeating pattern (although the repetition period may be large). For example, if the VideoFrame Rate is 60Hz, locked to SOF or BIB, then the VideoFrame Time at the Provider, T_P, is exactly 133.3333 ServiceInterval periods (0.016667/0.000125) and the arrival times of subsequent StartofVideoFrames at the sink will follow a repeating pattern, expressed in SI periods as follows: 133, 133, 134, 133, 133, 134, 133, …

3.1.3. Adaptive Video Sink

An adaptive isochronous Video Sink endpoint is able to sink data at any rate within its operating range. This implies that an adaptive isochronous Video endpoint runs an internal process that allows it to match its natural VideoFrame Rate to the data rate that is imposed at its interface.

When an AVFunction (Consumer) is receiving video data from the Controller (Provider) over an adaptive isochronous endpoint, T_P is implied in the arrival time T_C^i of subsequent StartofVideoFrame events at the AVFunction. As explained above, these StartofVideoFrame events are quantized by the ServiceInterval period ($T_C^i = m * T_{SI}$, where m is an integer value). However, by averaging the arrival times over a sufficiently large (sliding) time window, an accurate VideoFrame Time T_C and therefore VideoFrame Rate F_C can be derived at the AVFunction (Consumer).

4. Video Packetizing

This specification exclusively addresses VideoStreams that are comprised of uncompressed VideoSamples (pixels), organized in a well-defined VideoFrame Spatial Layout. Only progressively scanned VideoFrames are considered.

During each VideoFrame Time T, the total number of VideoSamples in a VideoFrame, N, needs to be sent over the USB. The following rules apply:

- Each SIP, associated with a VideoFrame shall contain exactly n VideoSamples, except for the last SIP, which may contain r VideoSamples and r shall always be less than or equal to n.
- The first VideoSample of a VideoFrame shall always be the first VideoSample in the SIP. This rule guarantees that a new VideoFrame always starts at the beginning of a SIP.
- There shall always be at least one Transfer Delimiter (see Section 2.1, "Transfer Delimiter") between successive VideoFrames.

The value n is critical in the operation of the isochronous video transport.

The minimum value for n is largely determined by the total amount of VideoSamples in the VideoFrame, N, and the VideoFrame Time T. Indeed, n shall be chosen at least large enough so that during each VideoFrame Time, there are enough opportunities to send the N VideoSamples over the USB:

$$n > CEILING(N/(FLOOR(T/T_{SI}) - 1)) = n_{min}$$

where T_{SI} is the ServiceInterval period. The -1 in the denominator ensures that the third rule stated above is always satisfied.

The maximum value for n is determined by the available bandwidth for the isochronous pipe and the available video buffer space on the AVFunction. In general, consuming less bandwidth per SIP on the USB will require more video buffering on the AVFunction. Whenever VideoSamples are produced or consumed using customary video timings, there is a Vertical Blanking Interval at the end of each VideoFrame where no new VideoSamples are produced or consumed. This is the inactive part of the VideoFrame. In order to reclaim this 'dead time' on the bus, during the active part of the VideoFrame, the video transmitter can send slightly less VideoSamples over the USB than it locally produces or consumes (δ in figures Figure 5-1 and Figure 5-2 below). It can then use these accumulated VideoSamples to send over the USB during the inactive part of the VideoFrame, minimizing the total required bandwidth per SIP on the USB. Evidently, this technique requires some additional video buffer space to temporarily hold the accumulated VideoSamples during each VideoFrame.

It should be a design goal to find the correct balance between consumed bandwidth and required video buffer space. From a USB bandwidth perspective, it is desirable to bring n as close as possible to n_{min}.

Some designs may benefit from having n be an integer multiple of the number of VideoSamples in a VideoLine so that all SIPs start with the first VideoSample of a VideoLine and contain an integer number of VideoLines.

The exact formulas for calculating n involve a number of different parameters and are presented in detail in Appendix B, "Calculations".

The AVFunction indirectly advertises the value of n for each supported VideoStream Configuration through the `<videoSIPSize>` element of the `<videoIsoStreamConfig>` Description as follows:

$$videoSIPSize = N_H + n * subSlotSize$$

where N_H is the AVHeader length in bytes and $subSlotSize$ is the VideoSubSlot size, also in bytes, for the VideoStream Configuration.

The following rules apply:

- For full-/high-speed endpoints:

$$videoSIPSize \leq (wMaxPacketSize[D12..11] + 1) * wMaxPacketSize[D10..0]$$

- For SuperSpeed endpoints:

$$videoSIPSize \leq wBytesPerInterval$$

5. Examples

The following sections are intended to illustrate the concepts defined above.

5.1. AVFunction as a Video Source

For this example, it is assumed that the actual Producer of the video data (a camera sensor, for example) uses regular video timings to produce the VideoSamples and all VideoSamples are self-contained (VideoSample = VideoParticle). Therefore, there exists the notion of VideoFrame, VideoLines, Horizontal Blanking Interval (HBI), and Vertical Blanking Interval (VBI), etc. at the Producer. A typical video timing diagram is presented in the area labeled "VideoTimings" in Figure 5-1. Individual VideoSamples are grouped into VideoLines (labeled L1, L2, etc.). Horizontal Blanking Intervals (HB) separate the (active parts of) VideoLines. Vertical Blanking Intervals (VB) separate the (active parts of) VideoFrames.

VideoSamples are stored in a local video buffer in the order in which they become available from the Producer. During the active part of the VideoFrame, the video Producer nominally produces $n + \delta$ VideoSamples during each USB ServiceInterval. Each ServiceInterval, n VideoSamples are sent over the USB in a single SIP, leaving δ excess VideoSamples that are temporarily accumulated in the local video buffer. At the end of the active part of the VideoFrame, no more new VideoSamples are produced but a number of VideoSamples (approx. $p * \delta$, where p is the number of ServiceIntervals during the active part of the videoFrame) are still available in the local video buffer. These VideoSamples are then sent during the inactive part of the VideoFrame, depleting the local video buffer before the start of a new VideoFrame is reached. In Figure 5-1, the area labeled "Buffer Management" graphically illustrates how the local video buffer is gradually filled over time until the end of the active part of the VideoFrame is reached. The local video buffer is then depleted during the inactive part of the VideoFrame. The area labeled "USB Transport" illustrates how during each ServiceInterval, n VideoSamples are transported over the USB. The last SIP, associated with a VideoFrame may be of smaller size. Note also that there is at least one 'empty' ServiceInterval between each VideoFrame VideoPayload. Finally, the area labeled "Application Layer" indicates when the VideoSamples that where transported over USB become available for actual processing on the receiver. Note that VideoSamples only become available for processing at each end of the ServiceInterval.

