Still photo by GTC member Steve Hall: the image is composited from six identical frames taken one stop apart and demonstrates the rich colours and depth that can be achieved through HDR

All things bright and beautiful

– HDR explained

High dynamic range (or HDR) is a topic that is currently generating more interest than ever, even as we start to see the next generation of three-letter abbreviations emerge. With the arrival of UHD, HFR and WCG, we're in danger of finding ourselves back in the hi-fi shop with the *Not the Nine o'Clock News* team (if you're not old enough to remember it, look it up on YouTube – it's very funny!). Trainer and technical expert **Neil Thompson** helps us to catch up with what we need to know about HDR before we have to start grappling with yet more new terms!

Dynamic range has always been a topic that generates a lot of debate. Who's got the most? How much is enough? How much can we see? How do we measure it?

In theory, we will soon be able to capture, manage and deliver to the home a much higher dynamic range than is currently possible, with the power to dazzle us as though we are indeed seeing the sunlight stream though a window. It is already possible to buy HDR displays from all the big names; to download HDR programming from Netflix and Amazon; to upload HDR content to YouTube; and to play HDR games on a PS4 Pro. Now it will be up to us to provide the content that will make this new technology stick.

So, assuming we are able to deliver HDR images to the homes of people who have bought their shiny new UHD or HDR displays, is anyone going to be impressed?

Well, probably, maybe. At present there are plenty of opportunities for something to go amiss along the way, with competing standards, different transmission paths and workflows, and the usual miasma of misinformation surrounding the introduction of a new consumer technology. When all goes well though, HDR looks fabulous. Its impact is immediate and obvious. Speculars shine, bright windows and shadowy interiors retain detail, snow dazzles. (I've tried to illustrate this in Figure 1 as well as Steve's gorgeous still life above but, to be honest, it is always a bit difficult in an SDR environment… unless Zerb is now being printed on HDR paper!)

More dynamic range (DR) is good, but how much more?

ITU* recommendation BT.2100 (on 'Image parameter values for high dynamic range television for use in production and international programme exchange') has been introduced to help define what qualifies as HDR. It tells us a good deal about the desired performance of the display technology and the transfer functions that can be used to manage HDR within our existing systems but not a lot about the front end, which is where, as camera people, our interest mainly lies.

Let's start by making some assumptions, just for the sake of argument. Any of these numbers could be plus/minus a great deal depending on your view of the world – or, indeed, the condition of your eyes.

We usually talk in 'stops' of dynamic range or contrast, each stop being a doubling or halving of the range. If we say a camera has a range of 14 stops of DR, we mean we can expose at the maximum point where we can still see an increase in output for an increase in input, and from that point we can halve our exposure 14 times, and still be left with signal visible above the noise.

It's all very well claiming that our camera can see 14 stops, but we probably really mean that the sensor is capable of resolving 14 stops. Exactly how much of that remains once we have gone through signal processing such as gamma correction, resampling to 8 or 10 bits and compression via a codec, is a different story.

So who's letting the side down?

	Probably about (stops):	Let's call it (stops):
High contrast scene in the real world	12–18	14
The human eye	12–15	14
High-end camera sensor	12–15	14
The broadcast infrastructure	6–10	9
Current generation monitor/TV/display	6–10	9
New generation HDR display	11–16	14

Frame grabs from an S-log 3 image, adjusted to simulate an extra two stops of dynamic range

***** *ITU is the United Nations specialised agency for information and communication technologies and develops technical standards: www.itu.int*

Looking at the 'Let's call it' approximations above, it's the 'broadcast infrastructure' and 'current generation displays' that are the weak links and need sorting out in order for us to truly tick the HDR box.

Fortunately, that's not too difficult. The general idea is that you take the HDR image from your camera sensor, squash it down to fit through the fixed doorway of the 'broadcast infrastructure' and deliver it to the home. Your shiny new HDR TV then recognises the recipe used to squash the pictures, unsquashes them… and, hey presto, end-to-end HDR.

> HDR looks fabulous. Its impact is immediate and obvious.

The DR of your TV can be extended at either end of the range: deeper into the shadows, up into the highlights or, ideally, both. Display technology and, more importantly, viewing environment limit the scope for extending the black range, so most of the burden will fall on increasing the luminance output of screens. ITU BT.2100 recommends a minimum output luminance of 1000 cd/m² (or nits) for HDR, whereas a monitor in a typical production environment would currently be set for 80 to 100 cd/m².

Log-type curves and transfer functions

There's still some bickering about what recipe to use to fit your 14 stops of camera sensor through the existing infrastructure but, for the moment, some manufacturers are using their log-type curves as an intermediate option. Sony, for instance, is using S-log 3. For once, we at the front end don't actually need to worry too much about the exact recipe: there are plenty of log-type transfer curves that will work as an intermediate stage, and squeezing a 14-stop range into a 10-bit file (and it does need to be 10 bits minimum) is exactly what S-log, Log-C, C-log, V-log *et al.* have been doing for several years now.

