4K

AV BEYOND THE BOX

4K SIGNAL MANAGEMENT

WHAT YOU NEED TO KNOW

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4K IS HERE!

Four years ago, the first commercial 4K displays came to market with five-figure price tags. Today, you can buy an Ultra HD television (3840x2160) for as little as $500, and display panel manufacturers are rapidly shifting production away from Full HD to 4K resolution. It's expected that 4K will shortly become the standard resolution for both display monitors and televisions.

But there's more to the story:

- High dynamic range (HDR) and wide color gamuts (WCG) are coming to 4K displays.
- High frame rates (HFR) will be possible, and there are already applications for these faster frame rates (virtual reality, immersive viewing).
- There is a new 4K Blu-ray format – Ultra HD Blu-ray – which incorporates both HDR and WCG image enhancements.
- Video cards with more powerful CPUs and expanded memory are making it possible to drive displays to 4K, 5K, and even 8K resolution.
- New 4K premium content has created the need for an upgraded copy protection standard (HDCP 2.2) that will reside on any interface that transmits and receives this content.
- All of these enhancements – 4K, HDR, WCG, HFR – will combine to push up both clock speeds and data rates through signal management equipment. To keep pace, new and faster versions of HDMI (2.0 and 2.1) and DisplayPort (1.3 and 1.4) have been announced.

If you find this new world of 4K confusing, you're not alone.

What do terms like "4K Certified" and "4K Ready" mean?

Is there an easier way to determine 4K compatibility?

Do I need to upgrade my existing hardware, or will it work as is?

What about those new versions of HDMI announced recently?

Which version of copy protection do I need to support?

Kramer has prepared this guide to help you better understand:

[1] What exactly this industry transition to 4K imaging involves

[2] What challenges it creates in interfacing, switching, and distributing 4K signals

[3] How more robust copy protection will impact 4K signal management equipment

THE MOVE TO 4K FROM FULL HD

The accelerating transition from Full HD to 4K imaging in professional and consumer applications is being driven by several factors, including a rollout of 4K movies and gaming content, plus the availability of next-generation Blu-ray disc media.

Another factor is a shift in manufacturing away from low-profit display panels that feature Full HD (1920x1080) resolution. The cost differential between Full HD and 4K (3840x2160, 4096x2160) display panels has essentially dropped to zero, and there is more profit in 4K panel manufacturing.

This doesn't mean that Full HD displays will quickly disappear – far from it. Prices have come down considerably on finished Full HD monitors and displays, which will sustain their popularity for classrooms, meeting rooms, and digital signage for a few more years.

Still, more and more 4K display products are coming to market and their size and fine pixel pitch makes these displays very attractive for certain vertical markets. By the end of this decade, 4K displays will command the lion's share of the direct-view display market for all applications.

[FIGURE 1]

77-inch 4K HDR OLED TV, Shown by LG Electronics at CES 2017

NEXT-GENERATION DISPLAY ENHANCEMENTS

Of all the next-generation display enhancements, the most exciting is **high dynamic range (HDR)**. A normal display can reproduce images with perhaps 9 to 11 stops of light, whereas an HDR display can reproduce images with as many as 18 stops of light, depending on the illumination system. Applications for HDR (besides consumer television) include virtual reality, 3D imaging, command and control, surveillance, and immersive environments.

Hand-in-hand with HDR is **wide color gamut (WCG) imaging**, which can reproduce a volume of colors closer to what the human eye sees. The widespread adoption of quantum dot (QD) backlights provides HDR images that also contain a larger range of saturated colors, as defined by ITU Recommendation BT.2020. The increasing popularity of fine-pitch light-emitting diode (LED) videowalls will also drive the move to HDR and WCG imaging.

[FIGURE 2]

34-inch Curved Widescreen LCD Monitor (3440x1800) with HDR and WCG by Samsung

Gaming, simulation, and virtual reality markets are all asking for **high frame rates (HFR)** for video, eliminating flicker and providing a very realistic viewing experience. Rates of 90, 100, and even 120 Hz are being proposed and standardized by various organizations, and emerging display technologies are up to the task of showing these high-speed images.

On top of everything else, it's now possible to buy desktop displays with **5K (5120x2880)** resolution, along with super-wide monitors equipped with HDR and WCG imaging. And large displays with **8K (7680x4320)** pixel resolution aren't far off.