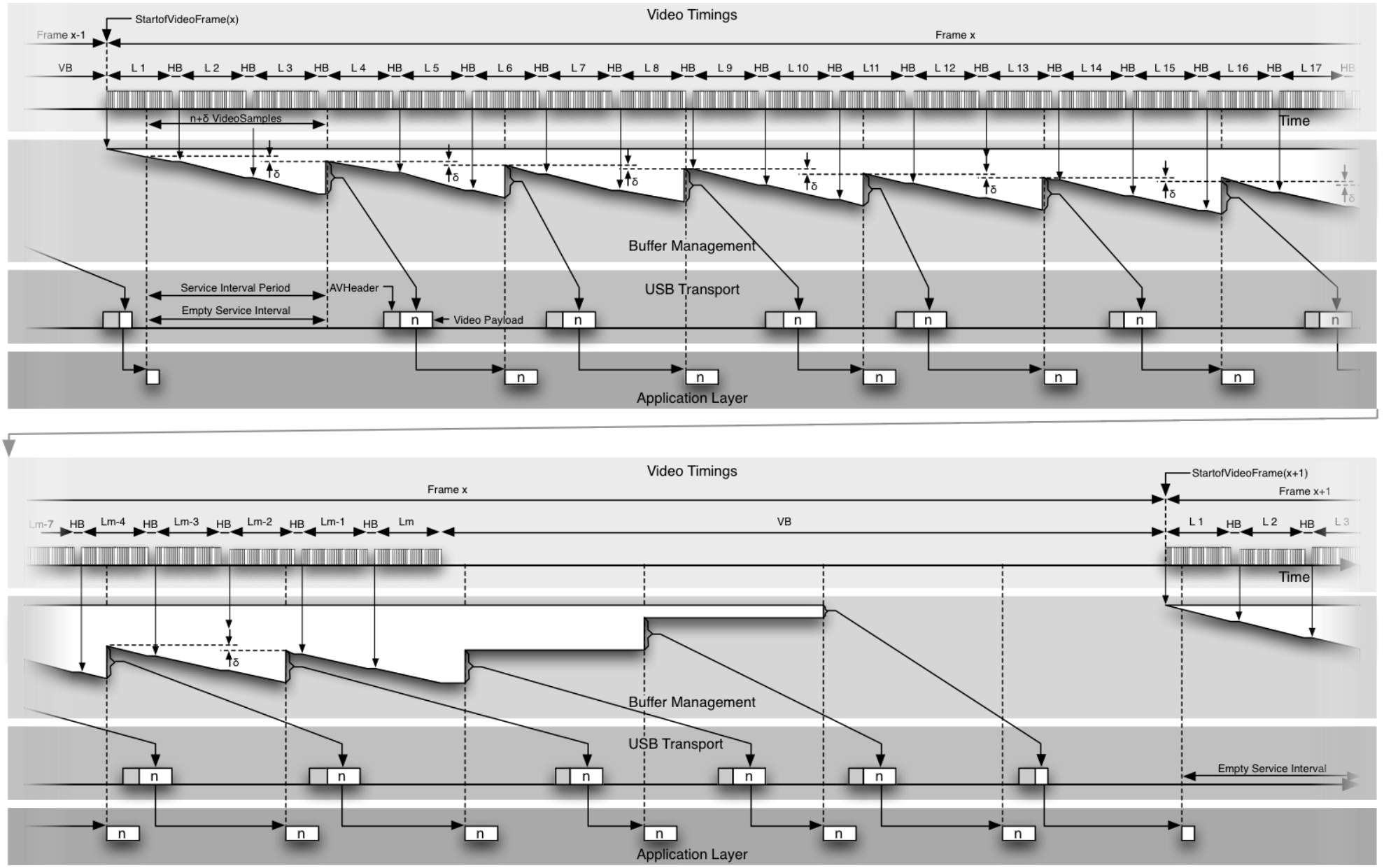


Figure 5-1: Video Source Packetizing Scheme

5.2. AVFunction as a Video Sink

In this example, it is again assumed that all VideoSamples are self-contained (VideoSample = VideoParticle).

The Application Layer presents VideoSamples to the USB transport and the USB transport consumes n VideoSamples at the beginning of each ServiceInterval. In Figure 5-2, the area labeled “Application Layer” describes this process. The area labeled “USB Transport” illustrates how during each ServiceInterval, n VideoSamples are transported over the USB in one SIP. The last SIP, associated with a VideoFrame may be of smaller size. Note also that there is at least one ‘empty’ ServiceInterval between each VideoFrame VideoPayload.

VideoSamples are stored in a local video buffer in the order in which they become available from the USB. During the active part of the VideoFrame, the video Consumer nominally consumes $n + \delta$ VideoSamples during each USB ServiceInterval. Each ServiceInterval, n VideoSamples are sent over the USB in a single SIP, creating a shortage of δ VideoSamples. To account for this shortage, the Video sink needs to buffer a number of VideoSamples (approx. $p * \delta$, where p is the number of ServiceIntervals during the active part of the videoFrame) before it can start the VideoFrame so that the Consumer does not run out of VideoSamples before the end of the active part of the VideoFrame. In Figure 5-2, The area labeled “Buffer Management” graphically illustrates how the local video buffer is first ‘pre’-filled during the inactive part of the VideoFrame. The local video buffer is then gradually depleted during the active part of the VideoFrame.

Finally, it is assumed that the actual Consumer of the video data (a display panel, for example) uses regular video timings to consume the VideoSamples. Therefore, there exists the notion of VideoFrame, VideoLines, Horizontal Blanking Interval (HB), and Vertical Blanking Interval (VB), etc. at the Consumer. A typical video timing diagram is presented in the area labeled “VideoTimings” in Figure 5-2. Individual VideoSamples are grouped into VideoLines (labeled L1, L2, etc.). Horizontal Blanking Intervals (HB) separate the (active parts of) the VideoLines. Vertical Blanking Intervals (VB) separate the (active parts of) the VideoFrames.

