CREATING 4K/UHD CONTENT

POSTER

Tektronix®

Creating 4K/UHD Content

Colorimetry

The television color specification is based on standards defined by the CIE (Commission Internationale de L'Éclairage) in 1931. The CIE specified an idealized set of primary XYZ tristimulus values. This set is a group of all-positive values converted from R'G'B' where Y is proportional to the luminance of the additive mix. This specification is used as the basis for color within 4K/UHDTV1 that supports both ITU-R BT.709 and BT2020.

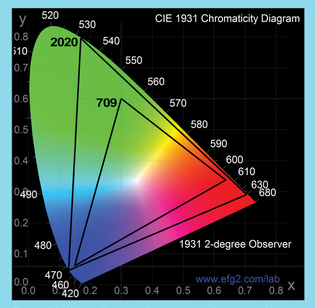


Figure A1: CIE xy diagram with color coordinates used by ITU-R BT 709 and 2020 color spaces.

Table A1: Illuminant (Ill.) Value

Source	X / Y
Illuminant A: Tungsten Filament Lamp, 2854°K	x = 0.4476 y = 0.4075
Illuminant B: Model of Noon Sunlight, 4800°K	x = 0.3484 y = 0.3516
Illuminant C: Model of Average Daylight, 6504°K	x = 0.3101 y = 0.3162
Illuminant D65: Daylight D Series, 6504°K	x = 0.3127 y = 0.3290
Illuminant (SMPTE431-2 DCI P3)	x = 0.3140 y = 0.3510

Table A2: Definition of Luma and Color Difference Values

	Rec 601	Rec 709	Rec 2020
Y'	0.299 R' + 0.587 G' + 0.114 B'	0.2126 R' + 0.7152 G' + 0.0722 B'	0.2627 R' + 0.6780G' + 0.0593B'
P'b	(B' – Y') / 1.772	(B' – Y') / 1.8556	(B' – Y') / 1.8814
P'r	(R' – Y') / 1.402	(R' – Y') / 1.5748	(R' – Y') / 1.4746

Table A3: CIE XY Coordinates for Various Color Gamuts

Gamut	Ill.	Red	Green	Blue
ITU-R BT. 2020	D_{65}	x = 0.708 y = 0.292	x = 0.170 y = 0.797	x = 0.131 y = 0.046
ITU-R BT. 709	D_{65}	x = 0.640 y = 0.330	x = 0.300 y = 0.600	x = 0.150 y = 0.060
SMPTE 431-2 (DCI-P3) XYZ		x = 0.680 y = 0.320	x = 0.265 y = 0.690	x = 0.150 y = 0.060
SMPTE	D_{65}	x = 0.630 y = 0.340	x = 0.310 y = 0.595	x = 0.155 y = 0.070
PAL/SECAM	D_{65}	x = 0.640 y = 0.330	x = 0.290 y = 0.600	x = 0.150 y = 0.060
NTSC (1953)	C	x = 0.670 y = 0.330	x = 0.210 y = 0.710	x = 0.140 y = 0.080

Figure A2. Using a 100% color bar signal to show conversion of RGB levels from 700 mv (100%) to 0mv (0%) for each color component with a color bar split field BT.2020 and BT.709 test signal. The WFM8300 was configured for BT.709 colorimetry as shown in the video session display.

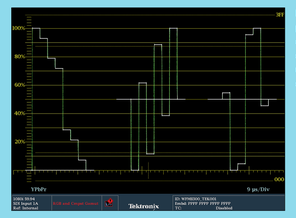


Figure A3. HD YPbPr paraded waveform display with 100% color bar test signal, using BT.709 colorimetry.

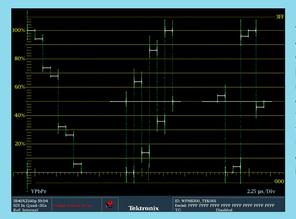


Figure A4. UHDTV1 YPbPr paraded waveform display with 100% color bar test signal, using BT.2020 colorimetry. Notice the difference in the levels between BT.709 and BT.2020 colorimetry shown in Figure A3 and A4.

Image Format / SMPTE Standards

Square Division separates the image into quad links for distribution.