With all this in mind, it would be smart and prudent to design your AV facilities to be future-proof; providing enough bandwidth to switch, distribute, and extend signals with resolutions of 4K pixels and beyond.

[FIGURE 3]

A 27-inch 5K (5120x2880) Desktop Monitor by LG

SWITCHING AND DISTRIBUTING 4K SIGNALS

As you saw earlier, the enhancements that 4K imaging provides will drive up clock rates considerably. Even a basic (4K30) image with normal color and dynamic range will double the clock frequency as it has four times the resolution of a Full HD image (2x horizontal and 2x vertical).

Here's an example: For a 1920x1080p signal refreshed at 60 Hz, the clock frequency is 148.5 MHz. Using a standard (CTA) blanking interval of 4400x2250 pixels, a 4K signal refreshed at 60 Hz will require a clock rate of 594 MHz. With 8-bit RGB color, the total data rate through your signal management system will be 17.82 gigabits per second (Gb/s).

Here's a tip: With two different versions of "4K" resolution to consider – plus 5K and unusual super-widescreen pixel counts – don't focus on the image resolution. Instead, calculate the required data rate (total pixels (x) refresh rate (x) color bit depth (x) color mode). If your signal management gear is fast enough to pass the calculated data rate, then it also will pass the desired resolution – with some caveats.

HDMI 1.3/1.4 AND 4K

Here's where marketing has really confused people: The most widely-used version of HDMI – 1.3/1.4 – has a maximum overall data rate of 10.2 gigabits per second (Gb/s); plenty fast enough to transport Full HD (1920x1080) and Wide UXGA (1920x1080) images. But can this version handle 4K?

It can, in a limited fashion. If we refresh the 4K signal from our example at half the speed, or 30 Hz, the clock rate drops to 297 MHz. That's easily accommodated by HDMI 1.3/1.4 with its maximum clock rate of 330 MHz. We can label this 4K compatibility mode **4K30 4:4:4**.

But we can accommodate faster refresh rates by using lower color resolution, such as 4:2:0. This is the color resolution used for DVD, Blu-ray, television, and streaming media. Now the frame rate can increase to 60 Hz through that same HDMI 1.3/1.4 connection, but the overall data rate remains the same. We'll label this 4K compatibility mode **4K60 4:2:0**.

In terms of speed, 4K30 4:4:4 and 4K60 4:2:0 are interchangeable. Signal management products with this designation can switch, distribute, and extend 4K signals, depending on whether all other connected hardware provides the correct Extended Display Identification Data (EDID) for 4K compatibility from displays all the way back to the video source.

Products labeled **4K30 4:4:4** and **4K60 4:2:0** provide a basic level of 4K signal support. Note, however, that these same products will not be able to transport and switch HDR and WCG signals, as those require faster interface speeds and also carry additional HDR/WCG metadata that's not compatible with HDMI 1.3/1.4.

HDMI 2.0 AND 4K

The HDMI 2.0 specification boosts the overall data rate through the interface to 18 Gb/s, which is an increase of nearly 80%. Why the need for extra speed?

As we saw in the previous section, HDMI 1.3/1.4 can only transport 4K signals with full color resolution (RGB or 4:4:4) at a maximum frame rate of 30 Hz. However, a 4K60 4:4:4 signal requires a clock frequency of 594 MHz, which is considerably faster than the 330 MHz maximum clock rate of HDMI 1.3/1.4.

INTERFACE	MAX. BIT RATE, GB/S	1080P/60 4:4:4 (RGB)	2160P/30 4:4:4 (RGB)	2160P/60 4:2:0	2160P/60 4:4:4 (RGB)	SUPPORTS HDR?	SUPPORTS DSC?	SUPPORTS USB TYPE-C ALT MODE?
HDMI 1.3/1.4	10.2	√	8-bit only	8-bit only	–	–	–	–
HDMI 2.0	18	√	√	√	8-bit only	V 2.0a	–	√
HDMI 2.1	48	√	√	√	to 16-bit	V 2.1a	√	√
DisplayPort 1.2	21.6	√	√	–	to 10-bit	–	–	–
DisplayPort 1.3	32.4	√	√	–	to 16-bit	–	√	√
DisplayPort 1.4	32.4	√	√	√	to 16-bit	√	√	√

[TABLE 1] – Comparison of Current and Future Versions of HDMI and DisplayPort

HDMI 2.0's higher clock frequency of 600 MHz means it can accommodate a 4K60 4:4:4 signal. Accordingly; switchers, distribution amplifiers, and signal extenders that are equipped with HDMI 2.0 ports can be labeled as 4K60 4:4:4 products.