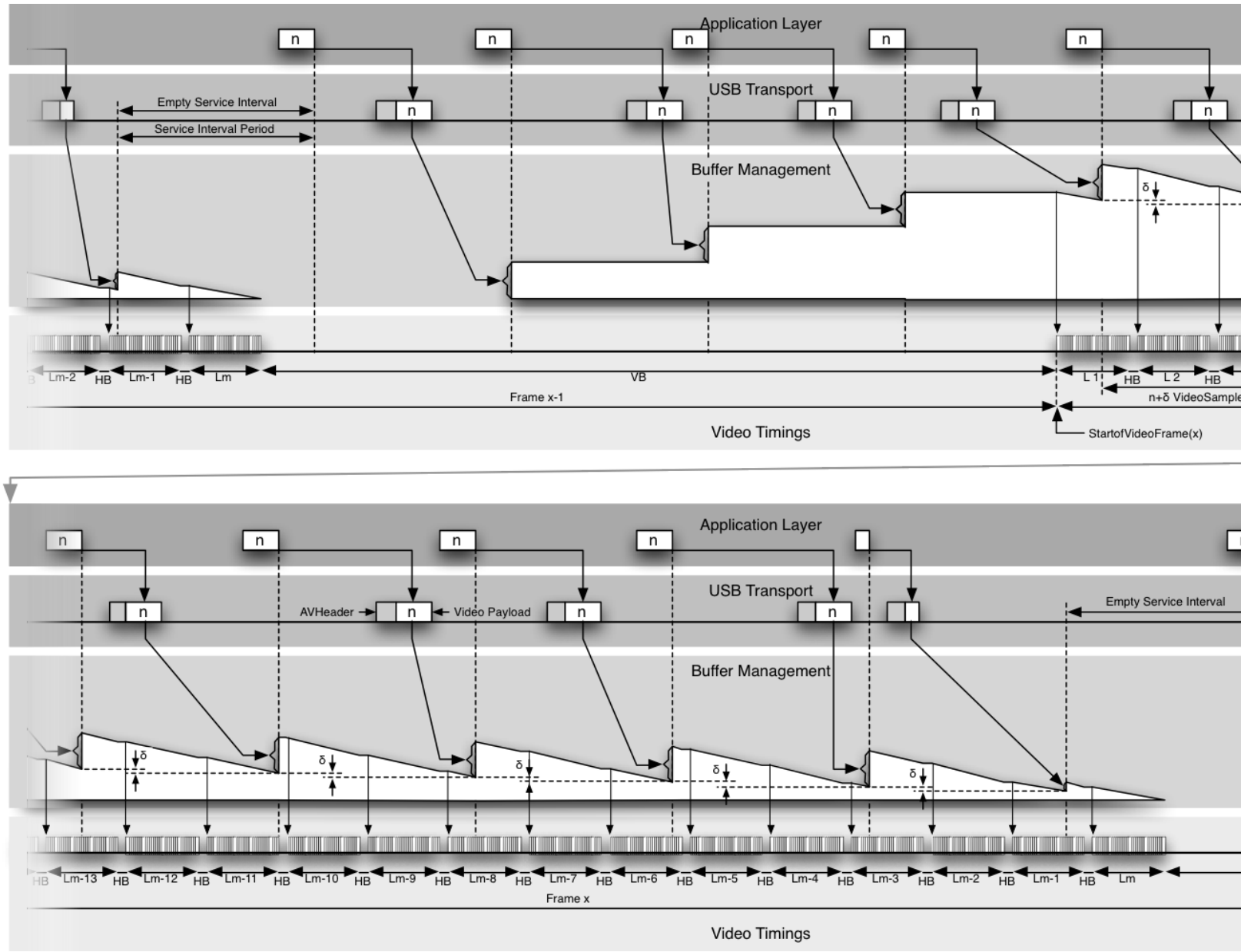


Figure 5-2: Video Sink Depacketizing Scheme

6. Video Data Format

The VideoStream is packetized as described in Section 4, “Video Packetizing” into one ServiceIntervalPacket (SIP) per ServiceInterval.

Each SIP shall start with a fixed-length AVHeader, followed by the actual Video Data.

6.1. AVHeader

The AVHeader is exactly 32 bytes long and has the following layout:

Table 6-1: AVHeader Layout

Offset	Field	Size	Value	Description
0	**wFlags**	2	Bitmap	D0: VideoFrameStart D1: VideoFrameIDValid D2: HDCPOn D3: HDCPValid D4: SIPSequenceNrValid D15..5: Reserved. Shall be set to 0.
2	**bVideoFrameID**	1	Number	VideoFrame ID.
3	**bReserved**	1	Number	Reserved. Shall be set to zero.
4	**dStreamCtr**	4	Number	The streamCtr value as assigned by the HDPC transmitter.
8	**qInputCtr**	8	Number	The inputCtr value associated with the first full 16-byte encrypted data block in the SIP.
16	**wSIPSequenceNr**	2	Number	Sequence Number of the SIP.
18	**Reserved**	14	Number	Reserved. Shall be set to zero.

The **wFlags** field provides information about the subsequent fields of the AVHeader as follows:

- Bit D0 (VideoFrameStart) indicates whether this SIP is the first SIP of a VideoFrame (D0=0b1) or not (D0=0b0). If set, this means that the first VideoSample in the SIP corresponds to VideoSample (0) of the new VideoFrame. Support for the VideoFrameStart bit is required for all implementations.
- Bit D1 (VideoFrameIDValid) indicates whether the **bVideoFrameID** field contains a valid value (D1=0b1) or not (D1=0b0). Implementations are allowed to always set the VideoFrameIDValid bit to 0b0, effectively indicating that they do not support a VideoFrame ID.
- Bit D2 (HDCPOn) indicates whether the current VideoStream is protected and is HDCP-encrypted (D2=0b1) or not (D2=0b0).
- Bit D3 (HDCPValid) indicates whether the **dStreamCtr** and **qInputCtr** fields contain valid values (D3=0b1) or not (D3=0b0).
- Bit D4 (SIPSequenceNrValid) indicates whether the **wSIPSequenceNr** field contains a valid value (D4=0b1) or not (D4=0b0). Implementations are allowed to always set the SIPSequenceNrValid bit to 0b0, effectively indicating that they do not support a SIP Sequence Number. However, for error recovery reasons, it is highly recommended that implementations support the SIP Sequence Number feature.
- Bits D15..5 are reserved and shall be set to zero.

The **bVideoFrameID** field contains the VideoFrame ID of the current VideoFrame. The VideoFrame ID is a counter value that is incremented by one for every new VideoFrame and rolls over to zero (0x00) when the value 255 (0xFF) is reached. If the VideoFrameIDValid bit in the **wFlags** field is not set, then the transmitter should set the **bVideoFrameID** field to zero and the receiver shall ignore the **bVideoFrameID** field.

The **bReserved** field shall be set to zero.

The **dStreamCtr** and **qInputCtr** fields are used by the HDCP protection mechanism. Whenever the isochronous pipe is transporting protected content, the HDCPOn bit in the **wFlags** field shall be set in the AVHeader of every SIP containing

protected Video Data. When the HDCPOn bit in the **wFlags** field is not set, then the HDCP-related fields are irrelevant and the transmitter should set them to zero and the receiver shall ignore them.

