

Understanding UHDTV and 4K formats and how to use them on LiveCore™ series?

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Introduction

After the relative failure of stereoscopic 3D to take hold in the consumer market, the new feature the industry is betting on is 4K. Surveys have proven that the market is more interested in high resolution images than in 3D content. As there are many formats of “4K”, it is important to understand the differences to make the best choice for the hardware in your system. This document aim is to demystify the topic and explain what the impacts on the hardware are.

1. What are 4K and UHDTV?

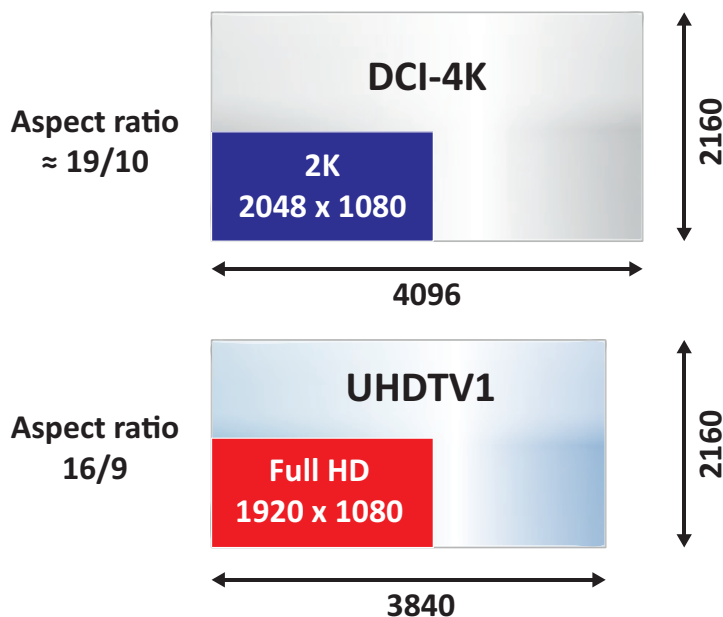
Originally the “4K” name comes from a resolution with a width of 4096 pixels. The explanation is quite simple:

$$4096 \text{ pixels} = 4 \times 1024 \text{ pixels} = 4 \times 2^{10} \text{ pixels} = 4 \text{ kilo pixels} \Rightarrow 4\text{K}$$

So 4K is a resolution of 4096 x 2160 pixels. This resolution is used by digital cinema industry: it is called **DCI 4K**. DCI stands for Digital Cinema Initiatives, the name of the organization that creates specifications for the digital cinema industry.

For consumer digital television, the 4K term is heavily used but the format usually discussed is actually **UHDTV1** resolution: 3840 x 2160. UHDTV 1 stands for Ultra High Definition Television 1, it is also known as **4K-UHDTV**. UHDTV2 is 7680 x 4320 pixels (i.e. 4 times UHDTV1 and 16 times Full HD) but this is another subject.

Please note that the aspect ratio is different between **DCI-4K** and **UHDTV1**: respectively 19/10 and 16/9.



2. Why is resolution information not enough to discuss 4K?

The bandwidth required to carry a 4K signal also depends on other factors than resolution.

2.1 The frame rate

The most obvious factor is the frame rate: carrying 4K at 60Hz requires twice the bandwidth of 4K at 30 Hz. The higher the frame rate, the higher the required bandwidth.

2.2 The chromaticity sampling scheme

This is a more technical point. However it is quite easy to explain. When carrying a YCbCr signal, each pixel is described by three values:

- **Y**: the luma information (brightness) which is a combination of R, G and B levels
- **Cb**: the blue chromaticity (difference of blue level and luma)
- **Cr**: the red chromaticity (difference of red level and luma)

Studies have shown that the human eye is more sensitive to luma variation than chromaticity changes. Therefore the bandwidth can be reduced and optimized: full luma information is transmitted whereas component differences can be subsampled. The visual result is quite satisfying for natural content (photos and videos) but may induce significant artifacts for digitally produced contents with important color transitions and lines.

The subsampling scheme has a name in the format of J:a:b. It describes the number of components in a block of 4x2 pixels:

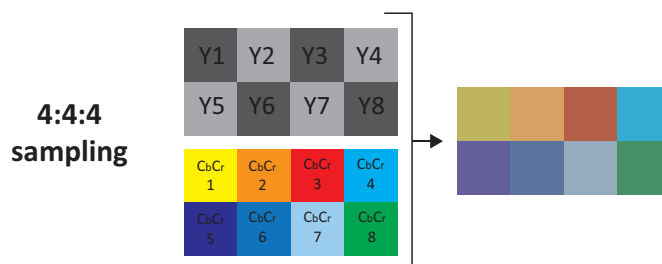
- **J**: it is the number of Luma information per line (most of the time, it is four as luma is rarely under-sampled)
- **a**: The number of chromaticity information in the first line
- **b**: The number of chromaticity changes in the second line (if 0, then it is identical to the first line)

Important: chromaticity subsampling is not possible when carrying a RGB signal.

