Atomos HDR Tech-Guide

As a technology manufacturer, it is not very often that you witness a single leap forward in technology that changes the way every professional works. Last year, like many others we witnessed the massive leap forward known as HDR (High Dynamic Range). HDR is truly one of those "you have to see it to believe it" technologies, pushing the boundaries of conventional capture and display capability and bridging the gap between what we see on TV monitors and reality as we see it with our eyes. Rather than increasing the number of pixels we see, HDR revamps the brightness range we can see in a single scene – displaying brighter and darker parts in a scene at the same time. In consumer terms it means a sunset will look more vivid and life-like while in filmmaking terms it means you no longer clip highlights or sacrifice shadow detail.

What's even better is that this giant leap forward in technology doesn't come with an equivalent quantum leap in equipment or infrastructure upgrades. The cameras you are using most probably already have the log HDR output required, unlike 4K the file size does not increase, content developers such as Netflix and the BBC are pushing for HDR content for distribution and end users are already buying HDR flat screens for the home throughout 2016. The missing piece of the HDR puzzle lies in the field monitoring and post production editing workflows. Of course, as Atomos have done with HD and 4K, we've worked hard to deliver a solution to make the whole HDR process faster, easier and more affordable.

In this tech guide, we'll help you with both a technical and real world understanding of what HDR and SDR (Standard Dynamic Range) is, clarify the common terms used to describe HDR and using the Atomos SDR to HDR slider that is on our user interface show you the trade offs between SDR to HDR so you can make the right shooting decision for different scenes.

Quick glossary.
Before we get into the details of HDR, we should first clarify some explanations of key terms. See attached appendix for a full explanation of the glossary terms below, they will assist you with understanding HDR;
HDR terms; Dynamic Range, Contrast, Brightness, Nits, Stops
Camera sensor basics; how a sensor converts light to digital
Monitor basics; calculating contrast ratio and the relationship to dynamic range
Recording basics; why Log curves are used
Brightness standards; Rec709 brightness standard and new standard for HDR (ST2084 or PQ)
Color standards; Rec709 color standard and the extended color space (gamut) for HDR (DCI-P3, BT2020)

With the basic definitions under control, let's show some real world benefits of shooting HDR and when to use it vs when to shoot normal SDR. Before we do, it's important to note the workflow when you are looking at the examples below;

Camera output;	Slog2, SGamut
Monitoring;	HDR or SDR as shown in examples
Recording;	Slog2 (Atomos monitor true HDR but still record the original Log in tact)
Post production;	Normal main edit using the ProRes/DNxHR files and color mastering using HDR tools in Adobe Premier Pro and AVID Media composer (e.g. HDR to SDR conversion, NIT scales on Luma wave forms etc) or use your AtomHDR monitor as your external reference monitor for HDR grading.

HDR vs SDR shooting
With such a powerful creative weapon as HDR it is still important to understand not every scene needs to be monitored in Max HDR and there are good reasons to still monitor in SDR or somewhere in between. In the examples below we've combined the AtomHDR slider control from our user interface with real life examples to show why you would use HDR for scenes with a wide brightness range and equally why you might prefer SDR if there isn't a huge brightness range in a scene.

A) SDR = 100% Rec709 | B) Mid HDR = 400% Rec709 for Slog2 | C) Max HDR = 1490% Rec709 for Slog2

