HDR

AV BEYOND THE BOX

HIGH DYNAMIC RANGE AND HOW IT WILL IMPACT AV

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HIGH DYNAMIC RANGE

High dynamic range (HDR) is here, and it's fast becoming a buzzword in the AV community even though most people don't really understand what the term describes or how it will impact video signal management and distribution.

High dynamic range is indeed a truly significant development in visual imaging. Consider that while the human eye has a dynamic contrast ratio approaching 1,000,000:1, the average LCD display is limited to about 5,000:1 peak contrast. You can easily see where the ability to reproduce a wider range of tonal values electronically is a game-changer.

There are several different ways to achieve high dynamic range. A standard dynamic range (SDR) camera might be able to capture 9 to 11 f-stops of light, easily reproduced by an LCD display with a peak brightness measurement of around 300 cd/m2 (nits). Or, we can use an organic light-emitting diode (OLED) display that may not be quite as bright but has much lower 'black' levels than an LCD display. It too can reproduce 11 luminance steps from black to 100% white.

HDR completely rewrites the equation. Some HDR-equipped cameras can capture as many as 22 stops of light, creating peak luminance values in the thousands of nits. It stands to reason that whatever display we use will need a lot more horsepower at the bright end. Consequently, we're now seeing Ultra HDTVs and 4K displays coming to market with a new backlight technology specifically designed for HDR – quantum dots (QD).

[FIGURE 1]

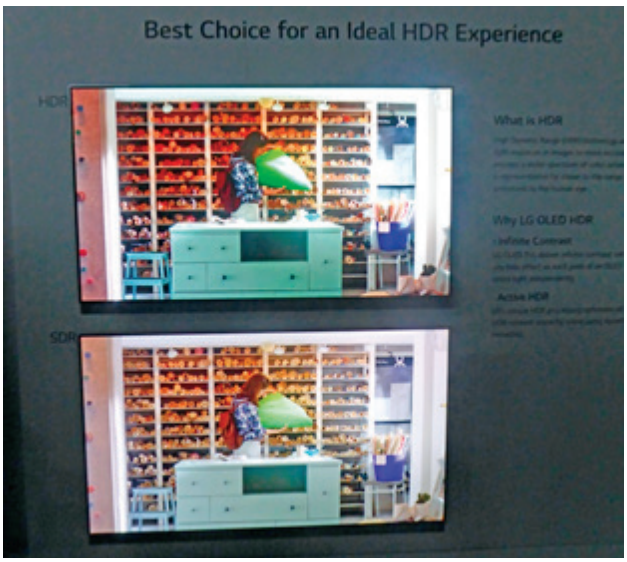
Samsung 65-inch Ultra HDTV with HDR capabilities at CES 2017

Quantum dots are tiny metal compounds that emit intense, saturated color light when stimulated by photons. To achieve red, green, and blue (RGB) imaging, a QD-equipped display employs a backlight of blue light-emitting diodes (LEDs) to light up a special optical film containing red and green quantum dots. This backlight also provides the blue necessary for RGB color mixing.

The result is a new generation of televisions and monitors that reproduce a peak white luminosity of 2,000 nits and a whole bunch of tonal values below that. But that peak white value doesn't stand for a full screen of diffuse white light: Rather, it represents specular highlights. Think of how the sun dances and reflects off moving water, or how intense sunlight appears through a window when standing in a dark room. With HDR imaging, you see everything in a scene from the deep shadows to intense beams of light reflecting off a glass of water.

You're probably thinking right now: ***What, exactly, has this to do with interfacing signals?*** Consider this: To reproduce the additional steps of luminance in an HDR image, we will need far more than the usual 8 bits per color pixel that has become standard in everything from Blu-ray discs to cable television.

No, we need more bits – at least 10 bits per pixel, and possibly 12 bits per pixel to correctly reproduce an HDR signal. And those additional bits will increase the payload traveling through our interfaces and over AV/IT connections.



