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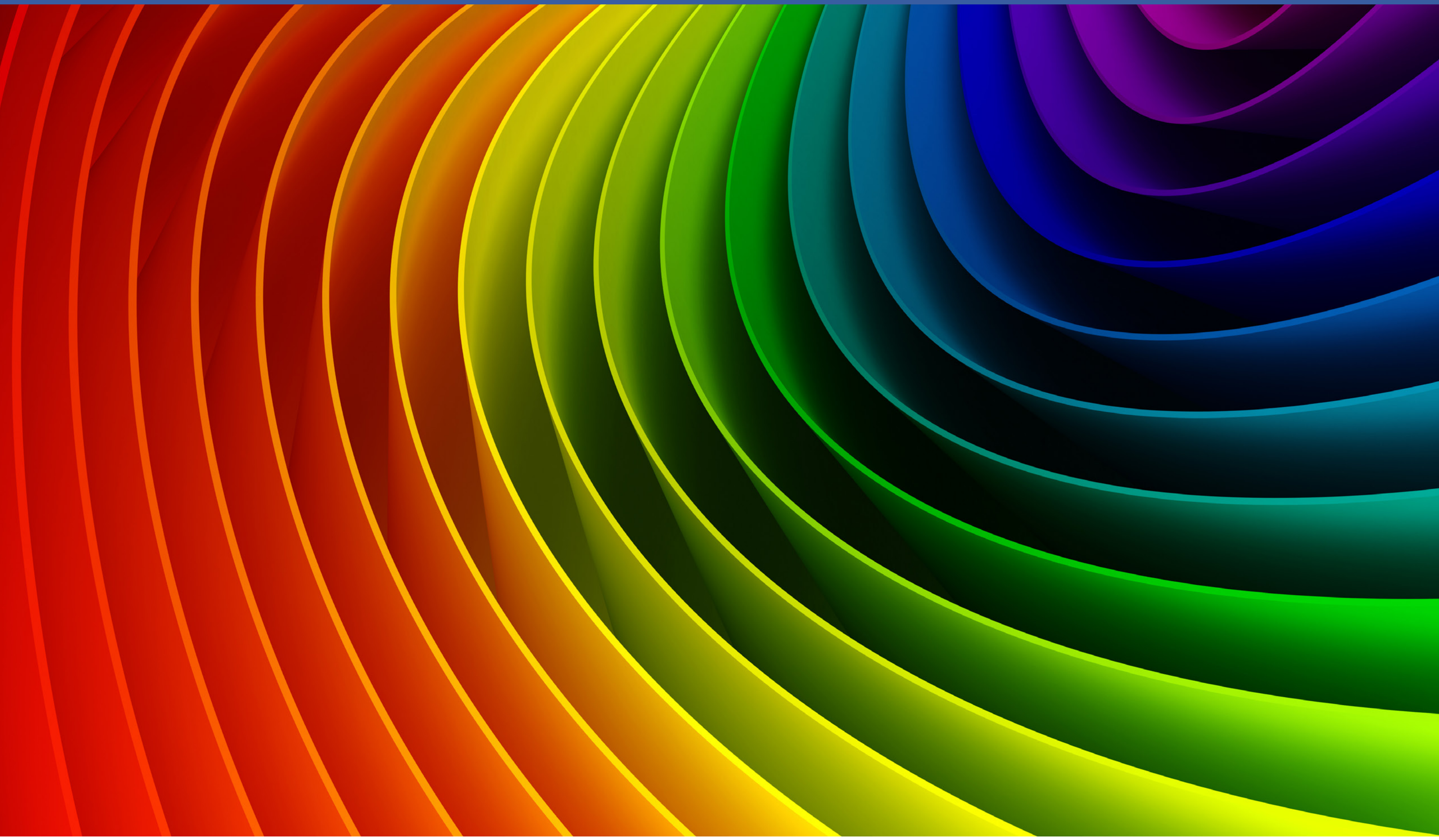


HDR and Its Impact on Workflow

How to integrate the benefits
of High Dynamic Range
into existing video production and distribution.

