SONY®

ChromaTRU™
Color Processing Technical Review

Sony Professional LCD Monitors

LUMA

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Introduction

During the past two decades, LCD devices have become an essential element in almost all electrical appliances – including handheld calculators, cellular phones, PDAs, video games and computer displays. While such applications have primarily used LCD technology for its portability and ease of handling, on-going research has now elevated LCD picture performance to a level approaching conventional CRTs.

The number of consumer LCD televisions seen on the market today and their continual picture enhancements are clear demonstrations of this progress.

Today's LCD display devices, used by many professional video equipment suppliers, have reached a level well suited for professional picture monitoring in both production and broadcast applications. While their brightness, contrast and viewing angle limitations were once a concern, these have now been brought to an acceptable level for most picture monitoring applications. However, one issue has yet to be resolved, an affect inherent in all LCD devices - lack of color matching between multiple monitors, and gamma curve discrepancies between CRTs – features that cannot be overlooked in high-end picture monitoring applications.

The Sony LUMA Professional LCD monitors* provide a revolutionary solution to these issues. Using innovative technology, they not only allow near perfect color matching between multiple LUMA monitors but also achieve white balance and gamma color characteristics comparable with a CRT display.

This manual introduces the innovative technology used to achieve these benefits, and includes a glossary on related terminology for a clear understanding. Reading through this manual will allow you to reinforce your demonstrations when you have a unit on hand, or allow you to logically explain how this mechanism works to lead your customers to a demo request.

We hope this document serves as an invaluable tool in your LUMA sales activities.

* Available on Separate-Type LUMA models.

Monitor image simulated

1 The reference for today's video systems – CRT color reproduction

From the advent of the first broadcast system, all video system components have been designed with consideration to the characteristics of a CRT system. This was the natural choice for many years given that CRT television was the only device for delivering video to household audiences.

A most well-known consideration is the 'reverse gamma' characteristics of a studio video camera. Although the raw light-to-signal characteristics exhibit a linear relation, all video cameras process their signals using a 0.45 gamma curve.

This gamma was required to compensate for the CRT's unique gamma curve of 2.2, making the entire 'image capture to light display' a linear system.

Today's technology offers a variety of display systems from LCD to plasma and EL displays – none of whose raw characteristics match the conventional CRT.

The issue of whether these technologies can be used in a professional environment is clear – how close can these match the characteristics of a CRT.

The LUMA Series ChromaTRU technology has finally given a solid answer.

2 The issues of using LCD technology in professional video systems

2-1 The limitations of LCDs today

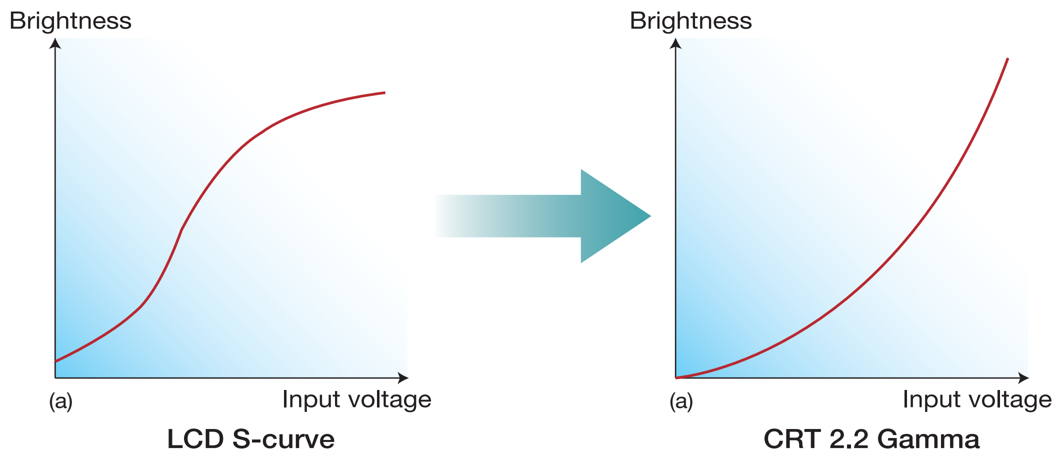
For many reasons, including its longevity, stability and high-paced improvements, LCD technology has become the choice for replacing the professional CRT by all prominent manufacturers. However, critical improvement issues still remain to make this transition. The following list shows these issues at a glance. These are attributable and common to the raw characteristics of all LCD devices.