Three of the most common sampling schemes are 4:4:4, 4:2:2 and 4:2:0.

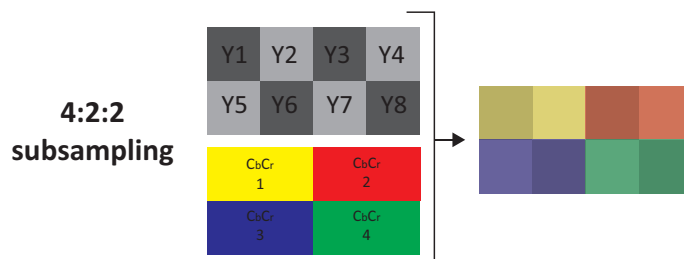
4:4:4

In this scheme, there is no under-sampling. The required bandwidth is maximum.



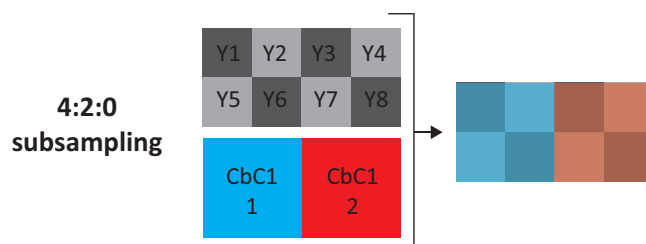
4:2:2

In this scheme, the horizontal number of chromaticity is divided by two: The required bandwidth is 2/3 of the bandwidth required by 4:4:4.



4:2:0

In this scheme, both horizontal and vertical numbers of chromaticity are divided by two: the bandwidth is half the bandwidth required by 4:4:4. This is the scheme employed for Blu-ray disc storage.



2.3. The Bit Depth

This is the number of bits used to encode each component of a pixel. Increasing the bit depth significantly increases the number of colors the device processing is able to support but also requires a more important bandwidth to handle the signal. The most common bit depths are 8, 10 or 12 bits. Professionals tend to admit that if the difference between 8 bits and 10 bits is clearly visible, the difference between 10 bits and 12 bits is very difficult to see for a non-experienced eye. If a system can handle 10 or more bits per component, it can be described as “Deep Color”.

Please note that a source with an important bit depth usually requires the use of a high quality display system as the LSB (Least Significant Bit) must be processed properly. Else the restituted image will be the same one as one obtained with a lower bit depth.

3. Carrying a 4K signal

Carrying a 4K signal requires a physical medium whose bandwidth is large enough to support the frame rate, the bit depth and the chromaticity sampling scheme.

The following chart indicates the pixel frequency required for different formats from 1080p60Hz to 2160p60Hz.

Format	Specified by	H blanking (H Front + H sync. + H Back)	V blanking (V Front + V sync. + V Back)	Pixel Frequency (MHz)
1080p 60Hz	CEA-861-F	280 (88+44+148)	45 (4+5+36)	148,5Mz
2560x1600 60Hz 4:4:4 RB*	VESA DMT v1r12	160 (48+32+80)	46 (3+6+37)	268,5MHz
3840x2160 30Hz 4:4:4	CEA-861-F	560 (176+88+296)	90 (8+10+72)	297MHz
3840x2160 60Hz 4:2:0	CEA-861-F	560 (176+88+296)	90 (8+10+72)	297MHz
3840x2160 60Hz 4:4:4	CEA-861-F	560 (176+88+296)	90 (8+10+72)	594MHz
4096x2160 60Hz 4:4:4	CEA-861-F	304 (88+88+128)	90 (8+10+72)	594MHz

* Reduced blanking

As expected 4K 60Hz 4:4:4 formats require four times the bandwidth of 1080p60 format.

At the present time, only HDMI 2.0 and DisplayPort 1.2 standards can handle a 4K 60Hz 4:4:4 signal using a single cable. However, the signal can't be transmitted over long distances: a few meters is the maximum, forcing the use of modulators/ demodulators over optical fiber. At the time this article is written, DisplayPort 1.3 has just been announced and will support 8K resolution.