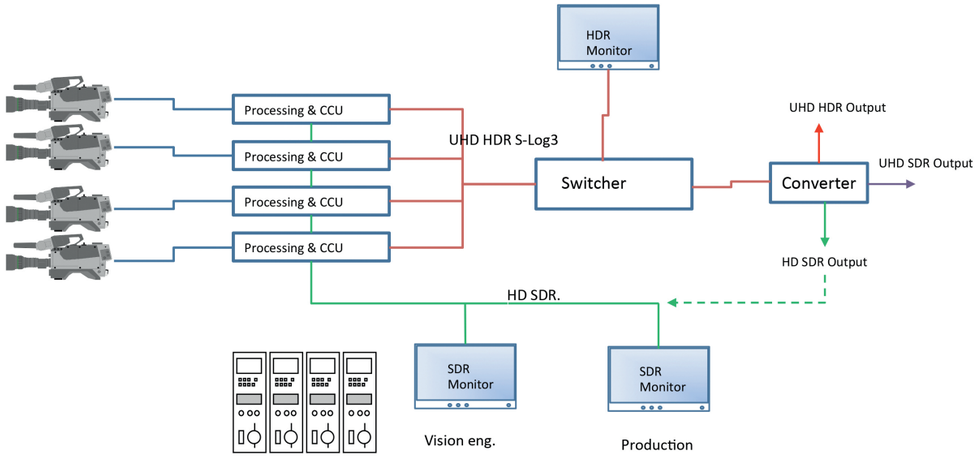
> Perhaps the easiest way to remove the fear from exposing and lighting for HDR is simply to remember that if you can repurpose existing Log/RAW archives for HDR, then there can't be too much wrong with carrying on with the way you have been doing it!

Outside this intermediate stage two transfer functions are recognised by BT.2100 for optical to electrical conversion (OETF) at the front end and the reverse process at the screen stage (EOTF). These are perceptual quantisation (PQ) and Hybrid Log-Gamma (HLG).

PQ is a proprietary solution developed by Dolby laboratories. It is designed for displays of brightness up to 10,000 cd/m².

HLG aims to provide a transfer characteristic that works well for both SDR and HDR displays. The BBC and NHK have both done a lot of work on this open standard. To the SDR world this should look a bit like a normal gamma curve with a smoothed-off knee, but in the HDR world the inverse transfer function in the display allows you to unlock wide DR.

But which is better? There are many articles that discuss the relative merits of the two, so let's just stick with recognising that both Log and RAW work fine as an intermediate. HLG comes into its own when you have just one transmission channel that must deal with both SDR and HDR. It's less important for internet-based services where you can put two versions of your programme on a server and the user then chooses either HDR or SDR.



Shooting for HDR

The question that now applies to all of us shooting content is how do you change your way of shooting for an HDR project? Well, if you've been shooting in a Log mode on a camera that's capable of handling a high dynamic range, then you have already been shooting for HDR. Your archive of Log gamma material from previous projects shot log-style on a Sony F5, ARRI ALEXA or Canon C300 etc. can be repurposed for HDR delivery. You might have shot it a little differently if you'd known this might be part of the plan, but you can be sure there will be a nice little market in repurposing Log or RAW archives for HDR delivery.

The current Log or RAW workflow is to capture 14 stops of DR and deliver all of this to the colourist. The colourist then decides how to chop and squeeze 14 stops into the 9-stop range that actually makes it to your screen at home. In an HDR world, we capture 14 stops and can deliver 14 stops. The colourist has much less 'wiggle room' but has to do what wiggling they can more carefully!

> More dynamic range is good, but how much more?

Again, the hugely important bonus is that most of the material recorded Log or RAW can be repurposed for HDR release for either standard... trebles all round!

Exposure and lighting

We live mostly in a world of modest contrast range. Occasionally we need to narrow our eyes and wait for our pupils to adjust to high contrast, but it's a bit like music – quiet interspersed with occasional loud tends to work well. Lighting everything for high contrast might be the musical equivalent of Death Metal, which just gives most people a headache!

From experience of showing HDR to lighting directors, they love it. The ability to hold colour and detail in highlights creates much more initial excitement than when first showing HD. It's always necessary though to remind people that this only makes it to the home viewer if all your ducks are in a row right through the transmission chain and into the home.

So let's suppose we are lighting a scene that will be delivered in both formats. Do you light for HDR and accept that SDR will struggle? Or light for SDR and not use the capabilities of HDR? The second option is obviously a waste of time so maybe it's best to light for high contrast when justified but don't overdo it, and remember that your SDR version will have to be graded as it's either Log or RAW. Your colourist will only be facing the same challenges as they currently do with high contrast scenes.

And here's an interesting side note: if you're shooting Log for HDR, you may be better rating the ISO of your camera higher than you might expect and exposing to the left a bit, saving the top of your range for high contrast highlights and speculars. This is pretty much as originally recommended by Sony for cameras such as the F5 and FS7, although many people have since chosen to rate the cameras a stop lower and expose to the right. (I say interesting... maybe I should get out more!)