[FIGURE 2]

Demonstration of HDR (top) and SDR (bottom) in OLED displays

Indeed, the basic standard for high dynamic range – HDR 10 – uses static metadata and 10-bit color to define an HDR signal. More advanced HDR systems like Dolby Vision and Samsung's proposed dynamic tone mapping may require 12-bit color for mastering, dithered down to 10 bits for delivery to an HDR display.

So how much of a difference does HDR make to bit rates? For an Ultra HD signal (3840x2160 pixels), the base data rate with a 60 Hz refresh rate and 8-bit RGB color is calculated as -

(4400x2250) x (60) x (3) x (10) = 17.82 gigabits per second (Gb/s)

With 10-bit color, the data rate rises to -

(4400x2250) x (60) x (3) x (12) = 21.3 gigabits per second (Gb/s)

That's too fast for HDMI 2.0, which has a capped data rate of 18 Gb/s. To get around that obstacle, content mastered at 10 bits per pixel can be formatted with reduced color resolution (4:2:0) -

(4400x2250) x (60) x (1.5) x (12) = 10.7 gigabits per second (Gb/s)

That data rate can easily pass through an HDMI 2.0 connection. 4:2:0 color is recognized by every consumer television and computer monitor, as is the RGB (4:4:4) format. And in fact, the Ultra HD HDR Blu-ray format uses 4:2:0 10-bit color resolution precisely for that reason.

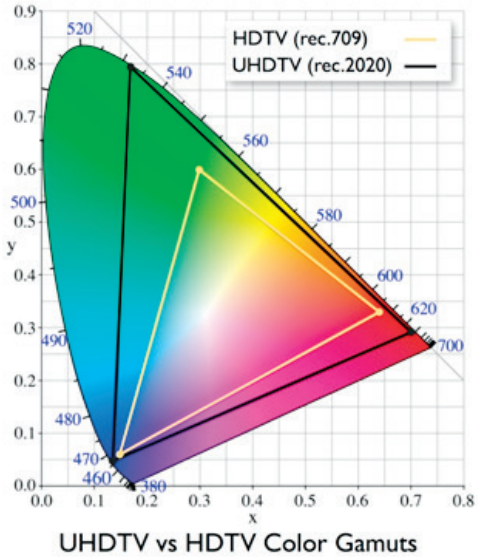
We can also transmit 10-bit HDR content using 4:2:2 color resolution through HDMI 2.0 –

(4400x2250) x (60) x (2) x (12) = 14.3 gigabits per second (Gb/s)

But we must first check to make sure the connected display supports this color resolution, which is more commonly used for production, editing, post-production, and transmission. Not all consumer displays will correctly recognize it and may attempt to display these signals using 4:2:0 values.

There's more to the story. High dynamic range isn't just about a wider range of luminance values. It also means a much wider color gamut (WCG) than before; one that is characterized by the International Telecommunications Union (ITU) as Recommendation BT.2020 (Rec.2020). This color space is much wider than the current Rec.BT.709 color space used for video content and which all current models of TVs and displays can easily reproduce.

The color volume in BT.2020 is so much larger that the green locus might only be reached by a laser-powered imaging system. And in fact, we're starting to see laser-powered cinema projectors come to market for precisely that reason. Quantum dot-equipped LCD TVs can cover a good portion of this wider color space, as can the latest generation of OLED TVs and LED videowalls.



[FIGURE 3]

Comparison of ITU BT.2020 and BT.709 color spaces

Add it all up – 20+ stops of luminance, plus billions (not millions) or color shades, and that's quite a payload of data we're jamming through a display interface or compressing for delivery through an IT network.

We do have some tools at our disposal to make the job easier: Display Stream Compression, introduced by VESA in 2014, allows us to apply light, entropy-based compression to HDMI 2.1 and DisplayPort 1.3/1.4 signals to reduce the bit rate. 2:1 is easy to do, and 3:1 is practical.

