

4K Transmission by SDI

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01 What is 4K?

Overview of 4K

Overview

"4K" indicates the pixel number of horizontal direction. "4K" is equal to "4000" because "K" means "1000". Therefore the pixel number of horizontal direction is 4000.

The number of pixel is 1920×1080 in conventional full HD systems. In contrast, that in 4K system increase by 4 times to 3840 (or 4096) $\times 2160$, which can make videos finer.

In this document, we will explain the transmission of 4K signals. There are various method for the transmission, for example, SDI, HDMI, and display ports. We will focus on SDI in particular.

Standard

The quality of video is considered to be determined by five factors; resolution, bit depth, frame rate, color gamut, and luminance.

In 1990, the standard for full HD, which is the current format, was codified by ITU-R Recommendation BT.709. Later, in 2012, the standards for 4K and 8K were codified by ITU-R Recommendation BT.2020. This advanced not only resolution but bit depth, frame rate, color gamut, and luminance, and we can view high-quality videos.

The radar chart below illustrates the video quality by the five factors. Here, larger pentagon means higher video quality.

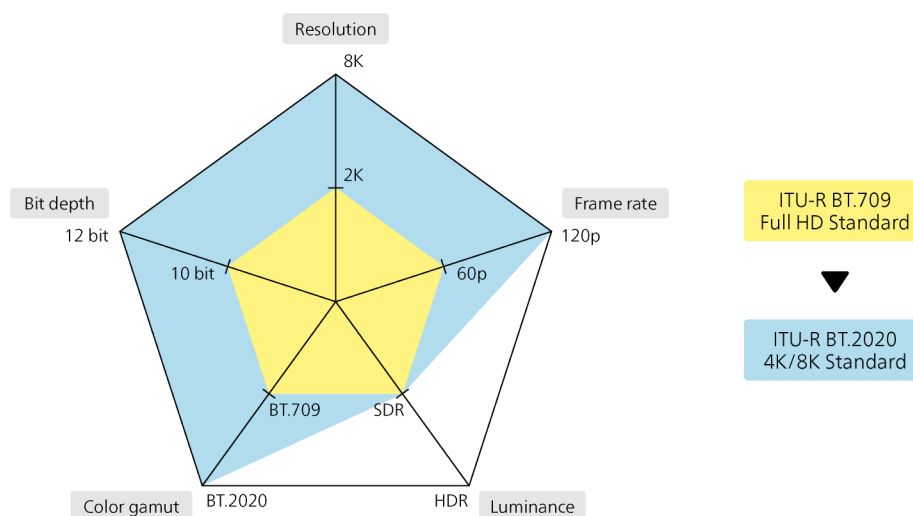


Figure | Rader chart

We will describe more detail on resolution, bit depth, frame rate, and color gamut as follows.

Resolution

Resolution is defined as the pixels number of video.

Resolution in the conventional full HD system (2K) is 1920×1080 , it is extended in the 4K system to 3840 (or 4096) $\times 2160$, which is equivalent to four times that of full HD system.

If display size is same, the area per pixel get smaller as number of pixel increases, which enable it to display videos more in detail.



Figure | 4K (Image)

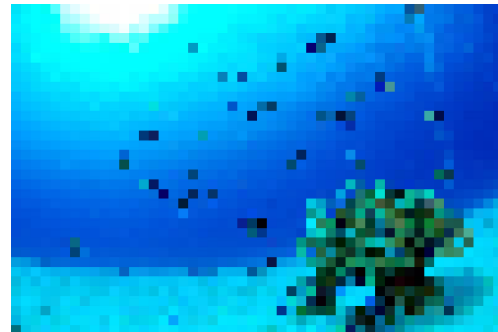


Figure | 2K (Image)

4K formats are categorized to TV broadcast and digital cinemas by their resolution.

The 4K for broadcasts defined by ITU-R* is called "4K UHD TV*", and its resolutions are 3840×2160 . In contrast, that for digital cinemas defined by DCI* is called "DCI 4K", its resolutions are 4096×2160 .

We call both of them "4K" in this documents.

* ITU; International Telecommunication Union

* UHD TV; Ultra High Definition Television

* DCI; Digital Cinema Initiatives

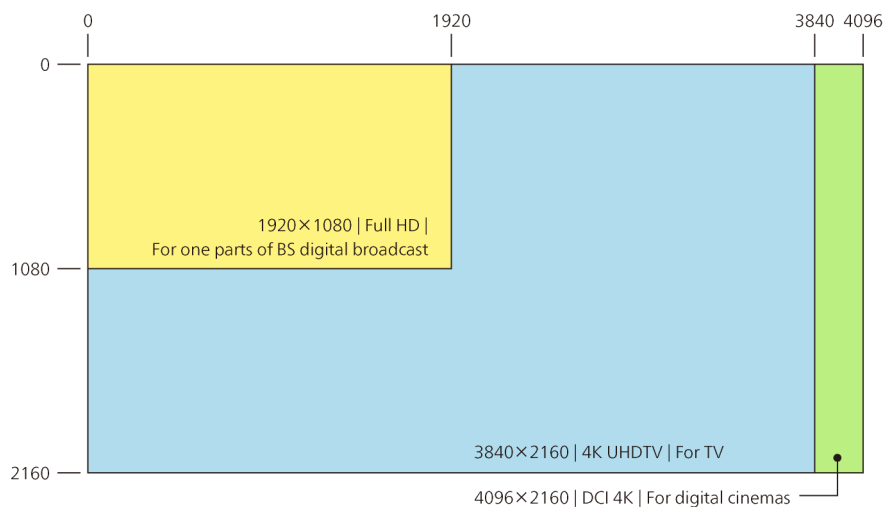


Figure | Resolution

Bit Depth

Bit depth is defined as the bits number per a unit, in this section, indicates the number of colors per pixel. For example, in the case of 8 bit, 256(equivalent to 2⁸) gradations are allotted for each of color components, RGB. That means about 16.77 million colors (equal to 256 (R) × 256 (G) × 256 (B)) can be displayed. In the conventional full HD system, bit depth is eight bit. On the other hand, that in 4K system is expanded to twelve bit. The larger bit depth means more colors can be displayed, which enable it to display smoother gradations.



Figure | 12bit (Image)



Figure | 8bit (Image)

Frame Rate

Frame rate is defined as frame number per second. In cinemas, that is 24p. In the conventional Full HD system, that is usually at or near 30p. On the other hand, in 4K system, that is expanded to 120p.

The motion gets smoother with higher frame rate.

Color Gamut

The color gamut indicates the range of color which can be expressed by each system. In the follows figure, the horseshoe shapes is called CIE chromaticity diagram, which shows the range that humans can recognize by their eyes. The conventional full HD system can cover the smaller triangle range in this figure, which is called BT.709 (= sRGB). On the other hand, in the 4K system, the triangle is expanded to the bigger one, which is called BT.2020.

The bigger triangle means it can cover wider range of color, which enable it to display more realistic color.