To compensate for this problem, multi-cable links were implemented. The currently available solutions often use four 3G-SDI links or two DisplayPort 1.1 links.

	DCI-4K / UHDTV-4K					
	4:2:0		4:2:2		4:4:4	
	30Hz	60Hz	30Hz	60Hz	30Hz	60Hz
3G-SDI	N/A	N/A	x4	x4	x4	N/A
6G-SDI	N/A	N/A	x1	N/A	N/A	N/A
DVI-D	N/A	N/A	N/A	N/A	x4	x4
DVI-D Dual-Link	N/A	N/A	N/A	N/A	x1	x2
HDMI 1.4	N/A	N/A	x1	x2	x1	x2
HDMI 2.0	x1	x1	x1	x1	x1	x1
DisplayPort 1.1	N/A	N/A	x1	x2	x1	x2
DisplayPort 1.2	N/A	N/A	x1	x1	x1	x1
DisplayPort 1.3	x1	x1	x1	x1	x1	x1

4. LiveCore™ series and 4K

4.1 Standard LiveCore™ Series

The standard **LiveCore™ series** supports resolutions up to 2560x1600@60Hz using Dual-Link DVI interfaces:

- on inputs #2, #6 & #10
- on outputs #1 & #3

All HDMI input plugs are partially implementing the HDMI1.4a standard.

However, the **SMX12x4**, **ASC3204** and **ASC4806** can create a 4K screen using their 4 outputs in hard-edge mode.

4.2 Standard LiveCore™ Series + 4K upgrades

Analog Way offers optional 4K upgrade kits for all the references in the **LiveCore™ series**: **NXT0802**, **NXT1604**, **SMX12x4**, **ASC1602**, **ASC3204** and **ASC4806**.

These kits include, among other things, new input and output boards using a new generation of chips compliant with the HDMI1.4b standard. They can handle resolutions up to 4096x2160@30Hz:

- on inputs #2, #6 and #10
- on outputs #2 & #4

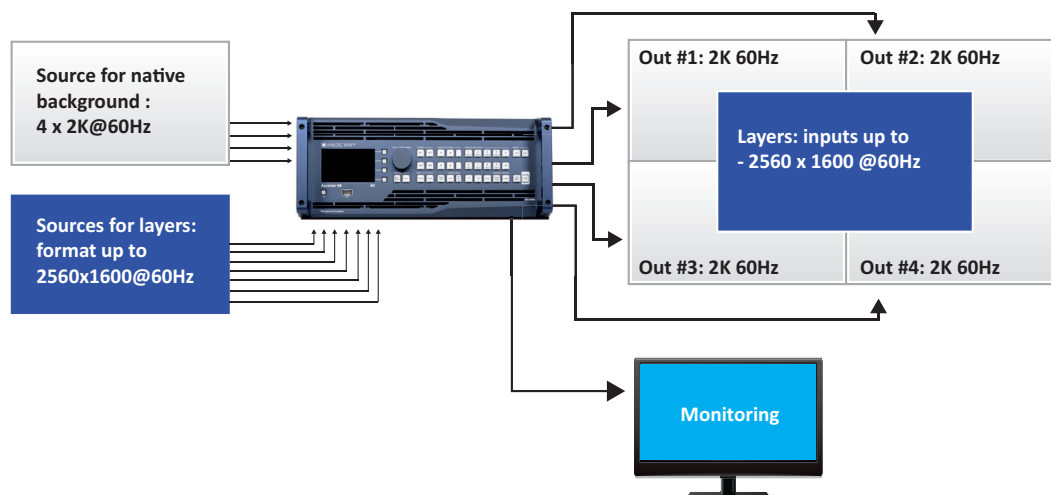
Moreover, the output boards can generate 4K 60Hz 4:2:0 formats as this chromaticity sampling scheme is also supported.

Please note that Dual-Link DVI interfaces available on standard **LiveCore™** devices are still available on 4K upgraded devices (inputs #2, #6 & #10, outputs #1 & #3)

4.3 LiveCore™ series: 4K use cases for standard LiveCore™ units

4.3.1 Use Case 1: LiveCore™ with four 2K 60Hz outputs

This use case only concerns LiveCore™ with four outputs.



In this configuration, four 2K 60Hz outputs (3G-SDI or DVI) are used in hard-edge mode to create a 4K screen. The native background is composed of four unscaled 2K 60Hz inputs or four 2K still frames, each assigned to an output.