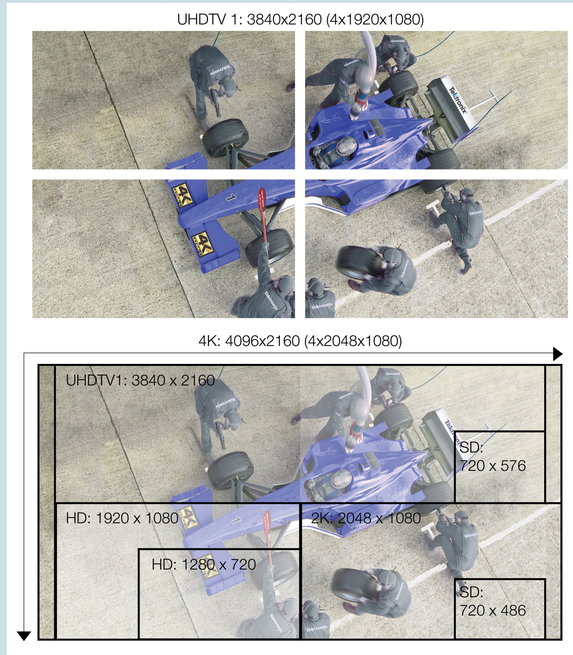


Table B1: SMPTE Standards

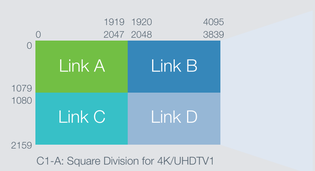
SMPTE	Standards
ST 125	SDTV Component Video Signal Coding for 4:4:4 and 4:2:2 for 13.5 MHz and 18 MHz Systems
ST 240	Television – 1125-Line High-Definition Production Systems – Signal Parameters
ST 259	Television – SDTV Digital Signal/Data – Serial Digital Interface
ST 272	Television – Formatting AES/EBU Audio and Auxiliary Data into Digital Video Ancillary Data Space
ST 274	Television – 1920 x 1080 Image Sample Structure, Digital Representation and Digital Timing Reference Sequences for Multiple Picture Rates
ST 296	1280 x 720 Progressive Image 4:2:2 and 4:4:4 Sample Structure – Analog & Digital Representation & Analog Interface
ST 299-0/1/2	24-Bit Digital Audio Format for SMPTE Bit-Serial Interfaces at 1.5 Gb/s and 3 Gb/s – Document Suite
ST 352	Payload Identification Codes for Serial Digital Interfaces
ST 372	Dual Link 1.5 Gb/s Digital Interface for 1920 x 1080 and 2048 x 1080 Picture Formats
ST 424	3 Gb/s Signal/Data Serial Interface
ST 425-0	(Revision of SMPTE 425-0:2012-06) SMPTE Bit-Serial Interfaces at 3 Gb/s – Roadmap for the 425 Document Suite
ST 425-1	Source Image Format and Ancillary Data Mapping for the 3 Gb/s Serial Interface
ST 425-2	Source Image Format & Ancillary Data Mapping for Stereoscopic Image Formats on a Single-Link 3 Gb/s Serial Interface
ST 425-3	Image Format and Ancillary Data Mapping for the Dual Link 3 Gb/s Serial Interface
ST 425-4	Dual 3 Gb/s Serial Digital Interface for Stereoscopic Image Transport
ST 425-5	Image Format and Ancillary Data Mapping for the Quad Link 3 Gb/s Serial Interface
ST 425-6	Quad 3 Gb/s Serial Digital Interface for Stereoscopic Image Transport
ST 431-1	D-Cinema Quality – Screen Luminance Level, Chromaticity and Uniformity
ST 435-0	10 Gb/s Serial Signal/Data Interface – Roadmap
ST 435-1	10 Gb/s Serial Signal/Data Interface – Part 1: Basic Stream Derivation
ST 435-2	10 Gb/s Serial Signal/Data Interface – Part 2: 10.692 Gb/s Stream – Basic Stream Mapping
ST 435-3	10 Gb/s Serial Signal/Data Interface – Part 3: 10.692 Gb/s Optical Fiber Interface
ST 2036-0	Ultra High Definition Television – Overview for the SMPTE ST 2036 Document Suite
ST 2036-1	Ultra High Definition Television – Image Parameter Values for Program Production
ST 2036-2	Ultra High Definition Television – Audio Characteristics & Audio Channel Mapping for Program Production
ST 2036-3	Ultra High Definition Television – Mapping into Single-link or Multi-link 10 Gb/s Serial Signal/Data Interface
SMPTE 2081-0	SMPTE Bit-Serial Interfaces at 6 Gb/s – Overview for the SMPTE ST 2081 Document Suite
SMPTE ST 2081-1	6 Gb/s Signal/Data Serial Interface – Electrical
SMPTE ST 2081-10	2160-Line and 1080-Line Source Image and Ancillary Data Mapping for Single-Link 6G-SDI
SMPTE 2082-0	12G-SDI Bit-Serial Interfaces – Overview for the SMPTE ST 2082 Document Suite
SMPTE ST 2082-1	12 Gb/s Signal/Data Serial Interface – Electrical
SMPTE ST 2082-10	2160-Line Source Image and Ancillary Data Mapping for 12G-SDI

