Understanding the HDR10 Ecosystem

Presented by HDR10+ Technologies, LLC

Introduction

In the digital age, the choice of consumer displays and projectors has never been better – and never more potentially confusing. Exciting new device technologies and distribution platforms are jostling for attention at the same time that video content itself is undergoing a dramatic transformation called Ultra High Definition (Ultra HD).

A new benchmark for high quality video, Ultra HD enriches entertainment with a suite of powerful advancements:

- **4K and 8K resolution** are delivering much greater picture detail than ever before.
- **Wide Color Gamut** enables content creators to produce and viewers to experience a greater range of hues for more vibrant images.
- **High Frame Rates** present fast-moving sports and action with unprecedented smoothness
- **High Dynamic Range (HDR)** delivers greater impact via darker "darks" and brighter "brights" along with more nuanced gradations for better delineation of on-screen shapes.

The global standards-setting body, the International Telecommunication Union (ITU), established this next-generation technology via two landmark standards: ITU R-BT.2020 for Ultra HD and ITU R-BT.2100 for High Dynamic Range.

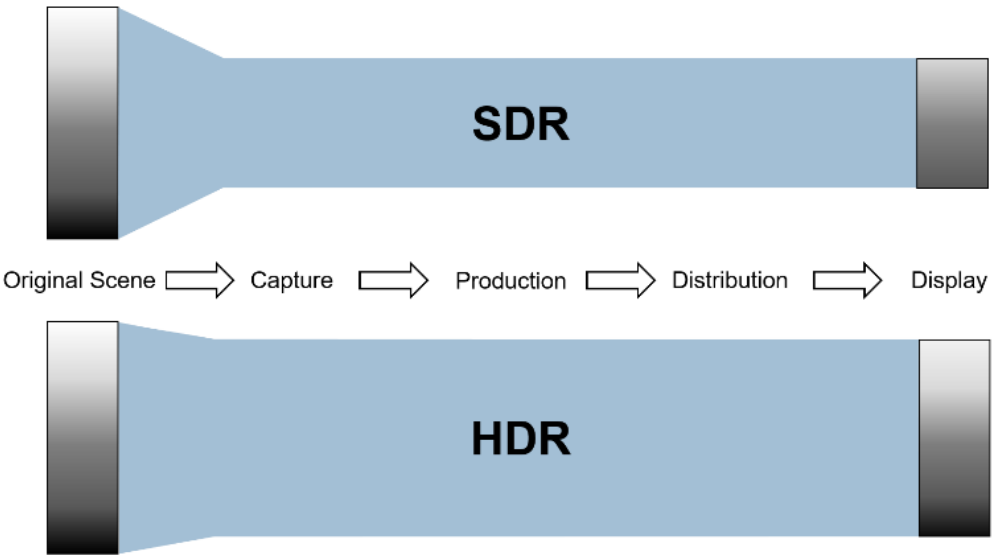
Although all of the technical advances under the Ultra HD umbrella are important, HDR is critical. While production professionals and A/V enthusiast publications understand the significance of HDR, it has not achieved awareness on par with its transformational contribution to picture quality. With nearly a half dozen formats vying for attention, only HDR10 has become the most widely adopted platform, utilized across the entertainment and electronics industries. Building upon this success, HDR10+ provides even higher performance, along with other essential benefits.

This paper explains the powerful advantages of HDR – and shows how the HDR10 / HDR10+ ecosystem delivers these advantages.

The importance of High Dynamic Range

Perceptual benefits of HDR

Visual arts have long attempted to depict an original scene as in real life: first in painting and drawing, then photography and cinematography. Until recently, these efforts have always been constrained by relatively limited dynamic range: the difference in a reproduction system's brightness from the darkest possible black to the brightest possible white.



SDR (top) doesn't come close to the full range of brightness we can perceive in the original scene. HDR (bottom) does.

2^46 ≅ 10^14

The human eye is capable of sensing light values from starlight to bright sunlight, a 10^{14} range of illuminance. In photographic terms, that's over 46 "f-stops" of dynamic range. But that total dynamic range is only achieved after many minutes of night vision adaptation. At any given moment, only a fraction of that range is available: estimated at around 13 to 16 stops.[1]

Based on the outmoded 1950s technology of Standard Dynamic Range (SDR), the original television imaging system could only capture, record, transmit and display less than 10 stops of dynamic range, limiting how content creators could convey scene brightness. Even the launch of HDTV in the 1990s did not change this.

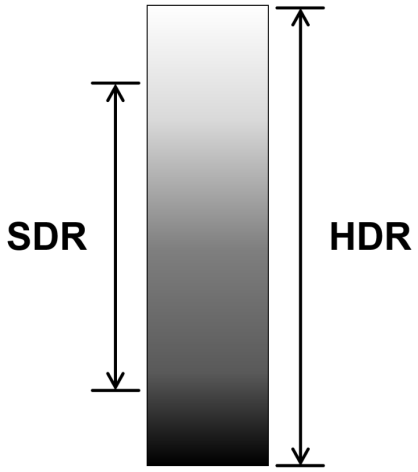
A giant step forward, High Dynamic Range (HDR) takes advantage of the latest cameras, processing, storage, distribution platforms and displays. It comes close to maintaining the full range of human vision from the original scene all the way through to the display. As a result, HDR opens up exciting new creative possibilities for directors, cinematographers and game developers, delivering a dramatically better, more engaging entertainment experience in movie theaters and on consumer televisions, projectors and even mobile devices.