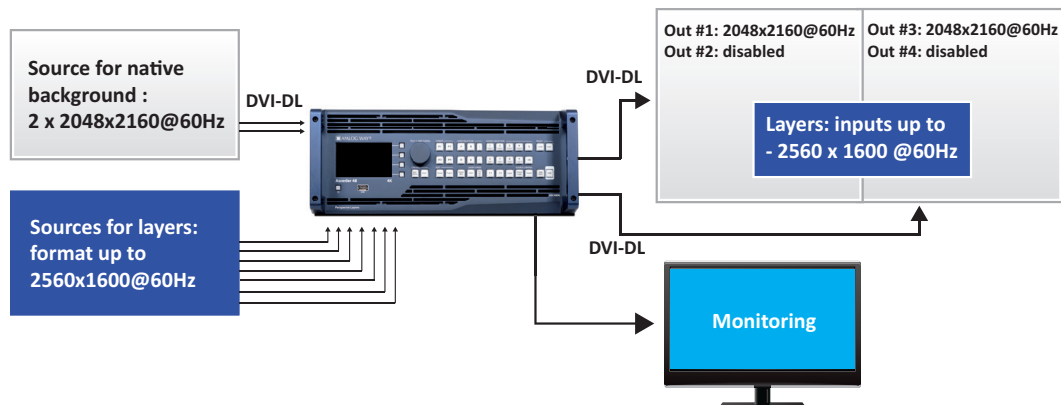
Layers accept inputs whose format can reach 2560x1600 pixels at 60 Hz.

The internal processing rate is 60Hz.

	SMX12x4 4K upgrade is not compulsory	ASC1602 4K upgrade is not compulsory	ASC3204 4K upgrade is not compulsory	ASC4806 4K upgrade is not compulsory
Output Configuration	4 x 2K 60Hz	4 x 2K 60Hz	4 x 2K 60Hz	4 x 2K 60Hz
Dual-Link inputs	Up to 3	Up to 3	Up to 3	Up to 3
Layer Configuration 1	1 x 4K Native Background 2 x 2K Layers	1 x 4K Native Background 4 x 2K Layers	1 x 4K Native Background 4 x 2K Layers	1 x 4K Native Background 6 x 2K Layers
Layer Configuration 2	1 x 4K Native Background 1 x Dual-Link Layer	1 x 4K Native Background 1 x Dual-Link Layer	1 x 4K Native Background 1 x Dual-Link Layer 2 x 2K Layers	1 x 4K Native Background 1 x Dual-Link Layer 4 x 2K Layers
Layer Configuration 3	N/A	N/A	1 x 4K Native Background 2 x Dual-Link Layers	1 x 4K Native Background 2 x Dual-Link Layers 2 x 2K Layers
Layer Configuration 4	N/A	N/A	N/A	1 x 4K Native Background 3 x Dual-Link Layers

4.3.2 Use Cases 2 : LiveCore with two DVI Dual-Link at 60Hz outputs

This use case only concerns LiveCore™ with four outputs.



In this configuration, two DVI Dual-Link outputs (2048x2160) are used side by side in hard-edge mode to create a 4K screen. The native background is composed of two unscaled 2048x2106@60Hz DVI Dual-Link inputs or two 2048x2160 still frames, each assigned to an output.

Layers accept inputs whose format can reach 2560x1600 pixels at 60 Hz.

The internal processing rate is 60Hz.