PRESENTED BY AJA VIDEO SYSTEMS

IN COLLABORATION WITH TVTechnology B&C

HDR and Its Impact on Workflow

This paper discusses the various High Dynamic Range formats in use today and how producers can integrate HDR into the production and distribution of their programming regardless of whether some, all, or none of their production equipment is HDR-ready. The sidebars within this paper discuss various HDR products as well as production companies that have already deployed High Dynamic Range. *by Phil Kurz*

The Quest for the Better Pixel

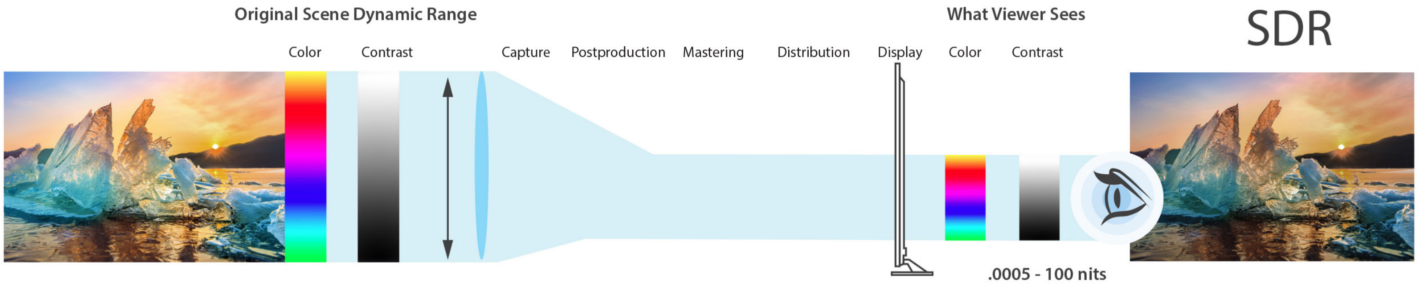
It's common today to hear lively discussions in seminar halls of industry gatherings about a rather unexpected concept: more pixels versus better pixels.

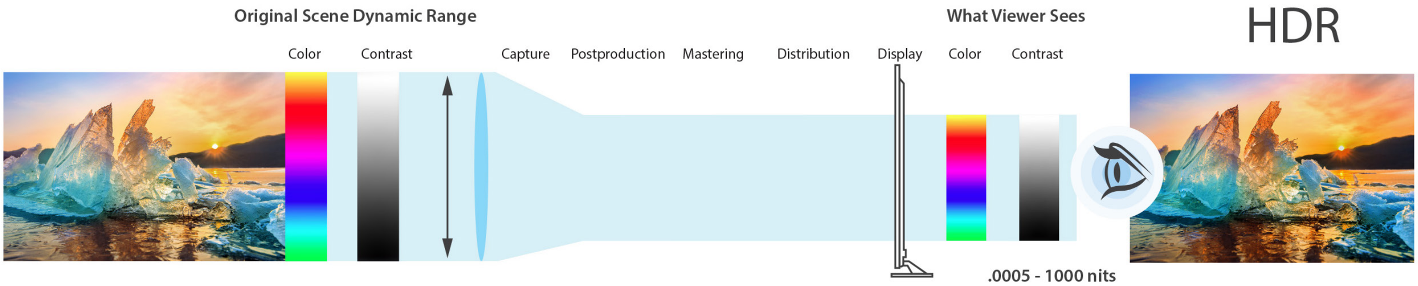
To the uninitiated, the comparison almost seems nonsensical. After all, doesn't the fact that a display has more pixels mean, by default, that the images it produces are better, and therefore that its pixels are better?

Actually, it doesn't—or, more precisely, it doesn't for anyone sitting beyond the distance where the human eye can detect the presence of more pixels. However, that's not to say that pixels can't be improved or made better than they are for the vast majority of viewers today.

Doing so is a matter of feeding the human visual system images that more closely approximate what people see in their daily lives, and accomplishing that goal in large part depends on two factors: first, the number of steps between the darkest black and the brightest white an image reproduces, and second, the number of colors, or gamut, it presents.

In other words, the closer a display's dynamic range and color





The number of colors and the dynamic range of the images that viewers see at home on an HDR display more closely approximate those of the original scene than those reproduced on an SDR monitor.

gamut can get to the human visual system, the better a pixel will be perceived to be. That's why the addition of high dynamic range (HDR) and wide color gamut (WCG) to 4K UHD production and displays is regarded as two of the most important enhancements to television since HDTV. And as many are finding, it's an easily perceivable quality jump for HD itself.

With HDR, previously undetectable picture details in a shadowy area of an image are revealed, and a bright noonday sun doesn't bloom. For photographers and videographers, that's the difference between six stops in standard dynamic range images and 17.6 stops in their HDR counterparts.