Technical benefits of HDR

Consumers, if they're aware of HDR at all, typically associate this technology with "brighter" pictures, which are measured in units called "nits." While brightness is a major aspect of HDR – it is only one part of the story. HDR is really about the entire dark-to-light range of tonal values, what cinematographers call "grayscale." HDR enables us to

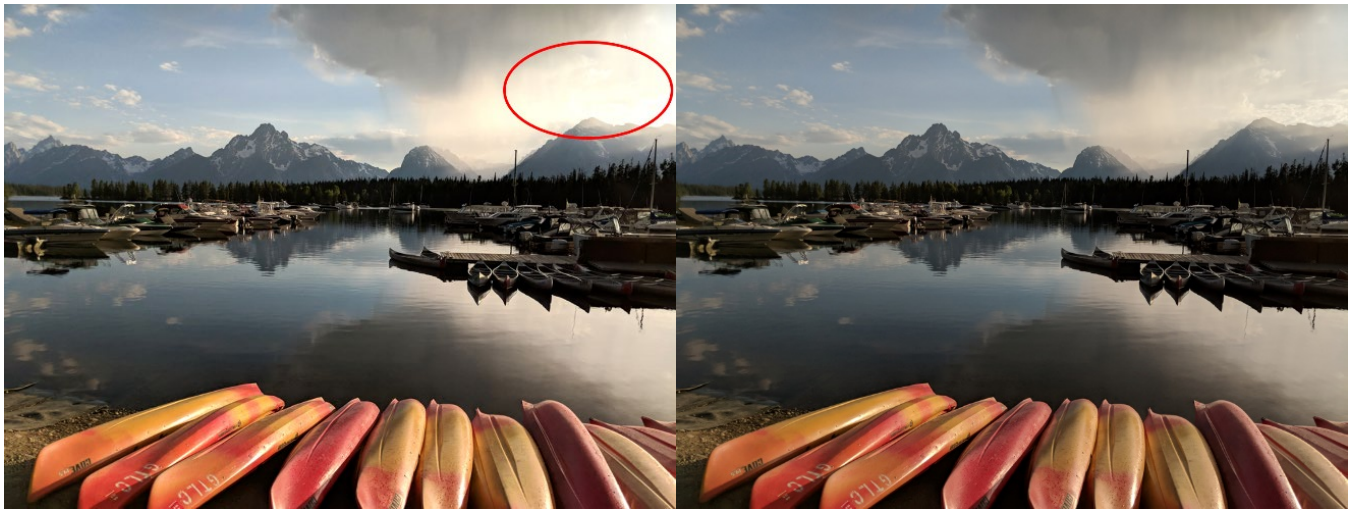
[1] According to experts from the American Society of Cinematographers, Canon, Pro Video Coalition and Sony.

see the entire grayscale: not just the highlights, but all the shadows and all the subtle gradations in between.



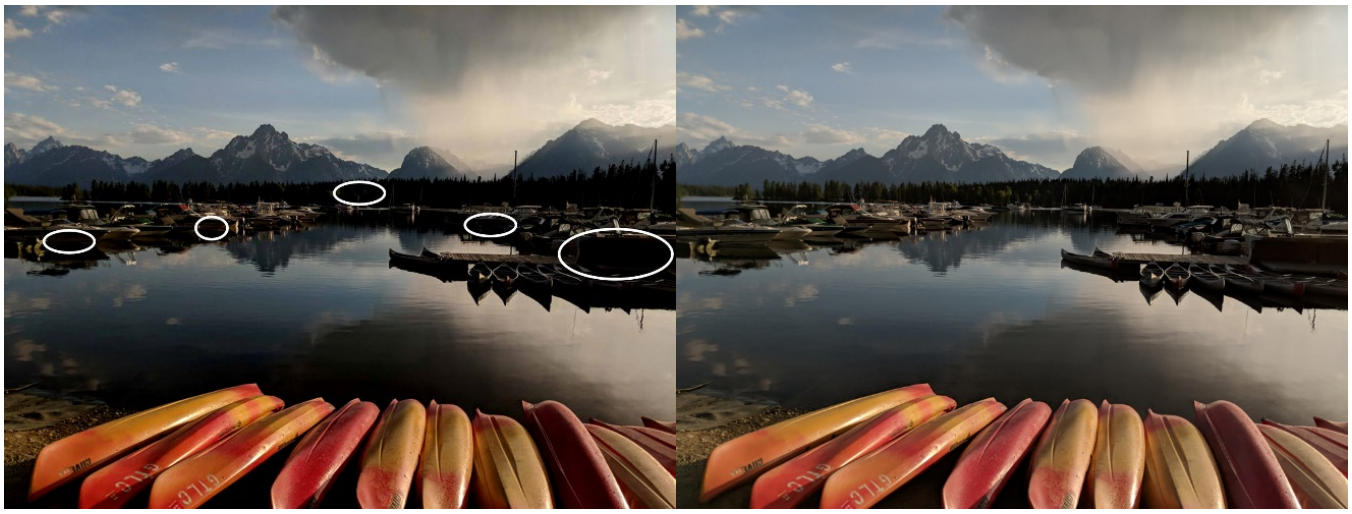
Today's cameras capture deep shadows and bright highlights. SDR can't reproduce them. HDR can.