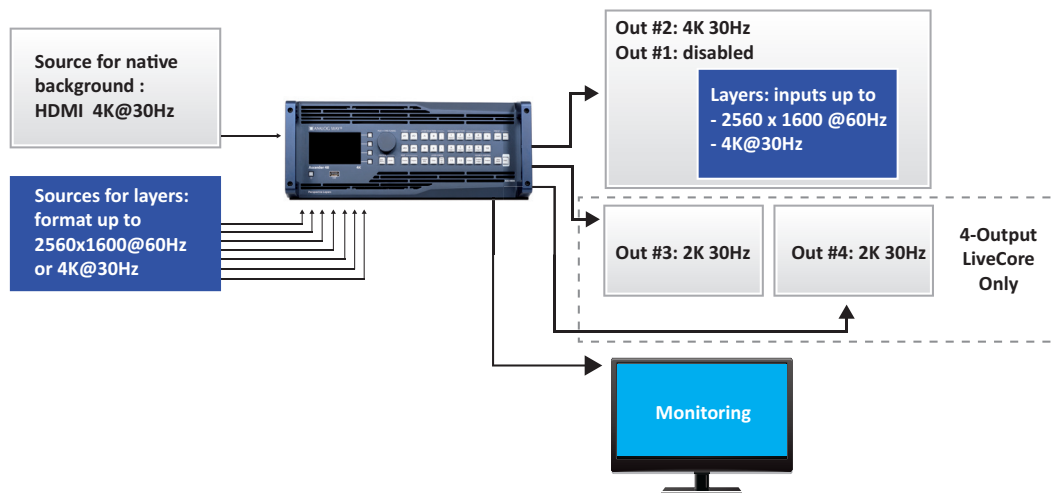
	SMX12x4 4K upgrade is not compulsory	ASC1602 4K upgrade is not compulsory	ASC3204 4K upgrade is not compulsory	ASC4806 4K upgrade is not compulsory
Output Configuration	2 x 2048x2160 60Hz	2 x 2048x2160 60Hz	2 x 2048x2160 60Hz	2 x 2048x2160 60Hz
Dual-Link inputs	Up to 3	Up to 3	Up to 3	Up to 3
Layer Configuration 1	1 x 4K Native Background 2 x 2K Layers	1 x 4K Native Background 4 x 2K Layers	1 x 4K Native Background 4 x 2K Layers	1 x 4K Native Background 6 x 2K Layers
Layer Configuration 2	1 x 4K Native Background 1 x Dual-Link Layer	1 x 4K Native Background 1 x Dual-Link Layer	1 x 4K Native Background 1 x Dual-Link Layer 2 x 2K Layers	1 x 4K Native Background 1 x Dual-Link Layer 4 x 2K Layers
Layer Configuration 3	N/A	N/A	1 x 4K Native Background 2 x Dual-Link Layers	1 x 4K Native Background 2 x Dual-Link Layers 2 x 2K Layers
Layer Configuration 4	N/A	N/A	N/A	1 x 4K Native Background 3 x Dual-Link Layers

4.4 LiveCore™ series: 4K use cases for 4K upgraded LiveCore™ units

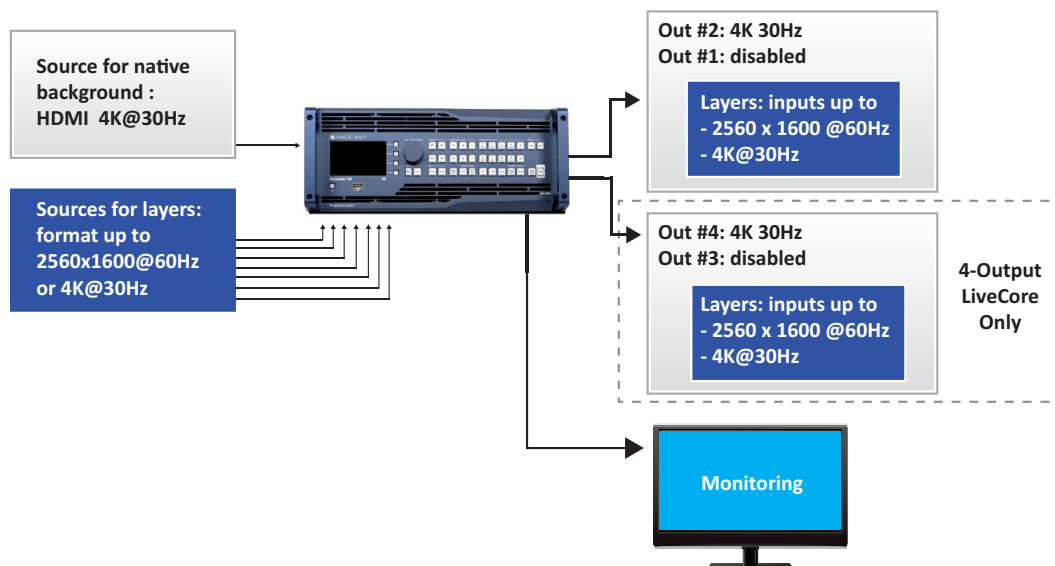
4.4.1 Use Cases 3 & 4: 4K LiveCore™ with at least one 4K @30Hz 4:4:4 output

These use cases only concern LiveCore™ devices with the 4K upgrade kit, whether they have 2 or 4 outputs.

Use case 3: 4K LiveCore™ with one 4K30Hz 4:4:4 output and two 2K 30Hz outputs



Use case 4: 4K LiveCore™ with two 4K 30Hz 4:4:4 outputs



In these configurations, at least one of the outputs generates a 4K 30Hz 4:4:4 format. The adjacent output is disabled (the implementation is similar to dual-link output setup). For LiveCore™ series with four outputs, the remaining outputs can be configured either in 2K (use case 2) or in 4K (use case 3).

