THE LUT GAME

If you haven't encountered the need for Look Up Tables (LUTs) yet it's only a matter of time. STEVE SHAW[1] lays out the ground rules for use

With the growth in digital cinematography based image capture, and especially with the desire to maintain a wide dynamic range image that mimics the flexibility provided by the traditional capture medium of film, has come a problem that, while comparatively simple in concept, is proving difficult for many to manage in actuality.

This problem is how best to view the captured image on-set or on-location...

This problem is compounded by the fact that for many production operations using a 'digital' camera has meant HD or SD 'video', with its direct-to-air colourimetry and contrast range, showing the exact image – or very close to – that will later be transmitted.

Combined with film's 'video assist' systems that have been, in the main, no more than low quality analogue SD video taps, from which no-one expects to see images close to final reality, the expectations for on-set 'digital cinematography' monitoring vary widely.

However, the mere mention of 'digital cinematography' has all those involved in the production expecting large size HD monitors on set, showing images they would be proud to see at home via their home theatre system.

The problem though is that if the DoP is shooting for 'digital cinematography', rather than HD 'video', the raw images will look flat and lifeless, exactly like projecting a film interpositive, with the captured image set to prevent crushed shadow details and clipped highlights, mimicking the capture characteristics of OCN film!

With cameras like the Thomson Viper this is even more prevalent as no attempt is made at white balancing; resulting in an image that is colour biased – with the colour bias depending on the illumination colour temperature, but a shade of green is a near certainty.

But this is 'digital', so why can't I, the director, the producer, and just about everyone else on the crew, see what they expect to see – pretty pictures? The DoP may know exactly what he/she is capturing, but attempting to explain how the final image will look when the on-set image is so unlike what is being described can get very awkward.

So, as a result of this need, all thoughts turn to using a LUT (Look Up Table) to manipulate the captured images for display on the on-set monitor – not for capture – and show 'pretty pictures' more in keeping with what the final look is expected to be.

And it's at this point things often start to go wrong.

View LUT, or Print LUT?

The problem is not so much with the idea of using LUTs, but with which type of LUT is being used.

LUTs can, in the main, do one of two things. The first is to display an image that is calibrated to match, as closely as possible and within an ideal viewing environment, the final film image as seen in a theatre, after all the processes following the present position within the film chain have be completed.

This is a Print LUT, or Grading LUT, and is used mainly within DI grading rooms where the underlying digital image parameters are themselves well understood and calibrated to a known datum, most probably based on the Kodak Cineon Digital Film File, as ratified by SMPTE as the dpx image format.

While there are variations to the specification, the norm is a 10-bit LOG RGB file format with a very specific digital to film relationship, which means everyone in the digital film chain knows exactly what the image 'should' look like when accurately film recorded to negative stock (OCN or internegative), printed, processed and projected.

There are obviously a whole range of potential failures with this process, not least within the chemical film processes involved, or with the accurate calibration of the digital viewing medium, be it monitor or projector. But experience and understanding tends to win through, and all involved in each step of the process know what is required and expected of them.

View LUTs, on the other hand, aim to deal with specific image parameters generated from a given source – most notably from a digital cinematography camera – and are designed to present the captured image in a way that closely approximates the desired final print image, but without the guarantees of a fully calibrated image format workflow, and usually on a less than calibrated on-set monitor.

What this means is that the colourimetry and contrast of any image being captured via any given digital camera will not necessarily conform to the expected Kodak Cineon/dpx specifications, and when combined with a less than ideally calibrated monitor, and less then ideal viewing conditions, means any LUT built to display a print approximation directly from the captured image data will be compromised when compared to a fully calibrated Print LUT, even if the LUT displayed image looks accurate.

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The reality, at least at present, is that no digital cinematography cameras adhere to, or closely match, the expected Kodak Cineon/dpx digital image characteristics, so any LUT used to present such an image as a final print image will be vastly different to a calibrated Print LUT used during final DI grading.

Note the profile of **FIG 2** (over page) View LUT working with a raw Viper Filmstream image, and compare that with the profile of the dpx Print LUT shown below **FIG 1**, while also noting the final LUT viewed images both look 'normalised'.

To aid the comparisons shown here it is assumed all images are being displayed on the same TV calibrated monitor at 65K colour temp, and at 20 nits brightness., thus taking the monitor out of the LUT calibration procedure.