1. **Inconsistent color temperature or color 'temperature shifts' throughout the grayscale, from black to white.**
2. **Inconsistent color reproduction from panel to panel even between same monitor models.**
3. **Gamma characteristics are compensated to try to match CRT but a CRT-like gamma is not achieved.**

2-2 The LCD characteristics that cause such problems

The raw 'input voltage versus light output' characteristics of an LCD monitor illustrates an alphabet 'S-shaped' curve, which is very different from a CRT's gamma. What adds more difficulty is that this 'S-shaped' curve varies on a panel-to-panel basis. The key to achieving a CRT-like gamma depends on how accurately this 'S-shaped' curve can be electrically compensated to match a 2.2 gamma. However, while the amount of compensation is significant, the fact that compensation must be achieved between two non-linear curves introduces extra difficulty.
A second issue is that CRTs use color phosphors and LCD's use color RGB filters to reproduce colors. Although highly pure RGB filters are used in professional LCD monitors, this different mechanism is another reason why the color of an LCD display does not perfectly match a CRT, either on a video monitor or on the CIE color map.

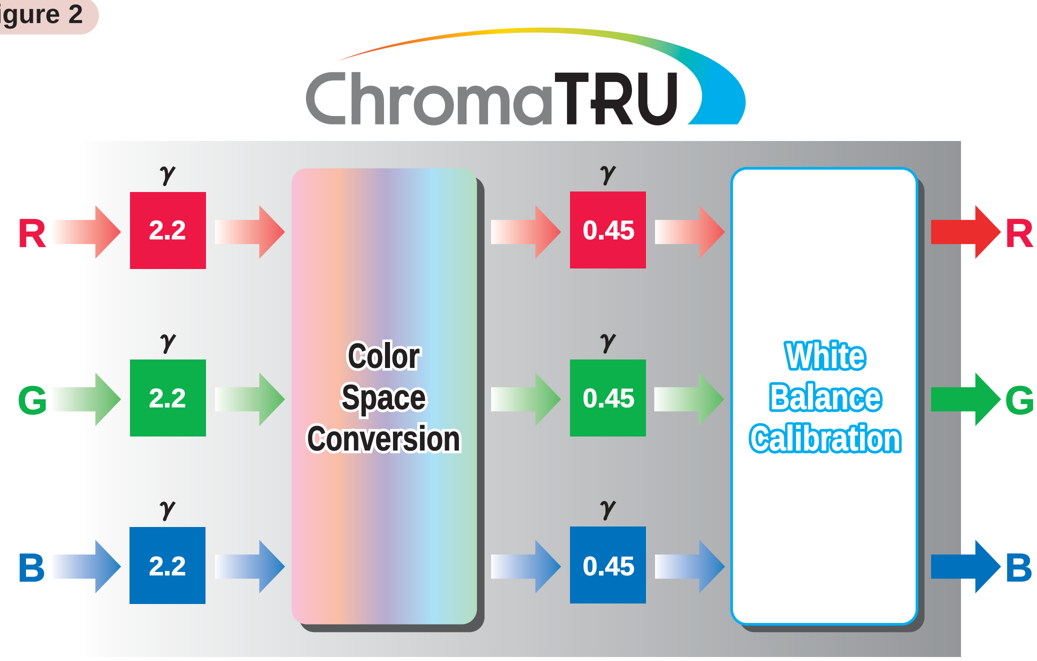
Figure 1



3 The Sony solution to these issues – ChromaTRU Color processing

Intensive research by Sony has led to the development of a method to overcome such problems – ChromaTRU processing – an innovative color calibration technology that eliminates these color discrepancies.
The diagram below shows a simplified flow of this ChromaTRU technology.

