Colour Matching Technology

For BVM-L Master Monitors

SONY

www.sonybiz.net/monitors

Colour Matching Technology
BVM-L420/BVM-L230 LCD Master Monitors

LCD Displays have come a long way from when they were first introduced in the 1970s and today perform better than CRTs in many ways including resolution, convergence, geometry and stability. However, two characteristics of LCDs are yet to be resolved to the level provided by CRT. The first is the varying gamma characteristics of LCD monitors, which differ largely from CRTs. The other is the inconsistency of the semi-liquid LCD inaccuracies between LCD panels manufactured in the same production lot, which leads to colour matching inconsistencies. These two characteristics are attributable to the LCD's mechanism and have been difficult to counteract until now.

Sony's intelligent colour matching technology is a unique development that overcomes and eliminates these effects. It combines Sony's decades of expertise in professional video, master monitoring and signal processing to achieve the best performance when using LCD technology. This new matching technology is the key enabler in developing the series of true master monitors – the BVM-L Series.

This document explains how Sony's colour matching technology - developed exclusively for Sony's BVM-LCD master monitors - resolves such colour accuracy issues by focusing on two core factors:

1) Colour Management System

2) LCD Gamma Accuracy

The Colour Matching Technology

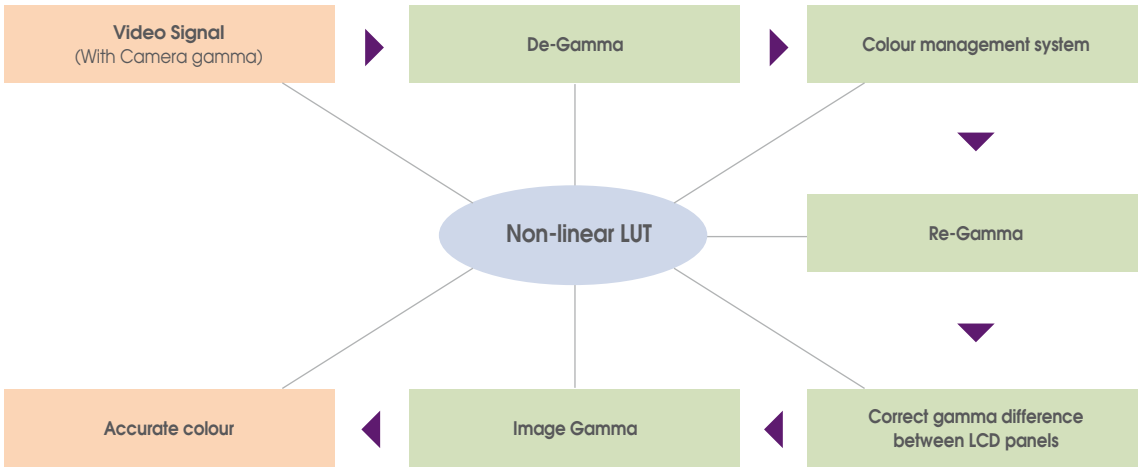
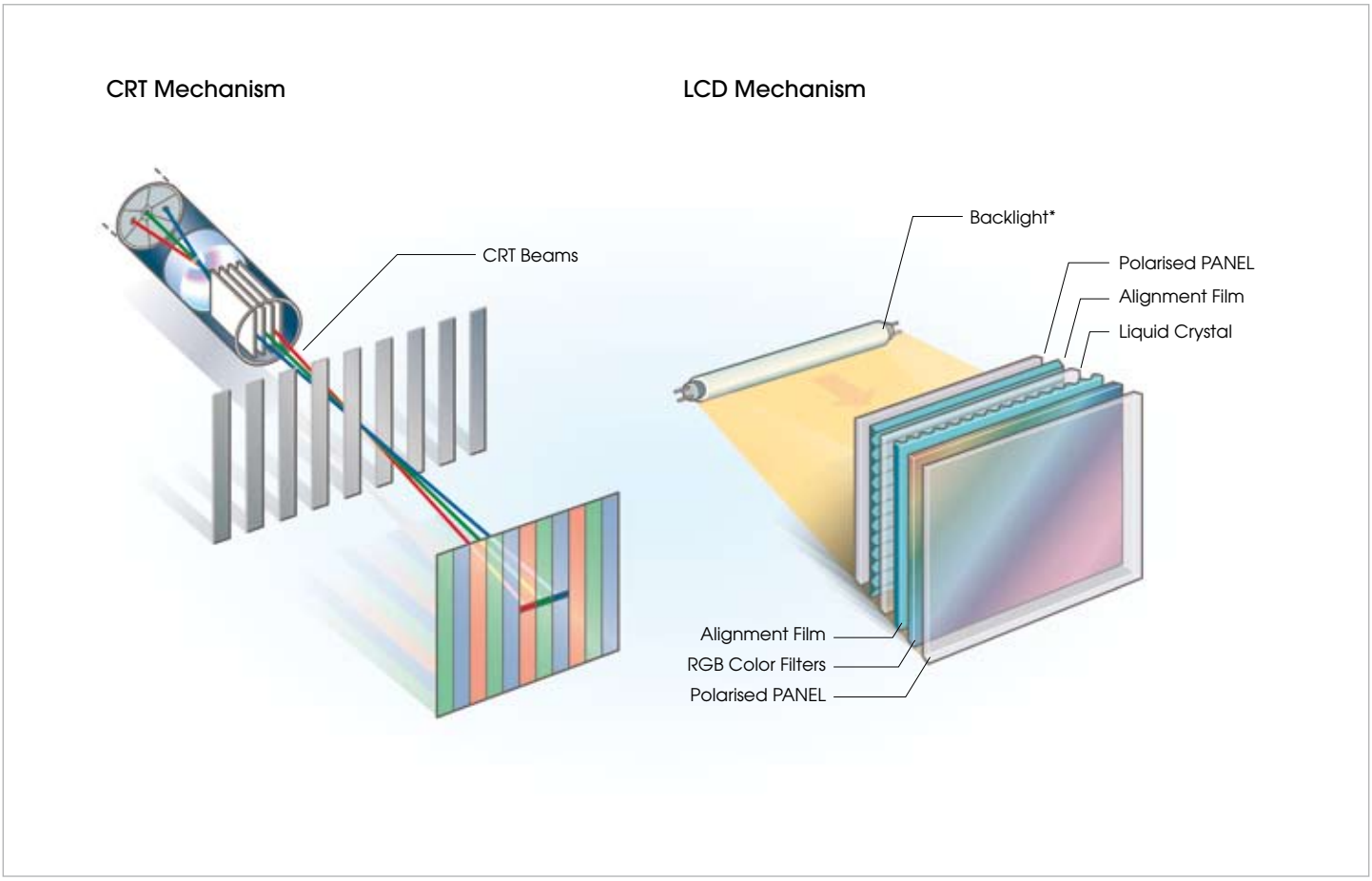