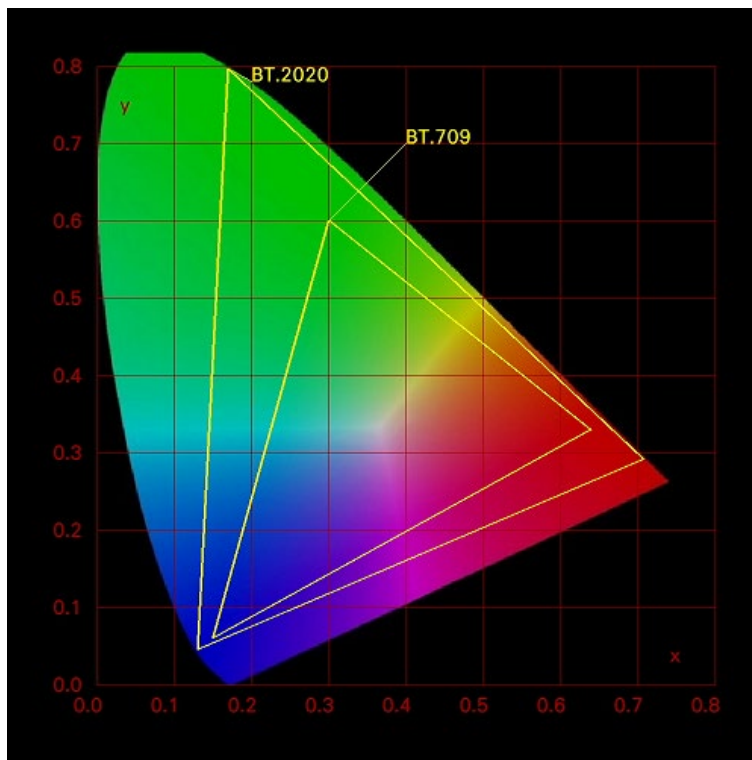


Figure | CIE chromaticity diagram (LV5600)

SDI Video Divided System

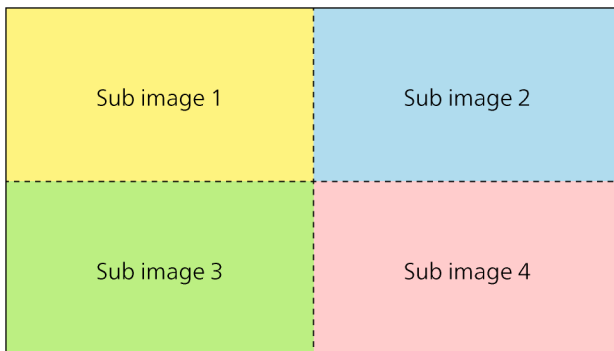
In the 4K systems, video is transmitted as it is divided into 4 parts. There are two types of dividing, one is "square division", the other is "2 sample interleave". And one of the four divided part is called "sub image".

Square Division System

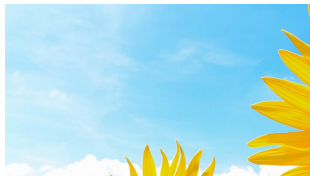
Square division is the method which divides videos into four sub images, upper right, upper left, lower right, lower left.

When videos are processed, one frame delay usually occurs.

We can't view the entire image by only one sub image.



Sub image 1



Sub image 2



Sub image 3



Sub image 4

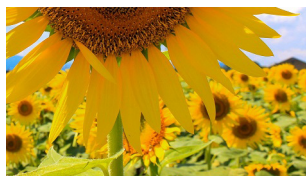


Figure | Square division system

2 Sample Inter Leave

2 sample interleave is the method which takes samples two by two and allotted them to 4 sub image adjacent to each other. Repeating this procedure throughout the picture, we can view entire image in each sub image.

When videos are processed, only two lines delay occurs.

We can view the whole picture from only one sub image.



1	1	2	2	1	1	2	2
3	3	4	4	3	3	4	4
1	1	2	2	1	1	2	2
3	3	4	4	3	3	4	4

• • •

•
•
•



Sub image 1



Sub image 2



Sub image 3



Sub image 4



Figure | 2 Sample inter leave system

Line Numbers and Sample Numbers

In this section, we will explain the description of the 4K line numbers and sample numbers, how they are defined, and how they are displayed in our LV5600s data dump with following example.

Terms

Division Transmission System	: Square division
Format	: 3G-A
Color System	: YCbCr 4:2:2
Quantization	: 10bit
Image	: 3840 × 2160
Frame Rate	: 59.94P

First, we will consider the 4K videos which have 3840 × 2160 pixels. Horizontal direction pixels are called "Sample, and numbered 0 to 3839. Vertical direction pixels are called "Line", and numbered 0 to 2159.

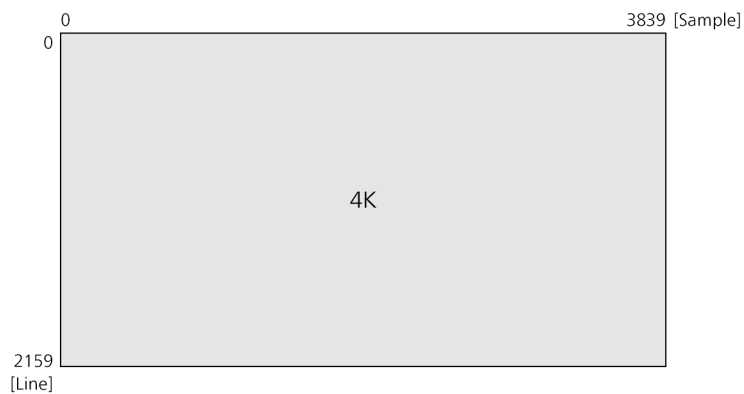


Figure | 4K Image

Next, we divide the 4K video into the four sub images following the square division method. We obtain the four dividing sub image with 1920 x 1080 pixels, from 0 to 1919 sample number and from 0 to 1079 line number.

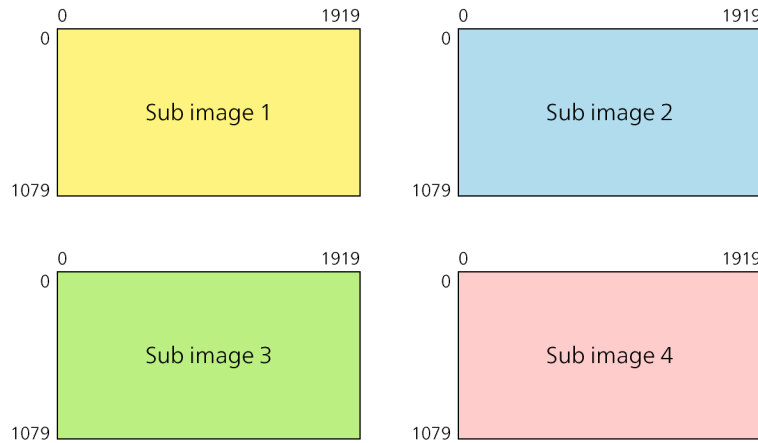


Figure | Sub Image

To map these divided sub images to 3G-A system, we add blanking data to each of them.

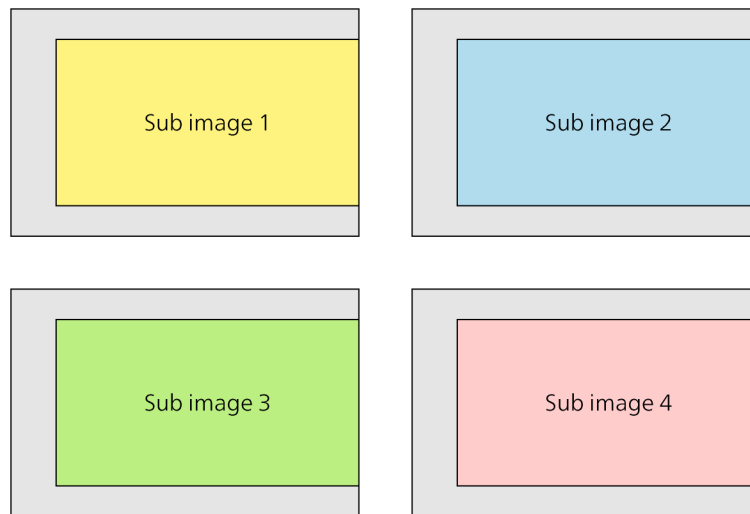


Figure | Sub Image

After mapping, sample and line numbers of one sub image are defined as follow the below. The picture excepted blanking data from entire area is called active picture. In the case below, active picture is 1980×1080 pixel area, whose sample number is from 0 to 1919, line number is from 42 to 1121.

This theory is same for sub image 2 to 4.