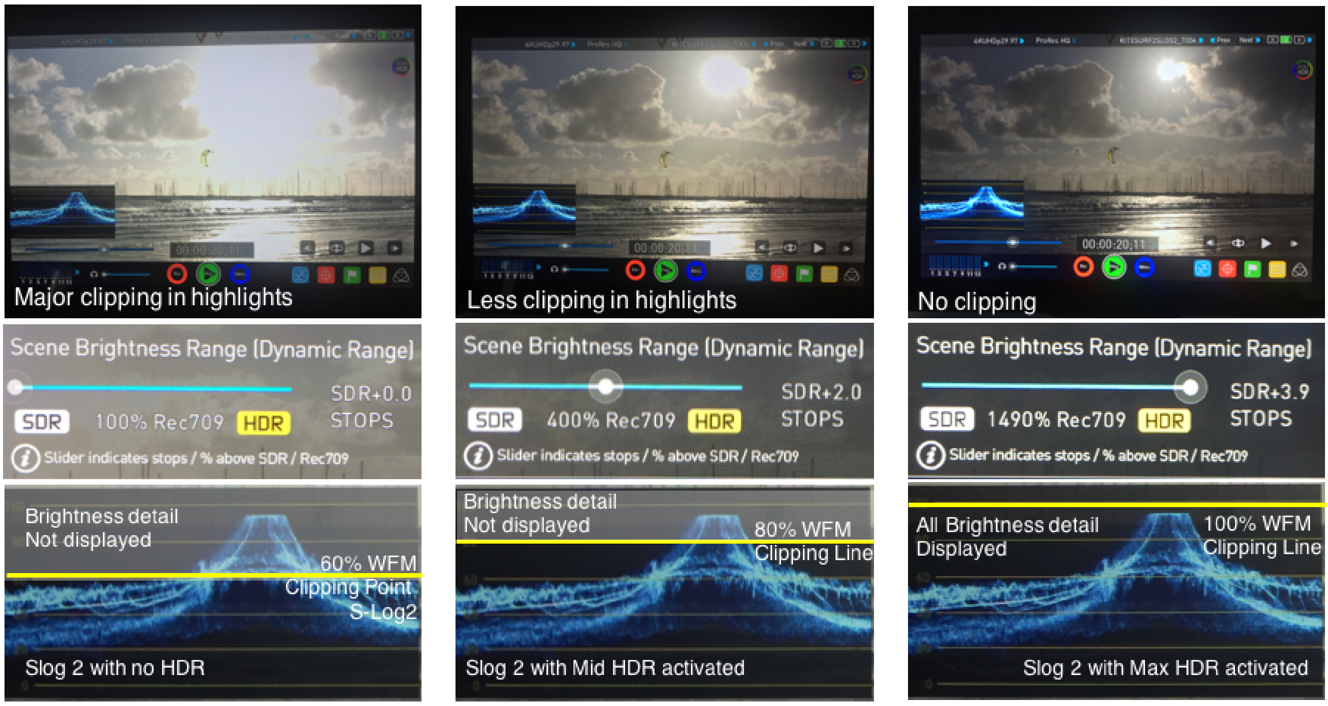


Figure 1 – Comparing Brightness range for Slog2 (% and Stops will change with different log curves)

Note: The SDR:HDR slider is NEW in AtomOS 7.01. The previous versions use this image, please update.

Comparing the three Brightness range settings in Figure 1 you will see that there is a huge difference in brightness range or level of clipping when you slide between SDR and HDR. It is clear to see that in Max HDR mode with the higher brightness range available more of the subtle detail in the clouds and sky are revealed. Essentially as you increase the HDR slider, you move the clipping higher on the WFM to reveal more detail across the entire image. In all 3 modes, the peak brightness remains at 1500nit (maximum capability of the monitor), however now with no clipping taking place in Max HDR mode there is a smaller area of the screen at the peak 1500nit brightness (just the centre of the sun, not the blown out image of the sun) and so the “overall brightness” of the image is reduced. Sliding back to Mid HDR (Figure 1B) gives you a mid point between overall image brightness and clipping of the highlights.