The HDCP-related fields shall have valid information at least at the beginning of each VideoFrame but may be valid more frequently. They are only relevant when the HDCPValid bit in the **wFlags** field is set. When the HDCPValid bit in the **wFlags** field is not set, the transmitter should set these fields to zero and the receiver shall ignore them.

- The **dStreamCtr** field contains the *streamCtr* value associated with the VideoStream as assigned by the HDCP transmitter.
- The **qInputCtr** field contains the *inputCtr* value associated with the first full 16-byte encrypted data block in the SIP.

The **wSIPSequenceNr** field contains the sequence number of the SIP. The SIP that contains the first Video Data associated with a VideoFrame shall have sequence number zero. Subsequent SIPs shall have monotonically incrementing (by one) sequence numbers.

The **Reserved** field is reserved and shall be set to zero.

6.2. VideoPayload

The VideoFrame VideoPayload shall be constructed according to one of the data layouts as described in Section 2.5.1, "Type I Format" and Section 2.5.2, "Type II Format. In all cases, the VideoPayload shall be 16-byte aligned. This is accomplished by zero-padding the actual VideoPayload to the nearest multiple of 16 bytes. The receiver can always calculate the number of padding bytes using the VideoFrame dimensional parameters and the value of the `<videoSIPSize>` element of the `<videoIsoStreamConfig>` Description.

6.3. Error Recovery

Isochronous pipes put an emphasis on timely delivery of the data rather than guaranteed delivery. Therefore, there are no retry mechanisms in place should a USB packet get corrupted during transmission. However, since all SIPs contain the same amount of VideoSamples (except for the last SIP of a VideoFrame), a receiver may be able to calculate exactly how many VideoSamples were lost in transmission and correctly position the remaining VideoSamples in the current VideoFrame.

Furthermore, each AVHeader contains a SIP sequence number so that the receiver can easily detect missing SIPs and can even account for a missing SIP that contains the first VideoPayload associated with a VideoFrame.

The receiver can use different types of error concealment to account for the lost VideoSamples. For example, if a frame buffer is available, the VideoSamples of the previous VideoFrame that correspond to the lost VideoSamples may be used to replace the lost VideoSamples.

7. Support for Content Protection

This specification allows the transport of video content that is subject to Digital Right Management rules. These rules imply the existence of robust link protection when this type of content is transported over the USB. The USB AV Device Class Definition relies on the content protection framework protocol provided by the USB Content Security Device Class Definition ([USBCS]) and mandates HDCP 2.1 as the encryption scheme to avoid transmission of content in the clear. The USB version of the HDCP 2.1 implementation is fully defined in the Content Security Method #5 specification ([USBCSM-5]). In-band provisions have been made here to allow compliant deployment of Content Security Method #5 (HDCP 2.1).

When link protection is enabled, only the VideoPayload shall be encrypted using HDCP 2.1 tools, whereas the AVHeader remains in the clear. The AVHeader shall include proper settings for the HDCPOn and HDCPValid bits in the **wFlags** field, and the **dStreamCtr** and **qInputCtr** fields, as described in Section 6.1, "AVHeader".

The HDCP information shall not be included unless it is certain that the receiver of the video content is HDCP-capable. The mechanisms for making this determination over USB are described in [USBCSM-5].

Each VideoStream Configuration (see Section 2.6, "VideoStreamConfig") reports in its VideoStreamConfig Description whether the HDCP Protocol is supported for that VideoStream Configuration through the `<@hdcp>` attribute.

Appendix A. VideoFrame Format Dimensions and Timings

The following sections summarize all VideoFrame related dimensions and timings that fully describe each VideoFrame Format. For more details, refer to Section 2.4.3, "VideoFrame Spatial Layout and Timing Aspects" and Section 2.4.4, "VideoFrame Organization".

A.1. DTV Formats

The following tables present the VideoFrame related dimensions and timings that fully describe the VideoFrame Format as defined by [CEA-861-E]. Note that only a subset of the [CEA-861-E]-defined formats is supported by this specification. All VideoFrame Formats are progressive scan. The Video Identification Code (VIC) as defined in [CEA-861-E] is indicated as a reference.

For the 2D Frame Organization, the VideoFrame Format describes the dimensions and timings of the actual single channel VideoFrame.

For all of the 3D2 Half Resolution Organizations (3D2TAB, 3D2SHOE, 3D2SHOO, 3D2SHEO, 3D2SHEE), the VideoFrame Format describes the dimensions and timings of the resulting VideoFrame after both Left and Right VideoFrame have been subsampled in half by either dropping every other line (3D2TAB) or by dropping every other column (all the 3D2SHxx Frame Organizations) and then merging the 2 subsampled VideoFrames into one resulting VideoFrame. Due to the subsampling by 2 and then the merging of the 2 subsampled VideoFrames into one resulting VideoFrame, this resulting VideoFrame has the exact same dimensions and timings as its corresponding 2D VideoFrame. Therefore, the same table applies to both the 2D Frame Organizations and all of the 3D Half Resolution Frame Organizations.

The following notations are used in the table:

- F: VideoFrame Rate (in Hz)
- VFID: VideoFrame Format ID used to identify the VideoFrame Format
- VFLVC: VideoFrame Format Legacy View Code used to identify the VideoFrame Format while in Legacy View
- VIC: Video Identification Code
- Aspect: The aspect ratio of the VideoFrame
- W_a: Active VideoFrame Width (in VideoSamples)
- H_a: Active VideoFrame Height (in VideoLines)
- W_t: Total VideoFrame Width (in VideoSamples)
- H_t: Total VideoFrame Height (in VideoLines)
- F_{vs}: VideoSample Rate (pixelclock) (in MHz) – for informational purposes only

Table A-1: DTV VideoFrame Dimensions and Timings for 2D and 3D2TAB/3D2SHxx Frame Organizations

F	VFID	VFLVC	VIC	Aspect	W_a	H_a	W_t	H_t	F_{vs}
60	640X480P	0x0002	1	4:3	640	480	800	525	25.200
60	720X480P	0x0004	2	4:3	720	480	858	525	27.027
60	720X480PH	0x0006	3	16:9	720	480	858	525	27.027
120	720X480P	0x0004	48	4:3	720	480	858	525	54.054
240	720X480P	0x0004	56	4:3	720	480	858	525	108.108
50	720X576P	0x0008	17	4:3	720	576	864	625	27.000
100	720X576P	0x0008	42	4:3	720	576	864	625	54.000
200	720X576P	0x0008	52	4:3	720	576	864	625	108.000
24	1280X720P	0x000A	60	16:9	1280	720	3300	750	59.400
25	1280X720P	0x000A	61	16:9	1280	720	3960	750	74.250
30	1280X720P	0x000A	62	16:9	1280	720	3300	750	74.250
50	1280X720P	0x000A	19	16:9	1280	720	1980	750	74.250