Table of contents

1. Colour Management System

1-1. Mechanism of the Display Device

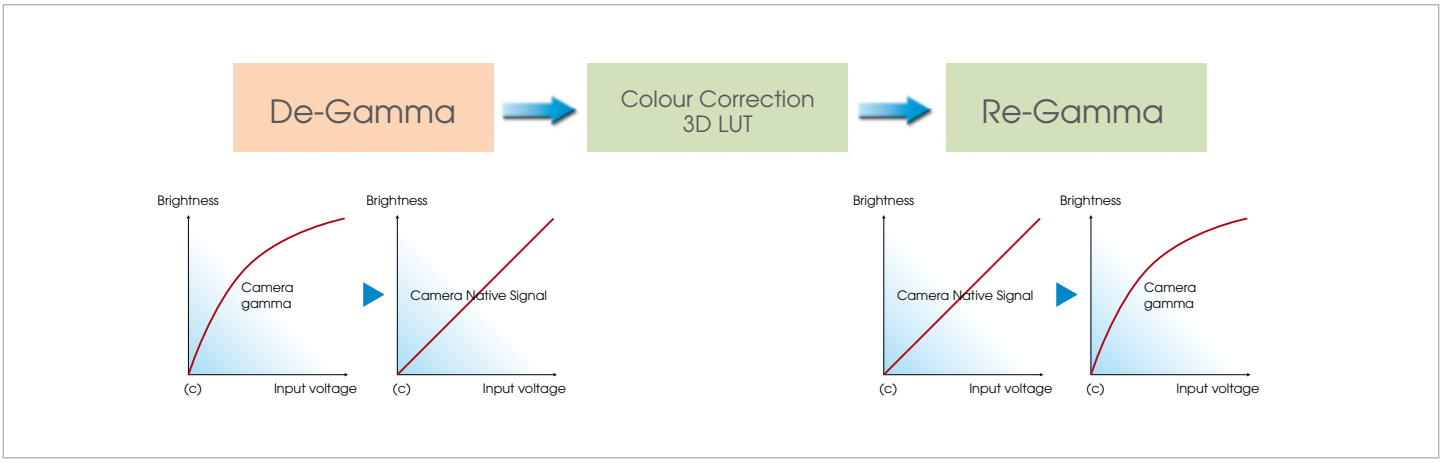
The colours reproduced from LCD panels are different from those reproduced on a CRT, even if the input source is the same video signal. This is due to the difference of their display mechanisms. A CRT emits light, using electronic beams, by stimulating red, green and blue phosphor materials. On the other hand, an LCD monitor controls the amount of light that passes through the LCD device and its translucent R/G/B colour filters.