Figure 2



3-1 Color Space Conversion

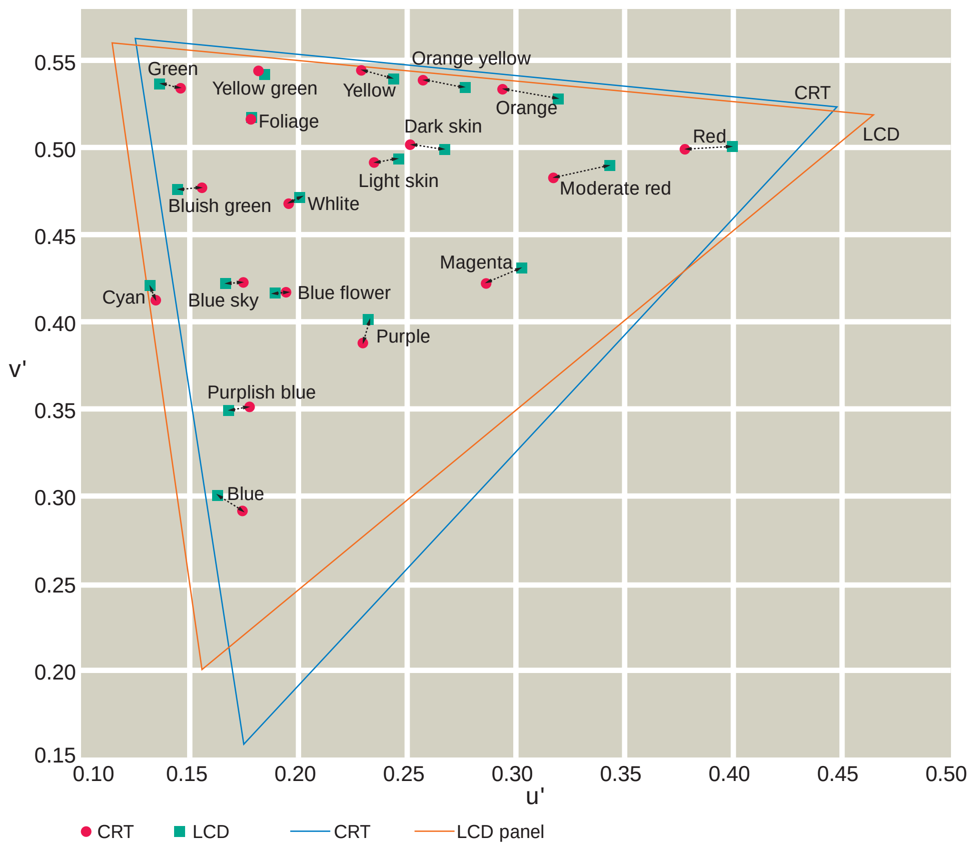
ChromaTRU technology comprises two main processes. The first process is called 'Color Space Conversion'.
The color coordinates of an LCD's RGB color filters and those of a CRT's RGB phosphors do not coincide on the CIE color map. This fact holds true for all LCD displays. As these 'RGB color primaries' are the basis of reproducing color in additive mixing, this means that the same color cannot be obtained from the two devices for the same RGB input signal (refer to Figure-3). This color discrepancy also varies from panel to panel since the color filters and backlight of each LCD panel present different characteristics even within the same series of models.

To compensate for this ‘color mismatch’ between LCD color filters and CRT phosphors, Color Space Conversion electrically creates new color primaries, from its native filter primaries, that emulate RGB phosphors. This is achieved by using a color conversion matrix that is customized for each LCD panel. Although the color space becomes slightly smaller than a CRT, these new primaries make the light emitted from the LCD panel the same as a CRT. RGB primaries are handled as linear signals, thus Color Space Conversion must also be performed in the linear domain. Since video signals are subject to a 0.45 gamma in the video camera, the RGB signals fed to Color Space Conversion must be reversed into their linear forms by applying a 1/0.45 gamma (≒ 2.2). In ChromaTRU processing, this conversion is processed with high precision to avoid any degradation. Once the Color Space Conversion matrix calculates the new color primaries, the RGB signals are converted back into their non-linear forms, again with high precision.

Figure 3 CIE Color Coordinates

The CIE u’v’ chart is used to evaluate the light output of display devices. In this diagram, the raw light output of an LCD is compared with that of a CRT. The triangular areas show their different color reproduction capabilities (Color Space).