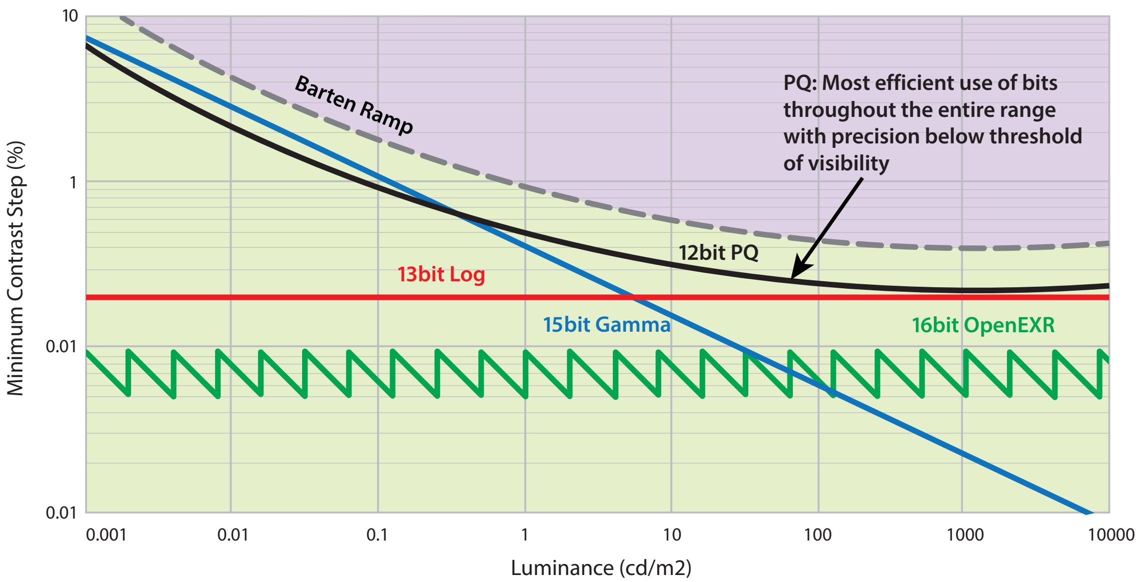
Add to that a wide color gamut that skyrockets the number of colors that can be reproduced from mere millions to a billion or more, and the result is a video image that approaches the higher end of what the human visual system can perceive with pixels that are clearly better.

While it is still early days for HDR and WCG, it's not too soon for producers to begin understanding more about the technologies that make them possible and to start planning for how they will introduce them into their existing production workflows.

The Flavors of HDR

Unlike the offerings of a certain ice cream shop, there aren't 31 flavors of high dynamic range—but there might as well be. Because just as it would be impossible to cram all of those different flavors of ice cream into one cone, it's not possible to lump all of the types of HDR into a single signal. And with the exception of one approach, it's not even possible to mash HDR and standard dynamic range (SDR) into the same video signal.

That exception is Hybrid Log Gamma (HLG). Developed cooperatively by the BBC and the national Japanese broadcaster NHK, HLG specifically addresses the complexity that broadcasters otherwise would face in their production and distribution chains if they were required to deliver separate SDR and HDR versions of the same program. After all, broadcasters can't abandon the hundreds of millions of homes with legacy SDR TV viewers simply to deliver HDR content to a relatively nascent, though quickly growing, audience segment.



Dolby Labs' extensive testing reveals the most efficient use of bits throughout the entire range with precision below the visibility threshold to be 11 bits, which was rounded up to 12 bits.

HLG combines SDR and HDR into one signal so that conventional SDR TVs can decode the dynamic range information they need and ignore the HDR part of the signal in a fashion that's reminiscent of how black-and-white TVs once ignored newly added chroma signals in the early days of color TV. With HLG, a typical gamma curve that legacy HDTVs can recognize is used for the lower part of the signal, and a logarithmic curve is used for the upper portion. Combined, they create HDR images in HLG-enabled televisions.

SDR imagery may be slightly affected by the wider ITU BT.2020 color gamut in bright areas and highly saturated colors, and HLG LUTs continue to evolve to address this. Attention may need to be paid during transforms to ensure that these aberrations are minimized.

