The Official 4K Report

May 2016

Executive summary

High-resolution 4K video has exploded onto the scene in the professional AV market in the last several years. IHS Technology predicts that 2016 4K panel shipments will make up 40% of the overall display market[1], just four years after the first 4K panels started shipping. And growth is strong; the same IHS report indicates that 2016 shipments of 4K panels are up 67% from 2015, even as overall panel shipments decline.

Yet there is still substantial market confusion as to what 4K truly means. While the 4K moniker ostensibly refers to video resolution, many other associated technologies have come along for the ride. Advancements in color formats, frame rates, and content protection all must be considered when specifying video distribution systems.

This report aims to provide a snapshot of the 4K market today as it applies to the professional AV market, and clear up misperceptions about 4K among AV professionals.

What is 4K video?

Many technologies have arrived in conjunction with 4K video, so it helps to break them out into separate pieces. 4K video started to gain industry traction in 2009, when the HDMI® 1.4 specification first added support. The HDMI 2.0 specification built on that, adding support for more frame rates and color formats.

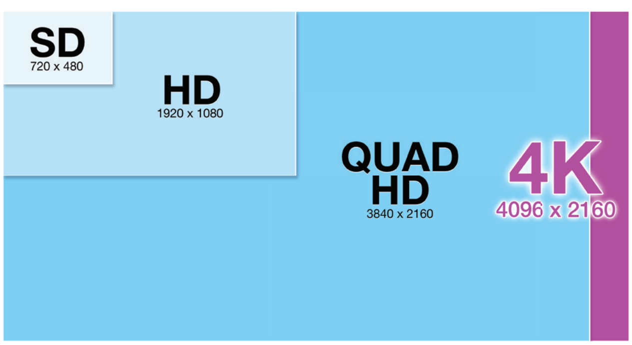
4K resolutions

The resolution of a video format refers to the dimensions of a video frame in pixels. A given resolution is defined by its pixel width and pixel height, sometimes referred to as the line width and line count, respectively.

Familiar HD format names such as 720p and 1080p are shorthand for their full resolution definitions: 1280x720 and 1920x1080, respectively. Pixel width precedes pixel height.

4K, on the other hand, has become shorthand for two resolutions:

- **3840x2160:** this 4K format is defined by the International Telecommunication Union (ITU) as Ultra-High-Definition (UHD) television. Most consumer-grade video sources and displays support this resolution.
- **4096x2160:** this 4K format is defined by Digital Cinema Initiatives (DCI) and is the dominant standard in the movie projection industry.



Most 4K PCs and video recording devices will support both the UHD and DCI formats, and most displays will render them. But 3840x2160 UHD has become the dominant format in the professional AV space. The majority of consumer and pro AV displays are 3840x2160 UHD native resolution.

3840x2160 is double the resolution of 1080p in both dimensions, resulting in an image with four times the pixel density when viewed on the same size display. This increased pixel count also greatly increases the data rate, or bandwidth, of the video signal.

Frame rates

Video frame rate is the number of images, or frames, per second that are included as part of the 4K signal. Frame rate is defined in units of frames per second (fps) or Hertz (Hz). These are the most common frame rates found today:

- **24 fps:** Most Hollywood movies are filmed at 24 fps. In the analog days, this frame rate provided a good balance between image quality and the amount of film used while shooting. Its use today continues due to a combination of institutional inertia and public perception that 24 fps looks “cinematic.”

[1] https://technology.ihs.com/551184/uhd-lcd-tv-panels-to-exceed-40-percent-of-total-shipment-area-in-2016-ihs-says

- **25/30 fps:** 30 fps is often used because it's exactly half the rate of the more common 60 fps, and thus conversion between the two is easily done. In Europe and elsewhere in the world, 25 and 50 fps are more common. These rates are sometimes used to create the similar cinematic effect of 24 fps, or may be employed in the digital space to address video processing overhead or video bandwidth concerns, which we'll address in a later section.
- **50/60 fps:** 50 fps (Europe) and 60 fps (U.S.) have become the standard for most consumer video and PC applications. These frame rates are required for rendering fast-motion content, such as sports or even stock tickers.
- **120 fps:** Video signals are rarely transmitted at 120 fps today. Many displays on the market boast support for 120 fps, but it's only used internal to the display itself. 120 fps is evenly divisible by 24, 30 and 60, so it's easy for the display to convert any input frame rate to its internally-used 120 fps. Many of these displays will also employ video processing techniques to smooth an image to simulate a true 120 fps signal, but these techniques frequently produce undesirable artifacts.