The green and red dots indicate the color of light output from an LCD and that from a CRT for certain RGB input signals. Note that the same light color is not obtained for the same video input.



3 The Sony solution to these issues – ChromaTRU Color processing

3-2 White Balance Calibration

Following the Color Space Conversion, a second important process called 'White Balance Calibration' is applied. This process has two significant roles; it compensates for the gamma discrepancies between the LCD panel and standard CRTs, and further eliminates any white balance inaccuracies typically seen in LCD monitors.

With conventional LCD monitors, white balance adjustment has been a challenging task. This is because the native characteristics of an LCD, combined with its color filters, is such that color temperature slightly shifts depending on the input signal's luminance level – regardless of the monitor being set to a specific color temperature.

In general, adjusting white balance makes all other colors come into correct color balance. This means that the gamma curves of the RGB channels must be the same since a consistent ratio must be maintained between them.

In other words, the light output between the RGB LCD sub-pixels must have the same ratio for all different video levels.

In ChromaTRU White Balance Calibration, a significant 208 compensation points are measured and used, from black level to white, to clamp and maintain a consistent color temperature. At the same time, each RGB channel is precisely adjusted to follow an accurate 2.2 CRT-like gamma.

Combining this New White Balance Calibration function with the earlier mentioned Color Space Conversion allows color matching between multiple LCD monitors with gamma characteristics just like CRT's.

3-3 The actual results

The effect of ChromaTRU processing can be seen on the CIE u'v' chart.

With CSC*1 and WB*1 Calibration activated, LUMA Series LCD monitors*2 reproduce colors almost identical to CRTs. In the chart on the next page, most Red dots (CRT) and X's (CSC + WBC) are located in the same position, meaning the same light output is obtained for the same video input.

*1 Hereafter, Color Space Conversion and White Balance Calibration are abbreviated as CSC and WBC, respectively

*2 LUMA Series Separate-type monitors only

Figure 4 CIE Chart with color samples

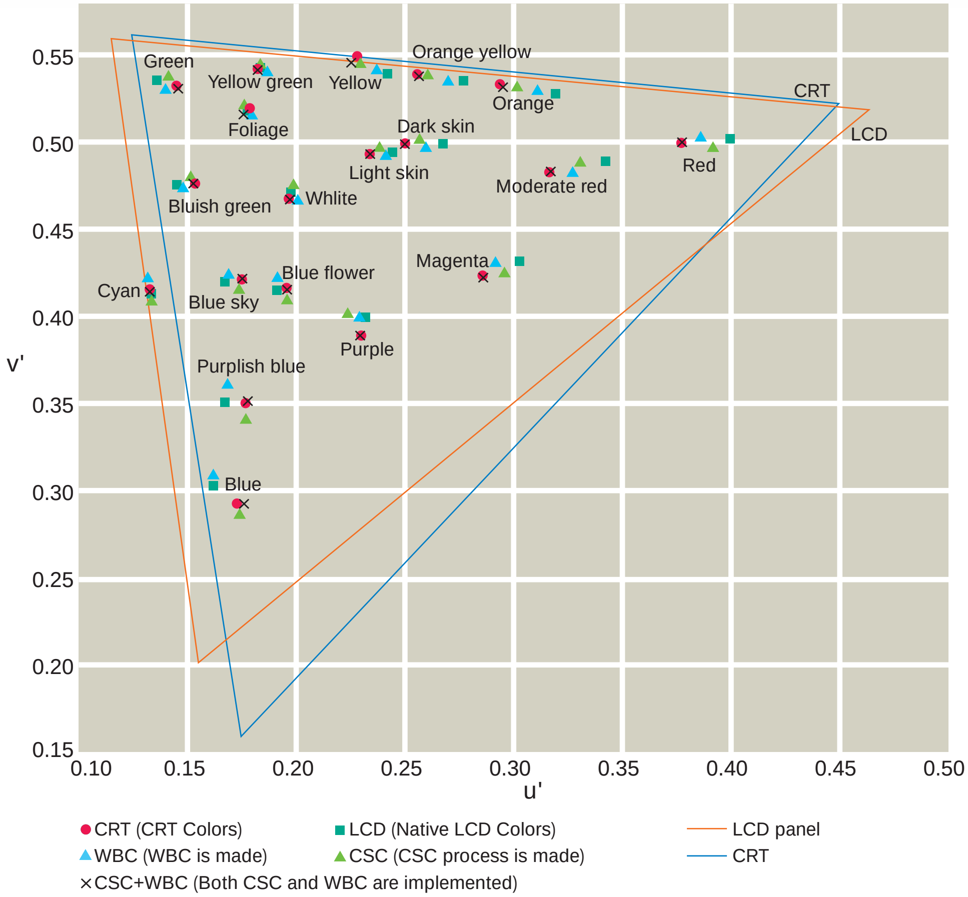
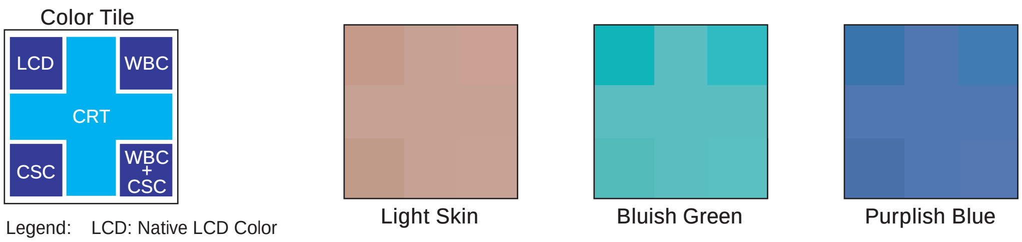