Transport / Timing

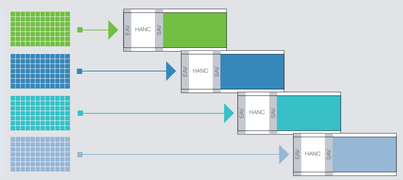
4K/UHDTV1 Quad Link requires that the image be segmented into two or four links depending on the frame rate of the video. In Quad Link there are two processes for segmenting the picture using either square division or two-sample interleave.

Square Division (Tile Mode)

In this process the image is divided into four quadrants and then sent on four separate SDI cables, see Figure C1-A. This process is the simplest method for segmenting the image but requires more memory to store each of the quadrants before assembling the complete image and is commonly used by a variety of post-production equipment.



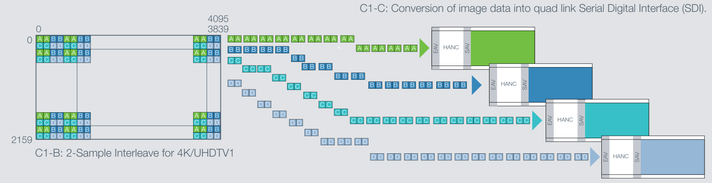
C1-A: Square Division for 4K/UHDTV1



C1-C: Conversion of image data into quad link Serial Digital Interface (SDI).

2-Sample Interleave

In this process groups of two pixels are separated from the image and sent on four different links as shown in Figure C1-B. This method requires less memory to be used and allows groups of pixels to be processed more quickly. However this process requires multiplexing of the data into four separate SDI streams. 2-Sample Interleaving has applications within the transmission process.



C1-B: 2-Sample Interleave for 4K/UHDTV1

Timing

Within Quad link SDI distribution for 4K/UHDTV1 each link will be routed differently within the network. Therefore care should be taken to ensure that each link is received at the device within certain tolerances. SMPTE standards define the timing difference between EAV (End of Active Video) / SAV (Start of Active Video) (see Figure C1-C) of Link A to Link D shall not exceed 400ns at the source. No specification is given for the receiving device and will depend up on the equipment as to how much timing difference the unit can tolerate.

The Tektronix 8000 Series Waveform Monitor and Rasterizers allow for 1024 clocks of timing difference between the inputs and will provide measurement of the timing difference between the inputs (Figure C2).

Table C1: Frame Rate Timing

Ensuring the correct frame delay is critical within these video systems and Table C1 shows the duration in milliseconds for each progressive frames rates.

Frame Rate (Hz)	23.98	24.00	25.00	29.97	30.00	47.95	48.00	50.00	59.94	60.00
Duration (ms)	41.71	41.67	40.00	33.37	33.33	20.86	20.83	20.00	16.68	16.67

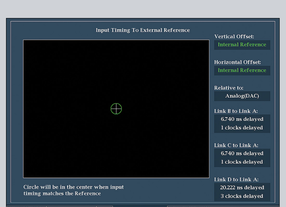


Figure C2. Input timing to external reference shown on the Tektronix WFM/WVR8000 Series Waveform Monitor.

Video Payload Identifier

The SMPTE ST 352 Video Payload Identifier (VPID) is carried within the Ancillary data space to assist a device in quickly decoding the video signal.