Sony's colour management system is a unique technology that fills the gap between these different mechanisms. It enables the BVM-L420/L230 master monitors to reproduce equivalent colours to the BVM-CRT Series.
Let's take a step-by-step look at how this mechanism works.

1-2. De-Gamma

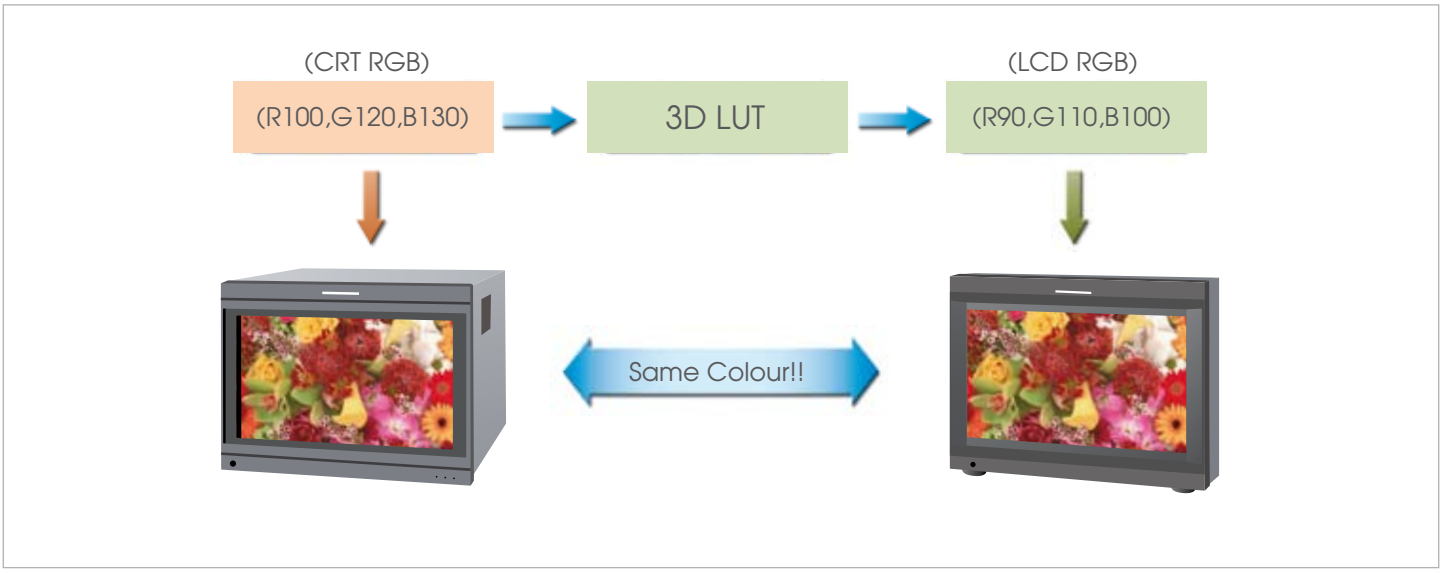
The video signal represents an exponential curve (γ=1/2.2) due to the gamma-correction applied in cameras. To achieve accurate colour management, the signal is handled in the linear domain.
The R, G and B video signals are first converted to proportional signals, respectively – by applying a reverse gamma to the exponential video signal. This process is called "de-gamma" in the colour management system. Note that the gamma is re-applied after the colour management process.