A constant barrage of HDR will be uncomfortable for the eyes. It will be important to 'keep your powder dry' for the scenes that really need the extended range, although I have a sneaking feeling you may come under pressure to light more scenes for high contrast than would be natural. Perhaps the easiest way to remove the fear from exposing and lighting for HDR is simply to remember that if you can repurpose existing Log/RAW archives for HDR, then there can't be too much wrong with carrying on with the way you have been doing it!

Recording

So, how do we record HDR? Because we're using an OETF to fit our extended range through the existing doorway into the broadcast infrastructure, nothing really changes for recording. We use the same codec, at the same data rate, onto the same cards as we ever did, so there is no increase in file size or software updates required for ingest. There's one thing to be careful of though. Make sure you're using a 10-bit codec. Because your pictures all have to shuffle up into the middle of the recording range to make room for all this new shadow detail and shiny highlights, you end up with fewer levels describing a given tonal range. With an 8-bit codec you could start to see contouring, much as you might if heavily grading Log images at 8-bit with current SDR workflows.

> Lighting everything for high contrast might be the musical equivalent of Death Metal, which just gives most people a headache!

Viewfinders

In the live world, your viewfinder options are limited. There aren't currently any HDR-capable viewfinders and, even if you can find an HDR on-camera monitor, it's unlikely your camera will have a suitable log-type output you can connect to it.

So, what will you be looking at? Well, depending on your system, you'll probably face a similar dilemma to working Log mode on current cameras. You can either look at a very flat image but everything is there, with your HDR squashed into the available SDR, just like looking at S-log 3 in the viewfinder of an F5 for instance. Or you may be able to look at your flat log image via a LUT, giving you something more contrasty, but burning out highlights and losing shadow detail.

But do you really need to see proper HDR in the viewfinder? You may find looking closely at a very bright screen uncomfortable and when you take your eye away to look around the dimly lit studio your eyes will take a while to adjust. When finding focus, a bright specular dazzling you in your screen may not be ideal, although on the other hand being able to appreciate how that specular will look to the home viewer might change how you frame the shot. Then again, the producer may want you to be thinking of the SDR viewers who are paying the wages. In summary, you're probably fine with an SDR viewfinder! It's still going to be about hitting focus; in fact, you'd probably still be OK with a monochrome tube!

Location monitoring

For single-camera work you have more options. We are starting to see a new generation of HDR screens from manufacturers like Small HD and Atomos. Battery-powered, 7" and upwards screen sizes, with over 1000 nits brightness are now available, and by the time of BVE we can expect more new products. Most cameras have a 'Log' output suitable for connection to these displays, and tools such as Ben Turley's LUTCalc enable you to create LUTs to convert from the various Log flavours to whichever EOTF your HDR monitor needs, if it doesn't already have suitable conversion built in.

You still need to think about whether it's necessary though. One major factor may be the viewing environment. You're often struggling with sunlight and high levels of ambient light on location, so trying to make decisions about DR may be futile. On the other hand, those are the very conditions when a high brightness monitor would be useful, just so you can see the picture, never mind whether it's HDR.

Live production

For live production, things get more complicated. For a long time to come, it's likely you will need to produce parallel outputs for SDR and HDR, and for a long time to come, the main revenue stream will be SDR. Fortunately, a 'look after the SDR and HDR will look after itself' approach can work. Just as well really, as adding full-on HDR to a truck or studio could get messy.

The racks engineer can also only expose the image once of course, and needs to find an exposure that works for both SDR and HDR. In cameras such as the Sony HDC-4300 you can have parallel outputs from the camera control unit, each with a different transfer function or gamma curve for SDR or HDR, and each with an offset for gain and black level, which can make our 'look after SDR' approach viable.

One suggestion is to use the SDR outputs from the cameras, with an appropriate gain and black level offset applied uniformly, purely for monitoring and racking, with the main SDR output being derived from the log intermediate at the final output stage (Figure 2). It is also possible to combine SDR and HDR transmission channels by using an HLG OETF, which is compatible with both SDR and HDR TVs.

In summary

HDR gives the end-user a clearly visible benefit – but only if it's done correctly end to end. We don't yet know exactly which standards will dominate but, in the meantime, we can just get on with it, with Log and RAW shielding us from the battles raging outside.

For production, it should actually be a lot less painful and costly than the transition to 4K/UHD. And, if you've bought a 4K TV without HDR you've been mugged... OK, OK, I did, but only a cheap one to check resolution – and yes, I know, it's UHD not 4K!

Fact File

Neil Thompson is a freelance engineer, specialising in camera systems and associated training. He started his career in television at BBC Television Film Studios in Ealing and then worked for many years for Sony, in various engineering, support and product management roles. Neil has a long association with the GTC and is proud to be an honorary member.

See more: www.imagemechanic.co.uk

Further reading

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