Another distinguishing characteristic of HLG is that it is scene-referred. In other words, the HLG signal represents and encodes the light detected by the camera. No additional control over dynamic range is provided or required. That's by design, because HLG is intended to deliver HDR signals from the camera to a home display without complication, which makes it well-suited for live productions such as sports.

The other major flavor of HDR is PQ, or Perceptual Quantizer. Like the chocolate in the freezer case at the ice cream shop, there isn't just chocolate—there's also chocolate with almonds and chocolate with marshmallows.

Unlike HLG, SMPTE ST 2084 PQ does not use a typical gamma curve in combination with a logarithmic curve. Rather, PQ represents the true light values of a scene and conveys them via a digital signal to be output as light by the display, from black up to 10,000 nits, which currently is beyond the upper brightness capacity of TVs. (A nit, a measure of brightness, is defined as candela per square meter.)

To represent true light values in a scene requires 16-bit code words. However,

HI5-4K-PLUS, HA5-4K ADDRESS HDR CONNECTIVITY FOR SDI-TO-HDMI DISPLAYS AND HDMI SOURCE ANALYSIS

As HDR grows in popularity with the public, producers will feel increased pressure to incorporate HDR into their productions. Doing so will create new challenges for their existing workflows.

AJA Video Systems has created the Hi5-4K-Plus to support the latest generation of affordable 4K monitors, which use an HDMI 2.0 connection, while providing full HDR support.

The Hi5-4K-Plus is an easy-to-use converter that makes it possible to connect professional 4K devices with Quad 3G-SDI, Quad 1.5-SDI, or Dual 3G-SDI outputs to HDMI 2.0 inputs, enabling professional 4:2:2/4:4:4 60p workflows.

At the same time, Hi5-4K-Plus can generate HDR metadata per the HDMI v2.0b/CTA-861-G standard. It also fully supports HLG over HDMI.

The Hi5-4K-Plus also compensates for the resolution difference between 4K (4096x2160) and UHD (3840x2160) so UltraHD monitors can be used in 4K productions and vice versa.

Supporting high frame rate productions up to 60p, the Hi5-4K-Plus also offers robust audio connectivity, carrying through up to eight channels of embedded audio in the incoming SDI signal to the HDMI output, ensuring audio-video sync.

The AJA Video HA5-4K is a mini-converter for applications in which conversion from HDMI to 4K SDI (Quad 3G SDI signal) output is required.

Offering analysis of incoming HDR Infoframe data over HDMI when used with AJA's Mini-Config software, the HA5-4K easily converts HDMI video from DSLRs, mirrorless cameras, action cameras, and prosumer 4K cameras for use in professional 4K SDI workflows.

The HA5-4K converts 4K as well as UHD resolution from HDMI to 3G-SDI at up to 50/60fps. For times when neither is required, the HA5-4K can be used to convert HD-HDMI to HD-SDI. It automatically senses an incoming HD resolution HDMI signal and converts it to a single 3G-SDI output.

The easy-to-use Hi5-4K-Plus converter generates HDR metadata in accordance with the HDMI v2.0b/CTA-861-G standard and fully supports HLG over HDMI.

The HA5-4K mini-converter offers analysis of HDR Infoframe data over HDMI when paired with AJA's Mini-Config software.

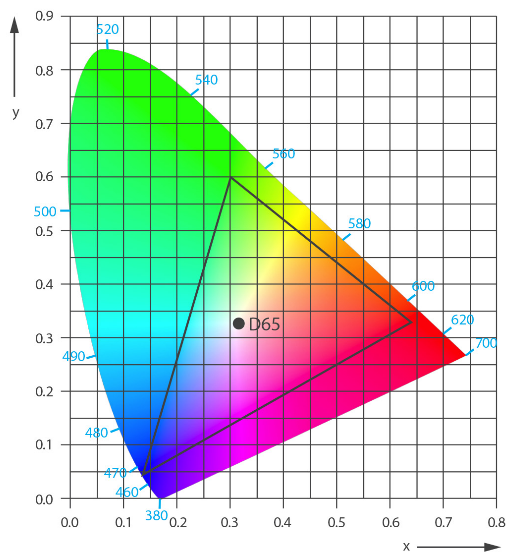
experiments conducted by Dolby Labs revealed that there's a more efficient way to use code words to reduce the number of bits required. Starting with the Barten Ramp, named for Peter Barten, author of *Contrast Sensitivity of the Human Eye and Its Effects on Image Quality*, Dolby set out to find the point at which viewers would spot that banding in images as the number of bits making up a code word was reduced. They defined this point as the Just Noticeable Difference (JND).