1-3. Colour Conversion

Now that the signal is ready for processing, Sony's colour management system converts the R, G and B colour data of the input signals into values that reproduce CRT equivalent colours on the LCD panel.

A 3D LUT is used to calculate the Red, Green and Blue colour data. The 3D LUT – or, in other words, the R/G/B Look-Up Table – is formed of numerical data representing the R/G/B signal levels.



1-4. Non-linear 3D LUT

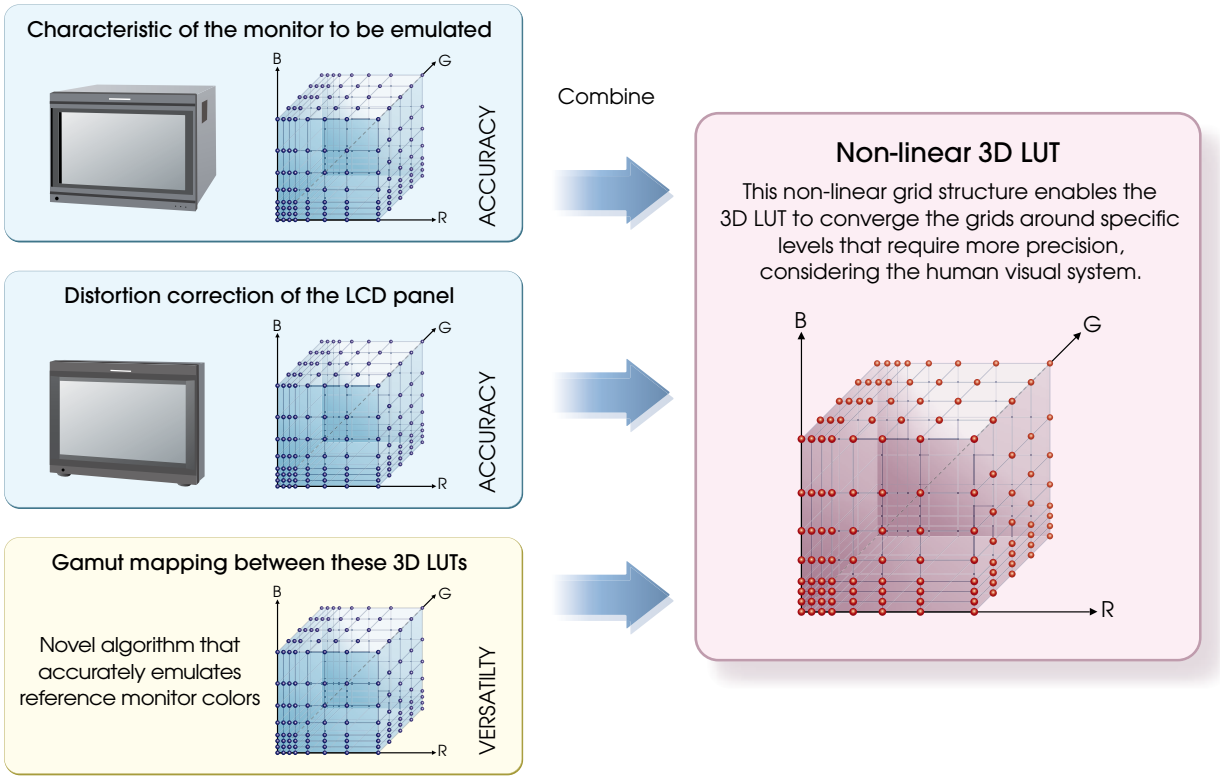
In this process, both the fundamental colour data representing the BVM-CRT image and BVM-LCD characteristic data are required to emulate BVM-CRT colours on the BVM LCD displays. The BVM-L420 and BVM-L230 store such data in the form of 3D LUTs.

CRT data 3D LUT

This 3D LUT holds the fundamental data of BVM-CRT colours. Sony has measured approximately 10,000 colours emitted by both the BVM-SMPTE phosphor and the BVM-EBU phosphor. The SMPTE phosphor colours are stored in the SMPTE-C LUT and the EBU phosphor colours are stored in the EBU-LUT.

