Extron

Distributing 4K and UHD Signals in Professional AV Environments

Table of Contents

Abstract

As 4K sources and displays become popular for more applications, the next challenge facing system designers and integrators is developing systems that fully support 4K video signals. This paper provides an introduction to the technology and standards, explores the design challenges, and offers practical solutions for incorporating 4K video into an AV system design.

white paper

Introduction to 4K Technology
4K Video Resolutions

Several years ago, 4K display systems were introduced to support high end applications like digital cinema, advanced visualization in scientific research and medical imaging, and immersive environments from military simulation to themed attractions. Now that 4K displays and sources are available in more form factors and at lower price points, the benefits of the higher resolution and greater pixel density offered by 4K is desired in more traditional AV installations. 4K technology is now being deployed in a broad range of locations, from executive briefing centers to lecture halls, digital signage displays, and even in the home.

In response to these needs, manufacturers are introducing an increasing number of displays and projectors that provide 4K resolutions up to 4096x2160 and Ultra High Definition - UHD resolutions up to 3840x2160. These higher resolutions provide four times the number of pixels of 1080p full HD as shown in Figure 1.
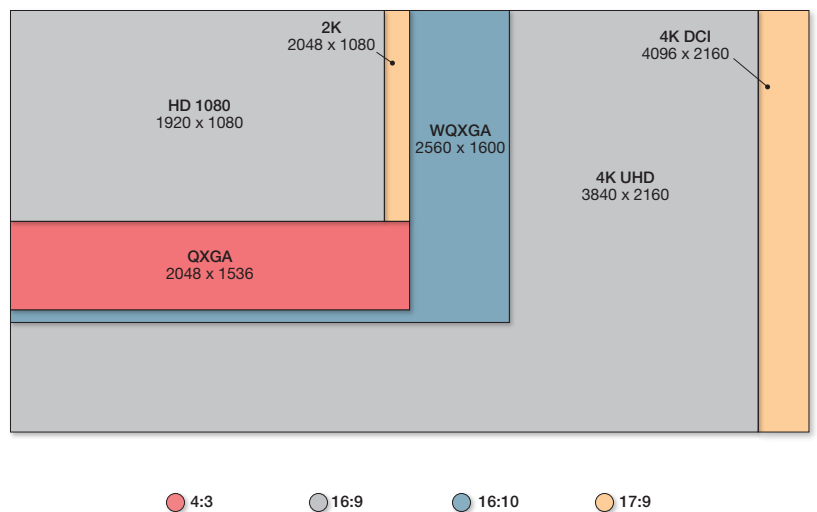

Figure 1: Video resolutions from 1080p through 4K

Data Rates for 4K and UHD Video Signals

The primary factors that affect the bandwidth required for a video signal are the resolution, frame rate, color bit depth, and chroma subsampling. As can be seen in Figure 1, UHD video is four times the resolution of a full HD 1080p signal and has four times the number of pixels within each frame. Moving this amount of data requires significant bandwidth as shown in Table 1. A 4K video signal with a full 60 Hz frame rate, 4:4:4 chroma subsampling, and 10-bit color requires a data rate of 22.28 Gbps.

Bandwidth Required for Video Signals					
Resolution	Frame rate	Chroma Subsampling	Pixel Clock	8-bit color	10-bit color
720p / 1080i	60 Hz	4:4:4	74.25 MHz	2.23 Gbps	2.78 Gbps
1080p / 2K	60 Hz	4:4:4	148.5 MHz	4.46 Gbps	5.57 Gbps
4K / UHD	30 Hz	4:4:4	297.00 MHz	8.91 Gbps	11.14 Gbps
4K / UHD	60 Hz	4:2:0	594.00 MHz	8.91 Gbps[1]	11.14 Gbps
4K / UHD	60 Hz	4:4:4	594.00 MHz	17.82 Gbps	22.28 Gbps

1. 4:2:0 color sampling support was added to HDMI 2.0. It is not supported in previous versions of the HDMI specification.

Table 1: Bandwidth requirements for 4K and UHD video signals

Effect of Chroma Subsampling on Video Quality

The impact on the quality of the video due to a reduced chroma subsampling depends on the type of video. The human visual system is more sensitive to brightness than color, such that the reduction in video quality of a Blu-ray movie may be imperceptible. For computer video, the reduction in quality becomes particularly evident. Computer imagery, such as computer-aided design drawings or maps, frequently has single-pixel line widths or transitions. Reduced chroma subsampling causes this fine pixel and line detail to blur or disappear. It is important to keep this in mind when designing a 4K system and select a transmission scheme that does not impact the quality of the displayed images.