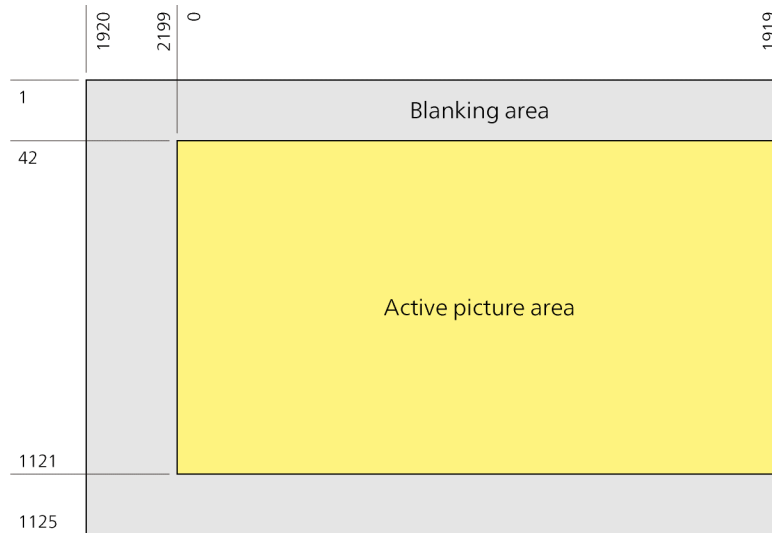


Figure | Sub image

Confirm the data dump displayed on the LV5600 while considering the above. The means of line and sample numbers depends on [F5] LINK.

When [F5] LINK is set to PICTURE

Line and sample number for 4K videos are shown.

Line numbers are displayed as "PIC LINE", and selectable from 0 to 2159.

Sample numbers are displayed as "PIC SAMPLE", and selectable from 0 to 3839.

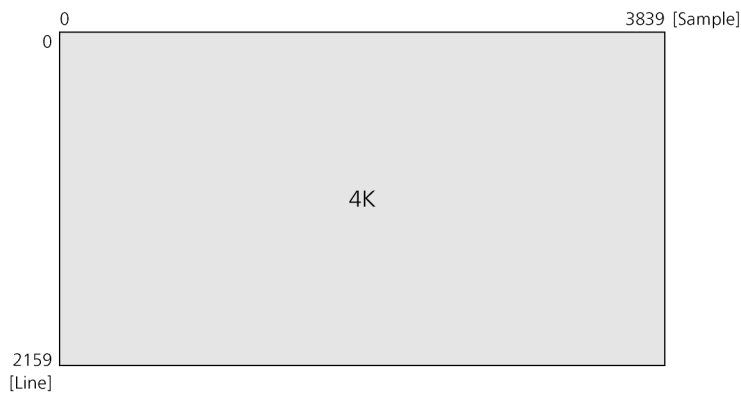


Figure | 4K video

3840x2160/59.94P YCbCr(422) 10bit 3G-A QUAD(S0) SDI A-D TIME: 14:58:54

DATA DUMP

PIC LINE No.0	Y	Cb	Cr
PIC SAMPLE			
< 0>	040	200	
< 1>	040		200
< 2>	040	200	
< 3>	041		200
< 4>	0CB	200	
< 5>	1F6		200
< 6>	321	200	
< 7>	3AB		200
< 8>	3AC	200	
< 9>	3AC		200
< 10>	3AC	200	
< 11>	3AC		200
< 12>	3AC	200	
< 13>	3AC		200
< 14>	3AC	200	
< 15>	3AC		200
< 16>	3AC	200	
< 17>	3AC		200
< 18>	3AC	200	
< 19>	3AC		200

F1 JUMP END F2 FD 1CLICK 1 F3 FD FUNCTION LINE F4 F5 LINK PICTURE F6 F7 up menu

PIC LINE (0 ~ 2159)
PIC SAMPLE (0 ~ 3839)
LINK

Figure | 3G-A data dump

When [F5] LINK is set to any of 1[A], 2[B], 3[C], 4[D].

Line and sample number which attached blanking area to each sub image are shown.

Line numbers are displayed as "LINE", and selectable from 1 to 1125.

Sample numbers are displayed as "SAMPLE", and selectable from 1 to 2199.

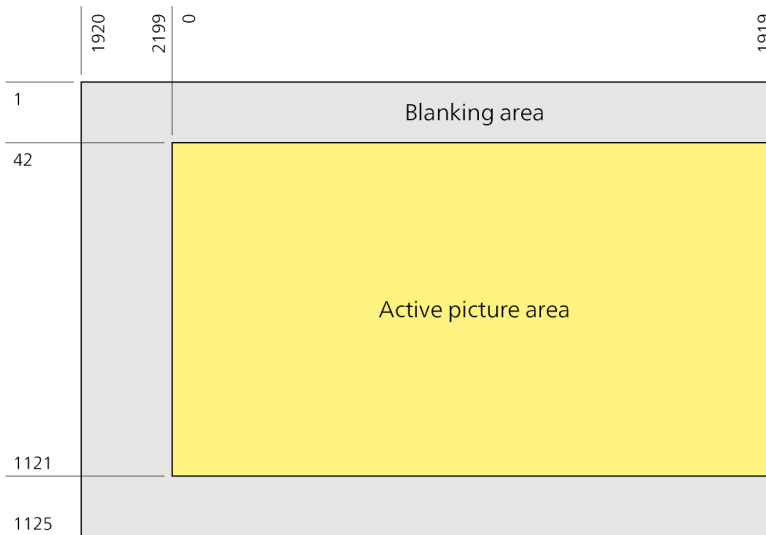


Figure | Sub image

3840x2160/59.94P YCbCr(422) 10bit 3G-A QUAD(SQ) SDI A-D TIME: 14:59:50

DATA DUMP	LINE No.1	Y	Cb/Cr	LINE (1 ~ 1125)
[SAV]	<2196>	3FF	3FF	SAMPLE (0 ~ 2199)
[SAV]	<2197>	000	000	
[SAV]	<2198>	000	000	
[SAV]	<2199>	2AC	2AC	
	< 0>	040	200	
	< 1>	040	200	
	< 2>	040	200	
	< 3>	040	200	
	< 4>	040	200	
	< 5>	040	200	
	< 6>	040	200	
	< 7>	040	200	
	< 8>	040	200	
	< 9>	040	200	
	< 10>	040	200	
	< 11>	040	200	
	< 12>	040	200	
	< 13>	040	200	
	< 14>	040	200	
	< 15>	040	200	

F1 JUMP SAV F2 FD 1CLICK 1 F3 FD FUNCTION LINE F4 DISPLAY SERIAL F5 LINK 1[A] F6 F7 up menu

LINK

Figure | 3G-A Data Dump

Note the case that format is 3G-B-DL and [F5] LINK is any of 1[A], 2[B], 3[C], 4[D].

3G-B-DL systems consist to stream1 and stream2 as follows. But it is different between "picture line number" allotted each stream and "transmission line number" in transmitting them.

For example, picture line number 42 is included in line number 21 from stream1, and line number 583 from stream2.

Picture line number		Transmission line number
Stream 1	Stream 2	
2	3	1
4	5	2
⋮	⋮	⋮
38	39	19
40	41	20
42	43	21
44	45	22
⋮	⋮	⋮
1118	1119	559
1120	1121	560
1122	1123	561
1124	1125	562
1	2	563
3	4	564
5	6	565
⋮	⋮	⋮
39	40	582
41	42	583
43	44	584
45	46	585
⋮	⋮	⋮
1119	1120	1122
1121	1122	1123
1123	1124	1124
1125	1	1125

The relations of "picture line number" and "transmission line number" is shown the table below.

Picture line number	Transmission line number	
	Stream1	Stream2
1	563	1125
m (even number from 2 to 1124)	m/2	m/2+562
n (odd number from 2 to 1124)	(n+1)/2+562	(n-1)/2

You can confirm this by changing the setting of [F4] DISPLAY in the LV5600.

For example, [F4] DISPLAY set to PICTURE and LINE No. set to 42, and change the setting of [F4] DISPLAY to SETRAM1.

Then LINE No. will be shown 21. As well, change [F4] DISPLAY to SETRAM2, LINE No. will be shown 583.

When [F4] DISPLAY is set to PICTURE.

LINE No. will be shown as "PIC LINE".

It is selectable from 1 to 1125.