BVM-LCD Panel Data 3D LUT

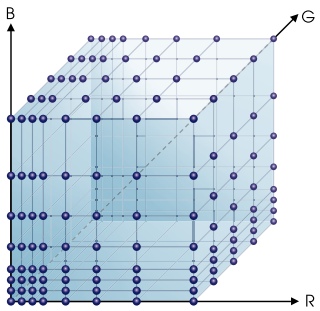
Clearly, the BVM-LCD characteristic data is required to control the LCD. This data is measured and stored in the 3D LUT and includes common characteristics taken from a wide sample of BVM-L230 panels. The equivalent amount of data is measured and stored in the BVM-L420 panel in another LUT.



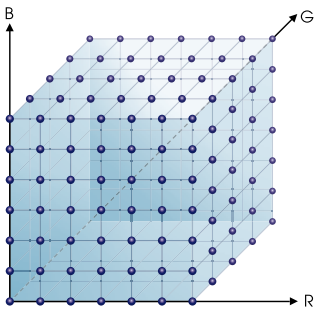
Using the data in these LUTs, Sony's colour management algorithm calculates the real-time input signal and then generates a third active LUT, in real time. The data in the real-time 3D LUT represents the conversion from CRT colour characteristics to LCD colour characteristics. In other words, this real-time 3D LUT works as a colour map that converts the input colour signal into the corresponding colour values on a sub-pixel basis. In this way, colours are reproduced on the BVM-LCD displays as they would be on a BVM-CRT monitor.

What makes Sony's 3D LUT algorithm so unique is that the values used for this conversion are spaced with irregular spacing, while conventional 3D LUTs are spaced equally.

These are called non-linear 3D LUTs. This spacing has been determined based on the human visual system. The human eye is sensitive to the grayscale in the black regions but insensitive in highlight areas. Therefore, this non-linear 3D LUT has more values allotted in the black regions with narrower spacing to achieve detailed grayscale compared to highlight areas. This algorithm allows the BVM-L420 and BVM-L230 to provide accurate reproduction in the black regions, which is equivalent to the BVM-CRT phosphor characteristics.



Sony non-linear 3D LUT



Conventional 3D LUT

1-5. Non-linear 3D Colour Conversion Main Feature

1. High accuracy of the BVM-CRT (both SMPTE-C and EBU) colour emulation over the entire grayscale.
2. High level of compatibility with the human visual system.
3. High level of accuracy in the conversion algorithm.
4. Very precise colour management scheme based on individual LCD panel measurement.

2. Gamma Accuracy

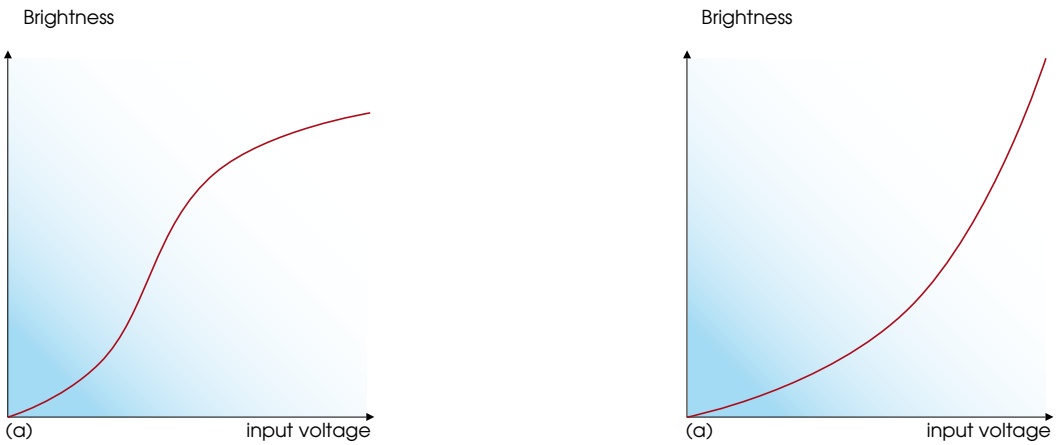
Once the appropriate colour data is processed through the colour management system, the video signal is restored to its original exponential gamma curve.

This is called "re-gamma". This re-gamma process must also include compensation of the LCD's gamma characteristics.