Bandwidth Capabilities of Current Digital Video Signal Formats

In 2005, the Digital Cinema Initiatives – DCI established a standard resolution of 4096x2160 for 4K digital cinema projectors, which is referred to as 4K DCI. This resolution maintains the same 17:9 aspect ratio as the 2K DCI resolution of 2048x1080. Projectors supporting 4K DCI were some of the first 4K display systems to appear on the market. The television industry adopted the Ultra High Definition – UHD resolution of 3840x2160, which maintains the same 16:9 aspect ratio of 1080p HD video.

HDMI

The HDMI 1.4a specification, released in 2009, specifies a maximum data rate of 10.2 Gbps. It can support 4K or UHD resolutions with 8-bit color at 24 Hz, 25 Hz, or 30 Hz frame rates over a single HDMI cable. Reducing chroma subsampling to 4:2:0 for a UHD 60 Hz signal appears to produce a bandwidth that falls within the limits of HDMI 1.4a. However, the specification does not include support for 4:2:0 color sampling.

The HDMI 2.0 specification, released in September 2013, increases the data rate to 18.0 Gbps for a 60 Hz maximum 4K/UHD frame rate over a single HDMI cable at 8-bit color or up to 30 Hz at 10-bit color. HDMI 2.0 also adds support for 4:2:0 color sampling. The luminance, Y of a YCbCr signal, with 4:2:0 color sampling is divided among two TMDS channels, and the chrominance, Cb and Cr, signals are combined onto a single TMDS channel. This enables a UHD 4:2:0 signal with a 60 Hz frame rate to be sent at

the same data rate as a 30 Hz UHD 4:4:4 signal. However, both the source and the display must support this mode of operation in order for the signal to pass successfully.

DisplayPort

DisplayPort data rates are also increasing to improve support for 4K video at a 60 Hz frame rate. With a 10.8 Gbps data rate, DisplayPort 1.1a supports an 8-bit UHD signal at a 30 Hz frame rate over a single cable. In 2009, DisplayPort 1.2 doubled the data rate to 21.6 Gbps, enabling a 10-bit 60 Hz UHD signal with 4:4:4 chroma subsampling over a single cable. This level of performance demonstrates that DisplayPort 1.2 is well suited for 4K applications that require high frame rates, accurate color rendition, and the ability to show a very high level of image detail.

3G-SDI

The limited bandwidth of 3G-SDI does not enable a single cable solution for transmitting 4K or UHD video. With a maximum 2.97 Gbps data rate, multiple lanes are required based on current standards. Some manufacturers are beginning to offer SDI products that operate at 6 or 12 Gbps. However, formal SMPTE standards supporting these data rates are still pending. The capabilities to carry 4K/UHD signals using the various transport standards are summarized in Table 2.

System Design and Integration Challenges
Supporting Multiple Resolutions

Based on the applications and desired functionality specified by technology users, it is very common to have multiple destinations in a system. This could be multiple monitors, streaming encoders, video processors, recording devices, or connections to an additional signal distribution system. When this occurs, care must be taken in order to address the resolutions that are supported by such a wide range of destination devices.

Table 2: Bandwidth capabilities of HDMI, DisplayPort, and 3G-SDI

Bandwidth Capabilities of Current Digital Video Formats				
Standard	**Bandwidth**	**Color Sampling**	**UHD @ 30 Hz**	**UHD @ 60 Hz**
HDMI 1.4a	10.2 Gbps	4:4:4	1 cable, 8-bit	2 cables, 8-bit
			4 cables, 10-bit	4 cables, 10-bit
HDMI 2.0	18.0 Gbps	4:4:4	1 cable, 10-bit	1 cable, 8-bit
				2 cables, 10-bit
HDMI 2.0	18.0 Gbps	4:2:0	n/a	1 cable, 10-bit
DisplayPort 1.1a	10.8 Gbps	4:4:4	1 cable, 8-bit	2 cables, 8-bit
				4 cables, 10-bit
DisplayPort 1.2	21.6 Gbps	4:4:4	1 cable, 10-bit	1 cable, 10-bit
HD-SDI	1.485 Gbps	4:2:2	4 cables, 10-bit	n/a
3G-SDI	2.97 Gbps	4:2:2	n/a	4 cables, 10-bit

Historically, it was relatively easy to deploy systems designed around 720p, 1080i, or 1080p resolutions. The aspect ratio control and scaling between these resolutions did not require extensive up or down conversion. With the introduction of 4K and UHD video into today's system designs, a certain level of care must be exercised in order to ensure that all signals can be successfully routed to all destinations.