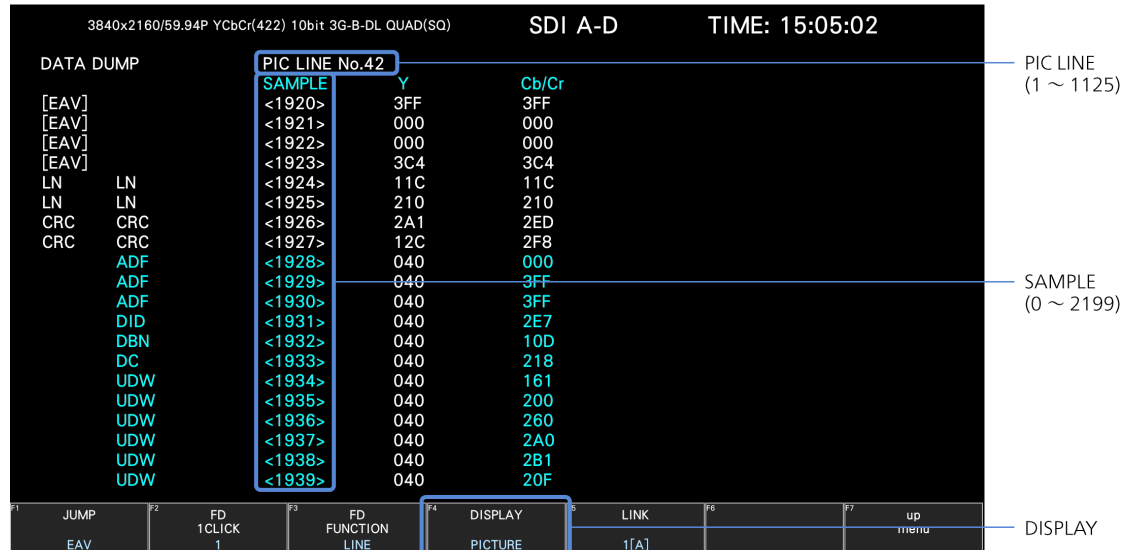


Figure | 3G-B-DL Data Dump

When [F4] DISPLAY is set to STREAM1.

LINE No. will be shown as "I/F LINE", which is the transmission line number in transmitting any line number of stream1.

It is selectable from 1 to 1125.

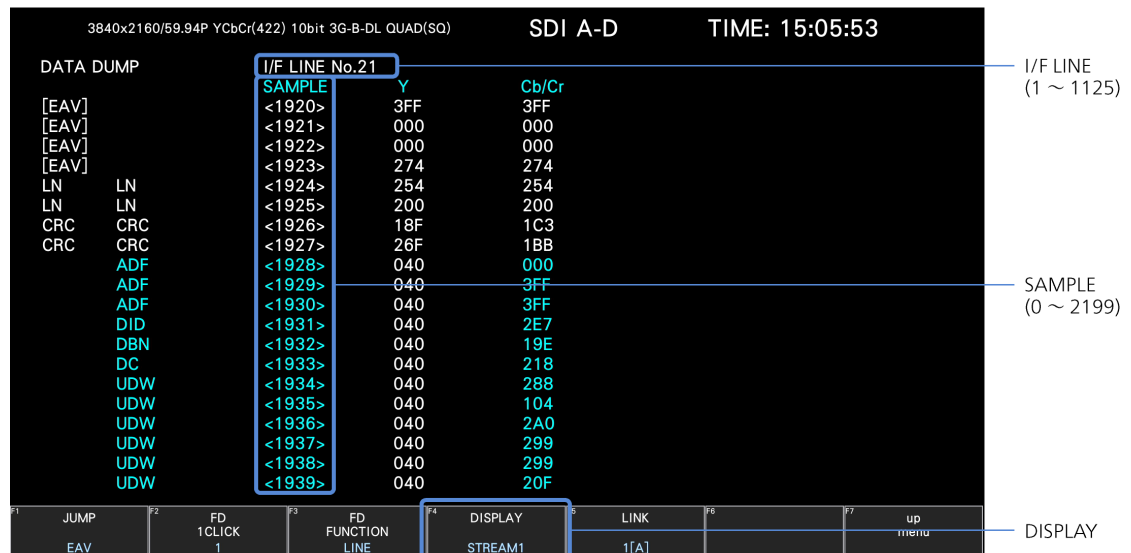


Figure | 3G-B-DL Data Dump

When [F4] DISPLAY is set to STREAM2.

LINE No. will be shown as "I/F LINE", which is the transmission line number in transmitting any line number of stream2.

It is selectable from 1 to 1125.

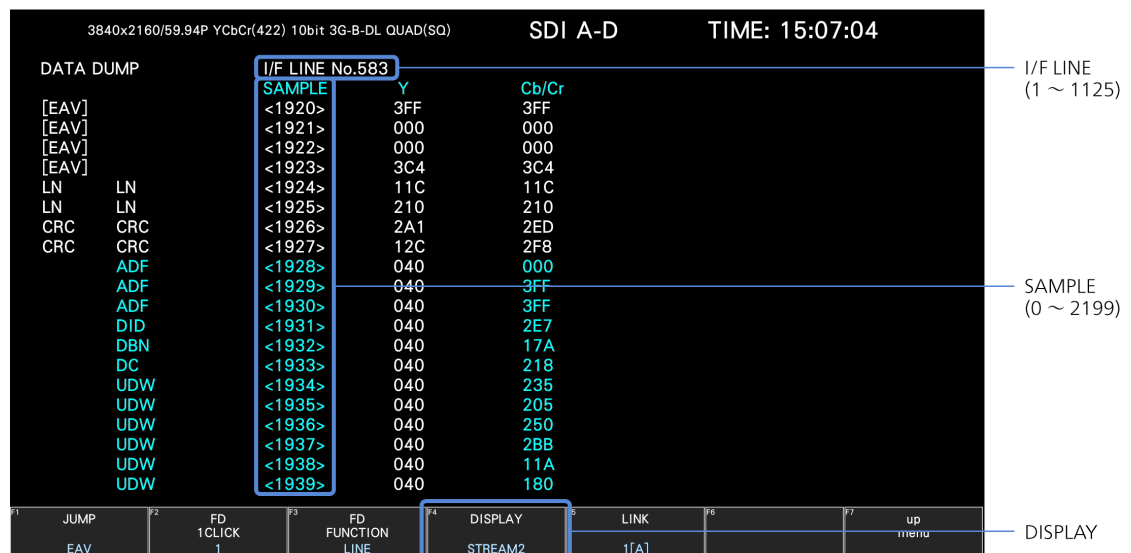


Figure | 3G-B-DL Data Dump

The Type of 4K Signals

4K signals have several formats.

In this section, we will explain the 4K signals below, in order.

4K Signals	Signal Constitutions	Standards	Video Division Transmission Method
3G Quad Link	3G-SDI Level A × 4 or 3G-SDI Level B Dual Link Mapping × 4	SMPTE ST 425-5	Square Division or 2 Sample Interleave
3G Dual Link (up to 4K/30p)	3G-SDI Level B Dual Stream Mapping × 2	SMPTE ST 425-3	Square Division or 2 Sample Interleave
12G Single Link	12G-SDI × 1	SMPTE ST 2082-10	2 Sample Interleave

02 Description of 4K (3G Quad Link)

About the 4K signal consisted of four 3G level A signals.

About the 4K signal consisted of four 3G level B Dual Link mappings

About 3G Quad Link

3G Quad Link is the 4K transmission system using four 3G-SDI level A signals (hereinafter called "3G-A") or four 3G-SDI level B Dual Link mappings (hereinafter called "3G-B").

4K videos (Source images) are separated to four sub images by square division method or two sample interleave method, and transmitted as 3G-A or 3G-B-DL signals.

But in case of square division method, note they are not recognized as 4K.