HDR starts with better reproduction of the grayscale extremes: deeper blacks and brighter highlights. You also get better detail in the brightest areas of the scene – without the losses that cinematographers call "blown out highlights."



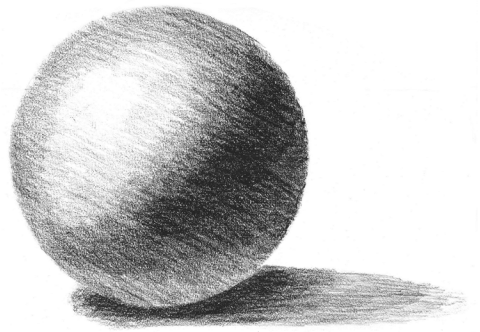
In the simulated SDR image at left, the circled highlights are "blown out." The simulated HDR image at right retains significant highlight detail in the clouds.

Additionally, you get better shadows – without the loss of visual information called "crushed shadows."



In the simulated SDR image at left, the circled shadow areas are "crushed." The simulated HDR image at right retains significant detail in the boats, pine trees and the dock.

You'll also see better expression of the "middle grays" that give on-screen objects their apparent shape.



Middle grays help us interpret on-screen objects, here defining the curvature of a ball on a flat surface.

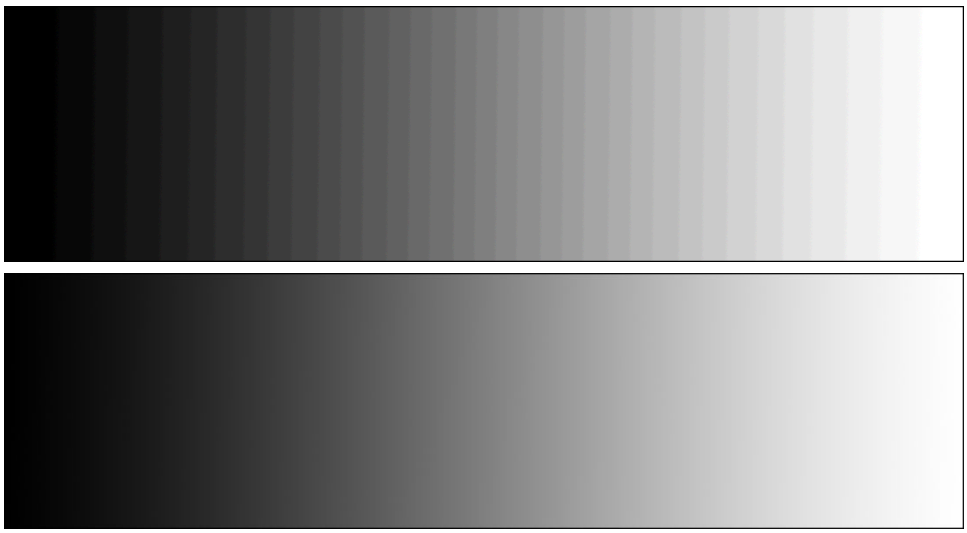
Creative benefits of HDR

To the casual observer, all these grayscale improvements may seem purely technical. However, to the creative community, these improvements go directly to the heart of visual storytelling, enabling a greater range of expression. Careful control of grayscale's light and shadow helps to establish mood, convey realistic skin tones and identify what to look for in a scene. In fact, grayscale is so important that for each individual scene, movie crews typically set up a unique configuration of lights, reflectors and diffusers to achieve just the right effect. Moreover, the director and cinematographer continue to dial in grayscale values during postproduction, via color correction and mastering.

By expanding and refining the grayscale, HDR dramatically improves movies, TV programs and videogames. HDR transforms the viewing experience, making it more involving, dynamic and closer to the creative intent. In short, HDR is “entertainment as it should be.”

The making of HDR10

Digital video systems use quantizing to encode grayscale. However, insufficient quantizing can mar the image by adding “banding” artifacts that can be noticeable on still images and particularly annoying on motion pictures. Designing a system with more quantizing bits can overcome this issue. Consumer high definition formats use 8-bit quantizing, which is adequate for SDR but insufficient for HDR. So when the ITU set the R-BT.2020 standard for Ultra HD, among other things they enabled dramatically expanded grayscale. By going to 10 bits, consumer Ultra HD content and devices can support supple HDR grayscale rendition. A 12-bit quantizing option is also available for professional and other advanced applications



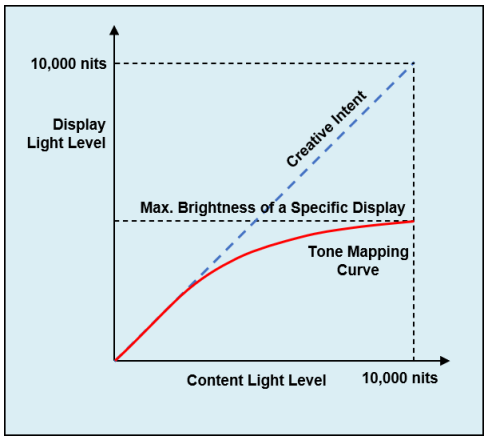
At the top, the distracting stripes of tone constitute “banding.” At the bottom, superior grayscale enables a smooth transition from dark to light.