Where does 4K matter?

While 4K brings with it many technologies for the integrator to consider, from the end user perspective, it's about a clearer picture. And as displays drop in price, larger displays are used in more applications and the resolution differences become obvious. And as 4K penetrates the home, end users will start demanding it at school and work.

High-resolution laptops

When we talk about 4K requirements in video distribution systems, we're really talking about 4K as the maximum supported resolution. The previous generation of video distribution systems supported up to 1080p or 1920x1200 resolutions, but many of today's PC and laptop resolutions exist in-between those and 4K.

For instance, five of the PC Magazine® Ten Best Business Laptops of 2015 sport displays with native "in-between" resolutions such as 2880x1620 or 3200x1800[2]. Distributing video at these resolutions requires 4K video distribution systems.

And while these laptops can surely output 1080p on their video outputs, doing so can create a jarring experience for the end user, even beyond the noticeable degradation in video quality from their laptop experience. When set to mirror mode, the laptop will change the resolution of the laptop display to match the limitations of a 1080p video distribution system, which rearranges the desktop and can reshuffle desktop icons. And in both mirror mode and extended desktop mode, users will find that content that fits nicely on their laptop screen will not fit so well on the in-room projector or display at the reduced resolution.

4K consumer content

Hollywood executives are pushing hard on 4K to capitalize on revenue opportunities and to enhance the end user viewing experience. Samsung® recently started shipping the first 4K Blu-ray® player, and 4K streaming products such as the Sony® FMP-X10, Roku® 4 player and Amazon® Fire® TV have been available for some time. Over 100 4K movie titles are expected to be available by year end in 4K Blu-ray and streaming formats[3].

4K adoption is spreading to cable and satellite as well, with providers such as Tivo®, DirectTV®, Dish® and Comcast® Xfinity® already having 4K offerings.

Touch displays, digital signage

High resolutions are paramount for displays that are in close proximity to the user. Touch screens require close proximity, as well, and have seen increased adoption in presentation rooms, especially those that incorporate digital whiteboards or unified communications (UC) systems. Digital signage displays are often employed in applications that lend themselves to up-close viewing, and increasingly utilize touch screens themselves.

Collaboration

Increasingly, small rooms are using technology for local collaboration. Windowing processors can merge content from multiple sources onto one screen in side-by-side or quad configurations. In these situations, content from each source is 25% the size it would be if it were full screen. Even when sitting very close to a 1080p screen, text can be difficult to read. A 4K display allows for four full-resolution 1080p sources on the same screen.

[2] http://www.pcmag.com/article2/0,2817,2362039,00.asp [3] http://hdguru.com/hollywood-executives-see-bright-future-for-4k-uhd/

Video transport infrastructure limitations

HDMI is the primary means through which we transmit digital video from content sources into video distribution systems. DisplayPort is a distant second in digital video; indeed, VGA still has a greater presence in the industry.

These video technologies are intended for short connections between devices. HDMI and DisplayPort specify a certain signal integrity over the length of the cable rather than a specific distance, but current technologies have limited the length of passive cables to approximately 10m. The increase in video speeds to support 4K is expected to reduce the length of passive cables to 3-5m.

USB-C is the latest upstart and may catch on in the coming years. USB-C can provide video, audio, USB signaling, and power up to 100W. The many abilities of USB-C are expected to drive significant utilization of that input on laptops, tablets, and phones.

The more relevant video transport protocols for the professional AV industry today are those used for signal extension and distribution. HDBaseT® dominates the market, though fiber and Ethernet-based solutions exist as well.

HDBaseT

HDBaseT is a technology that extends audio, video, Ethernet, and COM/IR control over standard structured copper cabling infrastructure. The HDBaseT Alliance has opened the technology and promoted its use as an industry standard. Many source, display, and switch manufacturers have integrated HDBaseT into their products. HDBaseT has a bandwidth of 10Gbps, which will become important as video speeds increase past this point. See “Bandwidth limitations” for further discussion.

Fiber

Several video distribution manufacturers support signal distribution over fiber. No dominant standard has emerged, so fiber solutions on the market are proprietary. Fiber allows for distribution over much longer distances than copper. Maximum distances vary from manufacturer to manufacturer, but most can support many kilometers with single-mode fiber.

One common misconception is that fiber solutions can support higher video bandwidths. While the fiber itself may support higher bandwidths, the electronics driving the fiber operate at the same speeds as those in HDBaseT solutions.