The maximum speed of HDMI 2.0 limits it to transporting an 8-bit RGB (4:4:4) 60 Hz 4K signal. However; by using half the color resolution as in our previous example, we can also transport a 4K60 signal with 10-bit 4:2:0 color through HDMI 2.0.

Why is that important? As we learned earlier, HDR and WCG are becoming an integral part of the Ultra HD Blu-ray format and streaming 4K content. And both will be encoded as 10-bit 4:2:0 color signals, which require the speed of HDMI 2.0.

For displaying HDR/WCG content, HDMI 2.0 must also recognize the HDR/WCG metadata present in the source signal. It does this with version HDMI 2.0a, which reads HDR metadata that follows the CTA 861.3 specification.

[FIGURE 4]

Demonstration of Dynamic HDR Content over HDMI 2.1 at CES 2017

HDMI 2.1 AND 4K

At CES 2017, the HDMI Forum announced version 2.1. The maximum data rate has been increased to 12 Gb/s per lane, and a fourth data lane has been added for a total of 48 Gb/s capacity. The same 19-pin connector is retained and older versions of HDMI will be compatible with version 2.1, as will the 'a' suffix for HDR metadata.

Maximum supported resolutions have increased to 8K (7680x4320p/60), while 4K content with 10-bit, 12-bit, and 16-bit color can be refreshed as fast as 120 Hz. HDI 2.1 will also support Display Stream Compression (DSC) for greater efficiency. Look for HDMI 2.1 to start appearing in products by the end of 2018.

DISPLAYPORT AND 4K

The current version of DisplayPort (1.2) is already fast enough (21.6 Gb/s) to transport a 4K/60 10-bit 4:4:4 signal, while the latest version (1.3/1.4) boosts that data rate to 32 Gb/s, fast enough to transport 12-bit and 16-bit 4K. In addition, DP 1.4 supports HDR/WCG metadata and is compatible with Display Stream Compression (DSC).

COPY PROTECTION AND 4K

"Premium" content (movies and TV shows) distributed via DVD and Blu-ray was originally encrypted with **High Bandwidth Digital Copy Protection (HDCP) versions 1.0 – 1.4**. This layer of authentication was added to the HDMI and DVI interfaces to prevent unauthorized copying, and used a three-step process to ensure a secure connection:

[1] The video source authenticates a 'sink' (TV, monitor, AV receiver, DA, switch), using Key Selection Vectors (KSVs)

[2] After authentication, a stream cipher encrypts the content, requiring frequent updating of keys after each encrypted frame of data is transmitted

[3] Hacked, cloned, or revoked keys are stored in data burned to the disc or are present in the video file, and are blocked out during the authentication process

Although it worked for simple player-to-TV connections, the original versions of HDCP presented serious challenges to manufacturers of signal switching and distribution equipment. HDCP required authentication every 1.5 seconds between sink and source, resulting in a screen of colored "hash" if no keys were successfully exchanged.

In 2010, a reverse-engineered master key for HDCP 1.4 was released on the Internet. Accordingly; Intel and Digital Content Protection, LLC determined that a more robust form of HDCP (2.0) was needed for the next generation of 4K movies, games, and TV programs, using any type of connection – not just HDMI, DVI, and DisplayPort.

HDCP 2.2

HDCP 2.2 is a major upgrade to version 2.0, announced in 2008 and hacked a few years later. Like version 2.0, version 2.2 can run on any interface – including HDMI, DisplayPort, DVI, and USB 2.0/3.0 – and was released in early 2013.

Versions 2.0 – 2.2 are very different from versions 1.0 – 1.4. They use a much more robust encryption system, based on 128-bit AES ciphers with 1024-and 3072-bit RSA public keys. A new authentication protocol is used, along with a locality check. Also, HDCP 2.2 is not backward-compatible with older versions of HDCP (1.0 – 1.4, 2.0-2.1) due to the security and hacking issues just mentioned.