F	VFID	VFLVC	VIC	Aspect	W_a	H_a	W_t	H_t	F_{vs}
60	1280X720P	0x000A	4	16:9	1280	720	1650	750	74.250
100	1280X720P	0x000A	41	16:9	1280	720	1980	750	148.500
120	1280X720P	0x000A	47	16:9	1280	720	1650	750	148.500
24	1920X1080P	0x000C	32	16:9	1920	1080	2750	1125	74.250
25	1920X1080P	0x000C	33	16:9	1920	1080	2640	1125	74.250
30	1920X1080P	0x000C	34	16:9	1920	1080	2200	1125	74.250
50	1920X1080P	0x000C	31	16:9	1920	1080	2640	1125	148.500
60	1920X1080P	0x000C	16	16:9	1920	1080	2200	1125	148.500
100	1920X1080P	0x000C	64	16:9	1920	1080	2640	1125	297.000
120	1920X1080P	0x000C	63	16:9	1920	1080	2200	1125	297.000

For the 3D2FP Frame Organization, the situation is different. The overall VideoFrame timing is maintained by doubling the VideoSample Rate to account for the fact that double the number of VideoSamples is present.

There are two possible VideoFormat representations when transporting the 3D2FP Frame Organization over USB:

- The Active Space is suppressed and is not sent over USB ($S_a = 0$).
- The Active Space is included in the VideoPayload sent over USB. The VFIDs reflect this through the –AS suffix.

The following table contains the detailed VideoFrame dimensions and timings. Note that the values for F_{vs} are double those of the previous table.

The following notations are used in the table:

- F: VideoFrame Rate (in Hz)
- VFID: VideoFrame Format ID used to identify the VideoFrame Format
- VFLVC: VideoFrame Format Legacy View Code used to identify the VideoFrame Format while in Legacy View
- VIC: Video Identification Code
- Aspect: The aspect ratio of the VideoFrame
- W_a: Active VideoFrame Width (in VideoSamples)
- H_a: Active VideoFrame Height (in VideoLines) for the Left and the Right VideoFrame
- S_a: Indicates the size of the Active Space (in VideoLines)
- H_{at}: Total Active VideoFrame Height (in VideoLines): $2 * H_a + S_a$
- W_t: Total VideoFrame Width (in VideoSamples)
- H_t: Total VideoFrame Height (in VideoLines)
- F_{vs}: VideoSample Rate (pixelclock) (in MHz) – for informational purposes only

Table A-2: DTV VideoFrame Dimensions and Timings for the 3D2FP Frame Organization

F	VFID	VFLVC	VIC	Aspect	W_a	H_a	S_a	H_{at}	W_t	H_t	F_{vs}
60	640X480P	0x0002	1	4:3	640	480	0	960	800	1050	50.400
60	640X480PAS	0x0003	1	4:3	640	480	45	1005	800	1050	50.400
60	720X480P	0x0004	2	4:3	720	480	0	960	858	1050	54.054
60	720X480PAS	0x0005	2	4:3	720	480	45	1005	858	1050	54.054
60	720X480PH	0x0006	3	16:9	720	480	0	960	858	1050	54.054
60	720X480PHAS	0x0007	3	16:9	720	480	45	1005	858	1050	54.054
120	720X480P	0x0004	48	4:3	720	480	0	960	858	1050	108.108
120	720X480PAS	0x0005	48	4:3	720	480	45	1005	858	1050	108.108
240	720X480P	0x0006	56	4:3	720	480	0	960	858	1050	216.216
240	720X480PAS	0x0007	56	4:3	720	480	45	1005	858	1050	216.216

F	VFID	VFLVC	VIC	Aspect	W_a	H_a	S_a	H_{at}	W_t	H_t	F_{vs}
50	720X576P	0x0008	17	4:3	720	576	0	1152	864	1250	54.000
50	720X576PAS	0x0009	17	4:3	720	576	49	1201	864	1250	54.000
100	720X576P	0x0008	42	4:3	720	576	0	1152	864	1250	108.000
100	720X576PAS	0x0009	42	4:3	720	576	49	1201	864	1250	108.000
200	720X576P	0x0008	52	4:3	720	576	0	1152	864	1250	216.000
200	720X576PAS	0x0009	52	4:3	720	576	49	1201	864	1250	216.000
24	1280X720P	0x000A	60	16:9	1280	720	0	1440	3300	1500	118.800
24	1280X720PAS	0x000B	60	16:9	1280	720	30	1470	3300	1500	118.800
25	1280X720P	0x000A	61	16:9	1280	720	0	1440	3960	1500	148.500
25	1280X720PAS	0x000B	61	16:9	1280	720	30	1470	3960	1500	148.500
30	1280X720P	0x000A	62	16:9	1280	720	0	1440	3300	1500	148.500
30	1280X720PAS	0x000B	62	16:9	1280	720	30	1470	3300	1500	148.500
50	1280X720P	0x000A	19	16:9	1280	720	0	1440	1980	1500	148.500
50	1280X720PAS	0x000B	19	16:9	1280	720	30	1470	1980	1500	148.500
60	1280X720P	0x000A	4	16:9	1280	720	0	1440	1650	1500	148.500
60	1280X720PAS	0x000B	4	16:9	1280	720	30	1470	1650	1500	148.500
100	1280X720P	0x000A	41	16:9	1280	720	0	1440	1980	1500	297.000
100	1280X720PAS	0x000B	41	16:9	1280	720	30	1470	1980	1500	297.000
120	1280X720P	0x000A	47	16:9	1280	720	0	1440	1650	1500	297.000
120	1280X720PAS	0x000B	47	16:9	1280	720	30	1470	1650	1500	297.000
24	1920X1080P	0x000C	32	16:9	1920	1080	0	2160	2750	2250	148.500
24	1920X1080PAS	0x000D	32	16:9	1920	1080	45	2205	2750	2250	148.500
25	1920X1080P	0x000C	33	16:9	1920	1080	0	2160	2640	2250	148.500
25	1920X1080PAS	0x000D	33	16:9	1920	1080	45	2205	2640	2250	148.500
30	1920X1080P	0x000C	34	16:9	1920	1080	0	2160	2200	2250	148.500
30	1920X1080PAS	0x000D	34	16:9	1920	1080	45	2205	2200	2250	148.500
50	1920X1080P	0x000C	31	16:9	1920	1080	0	2160	2640	2250	297.000
50	1920X1080PAS	0x000D	31	16:9	1920	1080	45	2205	2640	2250	297.000
60	1920X1080P	0x000C	16	16:9	1920	1080	0	2160	2200	2250	297.000
60	1920X1080PAS	0x000D	16	16:9	1920	1080	45	2205	2200	2250	297.000
100	1920X1080P	0x000C	64	16:9	1920	1080	0	2160	2640	2250	594.000
100	1920X1080PAS	0x000D	64	16:9	1920	1080	45	2205	2640	2250	594.000
120	1920X1080P	0x000C	63	16:9	1920	1080	0	2160	2200	2250	594.000
120	1920X1080PAS	0x000D	63	16:9	1920	1080	45	2205	2200	2250	594.000

A.2. Additional Formats

The following table presents the VideoFrame related dimensions and timings that fully describe each VideoFrame Format that are commonly used in PC Monitor environments. All VideoFrame Formats are progressive scan.