The 8000 Series Waveform Monitors and Rasterizers can show the VPID within the video session display and the data values can be found in the Ancillary Data Display or Datalist displays.

The VPID conforms to the SMPTE 291 Ancillary Data Packet and Space Formatting standard and contains the Ancillary Data Flag (ADF), Data Identifier (DID), Secondary Data Identifier (SDID), Data Count, User Data Words (UDW 1-4) and Checksum as shown in Table D1.

Note: There is no specific value to determine 2-Sample Interleave or Square Division. Therefore if the VPID is consistent with ST 425-3 or ST 425-5 we assume sample interleave. If the VPID is standard HD ST 292 or ST 425-1 (3G) the format is consider Square Division. The user can also manually configure this within the instrument.

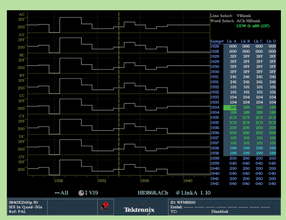


Figure D1. WFM8300 quad link Datalist display show the VPID ANC data for each link.

Table D1. Video Payload Identifier Ancillary Data Packet

Note: Please refer to latest standard for complete details of VPID information.

	Hex	B9	B8	B7	B6	B5	B4	B3	B2	B1	B0
ADF	000	0	0	0	0	0	0	0	0	0	0
	3FF	1	1	1	1	1	1	1	1	1	1
	3FF	1	1	1	1	1	1	1	1	1	1
DID	241	not b8	EP	0	1	0	0	0	0	0	1
SDID	101	not b8	EP	0	0	0	0	0	0	0	1
DC	104	not b8	EP	0	0	0	0	0	1	0	0
UDW 1	XXX	not b8	EP	Version ID	Payload Identifier (See Table D2)						
UDW 2	XXX	not b8	EP	Transport Interface (0) Progressive (1)	Picture Interface (0) Progressive (1)	Reserved 0	Reserved 0	Picture Rate (See Table D3)			
UDW 3	XXX	not b8	EP	Reserved 0[1] Aspect Ratio 4:3 (0), 16:9 (1)	Reserved 0 Horiz: Sampling 1920 (0), 2048 (1)	Reserved 0[2] Aspect Ratio 4:3 (0), 16:9 (1)	Reserved 0[3]	Sampling (See Table D4)			
UDW 4	XXX	not b8	EP	Channel B7 - B6 Single-link or ch1 of multi-channel (0_{10}), ch2 of multi-channel (1_{10}), ch3 of multi-channel (2_{10}), ch4 of multi-channel (3_{10}), ch5 Reserved (0) Channel B6 Dual link A (0h), B(1h)	Channel B7 - B5 Single-link or ch1 of multi-channel (0_{10}), ch2 of multi-channel (1_{10}), ch3 of multi-channel (2_{10}), ch4 of multi-channel (3_{10}), ch5 of multi-channel (4_{10}), ch6 of multi-channel (5_{10}), ch7 of multi-channel (6_{10}), ch8 of multi-channel (7_{10})	Reserved 0	Reserved 0	Reserved 0 Audio – 3G-SDI Link 2 or 2 to 4, (0) carries additional channels or audio not present (1) carries a copy of 3G-SDI Link 1audio	Bit Depth 8-bit (0_{10}), 10-bit (1_{10}), 12-bit (2_{10}), Reserved (3_{10}),	
Checksum	XXX	not b8	EP	Sum of B0-B8 of DID to Payload Byte 4							

[1] B7 used for Aspect Ratio in ST 425-1, 425-3 3G level A, 425-5 Quad Link 3G level A, 2081-10, 2082-10, [2] B5 used for Aspect Ratio in ST 292, 372, 435-1. 425-5 3G level B, [3] Byte B7, B4 or B5-B4 Colorimetry Rec 709*1 (0h) Color VANC Packet (1h) UHDTV*2 (2h) Unknown (3h)