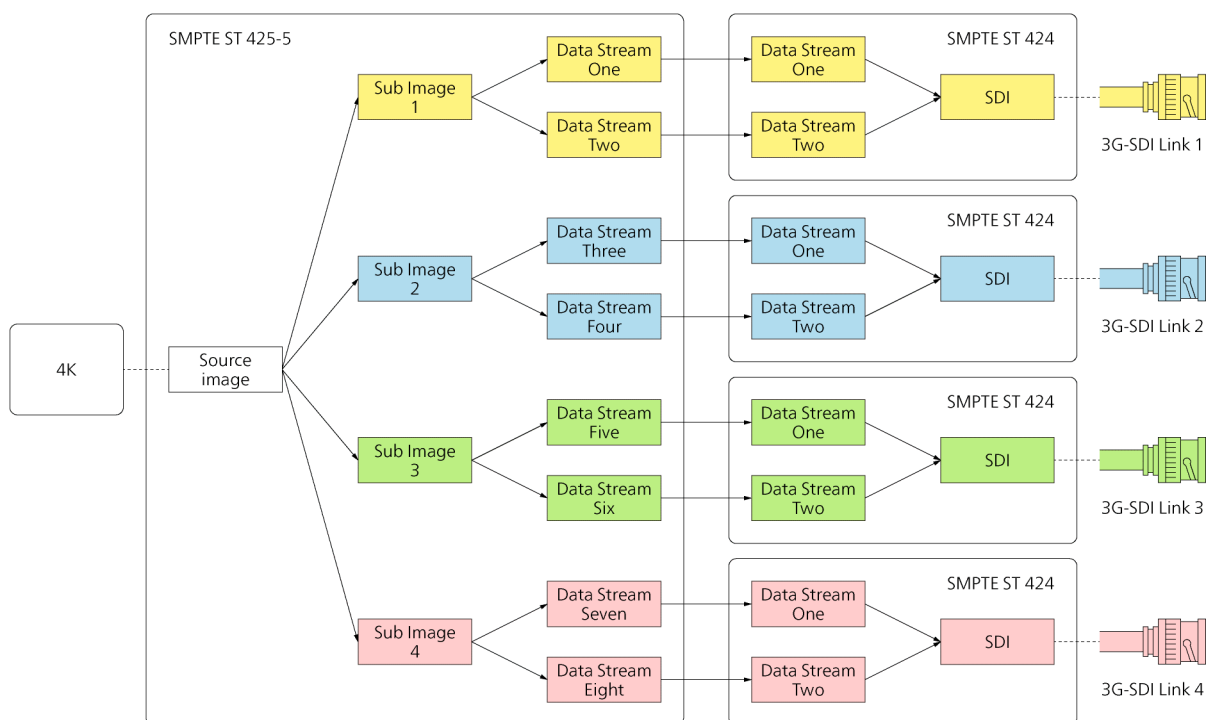
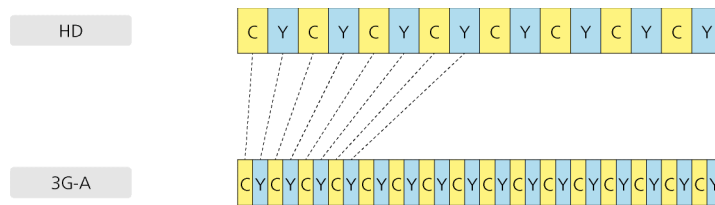


Figure | Excerpt from SMPTE ST 425-5

What is "3G-A" ?

3G-SDI has two types, which are 3G-A and 3G-B.

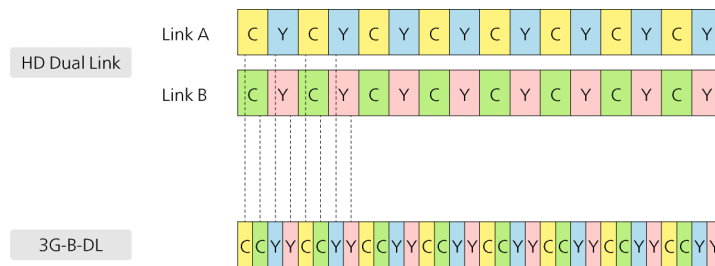
Among this, 3G-A is the format which has twice rate against HD-SDI (hereinafter called "HD").



What is "3G-B-DL"?

3G-SDI has two types, which are 3G-A and 3G-B. Further, 3G-B is categorized to 3G-B-DL and 3G-B-DS.

Among this, 3G-B-DL is the format which is united HD-SDI Dual Link, and has twice rate against HD.



03 Description of 4K (3G Dual Link)

About the 4K signal consisted of two 3G-SDI-levelB Dual Stream mappings

About 3G Dual Link

3G Dual Link is the 4K signal transmission method using 3G-SDI Dual stream mapping (hereinafter called "3G-B-DS").

4K videos (Source image) are separated to four sub images by square division method or two sample interleave method, and transmitted them as 3G-B-DS.

But in case of square division method, note they are not recognized as 4K.

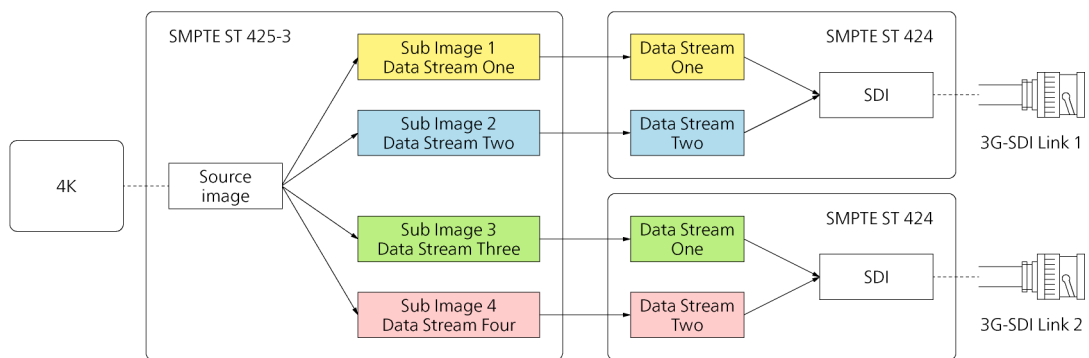
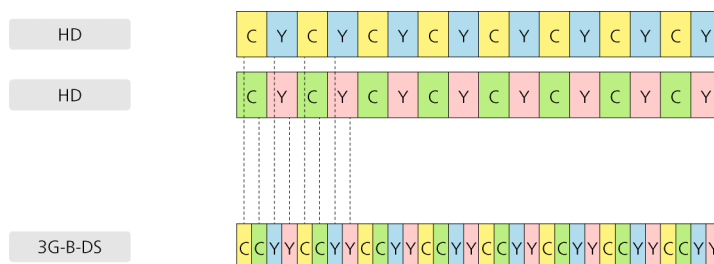


Figure | Excerpt from SMPTE ST 425-3

What is "3G-B-DS"?

3G-SDI has two types, which are 3G-A and 3G-B. Further, 3G-B is categorized to 3G-B-DL and 3G-B-DS.

Among this, 3G-B-DS is the format which is united two HD signals, and has twice rate against HD.



04 Description of 4K (12G Single Link)

About the 4K signal consisted of one 12G-SDI signal

About 12G Single Link

12G single link is the 4K transmission method using one 12G-SDI signal (hereinafter called "12G").

4K videos (Source image) are separated to four sub images by two sample interleave method. And they are transmitted as one 12G signal after multiplexed.