Dolby also defined a special curve that follows where humans detect the JND, known as the PQ curve. The researchers found this curve required 11-bit code words, which was rounded up to 12 bits.

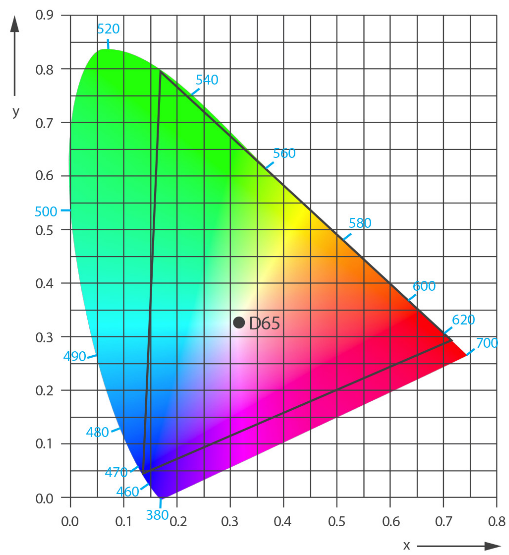
It's possible to apply this curve using fewer bits and to create an image that looks good to viewers, which the Consumer Technology Association did in defining HDR10, which uses the PQ curve and 10 bits. PQ also differs from HLG by giving creatives, such as a colorist in postproduction, a means to make adjustments to express their vision and then use metadata to control viewer TVs so that they reproduce images as intended. Effectively, concurrent metadata is sent with the video signal that communicates with the display over HDMI as to how to map both light and color most effectively for the display's capabilities.

The Rec. 2020 color space employed in many HDR displays more closely matches the limits of the human visual system than the Rec. 709 color space used by HDTVs.

Rec 709 color space



Rec 2020 color space



Three flavors of PQ are available today. HDR10 is an open HDR standard based on SMPTE ST 2084 PQ EOTF and Rec. 2020 with a bit depth of 10 bits. This approach to HDR leverages the SMPTE ST 2086 metadata standard to convey static data describing the color calibration of the mastering display to televisions and other displays. That calibration data includes the maximum frame average light level, known as MaxFALL, and maximum content light level, called MaxCLL. TVs then reproduce the images displayed based on this static HDR metadata.

HDR10+, supported by companies like Samsung, Amazon, 20th Century Fox, Panasonic, and Warner Brothers, builds on this approach with the addition of dynamic metadata—thus, the plus. Dynamic metadata allows creatives to adjust brightness and color volume on a scene-by-scene, or even frame-by-frame, basis. HDR10+ relies on Samsung's implementation of the SMPTE ST 2094-40 standard for this dynamic metadata.

Dolby Vision is Dolby Laboratories' proprietary implementation of PQ. While it implements SMPTE ST 2084 PQ EOTF and Rec. 2020 color space, one of its key differentiators is support for 12-bit color. Another is its support for both static and dynamic metadata, SMPTE ST 2086 and SMPTE ST 2094-10, respectively. Because it's Dolby's technology, its use by production equipment vendors and consumer electronics makers requires a license.

All three PQ approaches are display-referred systems. In other words, when a certain code value is assigned in postproduction, a certain number of nits will be reproduced on the television. Thus, if the TV receives the code word for 303 nits, it must put out 303 nits of brightness.

Together, HDR and WCG produce what truly can be described as a better pixel.

Like a hand in a glove, HDR fits with wide color gamut, or WCG. They're nearly inseparable because each HDR implementation specifies a color space recommendation and bit depth. Thus, HDR10 and HDR10+ use Rec. 2020 10-bit color, a far wider color palette than is available to an HDTV display that uses Rec. 709 8-bit color. Specifically, the former can reproduce 1,024 color tones per R, G, and B subpixel, or a total of 1.07 billion colors, while the latter is capable of just 256 tones for R, G, and B, or a total of 16.8 million colors. (That's 1,024 x 1,024 x 1,024 vs. 256 x 256 x 256.) A color depth of 12-bit takes the total to 6.8 billion. Together, HDR and WCG produce what truly can be described as a better pixel.

Production and Distribution

Technology aimed at producing a better pixel is one thing. Actually producing HDR, WCG content is quite another—particularly in these early days of HDR and WCG when most TVs in use are incapable of taking advantage of them. In the United States, for example, 60 million 4K UHDTVs were shipped last year, according to market research organization Statista. However, only 12.2 million were expected to be HDR-capable, an IHS Markit forecast predicted.