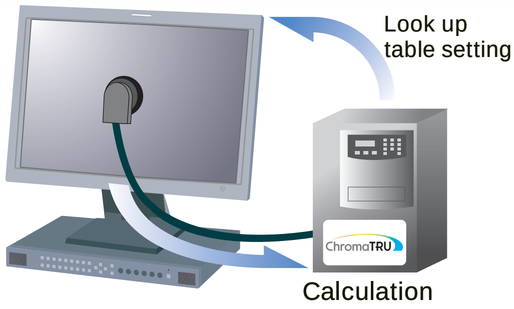
Figure 5

A color comparison between CRT and LCD, with different combinations of CSC and WBC applied. The color tiles indicate that the LCD colors obtained using WBC+CSC (right bottom corner) look almost identical to the colors reproduced from a 'CRT' (center tile).



Legend: LCD: Native LCD Color
CRT: CRT Color
WBC: White Balance Calibration applied
CSC: CSC process applied
WBC+CSC: CSC and WBC applied

3-4 The actual adjustment process



As has been discussed, the native color characteristics of an LCD panel are far different from a CRT.
They are also different from LCD to LCD. The goal with the ChromaTRU process (Color Space Conversion and White Balance Calibration) is to generate an LCD drive voltage that displays the input RGB signal as it would be seen on a CRT. In the below figure, this LCD drive voltage is indicated as R", G", B". The output of CSC is indicated as R', G', B'.
A key point to note is that CSC is a matrix process and the same conversion calculation is applied to all different levels of RGB input. In contrast, White Balance Calibration is a conversion process that differs for each RGB signal value and thus a lookup table (a numerical mapping table) is used. This table maps the color space corrected R'G'B' signal values to the White Balance corrected R"G"B" signal values – the signals that actually drive the LCD display. In actuality, the lookup table has as many as 208 variations of mapping.
As earlier mentioned, the matrix coefficients of CSC and lookup table values of White Balance Calibration are precisely calculated on an LCD panel basis at production. This calculation is done by measuring the raw light output of the LCD panel[*1] and comparing it with the output that would be obtained if the same RGB input was displayed on a CRT. A sophisticated analysis examines the results of this comparison[*2] and sets the correct matrix coefficients and lookup table values.
Once these are calculated, the data is registered to the LCD panel memory from the analyzing system so the Color Space Conversion matrix and White Balance lookup table are optimized for that panel.

*1 The light output without Color Space Conversion and White Balance Calibration.

*2 In actuality, the light output of each RGB channel is compared both in its CIE x/y-coordinates and CIE u'/v'-coordinates.