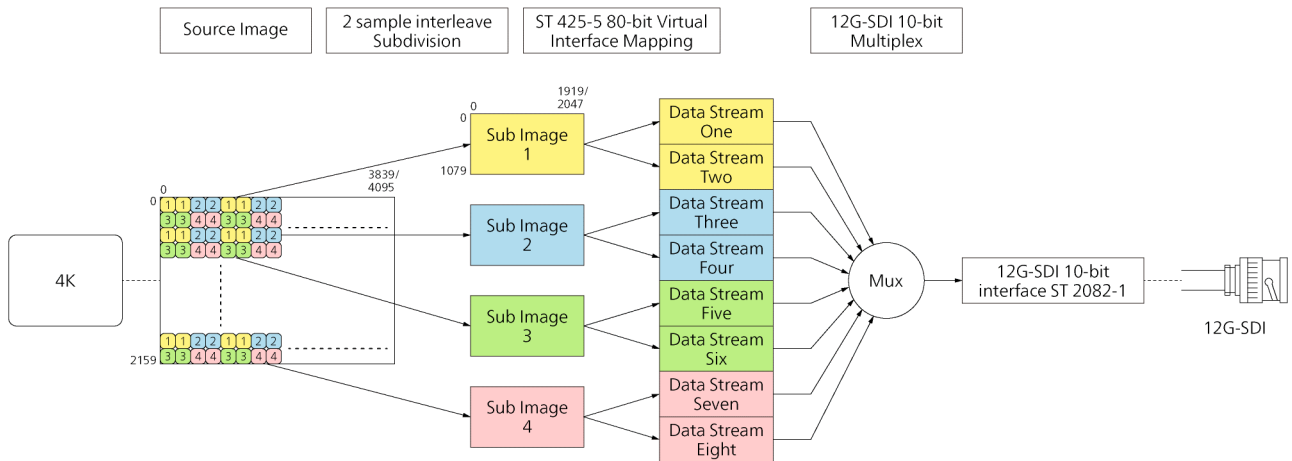


Figure | Excerpt from SMPTE ST 2082-10

The above-mentioned multiplex is performed in the order of 4 → 2 → 3 → 1 as follow the below.

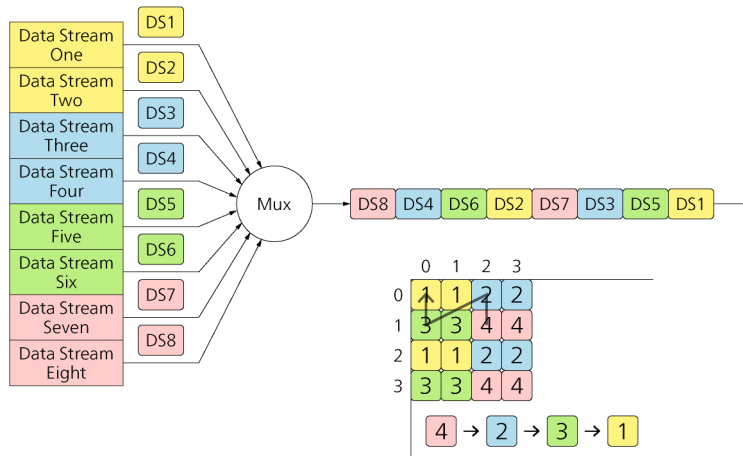


Figure | multiplex

12G-SDI Characteristics

Major 12G-SDI electrical Characteristics are shown below, along with that of 3G-SDI and HD-SDI.

The rise and fall times are determined between the 20% and 80% amplitude points.

Timing jitter indicates equal to or greater than 10Hz.

Alignment jitter indicates equal to or greater than 100kHz.

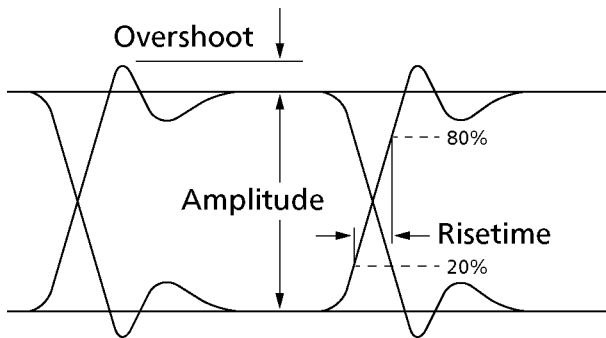


Figure | Eye Diagram

Item	12G-SDI	3G-SDI	HD-SDI
Standard	SMPTE ST 2082-1	SMPTE ST 424	SMPTE ST 292-1
Amplitude	800mV \pm 10%	800mV \pm 10%	800mV \pm 10%
Overshoot	No greater than 10%	No greater than 10%	No greater than 10%
Rise time	No greater than 45ps	No greater than 135ps	No greater than 270ps
Fall time			
Difference between rise time and fall time	No greater than 18ps	No greater than 50ps	No greater than 100ps
Timing jitter	No greater than 8UI	No greater than 2UI	No greater than 1UI
Alignment jitter	No greater than 0.3UI	No greater than 0.3UI	No greater than 0.2UI
Return loss	greater than 15dB (5MHz to 1.485GHz) greater than 10dB (1.485GHz to 3GHz) greater than 7dB (3GHz to 6GHz) greater than 4dB (6GHz to 12GHz)	greater than 15dB (5MHz to 1.485GHz) greater than 10dB (1.485GHz to 2.97GHz)	greater than 15dB (5MHz to 1.485GHz)

05 Measurement 4K Signal

The 4K signal output and measurement using our measurement instruments.

As an example, we will explain the measurement procedure for 4K signals generated by our sync generator "LT4610" by our waveform monitor "LV5600".

Other than LT4610, LT4610-SER02 is required to output 4K signals.

Other than LV5600, LV5600-SER28 and LV5600-SER29 are required to output 4K signals.

Measurement 3G Quad Link

Setting the LT4610

To set any of the below formats, follow the procedure below.

12G OPTION > SDI 1 > FORMAT > SYSTEM > 3G > select one of the below formats.

- 3G(QL)-A 3840x2160 Square
- 3G(QL)-A 3840x2160 2Sample
- 3G(QL)-A 4096x2160 Square
- 3G(QL)-A 4096x2160 2Sample
- 3G(QL)-B-DL 3840x2160 Square
- 3G(QL)-B-DL 3840x2160 2Sample
- 3G(QL)-B-DL 4096x2160 Square
- 3G(QL)-B-DL 4096x2160 2Sample

After the above setting, you also select color system, quantization, and framerate by "STRUCTURE" and "RATE".

Setting the LV5600

To set the system to 4K 3G Quad Link, follow the procedure below.

[SYS] > [F1] SIGNAL IN OUT > set System to "4K" and "3G Quad Link" on SDI IN SETUP1 tab

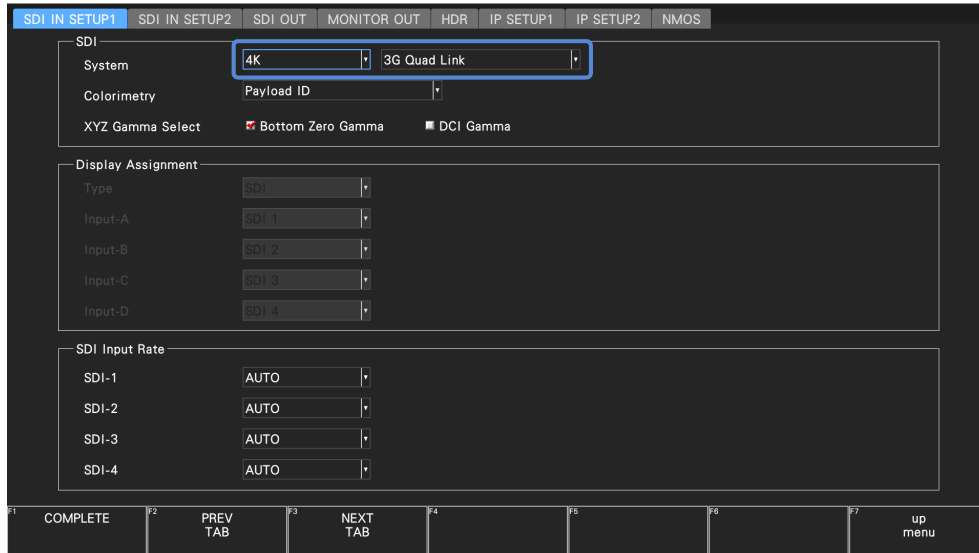


Figure | SDI IN SETUP1

Connection

Connect the LT4610 output terminal 1 to 4 and LV5600 SDI INPUT terminal 1 to 4 as the picture below.