HDR10 as a global standard

Encouraged by additional research and development in several industries, the ITU created another standard, this one for HDR encoding, called ITU R-BT.2100.

This includes a grayscale technique called Perceptual Quantization (PQ) which goes much further by using the 10-bit grayscale levels more efficiently. Unlike the encoding used in SDR, PQ concentrates the grayscale levels where your vision is most sensitive. With PQ, High Dynamic Range provides not only more digital bits, but also the most efficient use of each bit.

Each PQ grayscale level corresponds to a specific display light level, from 0 to 10,000 nits. The internal processing of each consumer display adjusts the highest PQ levels to fit within the display's brightness capability. This adjustment is called "tone mapping."



On the horizontal axis is the complete range of possible light levels in PQ-encoded content. On the vertical axis is the light level produced by an HDR10 display. The diagonal "creative intent" line describes a perfect match. However, because no consumer display can achieve the full 10,000 nits, the internal processing of each display adjusts the highest PQ levels to fit within the display's maximum brightness capability. This adjustment, called "tone mapping," gives you the full benefit of the display's brightest light levels, while maintaining excellent detail in the highlights.

HDR 10

The launch of HDR10

The establishment of the ITU R-BT.2100 standard for HDR caused an explosion of interest in compatible content creation and consumer products. In response to these developments, the trade group now known as the Consumer Technology Association (CTA) adopted an easy-to-implement configuration for HDR compatible displays. Announced in 2015 and built on the ITU standards, this was called the "HDR10 Media Profile" because it incorporates 10-bit grayscale quantizing.

HDR10 also includes a standards-based feature known as "static metadata." Metadata is simply any relevant information about the primary video and audio content. For example, when you mail a letter, the address and the return address are metadata while the letter itself is the content. Static metadata simply means one unchanging set of data is used for the entire program.

The static metadata in HDR10 includes the following:

- Color volume information
- Average light level of the brightest frame in the program
- Maximum light level of the brightest pixel in the program

Since different display technologies have different brightness capabilities, the static metadata gives each device the information it needs to retain maximum detail in the highlights while taking full advantage of the display's specific brightness.

In addition to all these compelling advantages, HDR10 provides other benefits:

- Any content creator can work with it.
- Device manufacturers can easily implement it.
- It's an open format that requires no licensing.
- No payments to patent holders are necessary.

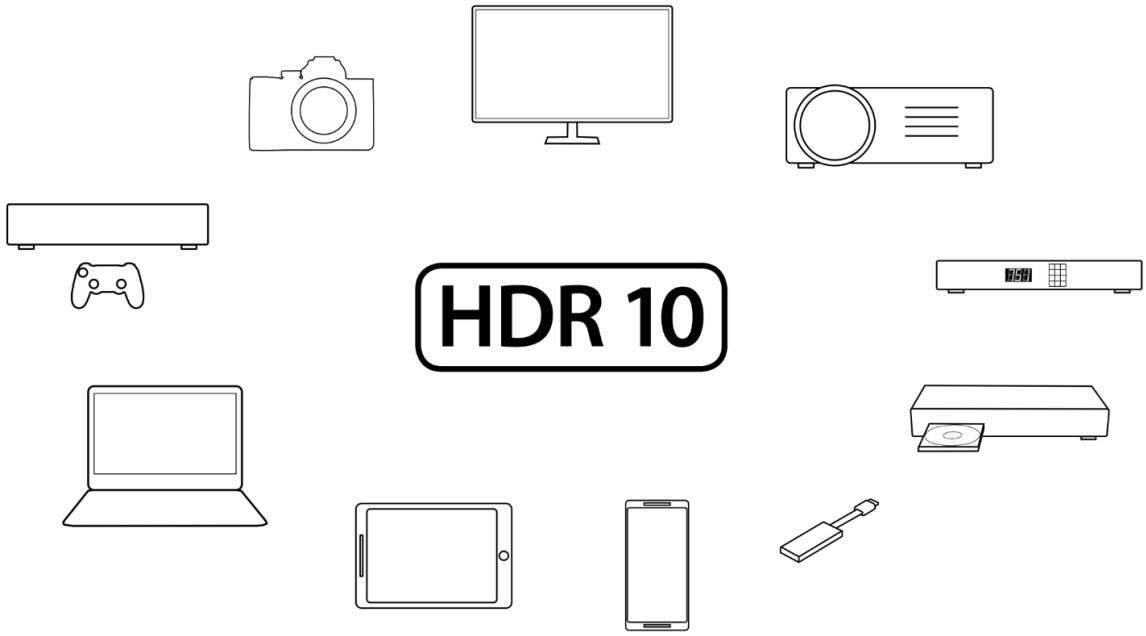
HDR10 is a major success

In a short period, HDR10 became a major success throughout the content, production, distribution and consumer electronics industries.