Figure 6

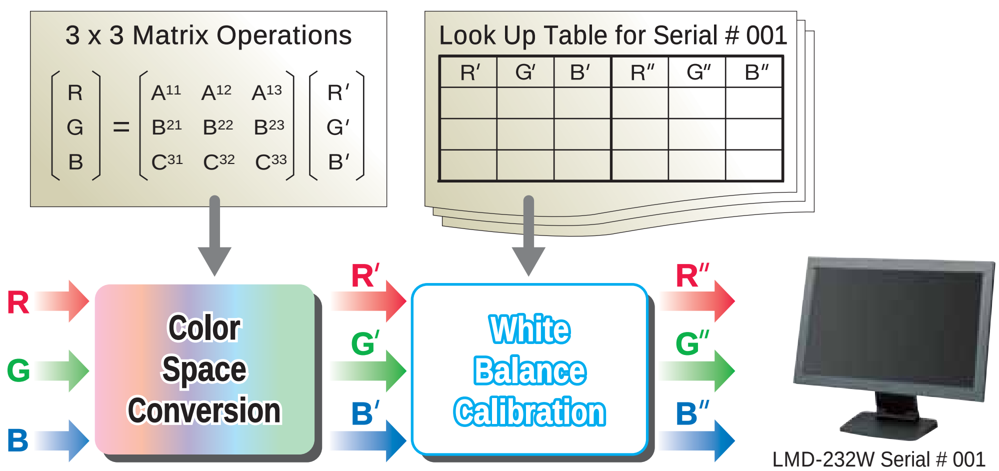
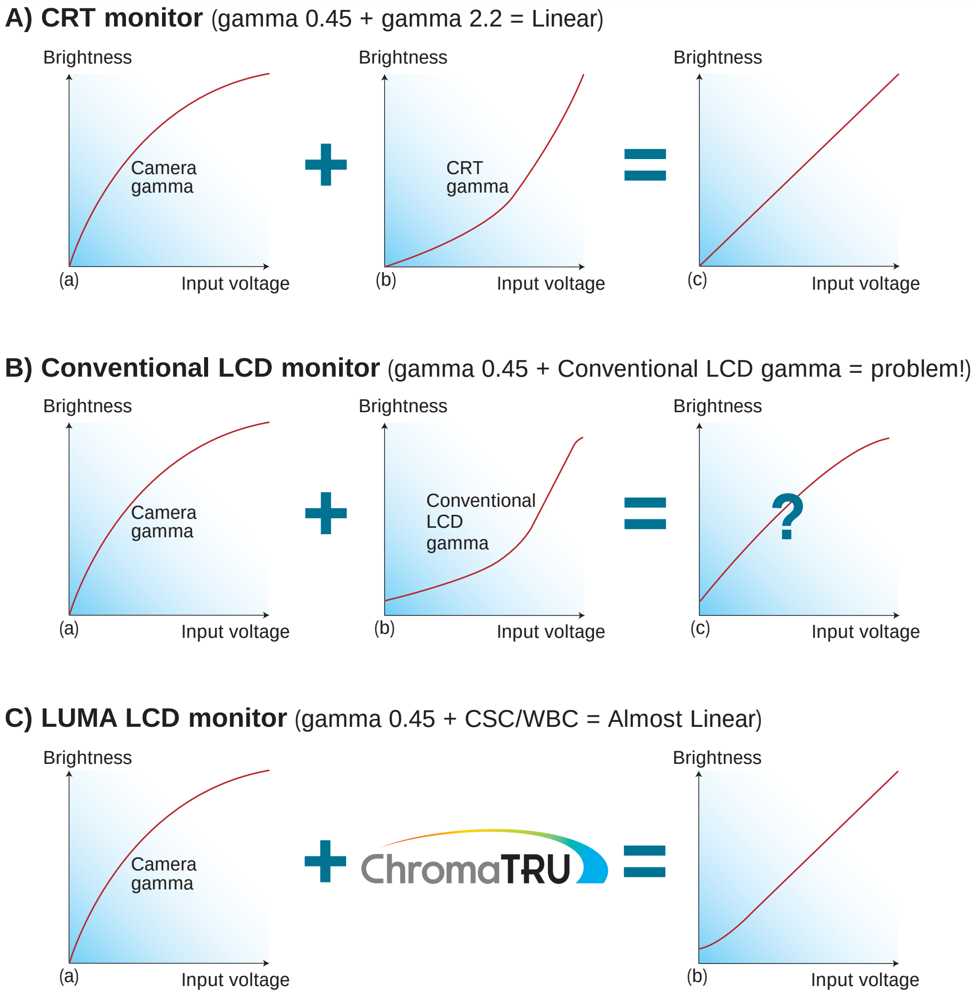


Figure 7



4 Conclusion

The different color characteristics of LCDs and their inconsistency from panel to panel had made it a challenge to position them as a replacement for CRTs.