The native background only accepts one 4K30Hz 4:4:4 input. 4K still frames will be supported in a subsequent firmware version.

Layers accept inputs whose format can reach:

- 2560x1600 pixels at 60 Hz
- 4K 30Hz 4:4:4.

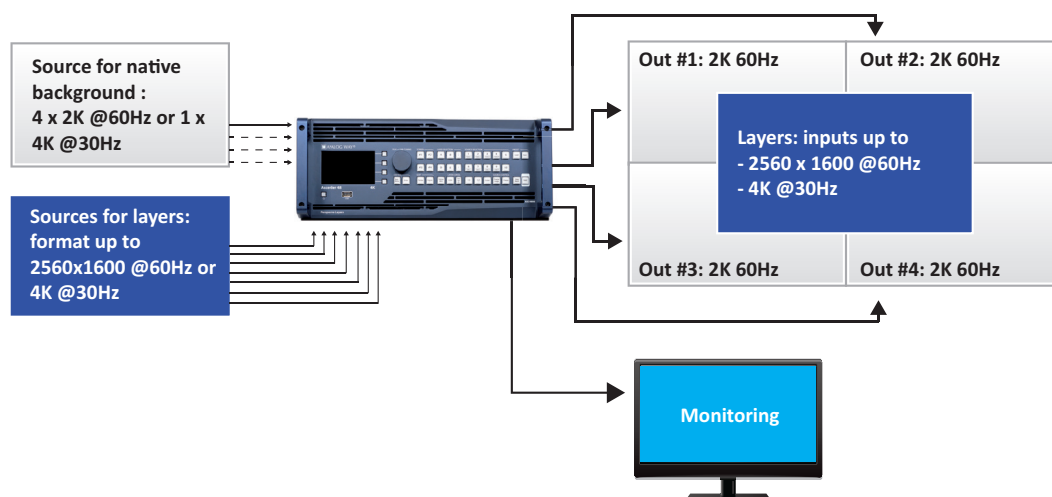
The internal processing rate is 30Hz. It implies that:

- All other available outputs must have a 30Hz rate
- All 60Hz inputs are frame-rate converted to 30Hz

	NXT0802 + 4K upgrade	NXT1604 + 4K upgrade	SMX12x4 + 4K upgrade	ASC1602 + 4K upgrade	ASC3204 + 4K upgrade	ASC4806 + 4K upgrade
Output Configuration	1 x 4K 30Hz	1 x 4K 30Hz	(1 x 4K 30Hz + 2 X 2K 30Hz) or 2 x 4K 30Hz	(1 x 4K 30Hz + 2 X 2K 30Hz) or 2 x 4K 30Hz	(1 x 4K 30Hz + 2 X 2K 30Hz) or 2 x 4K 30Hz	(1 x 4K 30Hz + 2 X 2K 30Hz) or 2 x 4K 30Hz
4K 30Hz or Dual-Link inputs	Up to 2	Up to 2	Up to 3	Up to 3	Up to 3	Up to 3
Layer Configuration 1	1 x 4K Native Background 2 x 2K Layers	1 x 4K Native Background 4 x 2K Layers	1 x 4K Native Background 2 x 2K Layers	1 x 4K Native Background 2 x 2K Layers	1 x 4K Native Background 4 x 2K Layers	1 x 4K Native Background 6 x 2K Layers
Layer Configuration 2	1 x 4K Native Background 1 x Dual-Link or 4K Layer	1 x 4K Native Background 1 x Dual-Link or 4K Layer 2 x 2K Layers	1 x 4K Native Background 1 x Dual-Link or 4K Layer	1 x 4K Native Background 1 x Dual-Link or 4K Layer	1 x 4K Native Background 1 x Dual-Link or 4K Layer 2 x 2K Layers	1 x 4K Native Background 1 x Dual-Link or 4K Layer 4 x 2K Layers
Layer Configuration 3	N/A	1 x 4K Native Background 2 x Dual-Link or 4K Layer	N/A	N/A	1 x 4K Native Background 2 x Dual-Link or 4K Layers	1 x 4K Native Background 2 x Dual-Link or 4K Layers 2 x 2K Layers
Layer Configuration 4	N/A	N/A	N/A	N/A	N/A	1 x 4K Native Background 3 x Dual-Link or 4K Layers

4.4.2 Use Cases 5: 4K LiveCore™ with four 2K 60Hz outputs

This use case only concerns LiveCore™ devices with 4 outputs and the 4K upgrade kit.