For the 2D Frame Organization, the VideoFrame Format describes the dimensions and timings of the actual single channel VideoFrame.

For all of the 3D2 Half Resolution Organizations (3D2TAB, 3D2SHOE, 3D2SHOO, 3D2SHEO, 3D2SHEE), the VideoFrame Format describes the dimensions and timings of the resulting VideoFrame after both Left and Right VideoFrame have been subsampled in half by either dropping every other line (3D2TAB) or by dropping every other

column (all the 3D2SHxx Frame Organizations) and then merging the 2 subsampled VideoFrames into one resulting VideoFrame. Due to the subsampling by 2 and then the merging of the 2 subsampled VideoFrames into one resulting VideoFrame, this resulting VideoFrame has the exact same dimensions and timings as its corresponding 2D VideoFrame. Therefore, the same table applies to both the 2D Frame Organizations and all of the 3D Half Resolution Frame Organizations.

The following notations are used in the table:

- F: VideoFrame Rate (in Hz)
- VFID: VideoFrame Format ID used to identify the VideoFrame Format
- VFLVC: VideoFrame Format Legacy View Code used to identify the VideoFrame Format while in Legacy View
- Aspect: The aspect ratio of the VideoFrame
- W_a: Active VideoFrame Width (in VideoSamples)
- H_a: Active VideoFrame Height (in VideoLines)
- W_t: Total VideoFrame Width (in VideoSamples)
- H_t: Total VideoFrame Height (in VideoLines)
- F_{vs}: VideoSample Rate (pixelclock) (in MHz) – for informational purposes only

Table A-3: Additional VideoFrame Dimensions and Timings for 2D and 3D2TAB/3D2SHxx Frame Organizations

F	VFID	VFLVC	Aspect	W_a	H_a	W_t	H_t	F_{vs}
100	640X480P	0x0002	4:3	640	480	848	509	43.160
60	768X576P	0x000E	4:3	768	576	976	597	34.960
100	768X576P	0x000E	4:7	768	576	1024	611	62.570
60	800X600P	0x0010	4:3	800	600	1056	628	40.000
100	800X600P	0x0010	4:3	800	600	1072	636	68.180
60	1024X768P	0x0012	4:3	1024	768	1344	806	65.000
100	1024X768P	0x0012	4:3	1024	768	1392	814	113.310
60	1152X864P	0x0014	4:3	1152	864	1520	895	81.620
100	1152X864P	0x0014	4:3	1152	864	1568	915	143.470
60	1280X768P	0x0016	5:3	1280	768	1664	798	79.672
60	1280X800P	0x0018	16:10	1280	800	1680	828	83.460
60	1280X960P	0x001A	16:9	1280	960	1712	994	102.100
60	1280X960P_1	0x001C	16:9	1280	960	1800	1000	108.000
100	1280X960P	0x001A	16:9	1280	960	1760	1017	178.990
60	1280X1024P	0x001E	5:3	1280	1024	1688	1066	108.000
100	1280X1024P	0x001E	5:3	1280	1024	1760	1085	190.960
60	1368X768P	0x0020	16:9	1368	768	1800	795	85.860
60	1400X1050P	0x0022	4:3	1400	1050	1880	1082	122.000
60	1400X1050P_1	0x0024	4:3	1400	1050	1880	1087	122.610
100	1400X1050P	0x0022	4:3	1400	1050	1928	1112	214.390
60	1440X900P	0x0026	16:10	1440	900	1904	932	106.470
60	1600X900P	0x0028	16:9	1600	900	2128	932	118.998
60	1600X1200P	0x002A	4:3	1600	1200	1920	1250	144.000
60	1600X1200P_1	0x002C	4:3	1600	1200	2160	1250	162.000
100	1600X1200P	0x002A	4:3	1600	1200	2208	1271	280.640
60	1680X1050P	0x002E	16:10	1680	1050	2256	1087	147.140
60	1792X1344P	0x0030	4:3	1792	1344	2448	1394	204.800
60	1856X1392P	0x0032	4:3	1856	1392	2528	1439	218.300

F	VFID	VFLVC	Aspect	W_a	H_a	W_t	H_t	F_{vs}
60	1920X1200P	0x0034	16:10	1920	1200	2592	1242	193.160
60	1920X1440P	0x0036	4:3	1920	1440	2600	1500	234.000
*	VENDOR	0xFFFE	*	*	*	*	*	*

* Defined by Vendor

For the 3D2FP Frame Organization, the situation is different. The overall VideoFrame timing is maintained by doubling the VideoSample Rate to account for the fact that double the number of VideoSamples is present.

There are two possible VideoFormat representaions when transporting the 3D2FP Frame Organization over USB:

- The Active Space is suppressed and is not sent over USB ($S_a = 0$).
- The Active Space is included in the VideoPayload sent over USB. The VFIDs reflect this through the –AS suffix.

The following table contains the detailed VideoFrame dimensions and timings. Note that the values for F_{vs} are double those of the previous table.