Ethernet

The network has recently emerged as a viable transport for digital video. There are several different technologies that can be used to put video on the network, many of which involve video compression to fit high-bandwidth video on lower-bandwidth networks. The three most common technologies today are H.264 compression, JPEG 2000 compression, and uncompressed video streams.

- **H.264 compression**

  H.264 video compression can enable transmission of high-quality video at low enough bandwidths (0.5 Mbps – 25Mbps) to co-exist on existing enterprise network infrastructure. H.264 solutions generally do not support 4K, so 4K video must be scaled to a lower resolution for streaming with this technology.

- **JPEG 2000 compression**

  JPEG 2000 compression takes the opposite approach of H.264, optimizing for latency rather than bandwidth. It does this by compressing a single video frame at a time, without attempting to save bandwidth by referencing data from other video frames that came before or after it. This compression method requires much more data per frame but each frame can be transmitted without having to wait for another frame to compare. Typical JPEG 2000 video streams for 1080p video are 250-300 Mbps and 4K video streams are 500-600 Mbps[4].

  As a result, JPEG 2000 streams do not play nicely on the enterprise network and require dedicated Gigabit networking infrastructure. Compression latency for JPEG 2000 solutions ranges from 50-200ms, while lower than H.264, this range is still too high for in-room presentations and/or video conferencing, which require latency of less than 50ms.

[4] http://toolstud.io

- **Uncompressed 10G**
  While video compression does make high-bandwidth video distribution achievable, it is not absolutely required, and uncompressed solutions do exist on the market. 1080p-class video utilizes about 4.5 Gbps and 4K30-class video utilizes about 9Gbps of bandwidth. Uncompressed video at these resolutions requires dedicated enterprise-grade 10G network infrastructure, which has several limitations:
  - 10G infrastructure is far more expensive than 1G networks
  - 10G does not support PoE
  - 10G Ethernet switches can be difficult to find in quiet, small form-factors appropriate for in-room solutions
  - 10G Ethernet over copper (10GBASE-T) requires category 6A cabling to reach 100m and is relatively expensive; typical datacenter 10G Ethernet connections run over single-mode or multi-mode fiber instead
  - Transporting multiple 10G video links between Ethernet switches requires very careful network design, involves very expensive 40GB or 100GB uplinks, and typically still results in difficult-to-manage bandwidth bottlenecks

  Due to these difficulties, uncompressed 10G video is much more appropriate for broadcast video applications with dedicated and carefully-designed network infrastructure, rather than the professional AV space.

Bandwidth limitations

All of these distribution technologies currently, and for the foreseeable future, cap out at a data rate of about 10 Gbps[5]. Most 4K source content and PCs support the same max data rate. Most modern displays support higher rates. Displays are always slightly ahead of the source and distribution markets, because they are not as directly affected by signal distribution challenges or lack of available content.

In a 1080p world, we always assumed our distribution equipment could support 60 frames per second and 4:4:4 color. In a 4K world, that pushes our data rates to 18 Gbps, so compromises must be made to fit within the 10 Gbps envelope.

There are two common ways to do this:

- **Cut the frame rate.** Using 30 fps video will ensure 4K content fits in the available bandwidth. Most laptops and PCs take this approach, and since most PC content is not fast-moving there is no noticeable degradation in video quality.
- **Use chroma sub-sampling.** The content for Blu-ray, cable and satellite boxes, and streaming sources is already encoded in 4:2:0, so the source will simply pass that on through the HDMI cable. In this way, it can preserve the integrity of the fast-motion content.

If Deep Color is desired, both a reduced frame rate and chroma subsampling may be employed. In reality, most native Deep Color content will be 4K Hollywood content, which is filmed at 24 fps and thus does not require frame rate reduction.

A truly flexible and scalable video distribution system must give the source the flexibility to optimize for 60 fps or for color, as the use case requires.

[5] While 40G and even 100G Ethernet networks exist, these are priced beyond the range of most professional AV installations.

Color Depth and Deep Color

Color depth refers to the number of data bits that are devoted to each pixel. The more bits per pixel, the more colors it can represent, and the “deeper” the color. This results in a finer gradient of color between pixels, allowing for smoother color transitions and reducing an undesirable effect known as “color banding”.

As an example, imagine we’re recording video of a clear blue sky. A blue sky is not actually uniformly blue; there are subtle but visible variations of color in different parts of the sky. The deeper the color depth of the video, the smoother the transitions between those variations will be. An image with less depth can result in color banding, as illustrated in figure 1.