These variations in resolution can be traced to differences between broadcast and cinema applications. Broadcast environments were typically based on a signal with 1920x1080 pixels. This led to the term Full HD when referring to a progressive scanned, or 1080p, signal. Digital cinema applications on the other hand were based on signals with 2048x1080 active pixels. This is referred to as a 2K video signal.

4K vs. UHD

With the introduction of 4K video into the vernacular of end-users, care must be taken to understand which version of video they are actually requesting. References to quad HD, UHD, or even 2160p are likely indicative of the resolution achieved by using four 1080p quadrants to achieve an overall resolution of 3840x2160. The cinematic-based variation is four quadrants of 2K which equates to an overall resolution of 4096x2160. The Society of Motion Picture and Television Engineers - SMPTE has stepped in to clarify things a little by using UHDTV1 to represent a signal with at least 3840x2160 active pixels and UHDTV2 to indicate 7680x4320. This is the 8K resolution that is currently in the research and development stages, including plans to record the 2014 Winter Olympics in Sochi using 8K technology.

These differences between 4K and UHD could lead to aspect ratio challenges as well as impact to the EDID management scheme for the overall system.

Extending 4K and UHD Signals over Long Distances

In order to extend, switch, matrix, or otherwise distribute a 4K/UHD signal, System Designers must consider the sources, destinations, and distances involved. For intermediate distances, 100 meters (328 feet) or less, twisted pair distribution is an easy and economical option. When longer distances are involved, fiber optics or streaming technologies are available. Depending on the products selected, there are essentially three distribution topologies that could be applied. These include One Cable/Pathway, Two Cables/Pathways, and Four Cables/Pathways.

One Cable/Pathway

To use a single cable or pathway, the design solution must be compatible with a 3840x2160 or a 4096x2160 video signal. Due to the bandwidth limitations of readily available transport schemes, the frame rate and/or color encoding must be reduced. If extended color gamut or high frame rates are not a design criteria for the system, this might be the most desirable method. These limitations won't be addressed by recently

ratified standards such as HDMI 2.0 or similar until integrated circuit – IC manufacturers release new chipsets into the supply chain.


Two Cables/Pathways

The dual cable/pathway solution is an interesting option that allows for higher frame rates, such as 60 Hz, and increased color depth. However, finding sources and destinations that are compatible with this unique resolution can be challenging. In order to support this method of distribution, all products in the signal chain must be able to pass either a 1920x2160 or a 2048x2160 signal. Two of these signals, basically left and right halves, are then integrated together by the display to create a 4K/UHD image.

Path 1
(1920x2160)

Path 2
(1920x2160)
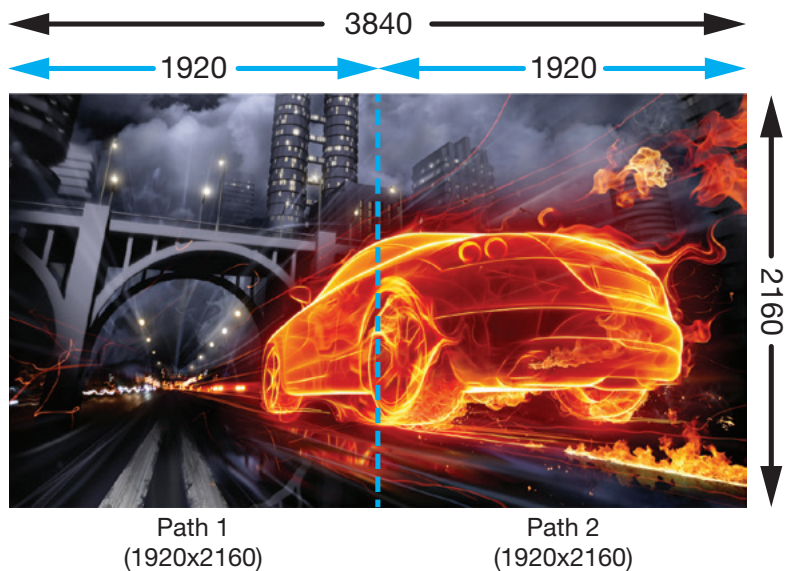
Four Cables/Pathways

The most common method for supporting 4K/UHD video with high frame rates in professional AV systems involves the use of four parallel signals. By using four 1920x1080 or 2048x1080 signals, the overall 4K/UHD signal is handled in quadrants. This allows for frame rates of 60 Hz or greater while still maintaining excellent color