The following notations are used in the table:

- F: VideoFrame Rate (in Hz)
- VFID: VideoFrame Format ID used to identify the VideoFrame Format
- VFLVC: VideoFrame Format Legacy View Code used to identify the VideoFrame Format while in Legacy View
- Aspect: The aspect ratio of the VideoFrame
- W_a: Active VideoFrame Width (in VideoSamples)
- H_a: Active VideoFrame Height (in VideoLines) for the Left and the Right VideoFrame
- S_a: Indicates the size of the Active Space (in VideoLines)
- H_{at}: Total Active VideoFrame Height (in VideoLines): $2 * H_a + S_a$
- W_t: Total VideoFrame Width (in VideoSamples)
- H_t: Total VideoFrame Height (in VideoLines)
- F_{vs}: VideoSample Rate (pixelclock) (in MHz) – for informational purposes only

Table A-4: Additional VideoFrame Dimensions and Timings for the 3D2FP Frame Organization

F	VFID	VFLVC	Aspect	W_a	H_a	S_a	H_{at}	W_t	H_t	F_{vs}
100	640X480P	0x0002	4:3	640	480	0	960	848	1018	86.320
100	640X480PAS	0x0003	4:3	640	480	29	989	848	1018	86.320
60	768X576P	0x000E	4:3	768	576	0	1152	976	1194	69.920
60	768X576PAS	0x000F	4:3	768	576	21	1173	976	1194	69.920
100	768X576P	0x000E	4:7	768	576	0	1152	1024	1222	125.140
100	768X576PAS	0x000F	4:7	768	576	35	1187	1024	1222	125.140
60	800X600P	0x0010	4:3	800	600	0	1200	1056	1256	80.000
60	800X600PAS	0x0011	4:3	800	600	28	1228	1056	1256	80.000
100	800X600P	0x0010	4:3	800	600	0	1200	1072	1272	136.360
100	800X600PAS	0x0011	4:3	800	600	36	1236	1072	1272	136.360
60	1024X768P	0x0012	4:3	1024	768	0	1536	1344	1612	130.000
60	1024X768PAS	0x0013	4:3	1024	768	38	1574	1344	1612	130.000
100	1024X768P	0x0012	4:3	1024	768	0	1536	1392	1628	226.620
100	1024X768PAS	0x0013	4:3	1024	768	46	1582	1392	1628	226.620
60	1152X864P	0x0014	4:3	1152	864	0	1728	1520	1790	163.240
60	1152X864PAS	0x0015	4:3	1152	864	31	1759	1520	1790	163.240
100	1152X864P	0x0014	4:3	1152	864	0	1728	1568	1830	286.940

F	VFID	VFLVC	Aspect	W_a	H_a	S_a	H_{at}	W_t	H_t	F_{vs}
100	1152X864PAS	0x0015	4:3	1152	864	51	1779	1568	1830	286.940
60	1280X768P	0x0016	5:3	1280	768	0	1536	1664	1596	159.344
60	1280X768PAS	0x0017	5:3	1280	768	30	1566	1664	1596	159.344
60	1280X800P	0x0018	16:10	1280	800	0	1600	1680	1656	166.920
60	1280X800PAS	0x0019	16:10	1280	800	28	1628	1680	1656	166.920
60	1280X960P	0x001A	16:9	1280	960	0	1920	1712	1988	204.200
60	1280X960PAS	0x001B	16:9	1280	960	34	1954	1712	1988	204.200
60	1280X960P_1	0x001C	16:9	1280	960	0	1920	1800	2000	216.000
60	1280X960P_1AS	0x001D	16:9	1280	960	40	1960	1800	2000	216.000
100	1280X960P	0x001A	16:9	1280	960	0	1920	1760	2034	357.980
100	1280X960PAS	0x001B	16:9	1280	960	57	1977	1760	2034	357.980
60	1280X1024P	0x001E	5:3	1280	1024	0	2048	1688	2122	216.000
60	1280X1024PAS	0x001F	5:3	1280	1024	42	2090	1688	2122	216.000
100	1280X1024P	0x001E	5:3	1280	1024	0	2048	1760	2170	381.920
100	1280X1024PAS	0x001F	5:3	1280	1024	61	3009	1760	2170	381.920
60	1368X768P	0x0020	16:9	1368	768	0	1536	1800	1590	171.720
60	1368X768PAS	0x0021	16:9	1368	768	27	1563	1800	1590	171.720
60	1400X1050P	0x0022	4:3	1400	1050	0	2100	1880	2164	244.000
60	1400X1050PAS	0x0023	4:3	1400	1050	32	2132	1880	2164	244.000
60	1400X1050P_1	0x0024	4:3	1400	1050	0	2100	1880	1087	244.320
60	1400X1050P_1AS	0x0025	4:3	1400	1050	37	2137	1880	1087	244.320
100	1400X1050P	0x0022	4:3	1400	1050	0	2100	1928	1112	428.780
100	1400X1050PAS	0x0023	4:3	1400	1050	62	2162	1928	1112	428.780
60	1440X900P	0x0026	16:10	1440	900	0	1800	1904	1864	212.940
60	1440X900PAS	0x0027	16:10	1440	900	32	1832	1904	1864	212.940
60	1600X900P	0x0028	16:9	1600	900	0	1800	2128	1864	237.996
60	1600X900PAS	0x0029	16:9	1600	900	32	1832	2128	1864	237.996
60	1600X1200P	0x002A	4:3	1600	1200	0	2400	1920	2500	288.000
60	1600X1200PAS	0x002B	4:3	1600	1200	50	2450	1920	2500	288.000
60	1600X1200P_1	0x002C	4:3	1600	1200	0	2400	2160	2500	324.000
60	1600X1200P_1AS	0x002D	4:3	1600	1200	50	2450	2160	2500	324.000
100	1600X1200P	0x002A	4:3	1600	1200	0	2400	2208	2542	561.280
100	1600X1200PAS	0x002B	4:3	1600	1200	71	2471	2208	2542	561.280
60	1680X1050P	0x002E	16:10	1680	1050	0	2100	2256	2174	294.280
60	1680X1050PAS	0x002F	16:10	1680	1050	37	2137	2256	2174	294.280
60	1792X1344P	0x0030	4:3	1792	1344	0	2688	2448	2788	409.600
60	1792X1344PAS	0x0031	4:3	1792	1344	50	2738	2448	2788	409.600
60	1856X1392P	0x0032	4:3	1856	1392	0	2784	2528	2878	436.600
60	1856X1392PAS	0x0033	4:3	1856	1392	47	2831	2528	2878	436.600
60	1920X1200P	0x0034	16:10	1920	1200	0	2400	2592	2484	386.320
60	1920X1200PAS	0x0035	16:10	1920	1200	42	2442	2592	2484	386.320
60	1920X1440P	0x0036	4:3	1920	1440	0	2880	2600	3000	468.000

F	VFID	VFLVC	Aspect	W_a	H_a	S_a	H_{at}	W_t	H_t	F_{vs}
60	1920X1440PAS	0x0037	4:3	1920	1440	60	2940	2600	3000	468.000
*	VENDOR	0xFFFE	*	*	*	*	*	*	*	*
*	VENDORAS	0xFFFF	*	*	*	*	*	*	*	*

* Defined by Vendor

Appendix B. Calculations

These calculations relate to the "Video & USB Timings" spreadsheet, that is an integral part of this document. The spreadsheet contains two separate tables, one for the 2D ad all 3D2 Half Resolution Frame Organizations, and one for the 3D2FP Frame Organization.