Table D2: SMPTE 352 Video Payload Identifier UDW 1

Byte 1 Bit 7-0		Std. Reference
Decimal	Hex	
129	81h	SMPTE ST 259 SD
132	84h	SMPTE ST 292-1 (720p)
133	85h	SMPTE ST 292-1 (1080)
135	87h	SMPTE ST 372 (Dual Link)
137	89h	SMPTE ST 425-1 (3G Lvl A)
138	8Ah	SMPTE ST 425-1 (3G Lvl B)
140	8Ch	SMPTE ST 425-1 (2x1080 3G B)
144	90h	SMPTE ST 435-1 (10 Gb)
148	94h	SMPTE ST 425-3 (Dual 3G A)
149	95h	SMPTE ST 425-3 (Dual 3G B DL)
150	96h	SMPTE ST 425-3 (Dual 3G B DS)
151	97h	SMPTE ST 425-5 (Quad 3G A)
152	98h	SMPTE ST 425-5 (Quad 3G B)
160	A0h	SMPTE ST 435-1 (0cta 10G)
161	A1h	SMPTE ST 2036-3 (4K 10G)
162	A2h	SMPTE ST 2036-3 (8K 10G)
165	A5h	SMPTE ST 2036-4 (4K 10G)
166	A6h	SMPTE ST 2036-4 (8K 10G)
179	B3h	SMPTE ST 2048-3 (4K 10G)
192	C0h	SMPTE ST 2081-10 Mode 1
193	C1h	SMPTE ST 2081-10 Mode 2
194	C2h	SMPTE ST 2081-11 Mode 1
196	C4h	SMPTE ST 2081-12 Mode 1
206	CEh	SMPTE ST 2082-10 Mode 1
207	CFh	SMPTE ST 2082-10 Mode 2

Table D3. Picture Rate

Value	Picture Rate
0h	No defined value
1h	Reserved
2h	24/1.001
3h	24
4h	48/1.001
5h	25
6h	30/1.001
7h	30
8h	48
9h	50
Ah	60/1.001
Bh	60
Ch	Reserved
Dh	Reserved
Eh	Reserved
Fh	Reserved

Table D4. Sampling Structure

Value	Sampling
0h	4:2:2 (YCbCr)
1h	4:4:4 (YCbCr)
2h	4:4:4 (G/B/R)
3h	4:2:0
4h	4:2:2:4 (YCbCrA)
5h	4:4:4:4 (YCbCrA)
6h	4:4:4:4 (G/B/R/A)
7h	SMPTE ST 2048-2 F-S
8h	4:2:2:4 (YCbCrD)
9h	4:4:4:4 (YCbCrD)
Ah	4:4:4:4 (G/B/R/D)
Bh	Reserved
Ch	Reserved
Dh	Reserved
Eh	Reserved
Fh	Reserved

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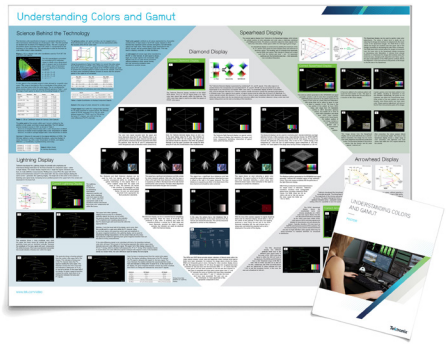
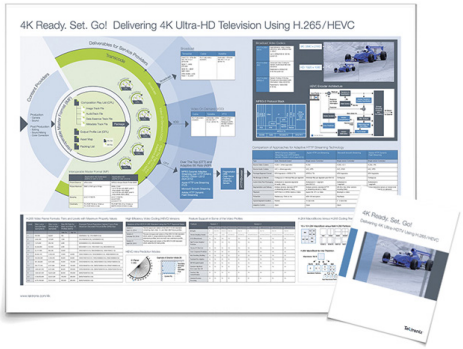


Understanding Colors and Gamut

Our poster on Colors and Gamut explains the science behind the ITU-R BT.2020 Wide Color Gamut (WCG) which has been used in the creation of many 4K/UHD HDR content. It includes explanations of various terms and definitions of HDR colorimetry which empower you to create stunning image content.

A Guide to 4K/UHD Monitoring and Measurement

Learn how to navigate the challenges of creating 4K/UHD content with High Dynamic Range (HDR) and extended color gamut when transitioning from HD to 4K/UHD workflows. Includes: Inter-Channel Timing for Quad Link 4K/UHD Signal, Video Payload Identifier (VPID), Colorimetry (ITU-R BT.709 & BT .2020) and Aspect Ratio Validation of Incoming 4K/UHD Content.



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