depth. In broadcast applications, this is the dominant method of signal distribution due to the fixed raster size of SDI signals. When using this method, the timing between the paths becomes important. Distribution and processing devices must be able to maintain a level of synchronization that prevents image artifacts from occurring when the four quadrants are composited together by the destination device.
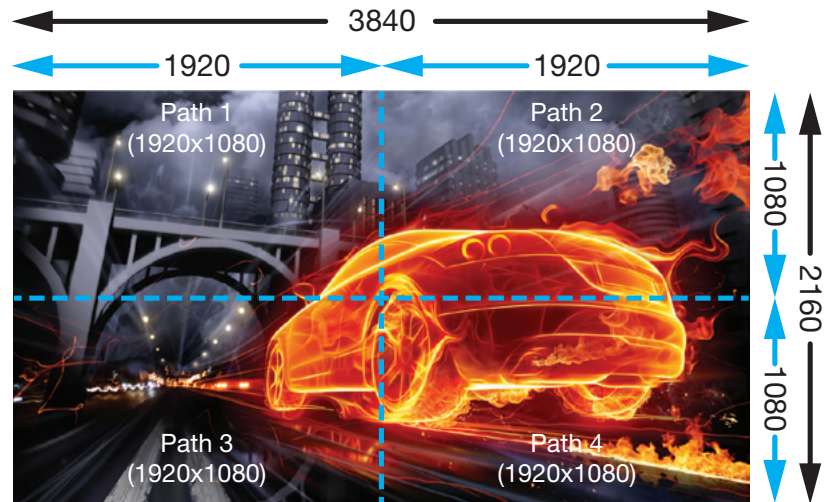
4K Sources and Displays

The available sources and displays capable of 4K or UHD video are growing at a remarkable pace. They use a variety of signal formats and connectivity. Consumer grade 4K televisions typically support a single HDMI 1.4a connector to provide UHD 3840x2160 resolution at 30 Hz or 4K 4096x2160 at 24 Hz, limited to 8-bit color depth.

In professional 4K AV systems, the display should be chosen to match the needs of the application. The requirements for the system may fall within the HDMI 1.4a capabilities, enabling a single wire solution. More demanding applications, such as medical imaging or simulation displays, require deep color and higher frame rates. Professional grade media players, displays, and projectors overcome the limitation of HDMI 1.4a by combining two or four DisplayPort, HDMI/DVI, or 3G-SDI signals to achieve deep-color UHD and 4K resolutions running at a full 60 Hz frame rate. Additionally, they often provide upscaling of 1080p signals to 4K resolutions. Table 3 summarizes the methods used by manufacturers to deliver 4K and UHD content with deep color and 60 Hz frame rates. In addition to solutions and support, Extron is ready with training to help you implement 4K systems using the appropriate methodology for today's applications.

Extron Training

Extron Institute is available to provide training to AV professionals that are faced with design and integration challenges in an ever-changing technology landscape. The School of Emerging Technologies is constantly evolving to address these trends. Coursework

Connections	Resolutions	Color Sampling	Color Depth Support	Available Products
1 x HDMI 2.0	1 x 4096x2160 @ 60 Hz 1 x 3840x2160 @ 60 Hz	4:4:4	8-bit color	Consumer grade 4K flat panel televisions. More displays and sources expected to be released.
1 x HDMI 2.0	1 x 4096x2160 @ 60 Hz 1 x 3840x2160 @ 60 Hz	4:2:0	10-bit color	No available devices at the time of this writing.
1 x HDMI 1.4a 1 x DisplayPort 1.1a	1 x 4096x2160 @ 30 Hz 1 x 3840x2160 @ 30 Hz	4:4:4	8-bit color	Apple Macbook Pro Computer Graphics Cards Professional grade 4K Flat Panel Displays from multiple manufacturers Consumer grade 4K Flat Panel Televisions
1 x DisplayPort 1.2	1 x 3840x2160 @ 60 Hz 1 x 4096x2160 @ 60 Hz	4:4:4	10-bit color	Computer Graphics Cards Professional grade 4K Flat Panel Displays from multiple manufacturers Displays from multiple manufacturers Professional grade 4K Projectors from multiple manufacturers
4 x HDMI 1.4a 4 x DVI 4 x DisplayPort 1.1a	4 x 1920x1080 @ 60 Hz 4 x 2048x2160 @ 60 Hz	4:4:4	10-bit color	REDRAY® Media Player Computer Graphics Cards Professional grade 4K Flat Panel Displays from multiple manufacturers Professional grade 4K Projectors from multiple manufacturers
4 x 3G-SDI	4 x 1920x1080 @ 60 Hz 4 x 2048x1080 @ 60 Hz	4:2:2	10-bit color	Broadcast equipment Professional grade 4K Flat Panel Displays from multiple manufacturers Professional grade 4K Projectors from multiple manufacturers
2 x DisplayPort 1.1a 2 x HDMI 1.4a	2 x 1920x2160 @ 60 Hz 2 x 2048x2160 @ 60 Hz	4:4:4	8-bit color	Computer Graphics Cards Professional grade 4K Flat Panel Displays from multiple manufacturers Professional grade 4K Projectors from multiple manufacturers