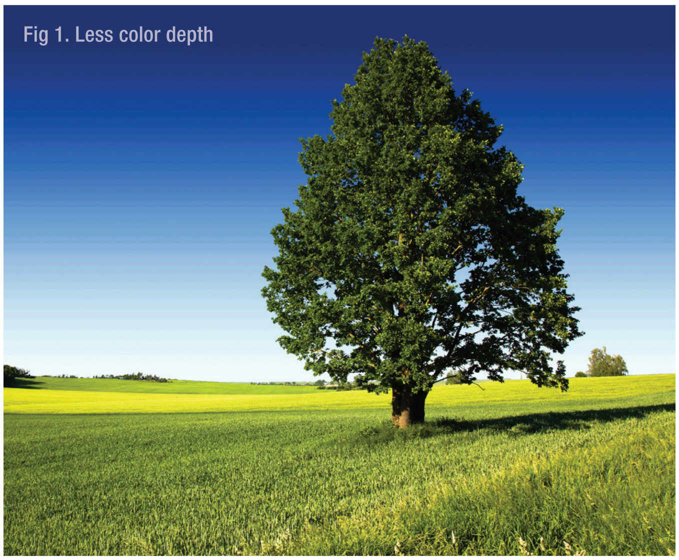


Fig 1. Less color depth


Fig 2. Greater color depth

In the world of consumer video and PC applications, the most common color depth is 24-bit. HDMI introduced Deep Color in revision 1.3 of the specification, which included 30-, 36- and 48-bit color. Deep Color never really caught on, but we’re beginning to see a resurgence of interest in 30-bit color as 4K video has become more popular.

To confuse matters, sometimes industry documentation will refer to color depth as the number of bits per pixel component, as opposed to the number of bits for the entire pixel. Each pixel has three components, i.e. red, green, and blue. So 24-bit color can also sometimes be described as 8-bit color, 30-bit color as 10-bit color, and so on.

The number of bits used to describe the color describe in binary how many different levels of color can be shown. So if 8 bits is used to describe a color, then 28 (256) levels of that color are possible. 10-bit color provides 210 (1024) levels and 12-bit color provides 212 (4096) levels of each color – red, green, and blue.

Deep Color (10-bit and 12-bit color) was not important until recently because most available content was only 8-bit, and the majority of LCD displays that were available at the time were only able to reproduce 256 levels for each color, meaning that the extra bits of information couldn’t be accurately reproduced.

With the arrival of new LCD display technology, LCD TVs are able to reproduce more color levels, making Deep Color relevant. In addition, OLED displays are beginning to appear on the market and they can accurately reproduce colors much better than current LCD technology.

New 4K Blu-ray technology with the Ultra HD Premium label will have content generated in 10-bit color. Content will be available in 10-bit color and can be reproduced by displays in 10-bit color, increasing the relevance of Deep Color technology.

Chroma subsampling

The HDMI 2.0 specification introduced 4:2:0 chroma subsampling to the world of HDMI. Chroma subsampling is a lightweight compression technique that takes advantage of how the human eye perceives color as opposed to light levels. Chroma subsampling is in wide use throughout the broadcast and consumer video industries. Notably, the Blu-ray Disc® Association uses chroma subsampling as one technique to fit high-resolution content onto discs, and Blu-ray has long been lauded as the gold standard in consumer video quality. The trend continues as we move to 4K, with 4K Blu-ray and broadcasters using chroma subsampling to save bandwidth.

Until recently, chroma subsampling had limited support in the HDMI specification. As a result, Blu-ray players and cable and satellite set-top boxes (STBs) had to remove the chroma subsampling, which increased the bandwidth of the signal with no increase in signal quality. With the advent of HDMI 2.0, source devices can now take advantage of the same chroma subsampling on the HDMI path that they were already using on their upstream distribution and processing paths.

The human eye is much more sensitive to light levels than color. Chroma subsampling takes advantage of this fact by sharing chroma (color) data across multiple pixels, while ensuring that each pixel gets its own luma (light level). HDMI now supports three common chroma subsampling formats:

- **4:4:4:** This format is, in effect, not subsampled. Every pixel gets full chroma and luma data. This format is rarely used outside of the computer industry.
- **4:2:2:** In this format, every other pixel has unique color data.
- **4:2:0:** In this format, four adjacent pixels share color data. This is the format used by the Blu-ray Disc Association, cable and satellite STBs, and streaming devices.