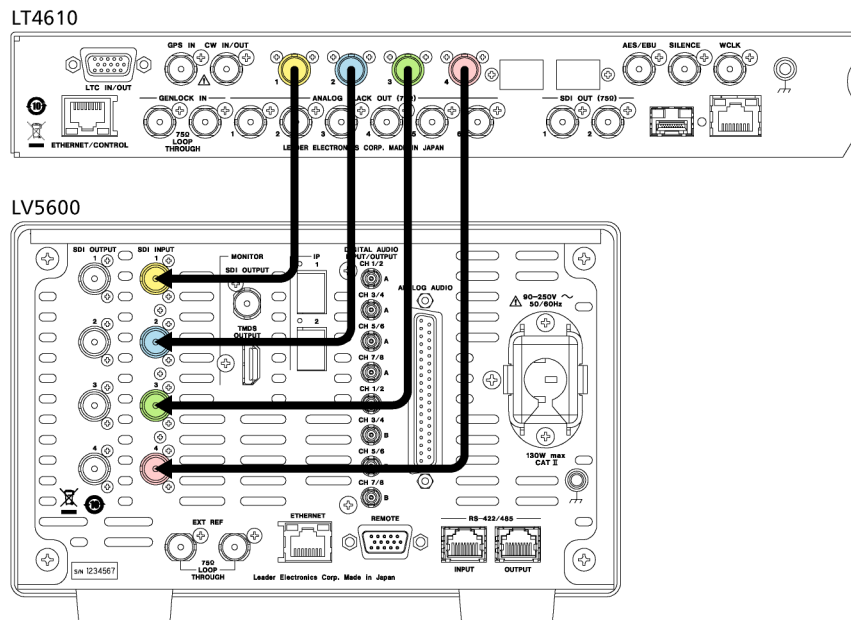


Figure | Connection of 3G Quad Link

Measurement

On screen of the LV5600, 4K signal measurement screen is displayed. The video division method is recognized automatically, and shown as (2S) or (SQ) with the format.

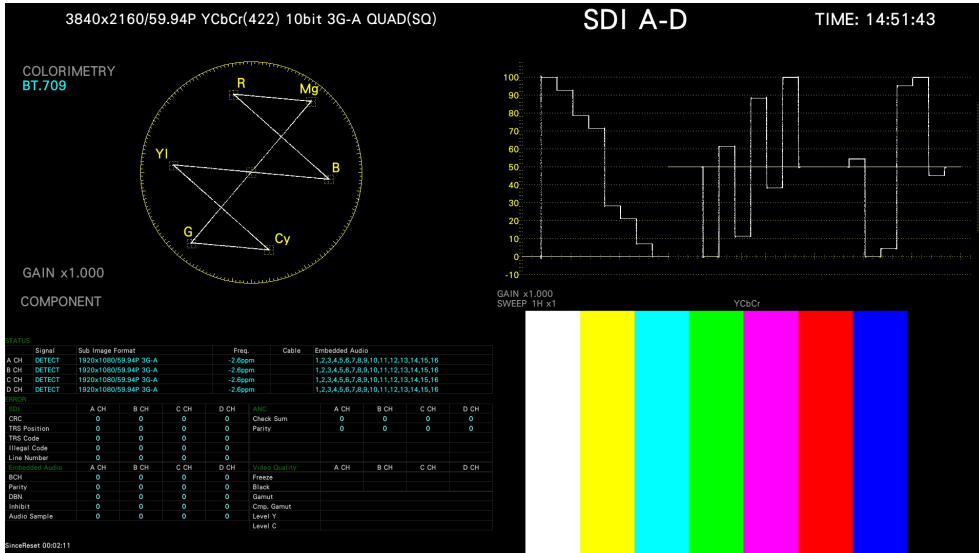


Figure | 3G Quad Link measurement screen

Measurement 3G Dual Link

Setting the LT4610

To set one of the below formats, follow the procedure below.

12G OPTION > SDI 1 > FORMAT > SYSTEM > 3G > select one of the below formats.

- 3G(DL)-B-DS 3840x2160 Square
- 3G(DL)-B-DS 3840x2160 2Sample
- 3G(DL)-B-DS 4096x2160 Square
- 3G(DL)-B-DS 4096x2160 2Sample

After the above setting, you also select color system, quantization, and framerate by "STRUCTURE" and "RATE".

Setting the LV5600

[SYS] > [F1] SIGNAL IN OUT > set System to "4K" and "3G Dual Link" on SDI IN SETUP1 tab

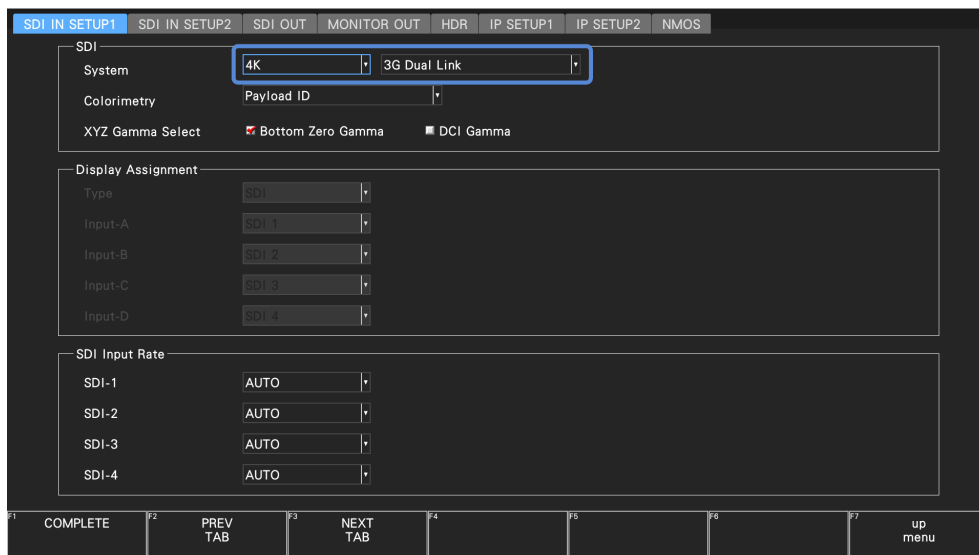


Figure | SDI IN SETUP1

Connection

Connect the LT4610 output terminal 1 and 2 and LV5600 SDI INPUT terminal 1 and 2 as the picture below.

You can also input to the LV5600 SDI INPUT 3 and 4. But you cannot measure the 4K signals from input 1 and 2 and from input 3 and 4 as the same time.

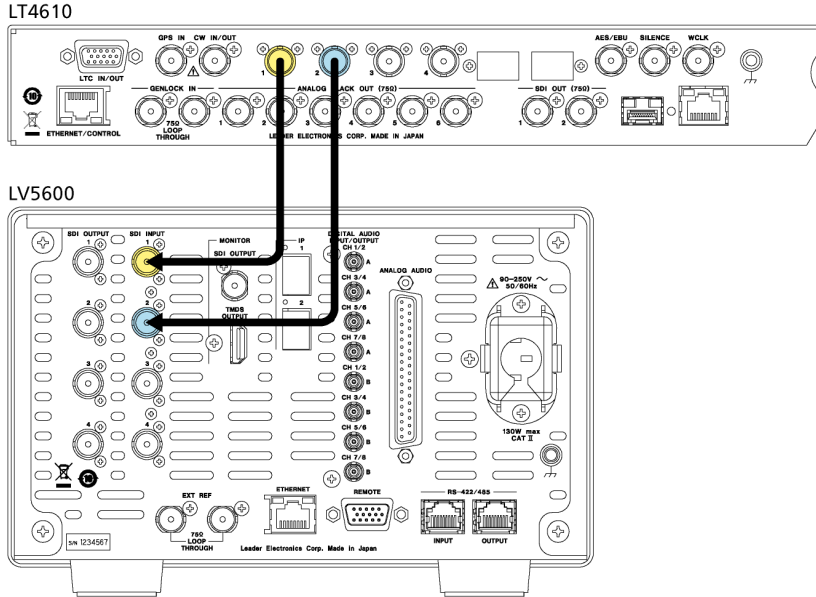


Figure | 3G Dual Link connection

Measurement

The 4K signal measurement screen is displayed on the LV5600.

The videos division method is recognized automatically, and displayed as (2S) or (SQ) in format.