In *content creation*, HDR10 is supported by professional monitors, color correction and mastering tools.

In *content distribution,* HDR10 enjoys widespread usage*:*

- Movies and television shows
- Cable & satellite programming
- Streaming services
- Ultra HD Blu-ray Disc
- Videogames



Finally, HDR10 is available on an incredibly broad range of *devices* from the biggest names in consumer electronics.

- Televisions
- Projectors
- Set-top boxes
- Media players
- Streaming devices
- Smartphones
- Tablets
- Personal computers
- Videogame consoles
- Digital cameras

HDR10 also enjoys support from many industry organizations.

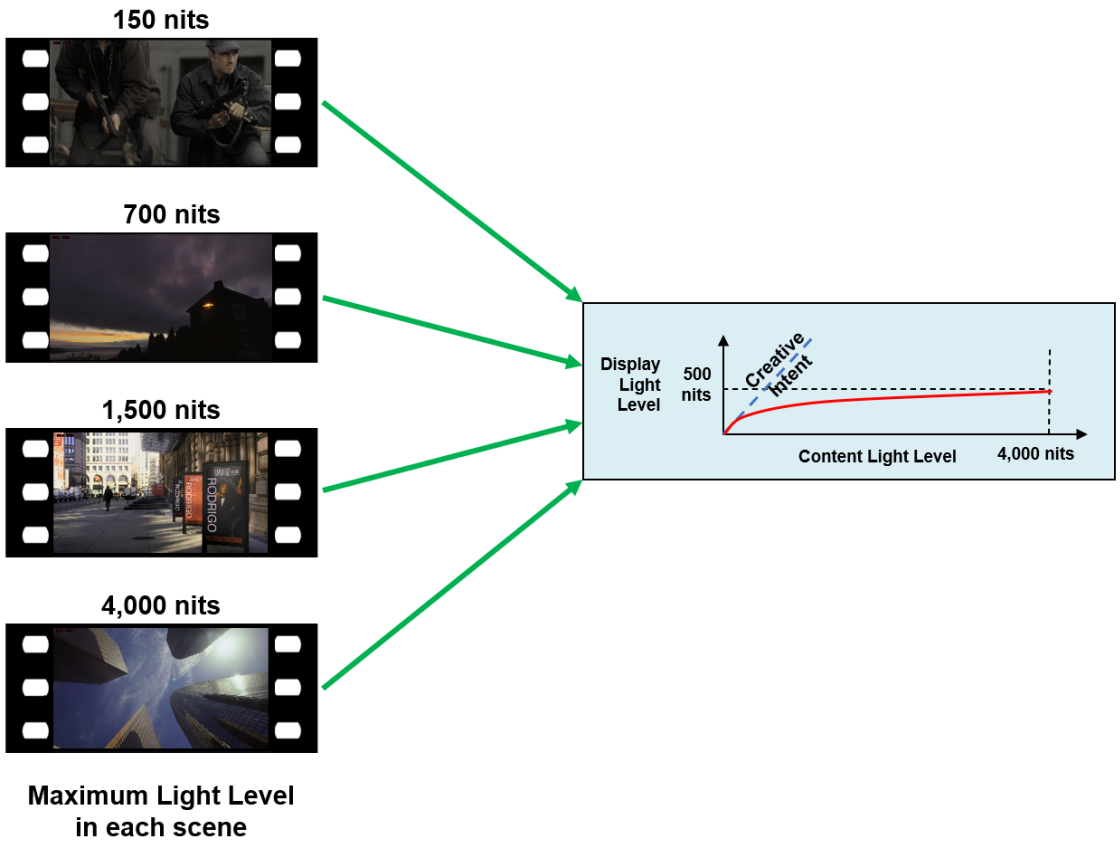
In addition to the Consumer Technology Association, HDR10 has been acknowledged by the 8K Association, Advanced Television Standards Committee (ATSC), Blu-ray Disc Association, HDMI Forum, Moving Picture Experts Group (MPEG), Society of Motion Picture and Television Engineers (SMPTE), UHD Alliance and the Ultra HD Forum.

In short, HDR10 has become a de facto standard.