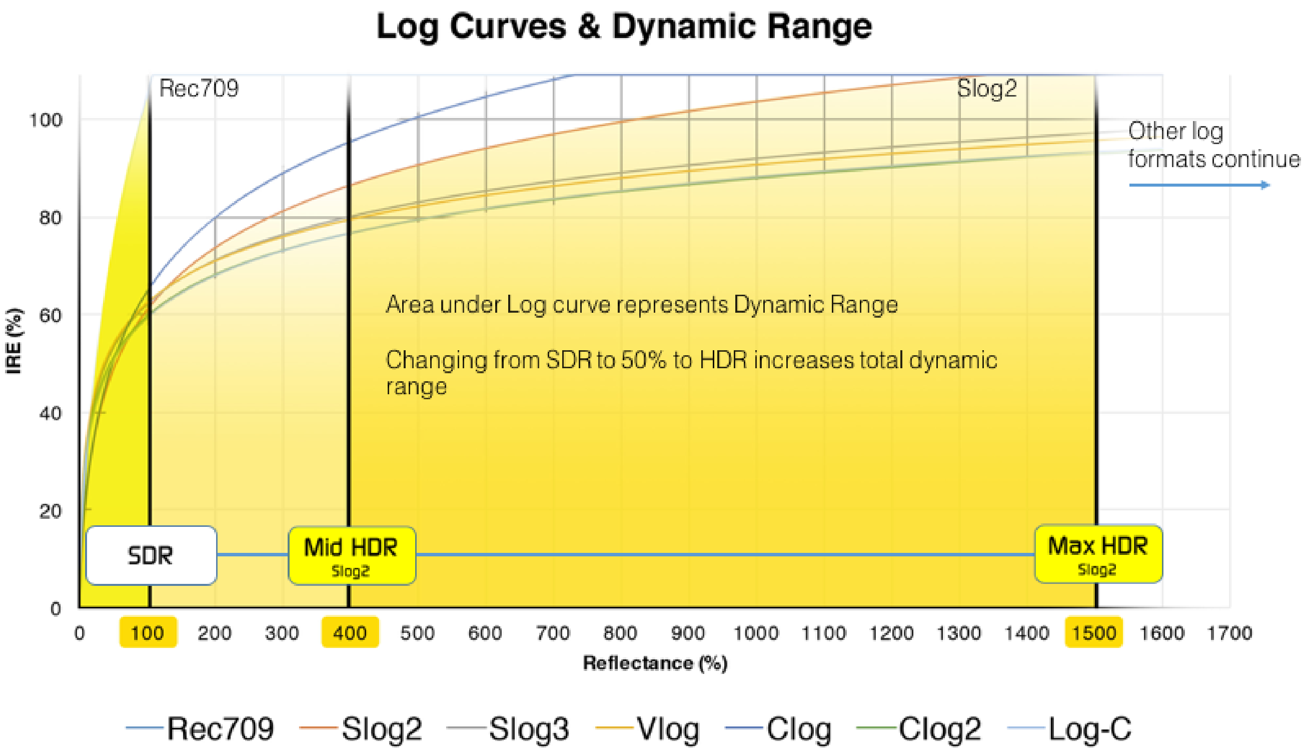


Figure 2 – Log luminance curve and Dynamic range

Looking at Figure 2 you can see how this real world example translates to on the typical Rec709 vs Log luminance curves. The area under the log curve represents Dynamic Range and as we slide from SDR (100% Rec709) to 50% HDR (400% Rec709) to HDR (1490% Rec709), we are sliding along the X-Axis of the log curve picking up more dynamic range above the SDR level.

So while for the high brightness range scene shown in Figure 1, using HDR over SDR is clearly a great choice (evident by the large amount of clipping in SDR mode), for other scenes without a high brightness range shooting SDR might be good to maximise overall screen brightness without a noticeable sacrifice in the highlights.

Furthermore, you now can see why we include a hood with our HDR models. Applying a hood to minimise ambient light and external reflections (no matter how low), maximises screen brightness and lets the user operate in the maximum HDR mode more often.

These examples above highlight the dramatic improvement HDR will make for creative storytelling and reinforce how outdated Rec709, the standard built for CRT technology, is for this new HDR world. What you see in the examples above is all due to improvements made with brightness range, color remains unchanged in terms of specification but you will see an improvement especially with 10-bit processing. The good news is that a new standard has been developed for HDR brightness, known as SMPTE ST 2084 or PQ. Atomos will support these standards on capture (PQ input for monitoring in post production) and on output (Output PQ to HDR compatible televisions).

Now with a better understanding of HDR, you can see why the AtomHDR engine provides a revolutionary step in on set monitoring, letting you make the decision to operate in either HDR mode (combining over 10 stops of dynamic range, 10-bit processing and 1500 nit brightness) or SDR mode for high bright external monitoring when dynamic range is not a factor.

By using the AtomHDR engine you can SEE WHAT YOU ARE ACTUALLY SHOOTING and correctly expose for HDR without the rules of thumb or exposure charts. The luma parade waveform shows the expanded dynamic range so you can see all the points of detail while keeping the highlights from clipping (Extended HDR WFM is due in release 7.1). At the same time as providing on-camera HDR monitoring, the High Bright 1500nit display also provides easy daylight viewing for SDR shooting. Cover SDR and HDR by recording log, exposing using AtomHDR monitor and deliver in either Rec709 or HDR using the recorded log footage.