2-1. Re-Gamma

In general, LCD panels have a so-called "S-shaped" gamma characteristic, which is completely different than a gamma curve of a CRT. Due to this S-shaped curve of the LCD, the correct colours can not be reproduced even if the appropriate R/G/B colour data is output from the preceding colour management system.

Moreover, the S-shaped gamma characteristics are different between the red, green and blue channels. This mismatch also causes a disruption of the R/G/B white balance. Therefore, careful consideration must be given to this re-gamma correction.



LCD S-curve

CRT Gamma

The input voltage vs. light output characteristics

2-2. The Accuracy of Re-Gamma

Sony has taken a unique approach to achieve accurate re-gamma. As with the colour management system, the BVM-L420 and BVM-L230 incorporate a variety of gamma LUTs in order to calculate their panel gamma characteristics based on actual measurement data of their light outputs.

BVM-LCD gamma LUT

Sony measures every BVM-L420 and BVM-L230 monitor at the factory. The measured gamma data is stored in the respective BVM-L monitors in the form of a gamma LUT.

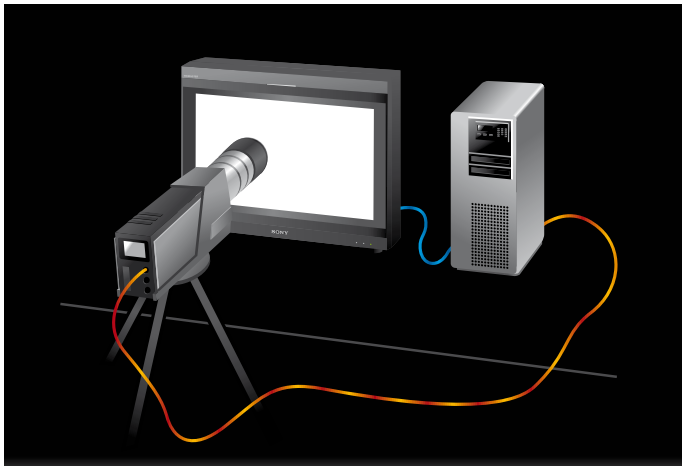
BVM-CRT gamma LUT

The fundamental gamma data of the BVM-CRT is also required for the BVM-L420 and BVM-L230 to emulate SMPTE-C and EBU colours. Sony measured a large number of individual gamma steps in the BVM-SMPTE and BVM-EBU phosphors to create respective "CRT gamma LUTs".

ITU-R BT.709 and D-Cine gamma LUTs

These are also fundamental gamma data to achieve accurate re-gamma processes. The 709 gamma LUT and D-Cine gamma LUT are stored in both the BVM-L420 and BVM-L230 and match the specifications given with each standard.

This gamma LUT data is used to correctly align R/G/B white balance over the entire grayscale range for each monitor. This process enables reproduction of an accurate white balance equivalent to that specificed for SMPTE-C and EBU phosphors as well as ITU-R BT.709 and D-Cine white point specifications. This is the biggest advantage of Sony's gamma adjustment.



2. Gamma Accuracy

2-3. Gamma Adjustment Main Feature

1. Accurate gamma adjustment using numbers of sampling data over the entire grayscale.
2. Gamma adjustment made at the factory per BVM-L monitor.
3. Precise adjustment according to each BVM-LCD monitor characteristic.
4. Gamma adjustment data is stored in respective BVM-L monitor as a gamma LUT.

2-4. More Accuracy

The light output level of an LCD panel varies depending on the display modes and/or frame rates. This situation causes inaccuracy of the gamma over the entire grayscale. Therefore, in addition to the gamma adjustment explained above, the BVM-L420 and BVM-L230 incorporate additional gamma LUTs for each display mode/ frame rate. The following gamma LUTs are examples that are used to calibrate the light output level:

- Progressive 50 Hz gamma LUT
- Progressive 60 Hz gamma LUT
- Interlace 50 Hz gamma LUT
- Interlace 60 Hz gamma LUT
- Black Insertion 50 Hz gamma LUT
- Black Insertion 60 Hz gamma LUT

This is another advantage of Sony's re-gamma process.