Here's how the locality check works. When an HDCP 2.2 video source is connected to and requests keys from a display, receiver, switch, distribution amplifier, or signal extender, it must get a response within 20 milliseconds or the connection is shut down completely. Only a new 'hot plug' connection or switch cycle that completely breaks the connection can be used again to try and exchange keys.

[FIGURE 5]

Ultra HD Blu-ray Player Requiring HDCP 2.2Cconnections from its HDMI 2.0 Output

IS MY 4K CONTENT PROTECTED, AND HOW?

As we've learned, 4K content can travel through an HDMI 1.3/1.4 interface as well as HDMI 2.0. And the version of copy protection in use does not have to be linked to the version of HDMI. As a result, there are now many HDMI switching and distribution products on the market that combine the older HDMI 1.3/1.4 interface with HDCP 2.2.

In general, all packaged and digital premium 4K content released after 2015 will be encrypted with HDCP version 2.2. If you anticipate playing back this content through your system, your display interfaces and signal management and distribution equipment will also need to be compliant with version 2.2 at every interface.

By itself, HDCP 2.2 is not backward-compatible with older versions. However, you can also support HDCP version 1.3/1.4 through the same interface, using a different set of keys. Check the specifications: Backward compatibility with older HDCP versions is up to the manufacturer of TVs, monitors, receivers, and signal management equipment.

Some models of UHD Blu-ray players will automatically down-rez 4K content to 1080p if HDCP 2.2 is not present but an older version of HDCP is detected. Most early models of 4K TVs (2012 – 2015) do not support HDCP 2.2.

HDCP AND WINDOWS, APPLE, ANDROID

Windows computers with 4K/30 output capability are now available. Using HDMI and DisplayPort outputs, these laptops can play back premium 4K content that has been streamed or downloaded to them. With a valid HDCP 2.2 connection, copy protection will only be present during playback. All other content (photos, documents, spreadsheets, etc.) will pass through the display interface without encryption.

In contrast; Apple computers, laptops, and set-top boxes look for the presence of HDCP keys when connected to a TV, monitor, AV receiver, or signal management equipment. If HDCP keys are present, the HDMI/DisplayPort connection is set to encryption mode, regardless of the content being played back or viewed.

This means that all connected devices downstream from the Apple device (TVs, monitors, and switching/distribution/signal management hardware) must present valid HDCP keys. Otherwise, they won't generate or display any content – not just protected content. Only a complete reset of the connection (i.e., a hot plug or power down/power up cycle) will work.

Tablets, smartphones, and Chromebooks using the Android OS automatically encrypt their output connections for all types of content, protected or otherwise. The same rules apply as with Apple products – everything playing back on the device, whether a movie or a simple spreadsheet, will be encrypted.

As of writing this paper, these devices all use HDCP versions up to 1.4 for playback, so they will not be able to display 4K premium content without HDCP 2.2 support.

SUMMARY

The transition away from a “Full HD” AV facility to 4K and beyond is well underway. While there will be abundant choices for 4K displays and 4K content, the biggest remaining challenge for designers, installers, and facility managers is to build a 4K signal management infrastructure that has sufficient bandwidth to transport, switch, and distribute 4K+ signals that also use new, more secure copy protection systems.

Kramer is ready when you are with a fast-growing portfolio of 4K signal management products to meet your needs, from basic (4K30 4:4:4, 4K60 4:2:0) to advanced (4K60 4:4:4).

ABOUT KRAMER

Since 1981, Kramer Electronics has been a leading player and pioneer in the Pro AV industry. With 26 global offices across six continents and support and distribution in over 100 countries, Kramer offers an extensive and innovative Pro AV solutions portfolio for Corporate, Education, Houses of Worship, Government, Live Events, Healthcare, and more.

For over three decades, Kramer has built its reputation on strong personal relationships with its customers and providing the highest level of service and support in the industry.

Kramer has won numerous awards, including the 2013 Pioneer of AV Award at InfoComm in honor of its Founder, President & Chairman, Dr. Joseph Kramer. Kramer’s award winning analog and IP-driven solutions for collaboration, streaming and control are at the forefront of an ever-evolving Pro AV industry. Kramer’s consistent sales growth and expansion into new markets is a testament to the company’s commitment to R&D and reliance on customer feedback.

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