Sony's ChromaTRU technology now helps overcome this challenge, bringing CRT color reproduction and precise panel-to-panel color matching into the world of professional LCD monitoring.

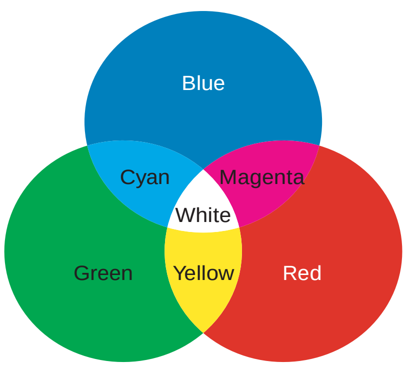
Glossary

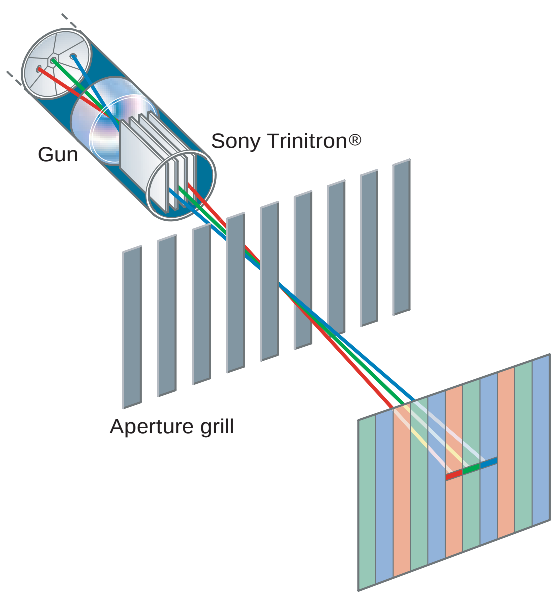
Additive Mixing

Prior to the development of the color video system, experiments in colorimetry proved that most colors visible to the human eye could be composed using the three primary colors, Red (R), Green (G), and Blue (B). This fact also holds true when separating a specific color – that is, any color can be separated into a combination/amount of these three primary color components. This principle is called Additive Mixing. The mechanism of reproducing color on a picture monitor is based on this principle, and is a good example for understanding how Additive Mixing works.

In a video monitor CRT tube, three R, G, and B guns each emit electrons (electron beams) corresponding to the amount of the R, G, and B components in the color to be reproduced. This results in the emission of Red, Green and Blue light from each of the R, G, and B phosphors, with their intensities proportional to their associated electron beams. To the human eye, these lights are perceived as one light beam, with the appropriate color reproduced when viewed from a certain distance.

The mechanism of a color video camera uses a reverse function of a picture monitor. The light that enters the camera's lens is first separated into the three primary colors, R, G, and B using a prism system. These color light components are converted into R, G and B signal voltages at their associated R, G, and B imager sensors (CCD or CMOS). The R, G, and B signals are then processed into the appropriate signal formats to construct the output video signal.