BVM-L230


SONY
SONY

3. Selectable Colour Space

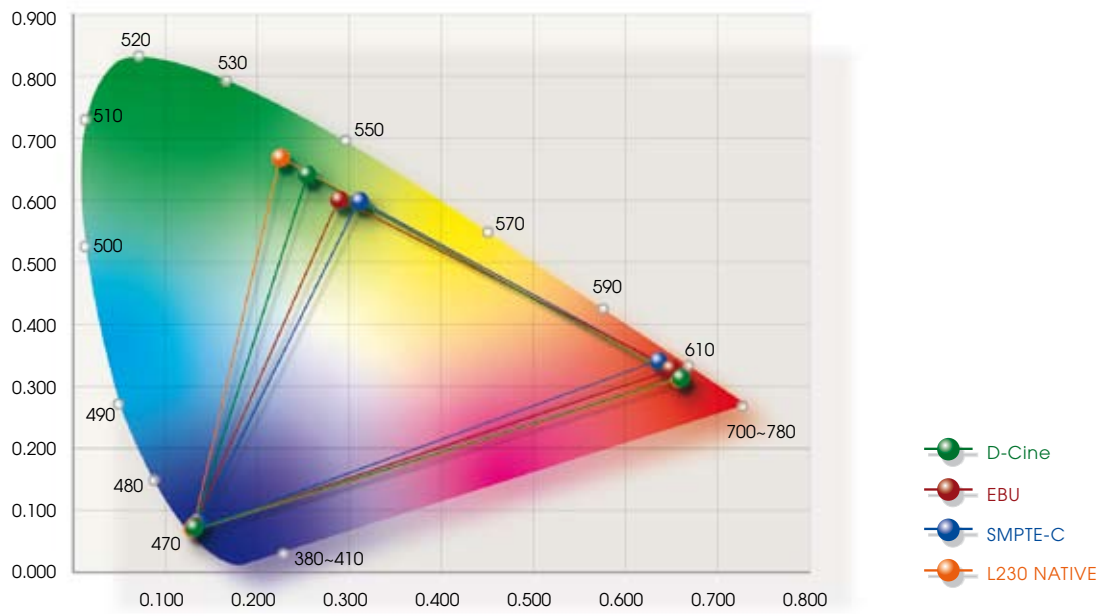
The BVM-L420/L230 LCD master monitors from Sony use an LED backlight system. The LED light source can, by nature, reproduce a wide colour space compared to BVM-CRT phosphors. This allows the BVM-L420 and BVM-L230 to reproduce colours not possible on a CRT.

In other words, while conventional CRT monitors support only one colour space, the BVM-L420/L230 can emulate multi-colour spaces. This is a revolutionary feature of the BVM-L Series LCD master monitors, achieved only through the use of Sony's colour management system.

3-1. Multi-colour Space Emulation

The BVM-L420 and BVM-L230 incorporate the following colour standards in the form of gamut 3D LUTs:

- SMPTE-C
- EBU
- ITU-R BT.709
- SMPTE RP 431-2-2007



3-2. D-Cine and SMPTE RP 431-2-2007

The D-Cine mode of the BVM-L420/L230 can emulate the colour gamut described in SMPTE RP 431-2-2007 (or DCI (P3)).
The colours of this SMPTE standard are not accurately reproduced on a CRT monitor. All colours across the entire grayscale are shifted and less saturated. This is because of the phosphor's RGB chromaticity limitation and absence of colour management.
Sony's colour management system supports the RGB chromaticity defined by the SMPTE RP 431-2-2007 and processes the colour conversion for all colour values based on the non-linear grids of the D-Cine 3D LUT. Therefore, the colours reproduced by the BVM-L420/L230 are identical* to this SMPTE RP 431-2-2007.
As explained earlier, Sony's colour management algorithm enables accurate reproduction of detailed contrast. Sony's colour management system can reproduce these SMPTE colours with accurate grayscale and no colour shift.

* The chromaticity of the green-red region is not covered in full, however, the colour shift is subtle in this region.