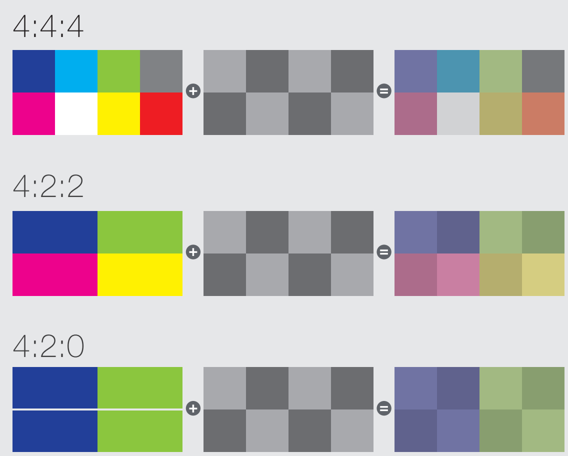
WHAT DO THE CHROMA SUBSAMPLING NUMBERS MEAN?

The chroma subsampling scheme is commonly expressed as a three part ratio **J:a:b** (e.g. 4:2:2) where the letters stand for:

J: horizontal sampling reference (width of the conceptual region; usually, 4)

a: number of chroma (color) samples in the first row of J pixels

b: number of changes of chroma (color) samples between first and second row of J pixels



4K and scaling

Scalers have always been a crucial component of any digital video distribution system, and they are even more important as 4K video gains traction in the market.

Resolution compatibility

While the pace of 4K adoption has been rapid, most installations today include a mix of 4K and 1080p sources, as well as in-between PC formats such as 2560x1440. Similarly, while the main room display may be 4K, smaller confidence monitors, video teleconferencing codecs or network streaming encoders may only support 1080p or even lower resolutions.

A proper video scaler will ensure that any video resolution from any source will work and provide the best image possible for any downstream display. Be sure to consider both upscaling and downscaling when designing a system. Upscaling is important for legacy sources paired with modern 4K displays, while downscaling is important for modern sources paired with small confidence monitors, network encoders, and VTC systems.

Frame rate compatibility

Various frame rates are now in use due to 4K adoption, so it's important to ensure your scalers can convert properly across 24, 25, 30, 50 and 60 fps for all resolutions. Many scaling devices on the market only support 4K video at 30 fps, which can cause 4K conversion from 60 fps sources to look choppy. Furthermore, these devices frequently don't support 4K scaling at 60 fps at all, rendering an otherwise 60 fps 4K capable distribution system as 30 fps only.

Fast switching

Even if a given display can support every resolution and frame rate that you expect in your system, most display devices on the market are not optimized for fast input switching. Even if they are, they are frequently optimized for fast switching between inputs on the display itself, as opposed to an upstream video distribution switch. When video changes at an upstream switch, the display gets no warning, loses lock on its signal, and must re-lock on the new signal. This process can take between 5 and 10 seconds or even longer depending on the display or projector, resulting in a negative user experience.

A well designed scaler that is intended for use with a video distribution system should be optimized for fast upstream switching. The scaler "free-runs" its output, ensuring that there is always a constant video signal being sent to the display. The scaler continuously monitors its input for the first signs of an upstream switch, quickly and cleanly dropping the original signal and locking on the new signal. The display never loses signal lock, so irrespective of the display type the entire process can take less than one second.

Updated content protection

The High Bandwidth Digital Content Protection (HDCP) protocol is commonly used to protect audiovisual content from unauthorized copying. The technology was developed by Intel®, but it was spun off to a separate organization, Digital Content Protection (DCP), LLC for licensing to different video distribution technologies. HDCP is used extensively with digital video transmission formats such as HDMI and HDBaseT.

Versions 1.2 through 1.4 of the HDCP specification were in heavy use with 1080p content, especially any Hollywood movies or TV shows. Versions 2.0 through 2.2 of the specification increased the level of encryption used for content protection, so Hollywood movies studios elected to require HDCP 2.2 for the distribution of their 4K video content. All consumer-facing 4K video sources will support HDCP 2.2, including new 4K Blu-ray players, cable and satellite set-top boxes, and network streaming devices. Laptops will be required to follow suit in order to support 4K streaming services and 4K Blu-ray discs.