Gamma

Gamma (γ) is a numerical value that indicates the response characteristics between the brightness of a display device (CRT/Flat panel display) and its input voltage. CRT tubes, due to their beam mechanisms, exhibit a characteristic in which the brightness of the CRT and the input voltage retain an exponential relation, instead of a proportional one (Figure-8 (a)). The exponent index that describes this relation is the CRT's gamma, which is usually around 2.2. Mathematically, this gamma is expressed as in the equation:

$$L = V^{\gamma}$$

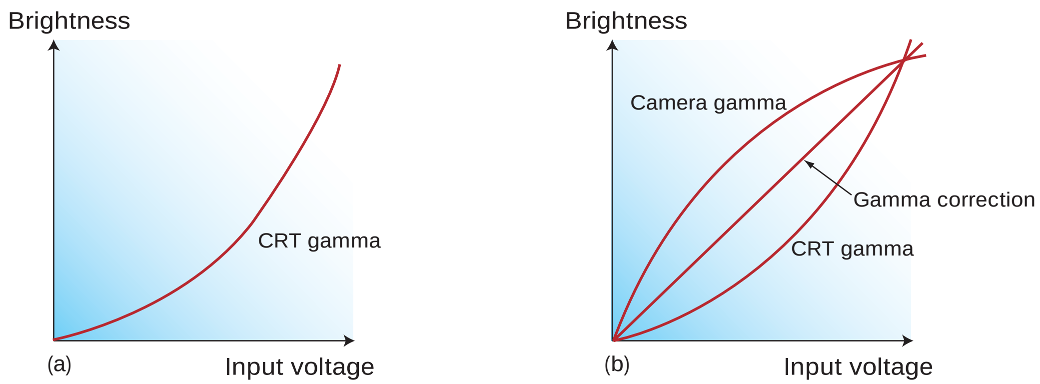
where L is the CRT brightness, and V is the input voltage.

On a CRT screen, this means that dark areas of a signal will look much darker than they actually are, and bright areas of the signal will look much brighter than they should be.

Needless to say, video systems must have a linear relation from the light-capturing device to the light-output device. Thus, the CRT's exponential characteristics must be compensated for somewhere in the system chain. This compensation is called gamma correction, and is performed within the image-capturing device – the video camera.

The goal in compensating for a CRT's gamma is to create a camera output signal that has a reverse relation to the CRT's gamma. In this way, the light that enters the camera will be in proportion to the brightness of the CRT picture tube. This means the camera should apply a gamma correction of about of 1/γ. The exponent γ '(1/γ) is what we call the camera's gamma, which is about 1/2.2 or 0.45.

Figure 8



Glossary

Color Temperature

Color temperature is a parameter used to describe the spectrum distribution of the light that an illuminant emits. For video or PC monitors, it is used to describe their base operating color, which is measured using the color white. Illuminants or monitors with low color temperatures tend to look reddish, while those with high color temperatures tend to look bluish.

In order to understand why we describe a monitor's color using 'temperature', a brief review of colorimetry is required.

Researchers in colorimetry discovered that the spectral distribution of light emitted from a piece of carbon (a black body that absorbs all radiation without transmission and reflection) is determined only by its temperature. When heated above a certain temperature, carbon will start glowing and emit a color spectrum particular to that temperature. This discovery led researchers to use the temperature of heated carbon as a reference to describe different spectrums of light. This is called color temperature.

Coming back to our subject, it might sound strange that a 'temperature' is used to describe a monitor's base operating color, white. However, as mentioned above, color temperature can describe the spectral distribution of different color tones using a single temperature number, also making it handy to describe the spectral distribution of a monitor's white color – the color that determines the monitor's overall picture color. For example, if a monitor is set up to display images with a reddish color tone, this adjustment can be precisely expressed using the monitor's color temperature.

Light Source	Color Temperature (approx.)
Skylight	12000 K - 18000 K
NoonSunlight	4900 K - 5800 K
Sunrise and Sunset	3000 K
12 V/100 W Halogen Lamp	3200 K
Candlelight	2900 K

White balance

To achieve consistent color reproduction on a monitor, the monitor must maintain the same color temperature throughout the entire gray scale. In other words, the monitor must provide the same color tone for all luminance levels of white – from black to gray, onto 100% white. This is called white balance.

Monitor white balance is adjusted during production for typical color temperatures, and adjustment by the operator is usually not required. For example, if the operator selects 6500K for the monitor's color temperature, the monitor will maintain the same white balance – that is, the white balance that translates into 6500K color temperature – throughout the entire gray scale.

Professional monitors do however, allow white balance and color temperature to be adjusted should the desired color temperature setting not be preset in the monitor.

In the case of LCD monitors, white balance tended to shift according to signal luminance level, making color matching between monitors a challenge.

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