We are so excited about the future world where 4K and HDR come together and encourage shooters from all walks of life to learn more about the capability of their sensor and put it to good use in a HDR end to end production. We believe we've made HDR easier to understand technically but more importantly made it simple in a real world usage on our product's user interface, so that more filmmakers can be comfortable adding HDR to their creative capabilities and in the end deliver more HDR content to end users.

Appendix 1 – Glossary

Dynamic Range, Contrast, Brightness
All of these terms are used to describe light in a scene – be it the intensity of the light or the difference in light intensity. Brightness is a measure of light, where the standard unit is a "nit" (1 nit = 1 candela/sq m) – more nits equals higher brightness. If you measure the brightness of maximum white and maximum black in a scene you can calculate the Contrast ratio, which is simply the nit measurement of white divided by the nit measurement of black. You can increase the contrast ratio by either decreasing the black figure (deeper blacks) or increasing the white figure (brighter whites). Dynamic range is a measure of the brightness range that exists in a scene. It's measured in "stops" where each stop is defined as a doubling of brightness or luminance. You can see that while Dynamic range and contrast are technically different with one measured in stops and one measured as a ratio of nits they both attempt to describe a similar factor, the range between the dark parts and the bright parts of an image i.e. Brightness range.

Camera capture world – Stops & Bits
A video camera system takes light (analog), captures it using a lens (analog), converts it to digital using a sensor (digital) and records it (digital).

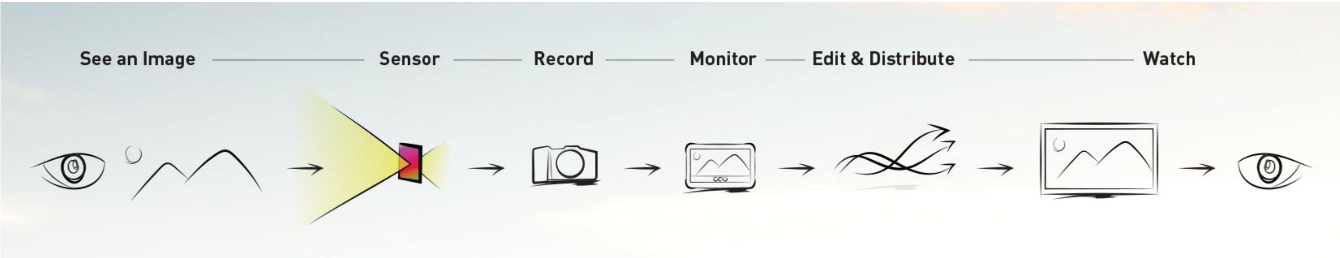


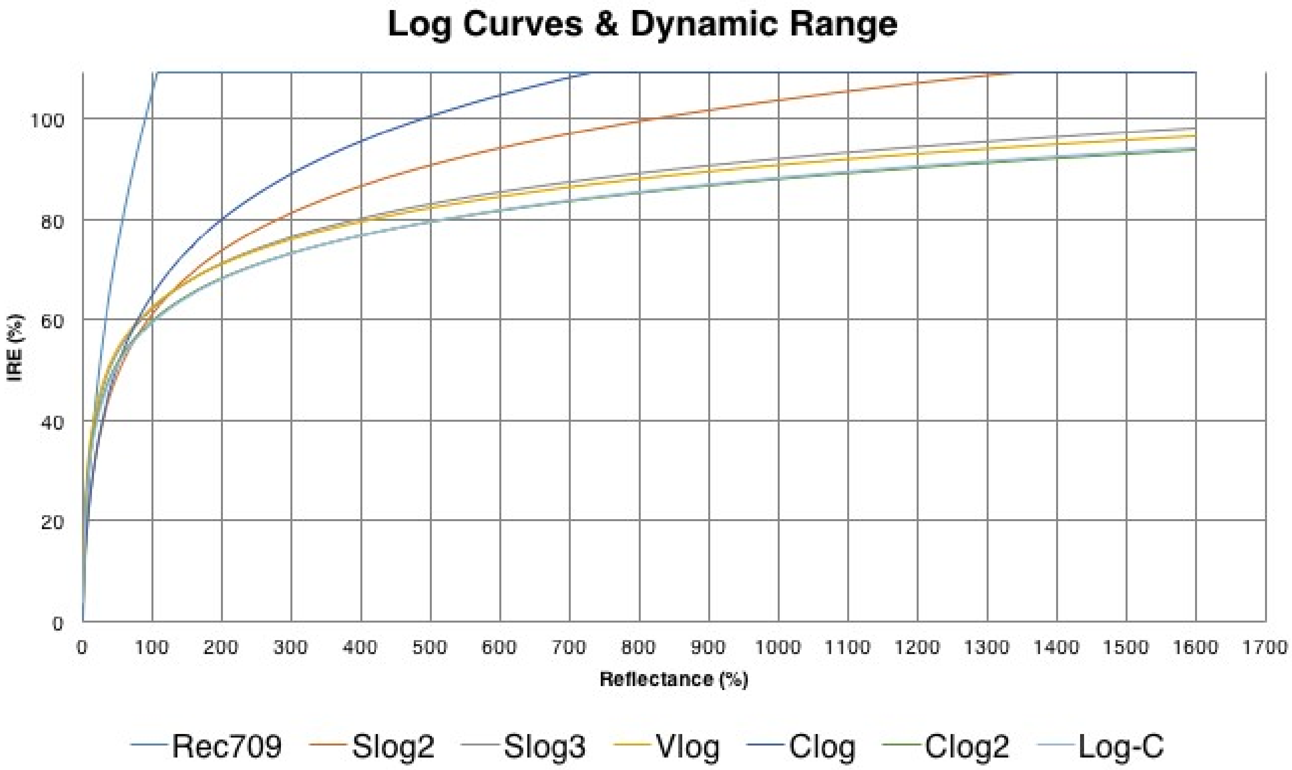
Figure 3 – HDR replicates what you see in the real world with what you see in the living room.