The **FIG 3** (overpage) set of diagrams show the same Viper Filmstream image as seen through a fully calibrated dpx based Print LUT, not a View LUT calibrated for the specific image parameters of the Viper.

The resultant image is far from an ideal print image, and hopefully, the reasons for the differences are obvious, but probably warrant more explanation.

The Film Recording Process

Any digital film recorder is calibrated to expect a 10-bit LOG image with very specific image parameters as its input source.

This means the image data must conform to a known and expected set of parameters that define what each digital value represents within the final film image, with, for example, film black (D-Min) equalling a digital value of 95 counts within a 10-bit image; 2pc black being 180; (Digital) LAD grey being 445; 18pc grey being 470; 90pc white being 685, with a granularity of 0.002 density per LSB.

As an aside, all film recorders internally use this Cineon/dpx LOG based image format, and therefore will translate any alternative image format into this prior to film recording. It is therefore of some creative benefit to either work in this format throughout, or at least translate into it prior to finalising any 'film' project to ensure what you see during the creative DI process

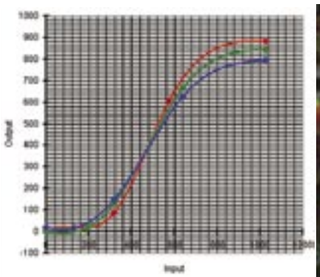

FIG 1:
Left: Calibrated dpx image
Graph: Print LUT
Right: Print Image via LUT

[1]www.digitalpraxis.net

FIG 2: Viper Image

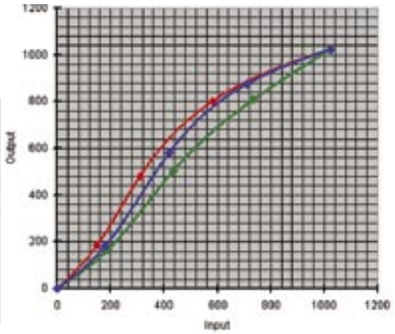

FIG 2: View LUT

FIG 2: 'Print' Image via View LUT

matches the final film print: if you rely on the film recorder to convert from, say TV gamma or linear colour space you can often be surprised by the final outcome.

So, when capturing with a digital cinematography camera that acquires a low contrast image that doesn't adhere to the Cineon/dpx image specifications, the LUT required for on-set viewing of the captured image in a near to final 'print' form will need to be substantially different to that for an image that meets the Cineon/dpx specification.

However, when grading an image for final film-out recording it MUST be graded through a fully calibrated Print LUT, so ensuring the final image is graded to match the necessary Cineon/dpx specifications required for the film recorder.

There are two ways to approach this...

The first is to run the non adherent image through a pre-grading conversion process to make it Cineon/dpx compliant. This requires an additional process prior to creative grading, which at best takes additional time, and at worse adds additional artefacts into the image as well as reducing image granularity, increasing noise.

The second more creative approach, which is also technically less likely to reduce image quality, is to simply grade the image through a fully calibrated Print LUT, forcing the image parameters to adhere to the Cineon/dpx specification when grading has been completed.

The issue with option two is that it takes more creative colourist work during the grading process, but with a better end result as the benefit.

What can be deduced from the above is that if a 'film-out' version is never going to be required, a 'Print LUT' is not necessary. However, at present any theatrical release will require a film version for distribution.

Viewing environment

The environment within which an image is viewed is also a critical component in the calibration process, and obviously there is a wide variation from a controlled DI grading room to the conditions found on-set or out on location.

Light spill, a brighter than ideal setting, off-axis viewing angles due to monitor crowding and unknown colour temperature light sources all combine to defeat even the best calibration.

Due to the rigours of life on-set/location the monitors used are also very unlikely to be Grade 1, presenting yet another variable the View LUTs need to overcome.

It's also fair to say the monitors used are unlikely to be as accurately calibrated as those used within a DI room.

Also, the monitor calibration used will impact the LUT needs as well. Should it be TV calibration or film?

All these issues impact on the requirements for LUTs used for on-set/location calibration as they will have to overcome the less than ideal viewing conditions, as well as compensating for the colourimetry of the image format being captured and display parameters of the monitor.

Fun and games all round!

On-set View LUT application

From the above it should now be obvious that the on-set requirements for a View LUT are somewhat different to the requirements for a Print LUT used within a fully calibrated DI grading environment using a Cineon/dpx based workflow for final film-out recording.