When the 338 million legacy TVs that *The Washington Post* estimates are in use in the United States are also considered, it becomes clear that a mixed production and distribution environment will be in place for the foreseeable future.

On the distribution side of the equation, HLG offers broadcasters a means to deliver HDR content to viewers watching new televisions equipped with HLG decoders while continuing to serve viewers using legacy SDR TVs with the same signal. Another approach is to simulcast content in HDR and SDR on separate channels or as on-demand content. For instance, Netflix is streaming HDR content in HDR10 and Dolby Vision while maintaining its SDR catalog for on-demand streaming. Similarly, Samsung and Amazon began streaming about a hundred TV shows using HDR10+ in December 2017 while continuing to offer SDR versions to customers.

When it comes to television production, producers will find themselves working in a mixed SDR-HDR ecosystem for the foreseeable future, as economics and depreciation schedules dictate that they wring as much use out of their legacy cameras, switchers, and other devices as possible. As a result, they will be required to convert SDR to HDR, one flavor of HDR to another, and HDR to SDR depending upon the unique circumstances of their production.

For example, in a live-production workflow the easiest to imagine may be converting the output of an established 1080i HD, Rec. 709 color video production workflow for delivery to broadcast, satellite, or cable TV distribution in HDR.

Another HDR conversion scenario involves productions in which there's a desire to produce UHD native-HDR content. For instance, a producer may wish to have the production switcher switching a show with HLG or PQ. That would require all camera inputs to be HDR. While many of the cameras that will be used output a native 4K HDR signal, others likely will not. In this situation, those SDR sources will need to be upconverted to UHD and the color volume will need to be converted from SDR to HDR before hitting the production switcher.

A similar scenario involves more complicated productions with a variety of other SDR signal sources, such as those from graphics devices, instant replay systems,

AJA ADDS HDR PLAYBACK SUPPORT TO KI PRO ULTRA PLUS

The Ki Pro Ultra Plus, a four-channel recorder/single-channel player for Apple ProRes workflows or single-channel recorder/player for 4K, UltraHD, 2K, HD Apple ProRes or Avid DNxHD MXR workflows, now supports HDR—both HLG and HDR10.

The Ki Pro Ultra Plus plays back 4K, UltraHD, and HD HDR to HDMI v2.0 compatible displays when updated with v2.0 firmware. The update enables HDR metadata per HDMI v2.0b/CTA-861-G to be generated, supports HLG HDR over HDMI, and delivers ProRes 4444 XQ encoding and playback for 2K/HD up to 60p.

Easy to carry or mount in a rack, the Ki Pro Ultra Plus offers multichannel recording and playback solutions that are equally well-suited to live- and post-production workflows.

The multichannel Ki Pro Ultra Plus with HDR support is designed for production and postproduction workflows.

For live workflows, the Ki Pro Ultra Plus simplifies multi-camera productions by recording up to four HD cameras per device. An individual profile setup is available on each channel in multichannel mode. For instance, one channel can record high-resolution Apple ProRes HQ for high-quality finishing, and a second can record Apple ProRes proxies.

A handy "Loss of Signal" color bar frame is inserted into a channel at the moment the Ki Pro Ultra Plus detects a loss of signal on an input. When the signal is restored, the channel continues to record the source. As a result, all channels maintain their synced timecode, saving an editor in postproduction the headache of resolving sync among multiple channels.

In postproduction, the Ki Pro Ultra Plus makes it easy to transfer recordings into a multichannel editing sequence. Each discrete recorded channel is timecode-accurate and can simply be dragged and dropped into an edit. Naming clips is up to the editor, but the Ki Pro Ultra Plus appends the name with a .1, .2, .3, or .4 to make it simple to keep track of assets in postproduction.

and video servers. In this scenario, these sources would need to be converted to HDR before the production switcher.

There are many other production hypotheticals that will also require signal conversion. Understanding the specifics of each at this time, however, is probably less important than realizing that the demand for HDR content is on an upward trajectory while the technology used to produce that content will be a mix of SDR- and HDR-native equipment for quite some time.

KONA 4, Io BRING HDR SUPPORT TO CAPTURE, PLAYOUT

AJA Video Systems has incorporated HDR support into its KONA and Io product portfolio to enable today's video producers to prepare for a soon-to-be-increasing number of HDR productions.