The sensor is the critical stage that converts analog light energy into 1's and 0's, the digital world. The accuracy of a sensor is an art in itself but one consideration is how many "1" and "0" steps are available to convert analog to digital. A perfect 10-bit linear ADC has 10 Stops, 12-bit linear ADC has 12 Stops, 14-bit linear ADC has14 Stops of dynamic range. In simple terms, to capture more stops of Dynamic range you need a camera sensor with a higher bit depth. When the analog signal is converted to digital the number of stops translated is limited by the bit-depth and the noise introduced during the conversion.

The reason current cameras use log curves is to fit more bit-depth/stops into a signal of fewer bits.

Monitor playback world – Stops & Nits
Monitors need to take the digital signal and convert it back to light to display. Each display technology has its own way of doing this, but in the end will have a brightness range capability that can be measured. For monitors, it is possible to correlate the brightness range measurements, whereby;
Log_2(Contrast Ratio) = Stops of Dynamic Range
For example, Atomos Flame panels have a peak white 1500nits, black level of 1.3nits. This equates to a contrast ratio of 1153 or 10.2 stops of dynamic range.

Recording world – Log curves vs Standard video
Before you can display an image you need to record it from the sensor. As explained above, the sensor sees light completely linearly, it measures every photon of light in bands of the 4096 steps that exist on a 12-bit sensor. When it comes to recording we need to match what can be displayed on monitors. The 12+ stops of dynamic range capable with modern day sensors are hamstrung by the 5-6 stop limit[1] of television standards still currently used (Rec709). Log curves solve this problem be "bending" the brightness curve to fit 12 or 14 stops of dynamic range into an 8 or 10-bit signal, but at the expense of no longer matching human perception so the image looks flat or washed out and is difficult to expose correctly. AtomHDR solves this.



Brightness standards
As we've described above, dynamic range is exclusively linked to the brightness not color. There are standards for brightness that are entirely separate to standards for color. Rec.709 brightness standard was developed for the capability of CRT televisions at the time which was 100nits. Now with HDR technology the capability of televisions far eclipse that maximum and so a new standard for HDR has been developed, known as SMPTE ST 2084 or PQ. Atomos will support these standards on capture (PQ input for monitoring in post production) and on output (Output PQ to HDR compatible televisions)

Color standards
In the same way that there are standards for the brightness, there are standards for color. The Rec.709 color standard was developed for CRT television capability at the time. Display technology has moved forward at a rapid rate, now with the capability of supporting wider color gamuts such as P3 and BT2020 on consumer and professional TVs and displays alike. The wow factor of HDR has been driven by a focus on brightness range rather than color, having said that the increased brightness range makes colors more vivid due to the additional color volume available.