3-3. RGB Chromaticity

The BVM-L420/L230 allows users to select the RGB chromaticity 3D LUT data for the colour standards below:

LUT Types	Colorimetry
BVM SMPTE-C	R (0.630, 0.340) G (0.310, 0.595) B (0.155, 0.070) W (0.313, 0.329)
BVM EBU	R (0.640, 0.330) G (0.290, 0.600) B (0.150, 0.060) W (0.313, 0.329)
ITU-R BT.709	R (0.640, 0.330) G (0.300, 0.600) B (0.150, 0.060) W (0.313, 0.329)

LUT Types	Colorimetry
D-Cine	R (0.680, 0.320) G (0.265, 0.690) B (0.150, 0.060) W (0.314, 0.351)
L230 NATIVE	R (0.661, 0.313) G (0.233, 0.664) B (0.154, 0.064)

4. Supplement

4-1. Colour Space

The colour space of the monitor is determined by its phosphor or light source. For example, the SMPTE-C and EBU colour standard are determined based on the RGB chromaticity of the CRT phosphor materials. Such broadcast colour spaces are set by defining the three chromaticities of red, green and blue.

< Display Devices >

	LCD	OLED	PDP	BVM-CRT
Light Source	Backlight + Colour Filters	Emissive Layer (Organic LED)	Phosphor (xenon gas)	Phosphor (EBU/SMPTE-C) (Chemical Compounds)

The characteristics of the light emitted from a monitor owe to its display device, light source and colour filters.

4-2. White Balance

To achieve consistent colour reproduction on a monitor, the monitor must maintain the same colour temperature throughout the entire grayscale. In other words, the monitor must provide the same colour tone for all luminance levels of white – from black to gray to 100% white. This is called white balance.
Monitor white balance of Sony BVM-LCD master monitors is adjusted during production for typical colour temperatures and adjustment by the operator is usually not required. For example, if the operator selects D65 for the monitor's colour temperature, the monitor will maintain the same white balance – that is, the white balance that translates to a colour temperature of D65 – throughout the entire grayscale.
In the case of LCD monitors, white balance has tended to shift according to the signal luminance level, making colour matching a challenge. This issue has now been resolved using Sony's colour management system.

4-3. Gamma Characteristics of LCDs

From the advent of the first broadcast system, all video system components have been designed with consideration to the gamma characteristics of a CRT system. A well-known example is the video camera. Although the raw incoming light-to-video signal characteristics exhibit a linear relation, all video cameras process their signals using a 0.45 gamma. This gamma is required to compensate for the CRT's gamma, making the entire 'image capture to light display' a linear system.

Today's video systems continue to operate on this CRT gamma. This poses an issue for flat panel devices that exhibit different gamma characteristics. In the case of an LCD monitor, the raw 'input voltage versus light output' characteristics illustrate an 'S-shaped' curve. This is due to the different operating principles of an LCD. This 'S-shaped' curve also varies from LCD panel to panel and between R/G/B channels within a single LCD monitor.
The decision to use an LCD display in a professional

environment depends on how closely it can match the characteristics of a CRT - in both colour and gamma characteristics. The key to achieving a CRT-like gamma is how accurately this 'S-shaped' curve can be electrically compensated for to match a CRT gamma. While the amount of compensation is significant, the fact that compensation must be performed between the three non-linear R/G/B curves introduces extra complexity.

The BVM-L420/BVM-L230 gamma adjustment technology overcomes this challenge, bringing BVM-CRT colour reproduction, precise panel-to-panel and channel-to-channel gamma curve matching into professional LCD monitoring.

5. Conclusion

The BVM-L420 and BVM-L230 LCD master monitors from Sony are designed according to the guidelines of Sony's master monitor specification, which are based on the BVM-CRT master monitors. The colour matching technology described in this document is just one example of the many unique technologies incorporated in the BVM-LCD master monitors.
We hope you find this document an interesting and useful tool in your sales activities.

Services from Sony

Recognising that every company and every challenge is unique, we offer a complete and comprehensive range of services all the way through consulting, planning, financing, implementation, training, servicing, maintenance and support. Choose exactly what's right for you, when and where you need it.

Professional Services
Tailor-made design, installation and project management of audio-visual and IT (AV/IT) systems using skills developed over 25 years of systems integration.

Financial Services
Innovative and flexible finance solutions designed to meet budgetary and financial requirements and constraints, enabling businesses to always have the most current technology.

Training Services
A range of off-the-shelf or customised training services from basic operation through to high-level technical maintenance.

Support Services
Fully integrated and customised support for products and systems throughout their operational life, combining proactive and reactive technical services.

Not all services are available in all countries. If you'd like to find out more about what we do, who we do it for and how we do it, visit www.sonybiz.net or contact Sony's local office.

Distributed by

CA-Colour Matching Technology/GB- / /2008