Currently, we're not aware of any AV manufacturers supporting HDMI or DisplayPort with DSC, but it would certainly make our lives a lot simpler – our 21 Gb/s 4K RGB signal could be transported at 10.5 Gb/s, and in fact we could easily step up to 12-bit color (12.5 Gb/s) if need be. Both modes would easily transit an HDMI 2.0 connection.

For AV over IT, we have a difficult choice to make. Do we favor light compression (up to 4:1 with Motion JPEG2000) for minimal latency, or do we look for greater transmission efficiency with higher compression using the H.265 HEVC codec? With H.265, we can transport 4K content in the 15 – 30 Mb/s range using 4:2:0 color and a small degree of latency.

Or we could employ Motion JPEG2000 to minimize latency. Our 10-bit RGB 4K signal cited earlier, with a nominal data rate of 21 Gb/s, can be packed down to 5.25 Gb/s using 4:1 M-JPEG2000, easily handled by a 10 Gb/s Ethernet switch. And we can achieve greater transmission efficiencies by using 4:2:0 color resolution and reducing the bit rate to 2.7 Gb/s. Lowering the frame rate to 30 Hz drops our data rate even further to 1.34 Gb/s.

The important thing to take away here is that when someone claims their signal management equipment is "HDR compatible" or "HDR ready," what they're really saying is that the hardware interfaces are fast enough to handle the required clock rate. That's it. It's all about speed, and one additional signaling enhancement.

[FIGURE 4]

(Left) A CES demonstration of HDR through HDMI 2.1 and (right) through DisplayPort 1.4

How do we let the display know that HDR/WCG content is present in the signal? The HDMI 2.0 and DisplayPort 1.4 interface specifications allow for info frames containing either static or dynamic metadata that tell the display how to format the HDR images. Without this data, the display will simply render HDR images incorrectly as overly-bright, washed-out SDR images, or very dark images with little detail.

For static HDR data, the extension to the HDMI specification is a single letter. For example, HDMI 2.0a means the interface will transport and recognize HDR10 static metadata, while HDMI 2.0b is used to signal dynamic metadata (such as Dolby Vision) and HDMI 2.0g indicates the data-less hybrid log gamma (HLG) format is in use.

SUMMARY

As long as a distribution amplifier, matrix switcher, or signal extender is (a) fast enough to handle an HDMI 2.0 or DisplayPort 1.4 signal and (b) passes through static and dynamic HDR metadata without altering it, that interface is considered HDR-ready or HDR-compatible. For the time being, HDMI 2.0 will be the dominant interface for transporting HDR content. On the computer side, look for display manufacturers to adopt DisplayPort 1.4 for HDR desktop monitors.

As for HDR distribution over IT networks; Motion JPEG2000 can be used, but a 10 Gb/s network and switch will be the minimum requirement. H.265 HEVC is a better choice if additional latency can be tolerated: UHD signals with HDR can be transported at 15-30 Mb/s over networks. (For comparison, UHD Blu-ray content streams from discs at 100-120 Mb/s.)

One thing is certain – HDR/WCG content will be available and an increasing number of televisions and displays will support this format. Combined with UHD and higher resolutions, HDR/WCG will push data rates to much higher levels than ever before. Consequently, it would be a wise move to build the capacity for these signals into future AV installations whichever way you choose to distribute them.

ABOUT KRAMER

Kramer Electronics, Ltd. is a leading manufacturer and distributor of pro AV products and IT management solutions for AV installations. With industry-leading hardware, cutting-edge cloud technologies and innovative software, the company's portfolio includes products and solutions for signal processing and distribution, control, AV/IT management, wireless presentation & collaboration, and end-to-end installer solutions.

The company was founded in 1981 and today serves customers in over 90 countries across six continents. Kramer has won numerous awards, including the 2013 Pioneer of AV Award at InfoComm in honor of its Founder, President & Chairman, Dr. Joseph Kramer.

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