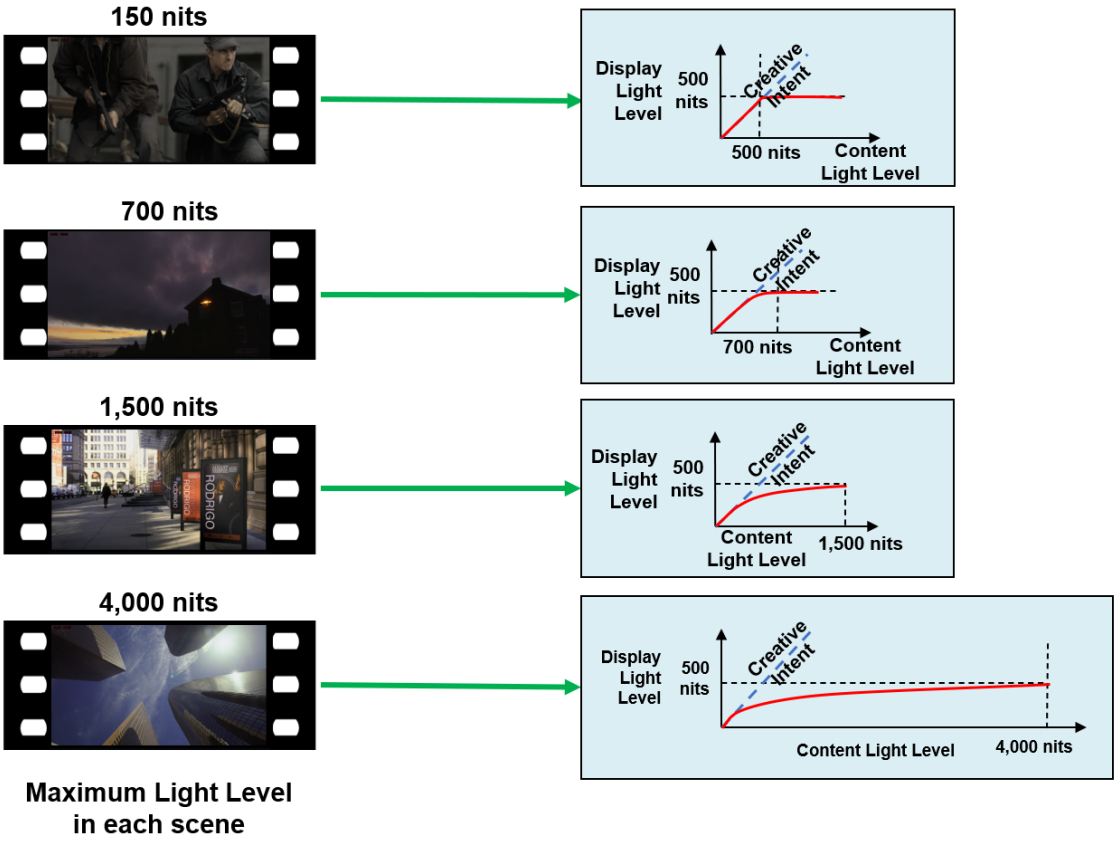
HDR 10+

The next step in the HDR10 ecosystem

As successful as HDR10 has become, like any static metadata system, it utilizes one-size-fits-all tone mapping for the entire program, which limits flexibility. To overcome this, a "dynamic metadata" system called HDR10+ was announced in April 2017. This direct extension of HDR10 is both backward and forward compatible and is seamless to implement. By using dynamic metadata, HDR10+ enables consumer devices to optimize tone mapping on a scene-by-scene and frame-by-frame basis.



Maximum light levels vary from scene to scene. For example, highlights in the skyscraper scene at the bottom extend to 4,000 nits. Static metadata generates a single tone mapping curve based on the maximum light level in the entire program.



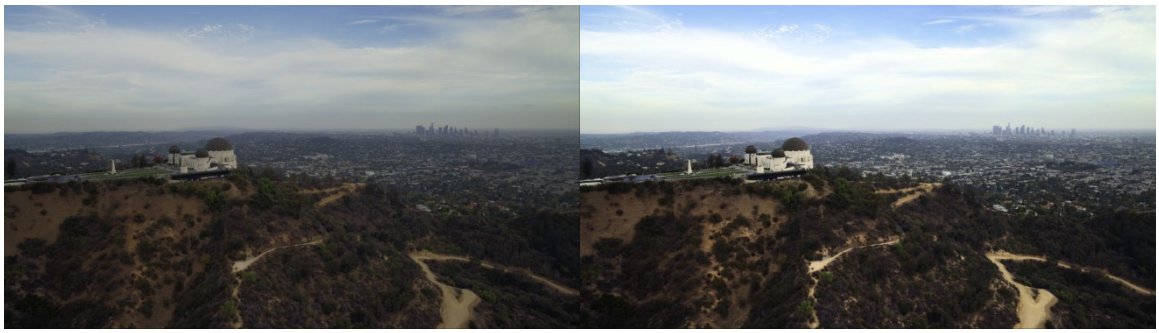
In contrast, dynamic metadata indicates the maximum light level for each scene, enabling the display to optimize the tone mapping curve on a scene-by-scene basis. You get a closer match to the creative intent line in low-light scenes, delivering much more detail in the shadows.

HDR10+ dynamic metadata benefits

Unlike other dynamic metadata systems, HDR10+ also identifies the most important areas of each scene to improve the reproduction of those areas. There are three steps.