In this configuration, four 2K 60Hz outputs (3G-SDI or DVI) are used in hard-edge mode to create a 4K screen. The native background accepts four 2K 60Hz inputs, four 2K still frames or one 4K30Hz 4:4:4 input. 4K stills frames will be supported in a subsequent firmware version. Layers accept inputs whose format can reach:

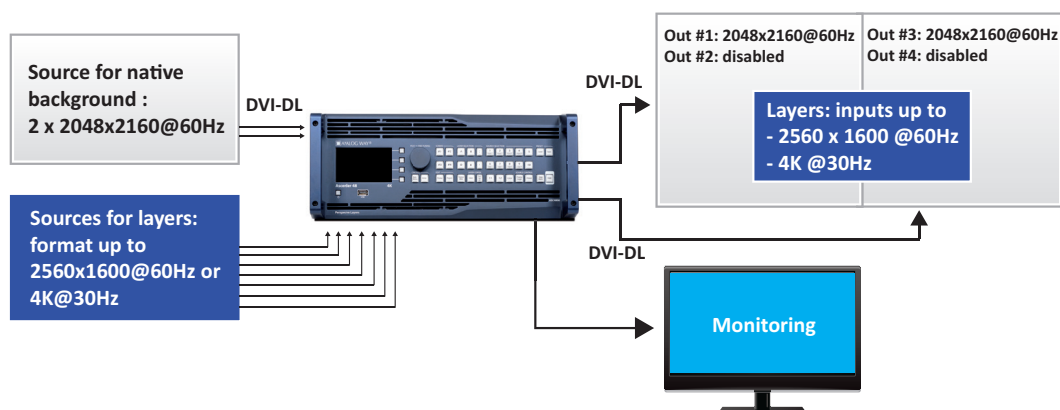
- 2560x1600 pixels at 60 Hz
- 4K 30Hz 4:4:4

The internal processing rate is 60Hz. However, effects on layers containing 4K30Hz contents will be performed with a 30Hz timing.

	SMX12x4 + 4K upgrade	ASC1602 + 4K upgrade	ASC3204 + 4K upgrade	ASC4806 + 4K upgrade
Output Configuration	4 x 2K 60Hz	4 x 2K 60Hz	4 x 2K 60Hz	4 x 2K 60Hz
4K 30Hz or Dual-Link inputs	Up to 3	Up to 3	Up to 3	Up to 3
Layer Configuration 1	1 x 4K Native Background 2 x 2K Layers	1 x 4K Native Background 2 x 2K Layers	1 x 4K Native Background 4 x 2K Layers	1 x 4K Native Background 6 x 2K Layers
Layer Configuration 2	1 x 4K Native Background 1 x Dual-Link or 4K Layer	1 x 4K Native Background 1 x Dual-Link or 4K Layer	1 x 4K Native Background 1 x Dual-Link or 4K Layer 2 x 2K Layers	1 x 4K Native Background 1 x Dual-Link or 4K Layer 4 x 2K Layers
Layer Configuration 3	N/A	N/A	1 x 4K Native Background 2 x Dual-Link or 4K Layers	1 x 4K Native Background 2 x Dual-Link or 4K Layers 2 x 2K Layers
Layer Configuration 4	N/A	N/A	N/A	1 x 4K Native Background 3 x Dual-Link or 4K Layers

4.4.3 Use Cases 6: 4K LiveCore™ with two DVI Dual-Link at 60Hz outputs

This use case only concerns LiveCore™ devices with 4 outputs and the 4K upgrade kit.



In this configuration, two DVI Dual-Link outputs (2048x2160) are used side by side in hard-edge mode to create a 4K screen. The native background is composed of two unscaled 2048x2106@60Hz DVI Dual-Link inputs or two 2048x2160 still frames, each assigned to an output.

Layers accept inputs whose format can reach:

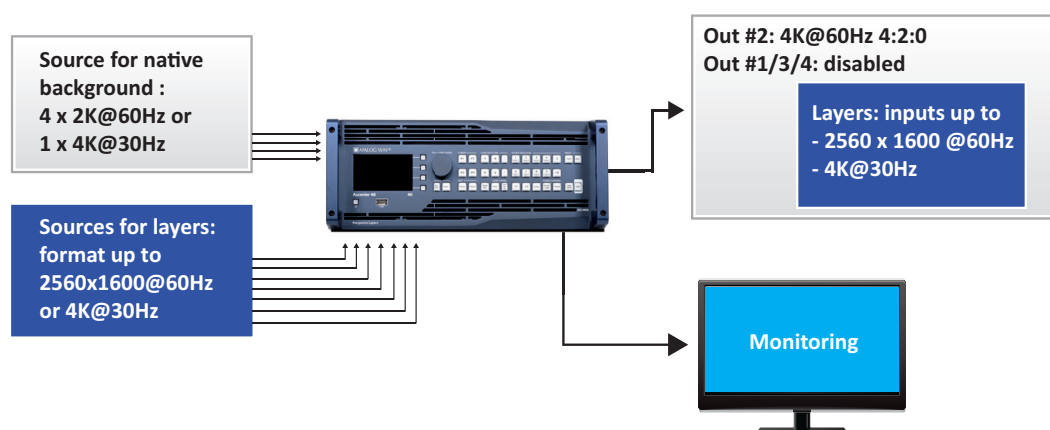
- 2560x1600 pixels at 60 Hz
- 4K 30Hz 4:4:4.

The internal processing rate is 60Hz. However, effects on layers containing 4K30Hz contents will be performed with a 30Hz timing.

	SMX12x4 + 4K upgrade	ASC1602 + 4K upgrade	ASC3204 + 4K upgrade	ASC4806 + 4K upgrade
Output Configuration	2 x 2048x2160 60Hz	2 x 2048x2160 60Hz	2 x 2048x2160 60Hz	2 x 2048x2160 60Hz
4K 30Hz or Dual-Link inputs	Up to 3	Up to 3	Up to 3	Up to 3
Layer Configuration 1	1 x 4K Native Background 2 x 2K Layers	1 x 4K Native Background 2 x 2K Layers	1 x 4K Native Background 4 x 2K Layers	1 x 4K Native Background 6 x 2K Layers
Layer Configuration 2	1 x 4K Native Background 1 x Dual-Link or 4K Layer	1 x 4K Native Background 1 x Dual-Link or 4K Layer	1 x 4K Native Background 1 x Dual-Link or 4K Layer 2 x 2K Layers	1 x 4K Native Background 1 x Dual-Link or 4K Layer 4 x 2K Layers
Layer Configuration 3	N/A	N/A	1 x 4K Native Background 2 x Dual-Link or 4K Layers	1 x 4K Native Background 2 x Dual-Link or 4K Layers 2 x 2K Layers
Layer Configuration 4	N/A	N/A	N/A	1 x 4K Native Background 3 x Dual-Link or 4K Layers

4.4.4 Use Cases 7: 4K LiveCore™ with one 4K 60Hz 4:2:0 output

This use case only concerns LiveCore™ devices with 4 outputs and the 4K upgrade kit.



In this configuration, output #2 generates a 4K 60Hz 4:2:0 format. All the other outputs are disabled.

The native background accepts four 2K 60Hz inputs, four 2K still frames or one 4K30Hz 4:4:4 input. 4K stills frames will be supported in a subsequent firmware version.

Layers accept inputs whose format can reach:

- 2560x1600 pixels at 60 Hz
- 4K 30Hz 4:4:4.

The internal processing rate is 60Hz. However, effect on layers containing 4K30Hz contents will be performed at 30Hz. Moreover, conversion from the 4:4:4 processing to the 4:2:0 output format adds one extra output frame to the output latency.

	SMX12x4 + 4K upgrade	ASC1602 + 4K upgrade	ASC3204 + 4K upgrade	ASC4806 + 4K upgrade
Output Configuration	1 x 4K 60Hz 4:2:0	1 x 4K 60Hz 4:2:0	1 x 4K 60Hz 4:2:0	1 x 4K 60Hz 4:2:0
4K 30Hz or Dual-Link inputs	Up to 3	Up to 3	Up to 3	Up to 3
Layer Configuration 1	1 x 4K Native Background 2 x 2K Layers	1 x 4K Native Background 2 x 2K Layers	1 x 4K Native Background 4 x 2K Layers	1 x 4K Native Background 6 x 2K Layers
Layer Configuration 2	1 x 4K Native Background 1 x Dual-Link or 4K Layer	1 x 4K Native Background 1 x Dual-Link or 4K Layer	1 x 4K Native Background 1 x Dual-Link or 4K Layer 2 x 2K Layers	1 x 4K Native Background 1 x Dual-Link or 4K Layer 4 x 2K Layers
Layer Configuration 3	N/A	N/A	1 x 4K Native Background 2 x Dual-Link or 4K Layers	1 x 4K Native Background 2 x Dual-Link or 4K Layers 2 x 2K Layers
Layer Configuration 4	N/A	N/A	N/A	1 x 4K Native Background 3 x Dual-Link or 4K Layers