AJA's new Io 4K Plus standalone capture and output device supports HLG and HDR10.

The KONA 4 desktop I/O card supports 4K, UltraHD, 2K, and HD HDR pipelines to HDMI-compatible displays. With v13 software and above, the KONA 4 provides HDR10 support with HDR10 Infoframe metadata in accordance with HDMI v2.0b/CTA-861-G and HLG support on HDMI HDR-enabled displays.

The KONA 4 offers bi-directional 3G-SDI connectivity for input and output as well as 16 channels of embedded audio over 3G-SDI and HDMI 2.0b monitoring output. It also comes with a built-in hardware keyer.

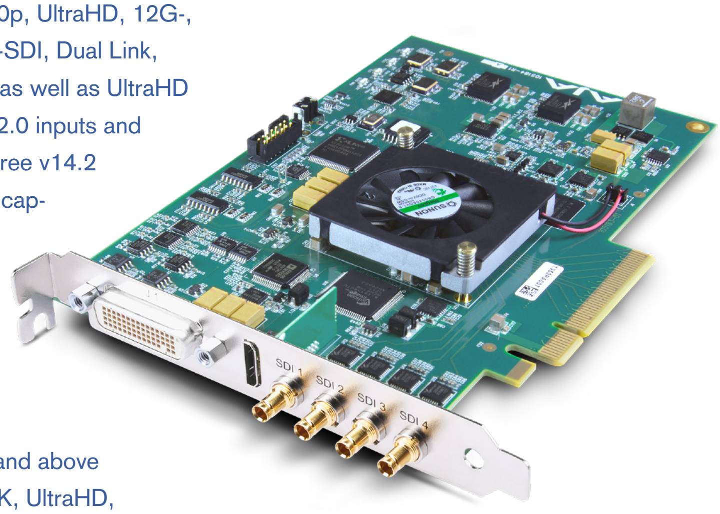
The companion K3G-Box offers LTC I/O, genlock input support, RS-422 control, three configurable BNC SD/HD analog video outputs, and 8-channel AES audio I/O, making the KONA 4 easy to integrate into a variety of workflows, including HDR, high frame rate, 4K, and multichannel HD for streaming.

AJA Video has also added HDR support to the wide range of options its Thunderbolt 3-enabled Io 4K Plus and Thunderbolt 2-enabled Io 4K professional mobile capture and output hardware can handle.

The new Io 4K Plus with HDR support is a standalone capture and output device with Thunderbolt 3, single-cable connectivity via two separate ports for workflows requiring 4K up to 60p, UltraHD, 12G-, 6G-, 3G-, and 1.5G-SDI, Dual Link, HD-SDI or SD-SDI, as well as UltraHD and HD over HDMI 2.0 inputs and outputs. Upcoming free v14.2 software adds HDR capture capabilities for Sony PlayStation game capture and more over HDMI 2.0.

The Io 4K Plus v13 and above software supports 4K, UltraHD, 2K, and HD HDR pipelines to HDMI-compatible displays with HLG and HDR10 with HDR Infoframe metadata in accordance with HDMI v2.0b/CTA-861-G.

The AJA Video Io 4K capture and output hardware leverages Thunderbolt 2 connectivity to enable the device to handle formats ranging from SD to HD, UltraHD, and full 4K over 3G-SDI and HDMI with support for HDR10 with HDR Infoframe metadata per HDMI v2.0b/CTA-861-G. Desktop Software v13 and above adds HLG support over HDMI for the latest versions of Adobe Premiere CC.



The AJA KONA 4 desktop I/O card supports 4K, UltraHD, 2K, and HD HDR pipelines to HDMI-compatible displays.

The AJA FS-HDR is providing the new BetaMedia-DBW Esterna 14 OB van with the flexibility to satisfy signal conversion requirements that can change from production to production.

AJA FS-HDR Powers Real-Time Conversion for Live Productions

The new AJA HDR and SDR 1RU Video Converter earns high marks from leading sports producers.

When the Pittsburgh Penguins and Vegas Golden Knights took to the ice last December, a select group of fans watching AT&T DIRECTV on their 4K UHD TVs saw a game unlike any other—not because the action was atypical, but because the action looked truer to life than ever before.