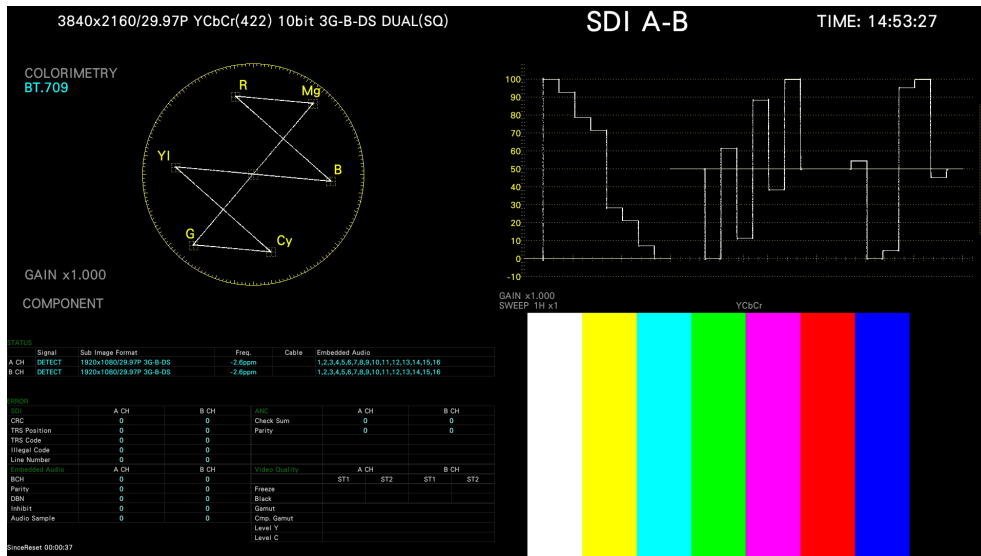


Figure | 3G Dual Link measurement screen

Measurement 12G Single Link

Setting the LT4610

To set one of the below formats, follow the procedure below.

12G OPTION > SDI 1 > FORMAT > SYSTEM > 12G > select any of the below formats

- 12G 3840x2160 12G
- 12G 4096x2160 12G

After the above setting, you also select color system, quantization, and framerate by "STRUCTURE" and "RATE".

Setting the LV5600

[SYS] > [F1] SIGNAL IN OUT > set System to "4K" and "12G" on SDI IN SETUP1 tab

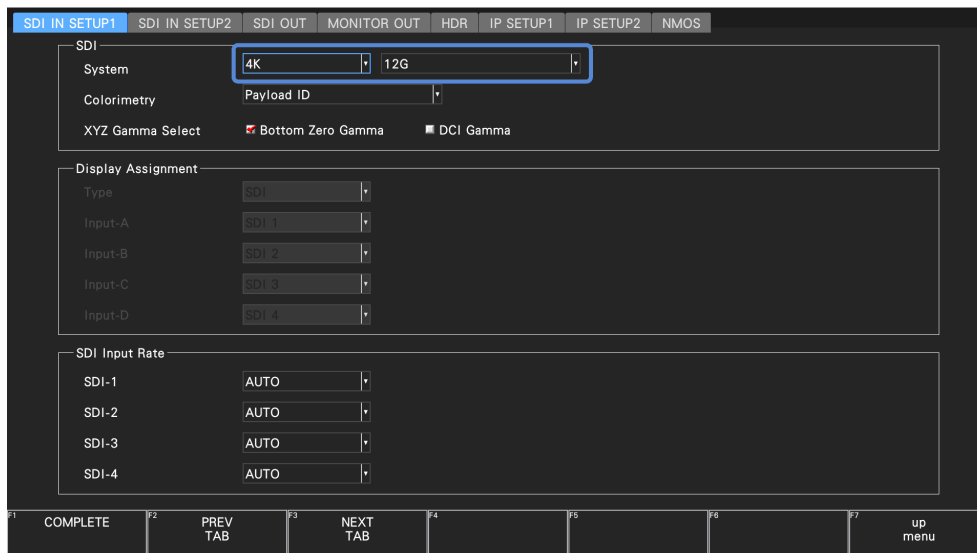


Figure | SDI IN SETUP1

Connection

Connect the LT4610 output terminal 1 and LV5600 SDI INPUT terminal 1 as the picture below. You can also input to the LV5600 SDI INPUT 2 to 4. But you cannot measure 4K signals from input 1 to 4 as the same time.

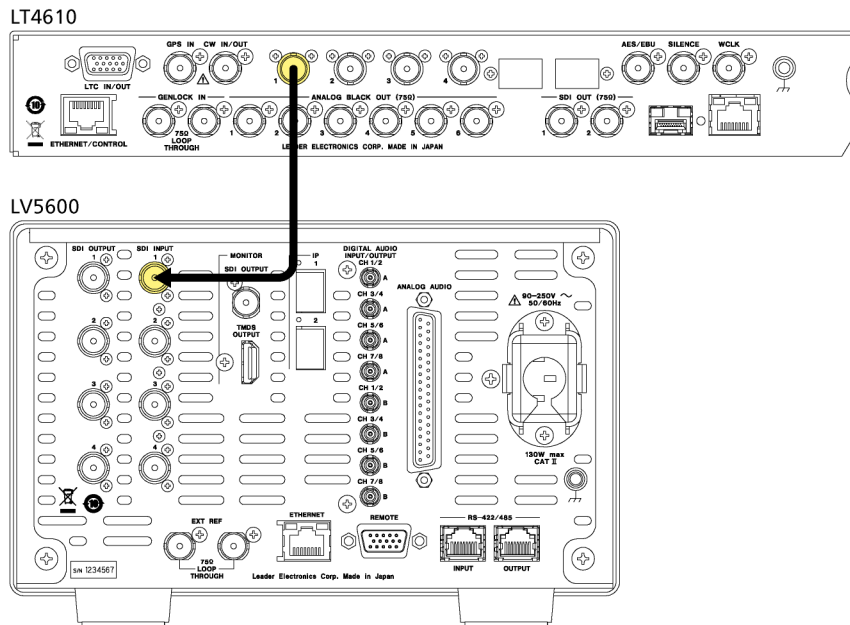


Figure | 12G single link connection

Measurement

On the screen of the LV5600, 4K signal measurement screen is shown.

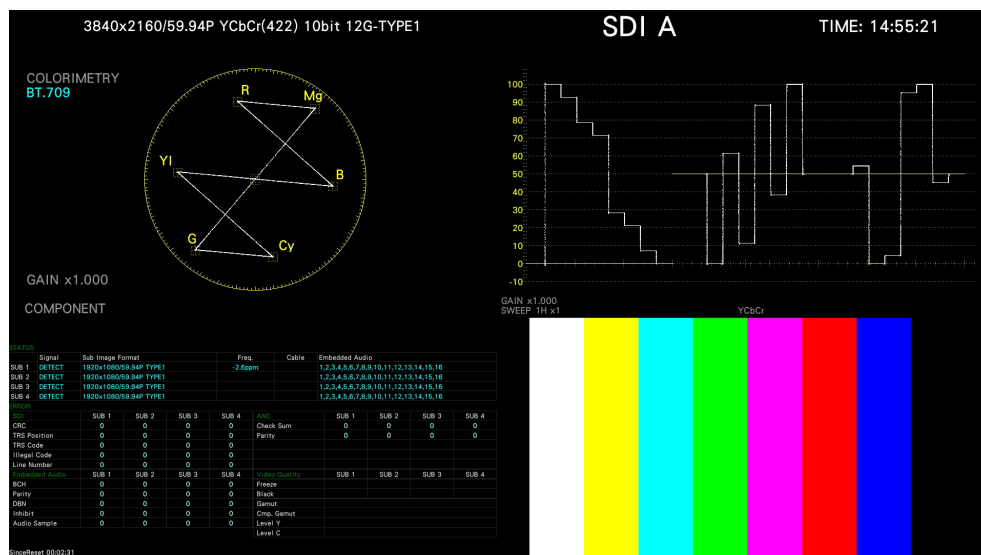


Figure | 12G single link measurement screen

06 Glossary

About terms related to 4K

Term	Definition
2 sample interleave	The method which takes samples two by two and allotted them to 4 sub image adjacent to each other
Square division	The method which divides videos into four sub images

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