There are a few important facts to understand with respect to HDCP 2.2:

- The content source decides what level of content protection is required throughout the video distribution system. If the content source enables HDCP 2.2, every piece of active video equipment that processes, switches, or otherwise propagates the signal must support HDCP 2.2. This includes switchers, HDBaseT transmitters and receivers, and AVRs. Passive devices, such as cables and couplers, are HDCP agnostic.
- HDCP 2.2 is a hardware upgrade. The HDCP 2.2 protocol is based on Internet standard encryption algorithms, while the HDCP 1.4 protocol is based on a weaker non-standard encryption mechanism. Do not expect any devices that support HDCP 1.4 today to support HDCP 2.2 via a firmware update.
- Not all 4K devices support HDCP 2.2. While HDCP 2.2 should be considered a crucial component to a modern video distribution system, not all such systems have support. Also many of the earliest 4K displays may not include 4K support.

What's next?

Just as 4K video is becoming mainstream, chipset manufacturers are hard at work on the next generations of HDMI and other video distribution technologies. Expect to start seeing the following technologies in the coming years; some even sooner!

4K60 4:4:4 via video distribution technologies

As of this writing, 4K video at 60 fps with full 4:4:4 color is just starting to appear for HDMI products. However, it will be another year or so before this resolution becomes available in a video distribution technology that can send this 18 Gbps video signal farther than a few feet.

Fig 1. Current resolution

Fig 2. HDR (artist's rendering)

High Dynamic Range (HDR) video

Many display manufacturers have been demonstrating HDR video and generating significant buzz at recent industry trade shows like CES, InfoComm® and CEDIA® Expo. Current video formats and displays have a comparatively limited dynamic range of light. That is, the difference between the darkest and lightest parts of the image are well short of what can be perceived by the human eye. Images with very bright and very dark regions often result in either washed out brights or muddy darks. HDR provides a crystal clear image across a much broader dynamic range, with spectacular results.

While HDR technology itself does not require extra bandwidth, the HDMI specification requires HDR to be paired with a minimum of 30-bit Deep Color, which does increase the bandwidth. As a result, HDR video at 60 fps will be supported along with 4K60 4:4:4 distribution technologies.

8K video

NHK® Japan, in co-operation with Sony, has emerged as an early driver for 8K video. NHK has committed to recording and broadcasting the 2020 Olympics in Tokyo in 8K video to select venues[6]. That doesn't mean that you will be watching these Olympics at home in 8K; the video distribution architecture will not be in place, and 8K TVs will likely not yet be available for the mass market. To help understand why, 8K video at 60 fps and full 4:4:4 color will consume nearly 72 Gbps of bandwidth!

Higher frame rates

Future versions of the HDMI specification are expected to define support for higher video frame rates, such as 120 fps and 240 fps. These frame rates will result in even smoother fast-motion video, doubling or even quadrupling video bandwidths in the process!

[6] http://www.japantimes.co.jp/news/2015/08/24/reference/japan-backs-next-generation-8k-technology-ahead-of-2020-games/

Conclusion

Across all markets, customers of the professional AV industry are rapidly adopting 4K. New large-format displays are more likely to support 4K than not. Student and business laptops, streaming devices and set top boxes are readily available and are expected to be supported not only in the home, but also by in-room technology at work and school.

But as we've learned, supporting 4K involves much more than simply supporting a specific video resolution. Bandwidths, frame rates, color formats, and new copy protection mechanisms all must be considered during system design and specification. And for the next several years, legacy sources, VTCs, and small screens will coexist in our 4K systems and must be carefully managed.

The good news is solutions to these challenges do exist, and a professional integrator can design a system flexible enough to meet the needs of our fast-changing market.

Appendix

HDBaseT and DM®

HDBaseT is a transport technology developed by Valens®, a chip manufacturer. It enables long distance transmission of protected digital video content over a single twisted pair cable. It's a very efficient, low-cost method of digital AV distribution, which has become a standard infrastructure for our industry.

Crestron was the first end-to-end HDBaseT certified solution. Many products in the latest generation of DM leverage HDBaseT technology. Other transport technologies supported by DM include fiber, which is great for transmitting uncompressed video over even longer distances, and network streaming, which is great for leveraging existing network infrastructure.

DM then adds powerful features to these transports, including EDID and HDCP management and intelligent video processing, such as 4K60 scaling, 4K video wall processing, and adaptive color space conversion.

DM also adds audio processing, including DSP downmixing, break away audio routing, mic mixing and processing, and analog audio extraction from the HDMI signal.

DM also provides communication between third-party sources and displays, system-wide debugging tools, and USB-HID extension and routing.

There's also advanced network management for large distribution systems, such as only exposing one IP address to the LAN, and separating device control traffic from the LAN.

DM supports CEC/Serial/IR/Relay device control via the network, simplifying system design and installation.

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