1. During HDR10+ mastering, the system gathers comprehensive "luminance distribution" statistics that describe all the grayscale levels of each scene. The metadata include the exact number of pixels in nine different grayscale ranges.
2. The mastering system then uses this data to construct a highly sophisticated, customized tone mapping curve for each scene. This "guided curve" is also included in the metadata.
3. As with HDR10, each consumer device adjusts the tone mapping curve according to the specific brightness capability of the individual display.

As a result, HDR10+ does much more than deliver highlights optimized on a scene-by-scene basis. You also get better rendering of subtle shades in the most important areas of each scene, where image elements like skin tones reside.



On the left, tone mapping with static metadata. On the right, HDR10+ guided tone mapping with dynamic metadata.

While each frame contains millions of pixels, all this dynamic metadata adds just a few hundred bits per frame, making the additional metadata easy to encode and distribute.

Finally, HDR10+ supports other improvements in picture quality.

- 8K resolution
- Quantization up to 16 bits
- Display brightness up to 10,000 nits

To deliver all these technical benefits as a consistent user experience, HDR10+ Technologies, LLC was created. Since June 2018, the organization has been certifying HDR10+ compatible content, devices, tools and services, which can then display the full color HDR10+ logo shown above. This also helps promote consumer awareness.

The growing acceptance of HDR10+

From an industry perspective, HDR10+ provides powerful advantages in everything from professional content creation to consumer electronics.

1. Simple program production. Content creators can focus on making the best HDR content, knowing that HDR10+ consumer devices will provide optimum performance. HDR10+ mastering is straightforward and is supported by a choice of production tools which also make it simple to upgrade previously-produced HDR10 content to HDR10+.

2. Total system compatibility. As part of the HDR10 ecosystem, HDR10+ content works seamlessly with both HDR10 and HDR10+ devices. This content will display on HDR10 devices, which simply ignore the dynamic metadata. HDR10 content also plays as intended on HDR10+ devices.

At left, HDR10+ displays realize the full benefit of HDR10+ content, which also works seamlessly on HDR10 displays. At right, HDR10+ displays support HDR10 content as well.

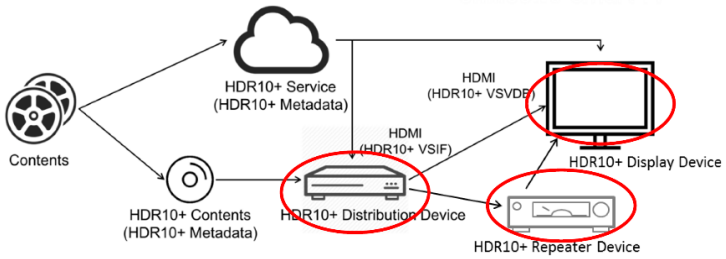
3. Ease of implementation. Like HDR10, HDR10+ is an open standard, works with a range of video codecs, requires no licensing fees and provides device optimization to take full advantage of the brightness of each specific display technology.

4. Robust standardization. HDR10+ has been established as SMPTE standard ST 2094-40 and has been recognized by the Blu-ray Disc Association, Consumer Technology Association, Digital Video Broadcasting, Society of Cable Television Engineers, Web Application Video Ecosystem and Airline Passenger Experience Association. Work continues on additional standards.

5. Growing industry support. Over 100 companies have already signed on as HDR10+ adopters.

- **Movies and other content** from 20th Century Studios, IMAX, Lionsgate, Paramount Pictures, Universal, ViacomCBS and Warner Brothers
- **Streaming platforms** including Amazon Prime Video, Google TV, Megogo, Paramount+, Rakuten and YouTube
- **TV manufacturers** including Hisense, Panasonic, Samsung, TCL, TPVision and Vizio
- **Mobile device manufacturers** including Motorola Mobility, OnePlus, Oppo, RealMe, Samsung, Vivo and Xiaomi
- **Streaming devices** including Amazon Fire, Chromecast with Google TV and Roku
- **Blu-ray Disc players** from Panasonic, Pioneer and Samsung
- **A/V receivers** from Marantz and Onkyo
- **System on Chip (SoC) fabricators** including Amlogic, MediaTek, Qualcomm and Realtek
- **Professional tools and production facilities**

6. Playback compliance. Best of all, HDR10+ Technologies, LLC conducts a thorough device certification program. To qualify, televisions and mobile devices must pass over a dozen tests, offered at seven test centers around the world. Over 3,000 different devices have already been certified by this rigorous process and can display the HDR10+ logo.