However, this is not to say an on-set View LUT is any less important, or less calibrated for viewing - the likely non-optimal viewing conditions aside – just that a LUT used on-set for digital cinematography capture is not viable as a final Print calibrated LUT.

FIG 3: Viper Image

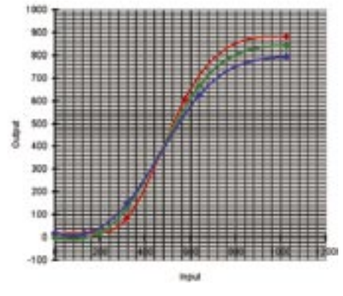

FIG 3: Print LUT

FIG 3: 'Print' Image via Print LUT

Using on-set values for DI grading

The outcome of this is that any colour decisions made on-set will not easily translate to the on-line DI environment with it's perfect viewing conditions, print calibration and Cineon/dpx image file expectations.

The best that can realistically be hoped is for is that on-set colour decisions can assist in the on-line colour grading, helping lock the look as quickly as possible. And the benefit this offers cannot be dismissed as the interaction of DoP and colourist is a key component of the workflow.

Technically, it is possible to use colour maths to subtract the on-set View LUT from the final Print LUT to generate a grading starting point – but the any good colourist is going to get there faster, and with higher quality due to the lack of additional processes undergone and the resulting decrease in image granularity.

But that is not to suggest on-set View LUTs can be rough and ready approximations.

The better the LUT the better the captured image.

But, on-set LUT systems are not exactly common place yet, with few monitoring systems allowing for user LUT application, and those that do being limited to 1D LUTs, which are less capable of full calibration than 3D LUTs.

As an example, Cine-Tal's monitor range are 3D LUT capable, while the more common Black Magic boxes used in conjunction with off-the-shelf TFT/LCD PC monitors are only 1D LUT capable.

An alternative is to use a separate external 3D Cube/LUT holder, such as Kodak's TCS box or Filmlight's Truelight system.

However, for less then blockbuster budgets the use of such expensive post-production systems is not a serious reality; unless you can call in a lot of favours and blag a system – but then you need a quality monitor to match, and a good viewing environment... I think there is a business opportunity here for a small, cheap on-set/location 3D LUT box with simple calibration control, aimed at the less than ideal monitors and viewing environment found on-set/location. Any takers?

1D vs. 3D LUTs

A small word or two is probably worth while on 1D vs. 3D LUTs.

1D LUTs effectively take input R, G and B values separately and generates from them new R, G and B values as simple input to output translations.

The LUT diagrams within this article are all 1D LUTs.

3D LUTs, or rather 3D Cubes, are much more complex, and without getting too scientific can control Hue, Saturation and Luminance output for any given R, G, B input. And it's the addition of saturation control that can be of some additional benefit over 1D LUTs.

But I have to confess at this point that for most digital cinematography I have been involved in a good 1D LUT has proved more than capable of meeting the needs of on-set/location image capture monitoring, due primarily to the limitations outlined above for the on-set/location viewing environment.

(All the LUTs used for this comparison were generated with the Digital Praxis ViewLUT Builder – see www.digitalpraxis.net for more information.)

Monitor & Viewing Environment Calibration

Before any calibration work can be undertaken the viewing environment and monitor needs to be set to known values. The viewing environment is almost definitely beyond immediate control – with needs of the set outweighing needs of monitoring – but, monitor set-up is often overlooked when it can be easily be controlled.

Having said that, as with most things to do with LUTs and calibration, there is two alternative approaches to monitor calibration.

The first is to set the monitor to its default set-up, be that TV video specifications (colour temperature, brightness and contrast), or PC settings, and then rely on the LUT to 'distort' the image being shown to meet the desired colour parameters, usually those of a film projection.

The second approach is to deliberately pre-set the monitor to 'film' colour specifications, relying on the LUT to manage image discrepancies only, not monitor colour temperature, brightness or contrast.

The main benefit of the second approach is that any secondary monitoring of the image after the LUT has been applied – for example via waveform or vectorscope – will be neutral with normal black and white levels. If the LUT is being used to calibrate the monitor too the image will appear distorted on a waveform/vectorscope, so making such devices effectively unusable.

But at the end of the day you simply have to make your choices, and then make the choice work – accepting all the limitations outlined above for on-set/location monitoring. HD