The numbers between brackets are repeated in the corresponding headers of the columns in the spreadsheet.

(0.1) VideoFrame Rate (in Hz): F

(0.2) VideoFrame Time (in seconds): $T = 1/F$

(0.3) Service Interval (in seconds): T_{SI}

(0.4) Bits per VideoSample: b_{vs}

(0.5) Bytes per VideoSample: $B_{vs} = b_{vs}/8$

(1) Active VideoFrame Width (in VideoSamples): W_a

(2a) Active VideoFrame Height (in VideoLines) for both Left and Right VideoFrame (if applicable): H_a

(2b) Active Space (in VideoLines): S_a

(2) Total Active VideoFrame Height (in VideoLines): $H_{at} = 2 * H_a + S_a$

(3) Total (active) VideoSamples in the VideoFrame: $N = W_a * H_{at}$

(4) Inactive VideoSamples in a VideoLine: W_i

(5) Total VideoSamples in a VideoLine: $W_t = W_a + W_i$

(6) Inactive VideoLines in a VideoFrame: H_i

(7) Total VideoLines in a VideoFrame: $H_t = H_{at} + H_i$

(8) Total (active+inactive) VideoSamples in the VideoFrame: $N_t = W_t * H_t$

(9) Ratio Active Total VideoSamples/VideoLine: R_{vsat}

(10) Ratio Active Total VideoLines/VideoFrame: R_{Lat}

(11) VideoSample Time (in seconds): $T_{vs} = T/N_t$

(12) VideoSample Frequency (Pixelclock) (in Hz): $F_{vs} = 1/T_{vs} = N_t/T$

(13) Active Line Time (in seconds): $T_{La} = W_a * T_{vs}$

(14) Inactive Line Time (in seconds) i.e. Horizontal Blanking (HB): $T_{Li} = W_i * T_{vs}$

(15) Total Line Time (in seconds): $T_{Lt} = W_t * T_{vs} = (W_a + W_i) * T_{vs}$

(16) Active VideoFrame Time (in seconds): $T_a = T - T_i$

(17) Inactive VideoFrame Time (in seconds) i.e. Vertical Blanking (VB): $T_i = H_i * T_{Lt}$

(18) Number of SI during the VideoFrame: $R_{SIpf} = T/T_{SI}$

(19) Useable Integer Number of SI during the VideoFrame (taking into account the required Transfer delimiter):

$N_{SIpf} = INT(R_{SIpf}) - 1$

(20) VideoPayload per useable SI (in VideoSamples and rounded up): $N_{pSI} = CEILING(N/N_{SIpf})$

(21) VideoPayload per VideoFrame (in Bytes): $N_{BpSI} = N_{pSI} * B_{vs}$

(22) Header Length (in Bytes): $N_H = 32$

Option 1: Derive Desired VideoPayload per SI from Minimum BW considerations

- Spread total VideoPayload as evenly as possible over useable SIs.
- Include Safety guardband for fluctuations in VideoFrame Rate (in %): $Safety$
- (23.1a) Option 1: Desired VideoPayload per SI (rounded down to a complete VideoSample:

  $$N_{BpSI}^{1} = INT\left(N_{BpSI} * \frac{\left(1 + \frac{Safety}{100}\right)}{B_{vs}}\right) * B_{vs}$$

- (23.1b) Desired VideoPayload per SI (including AVHeader):

  $$N_{(H+B)pSI}^{1} = N_H + N_{BpSI}^{1}$$

Option 2: Derive Desired VideoPayload per SI from an integer (minimum) number of VideoLines per SI

- (23.2a) Average VideoLines per SI: $R_{LpSI} = H_{at}/R_{SIpf}$
- (23.2b) Full VideoLines per SI: $N_{LpSI} = CEILING(R_{LpSI}, 1)$
- (23.2c) Manually adjust number of lines: $N_{LpSI} = N_{LpSI} + 0|1|2$
- (23.2d) Associated VideoPayload per SI: $N_{BpSI}^{2} = N_{LpSI} * W_a * B_{vs}$
- (23.2e) Total (Including AVHeader) Payload per SI (in Bytes): $N_{(H+B)pSI}^{2} = N_H + N_{BpSI}^{2}$

(23) Desired VideoPayload per SI: $N_{(H+B)pSI}^{1|2}$

(24) Overflow Indicator colors those entries that surpass USB3.0 bandwidth possibilities red

(25) SI needed to transport VideoFrame: $R_{SIpF}^{1|2} = N_{Bpf}/N_{(H+B)pSI}^{1|2}$

(26) Integer SI needed to transport VideoFrame: $N_{SIpF}^{1|2} = INT\left(R_{SIpF}^{1|2}\right)$

(27) Remaining Bytes in last SI: $N_{BLastSI}^{1|2} = N_{Bpf} - \left(N_{SIpF}^{1|2} * N_{BpSI}^{1|2}\right) + N_H$

(28) Bus Transactions needed for full-length Total Payload: $N_{trans}^{1|2} = CEILING\left(\frac{N_{(H+B)pSI}^{1|2}}{1024}, 1\right)$

(29) Mult: $Mult^{1|2} = ((N_{trans}^{1|2} - 1)\ DIV\ 16) - 1$

(30) MaxBurst: $MaxBurst^{1|2} = CEILING\left(\frac{N_{trans}^{1|2}}{Mult^{1|2}}, 1\right)$

(31) Active part of a VideoFrame (in seconds): $T_{aCorr} = T_a - T_{Li}$

- (Recovering the Horizontal Blanking time from the last active VideoLine – probably does not matter)

(32) Number of Full SI during the active part of the VideoFrame: $N_{SIpaf} = INT\left(\frac{T_{aCorr}}{T_{SI}}\right)$

(33) Outgoing VideoPayload during active part of the VideoFrame: $N_{Bpaf}^{1|2} = N_{BpSI}^{1|2} * N_{SIpaf}$

(34) Buffer requirement due to spreading:

IF $N_{Bpf} - N_{Bpaf}^{1|2} \geq 0$ THEN

$$N_{Spread}^{1|2} = N_{Bpf} - N_{Bpaf}^{1|2}$$

ELSE

$$N_{Spread}^{1|2} = 0$$

(35) Buffer requirements due to SI processing: $N_{SIProc} = CEILING(2{*}R_{BpSI}/B_{vs}, 1) * B_{vs}$

- Estimated at 2*SI

(37) Total buffer requirements: $N_{Buffer}^{1|2} = N_{Spread}^{1|2} + N_{SIProc}$