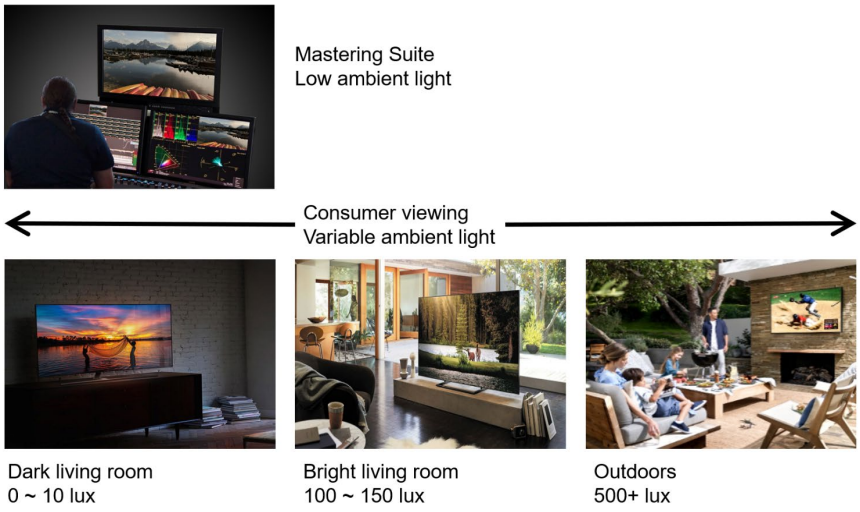


HDR10+ certification covers "distribution" devices like set top boxes and Blu-ray Disc players and "repeater" devices like AV receivers as well as "displays."

HDR10+ ADAPTIVE

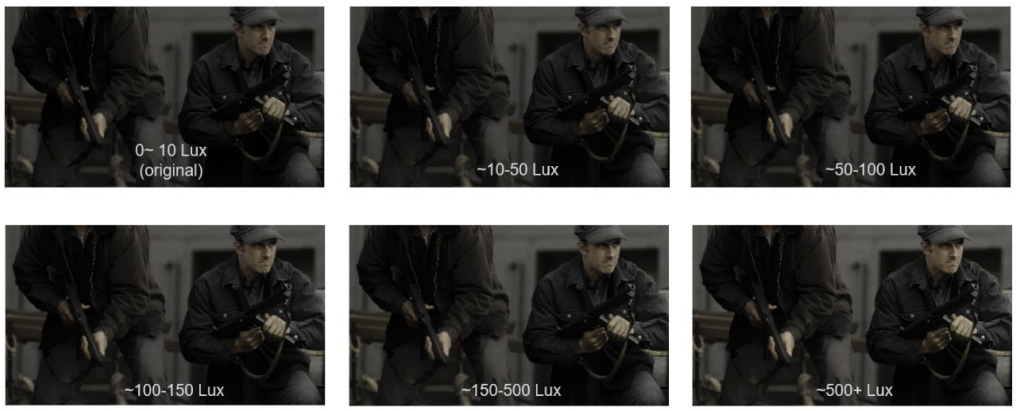
HDR10+ ADAPTIVE - A road to the future

Another critical consideration for HDR is the impact of ambient light on the viewing experience. Bright ambient light limits your ability to see shadow detail on the screen. For this reason, the mastering suites that content creators use for movies and TV programs purposely keep the ambient light low. Of course, in consumer viewing, ambient light varies greatly, depending on indoor or outdoor usage, time of day, window treatments and number and intensity of room lights.



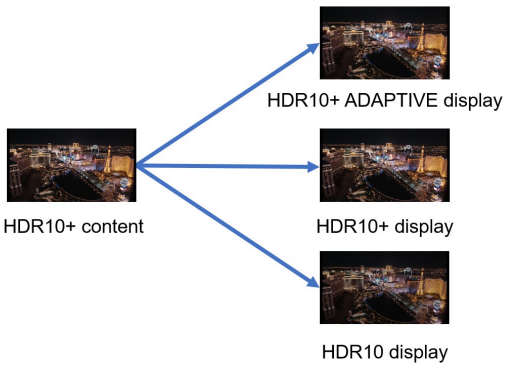
While mastering suites maintain low light (top), the ambient light levels in consumer viewing vary tremendously (bottom).

To address this, a new feature called HDR10+ ADAPTIVE delivers more consistent performance across a wide range of lighting conditions. The system takes advantage of light sensors built into the device and HDR10+ dynamic metadata to constantly adjust the presentation according to scene content and the amount of ambient light. For example, you get maximum adjustment for very dark scenes in very bright viewing environments: increasing brightness levels for better visibility. No adjustment is needed in very dark viewing environments.



When the ambient light is bright, HDR10+ ADAPTIVE provides precisely calibrated brightness enhancement of dark scenes.

HDR10+ ADAPTIVE devices achieve optimal performance in every viewing environment. HDR10+ ADAPTIVE also works hand-in-hand with emerging features like Filmmaker Mode, which enables compatible devices to show movies and television programs the way their creators meant them to be seen. Best of all, content creators don't need to produce a separate HDR10+ ADAPTIVE version. In fact, a single HDR10+ program can realize the optimum performance each consumer device can deliver.



A single HDR10+ program serves all the displays in the HDR10 ecosystem.

Additional HDR10+ enhancements are being developed for future applications. Stay tuned for further announcements.

Closing thoughts

As the experts already know, High Dynamic Range provides a more realistic, more exciting, more captivating entertainment experience. And to take full advantage, the HDR10 ecosystem is the key.

HDR10 enjoys broad support from movie studios, streaming companies and a comprehensive list of device manufacturers. HDR10+ carries this further with even higher performance. And with new advancements on the horizon like HDR10+ ADAPTIVE, this ecosystem will continue to delight and entertain audiences for years to come.

For more information, visit **hdr10plus.org**