Table 3: Methods for displaying 4K signals at various frame rates and color depths

now incorporates extensive instruction on 4K and UHD technologies. Updated materials address increased resolution demands, extended color bit-depth, frame rates, dynamic range, and the impact these have on the data rate and infrastructure components. In addition to instructor-led training, demonstrations and hands-on experience with 4K solutions allow attendees to reinforce their understanding of design concepts and techniques required to support these emerging technologies.

Training is offered worldwide at Extron offices and other locations through the Extron Institute On The Road - EIOTR program. To learn more about courses available through Extron Institute, please contact your Extron Customer Support Representative.

Extron 4K Solutions

Extron 4K video solutions provide high-performance signal extension, routing, and distribution for 4K and UHD digital video signals. The wide variety of 4K ready product solutions include videowall processors, streaming encoders and decoders, media players, and fiber optic and twisted pair signal distribution products. Extron 4K solutions support an extensive list of displays and do not limit your designs to a short list of certified displays.

- Support extensive range of displays, projectors, and sources from a wide variety of manufacturers

- Support for 4K and UHD video at a full 60 Hz frame rate

- Extend, switch, and distribute 4K and UHD video over CATx cabling up to 330 feet (100 meters)

- Extend, switch, and distribute 4K and UHD video over fiber optic cabling up to 30 km (18.75 miles)

- XTP DTP 24 cable achieves full transmission distance up to 330 feet (100 meters) at 4K and UHD resolutions without cable length restrictions

- Key Minder® continuously verifies HDCP compliance for quick, reliable switching

- EDID Minder® automatically manages EDID communication between connected devices

- SpeedSwitch® Technology provides exceptional switching speed for HDCP-encrypted content

- Scalable HDCP-compliant videowall processors are optimized for use with 4K displays, windowing large numbers of standard definition, high definition, and UHD sources across displays with resolutions up to 3840x2160 or greater

- Stream 4K material with low latency and visually lossless quality

- Media players for playback of film and video productions prepared for Ultra HD 3840x2160 and Digital Cinema 4K resolution 4096x2160 displays

For assistance designing your 4K system, please contact your local Extron Customer Support representative. An Extron Applications Engineer will be assigned to your project and will work with you to ensure your complete satisfaction.

Conclusion

Driven by the need for higher resolutions in simulation, defense, medical, themed attractions, digital cinema, and other environments, the introduction of new source equipment and display devices intended for 4K/UHD video is outpacing standards development. Since there is no connectivity standard for 4K/UHD signals, the transport method, frame rates, and color encoding scheme dictate the required number of connections. Looking beyond the physical connections, other factors include pixel clocks, data rates, active pixel counts, sampling schemes, and more.

By increasing your knowledge of the technology and understanding as the governing bodies of the AV industry establish and evolve the standards, you will be able to design and deploy open architecture systems that do not reduce your design options to a single distribution scheme. A certificate without standards is not an assurance of building successful systems.

This white paper can be your first step toward being an expert on these emerging technologies. Understanding product capabilities while becoming educated on the technology is the best practice to ensure that your systems meet the rigorous demands of a 4K or UHD application.

Extron Electronics, headquartered in Anaheim, CA, is a leading manufacturer of professional AV system integration products. Extron products are used to integrate video and audio into presentation systems in a wide variety of locations, including classrooms and auditoriums in schools and colleges, corporate boardrooms, houses of worship, command-and-control centers, sports stadiums, airports, broadcast studios, restaurants, malls, and museums.

www.extron.com

──────── Worldwide Sales Offices ────────

Anaheim • Raleigh • Silicon Valley • Dallas • New York • Washington, DC • Toronto • Mexico City • Paris • London • Frankfurt
Amersfoort • Moscow • Dubai • Johannesburg • New Delhi • Bangalore • Singapore • Seoul • Shanghai • Beijing • Tokyo

UNITED STATES	EUROPE	ASIA	MIDDLE EAST
+800.633.9876	+800.3987.6673	+800.7339.8766	+971.4.299.1800
Inside USA/Canada	Inside Europe	Inside Asia	
+1.714.491.1500	+31.33.453.4040	+65.6383.4400	

Extron