Mobile TV Group (MTVG), which produced the game from its new 53-foot 4K Double Expando production unit, was able to deliver that next-level viewing experience because it incorporated High Dynamic Range (HDR) into the production—a first for AT&T DIRECTV—with the help of 14 AJA Video Systems real-time FS-HDR frame sync/HDR converters.

“We’re big on picture quality and always looking at technology like the FS-HDR that can help us advance the quality of content for audiences,” says MTVG Director of Engineering Peter Wehner.

The FS-HDR, which grew out of the work AJA did designing its FS4 4K/UHD frame sync, up, down, and cross converter, is the ultimate dynamic range and camera log converter. To that core technology, AJA added the Colorfront Engine™ video and color space processing algorithms with support for SDR and HDR—both Hybrid Log Gamma (HLG) and Perceptual Quantizer (PQ). FS-HDR is capable of supporting a Single Master HDR workflow with simultaneous HDR and SDR outputs, minimizing the disruption for current pipelines as they introduce HDR into their set of deliverables.

What makes the Colorfront Engine™ special is the way it transforms color. Rather than using a fixed 3D LUT to map from one color space to another, Academy Award-winning Colorfront CTO Bill Feighter and lead engineer Tamas Perlaki developed Colorfront’s algorithms to compute transforms based on the human visual system. Thus, colors look more natural, maintaining perceptual integrity and creative intent.

The FS-HDR works out of the box for live SDR to HDR, HDR to SDR, and HDR to HDR transformations, and a recent firmware upgrade adds 17 parametric controls for quick adjustments, which are crucial in live environments with the potential for mixed camera packages.

That's one application that Italy's BetaMedia-DBW has found for the FS-HDR. Its new Esterna IP-based 4K HDR Outside Broadcast vehicle is equipped with 24 FS-HDR units. Not only do they deliver real-time SDR and HDR conversions, but they also provide camera log format conversions to harmonize signal sources to the OB vehicle's S-Log3/2SI/2160/50p house profile.

The FS-HDR can convert Sony S-Log3 S-Gamut3, Sony S-Log3 S-Gamut3 Cine, Sony S-Log3 BT.2020, ARRI LogC Wide Gamut, Panasonic Vlog, Red Log3G10 Wide Gamut, Canon Log2, and Canon Log 3.

In its single-channel mode, the FS-HDR converts 4K, UltraHD, 2K, HD, and SD sources. In its four-channel mode, the unit handles 2K/HD video for multi-channel HDR/SDR needs while enabling each channel to be configured individually.

On any given day, the way both MTVG and BetaMedia-DBW configure their FS-HDRs will change, depending upon show requirements. One day the units may convert 4K HDR to 1080p SDR. The next they may be called upon to upconvert SDR to HDR.

The new Mobile TV Group 4K HDR Double Expando is equipped with 14 AJA FS-HDR frame sync/HDR converters.

"I find it amazing how much AJA can cram into one rack unit; not only do we get HDR and format conversion, but also live color correction," says MTVG's Wehner. "It helps us ensure a consistent look for 4K HDR and HD SDR feeds, even when working with mixed camera sources and formats."

"We're big on picture quality and always looking at technology like the FS-HDR that can help us advance the quality of content for audiences"

— MTVG Director of Engineering Peter Wehner

That’s a Wrap

Television has begun a grand journey towards delivering better pixels, something viewers increasingly will expect. In less than five years, annual shipments of HDR-enabled televisions to consumers will climb to 245 million, according to ABI Research.

Programmers, producers, and commercial clients who ignore the accompanying demand for HDR content do so at their own peril. They must ask themselves whether it’s more desirable to stand out from the rest today because their pixels are better or to stand out in the not-too-distant future because their inferior pixels are surrounded by an ocean of HDR/WCG content. Either way, viewers will notice.

High dynamic range and wide color gamut are the twin foundational pillars to creating better pixels. Together, they produce images that are more pleasing by more closely aligning with the upper reaches of the human visual system.

Producers choosing to walk the path to better pixels—even in these early days—can do so with confidence. They can be assured that taking on HDR and WCG today will not require the complexity and expense of two separate production workflows. Equally important, they can be certain that doing so will put their content in sync with where consumers and their televisions are headed. Better pixels are at hand. The time to begin planning how best to leverage them in production is upon us.

For more on the latest on HDR and the quest for the better pixel

ABOUT THE AUTHOR

Phil Kurz is a TVTechnology contributing editor. He has covered television technology for more than 30 years.