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APPLICATION NOTE

Color Gamut Issues in Digital Systems

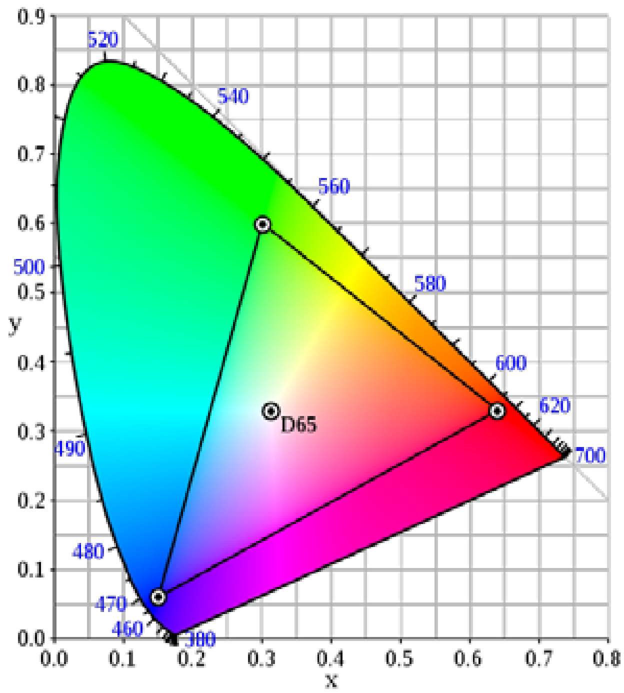
Color gamut is a key component of expressing how accurately devices and systems present images to the human color vision system. At one time, this was only relevant to the world of film and print, and later to designers of color television cameras and receivers.

Perhaps surprisingly, the more recent advent of digital video processing has highlighted the pertinence of color gamut to a wider technical audience. The multigeneration transparency of digital video has allowed endless editing and manipulation of video sequences for different purposes, but this creative bonus can bring about its own issues. Enter the multiformat world, where content may have been created or ingested in different formats. Signals originally created in one format need to be converted to others. This is not a technically difficult process, but is one that can cause "illegal" colors. If not identified and corrected at an early stage, problems can arise downstream, as described in this paper.

During the production process, there are particularly discerning viewers to consider — pity the poor post house whose agency client spots that their logo or product colors don't match the carefully crafted Pantone specifications! Early correction is the key to avoiding these kinds of issues. For this reason, content interchange between facilities increasingly includes compliance testing. In addition to subjective testing, these checks incorporate technical parameters including color gamut. If any of these parameters have not been compliance-checked, the material may be rejected and returned, involving time-consuming and expensive corrective work — which may not even be feasible when working within tight production deadlines.

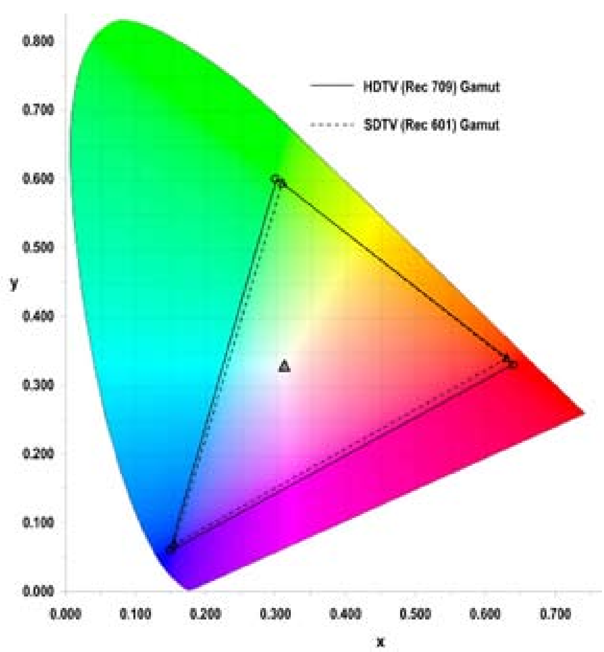
Equally important are the potential problems generated downstream if uncorrected signals are processed on the way to consumer delivery. Gamut transgressions are likely to cause picture breakup and glitches, which disturb the viewing experience.

In today's HD-dominated world, the number of format translation possibilities is further complicated by SD/HD up- and down-conversions that are dictated by content origination and platform delivery formats. With the increased picture quality and dimensions that HD provides, the viewers' (and clients') expectations and observations are heightened even further.



Shown at left is the CIE 1931 color space chromaticity diagram, created by the International Commission on Illumination (CIE) in 1931. The outer curved boundary represents all of the chromaticities visible to the average person, with wavelengths shown in nanometers; this region is called the gamut of human vision. No device yet designed has a gamut large enough to accurately present the entirety. In this example, the inner triangle is the gamut available to a particular display monitor. The corners of the triangle are the primary colors for this device.

This chart is the reference used for the colorimetry aspects of all television standards, which became defined as SMPTE standards, and ultimately, published as global, ITU (International Telecommunication Union) Broadcast Practices.

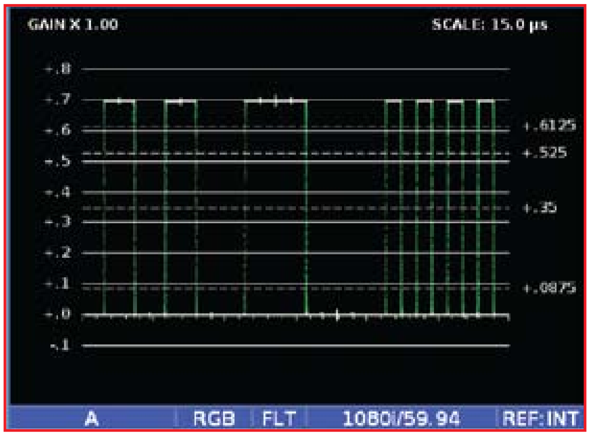


ITU-R BT.601 had long been the definitive document for digital television standards, including colorimetry aspects. With the advent of HD and new display technologies, ITU-R BT.709 was developed and has been widely accepted for display devices, TVs, computers and more. For illustration purposes, the diagram to the left shows this and the other most commonly used colorimetries. However, it is important to note that the differences are minimal. In practice, differences are subtle and usually undetectable.

What are Illegal Colors?

Gamut errors are produced when a video signal's luminance and chrominance components (now expressed as signal levels) combine to create a color that is not legal (i.e., not defined) for a display or transmission system.

When viewed on a waveform monitor, we know that signals have standardized legal limits. For RGB, these limits are 0–700 mV for each component. In the color difference domain, the Y' component is also 0–700 mV, while the P'b and P'r components are both ±350 mV. The waveform display of a traditional color bar test signal is shown below in both formats.



It is the RGB limits that are used to describe electronic color gamut, since these components are independent from each other. Remember that the color difference components (from which SDI video is produced) are the result of a matrixing operation on those reference R, G and B signals.

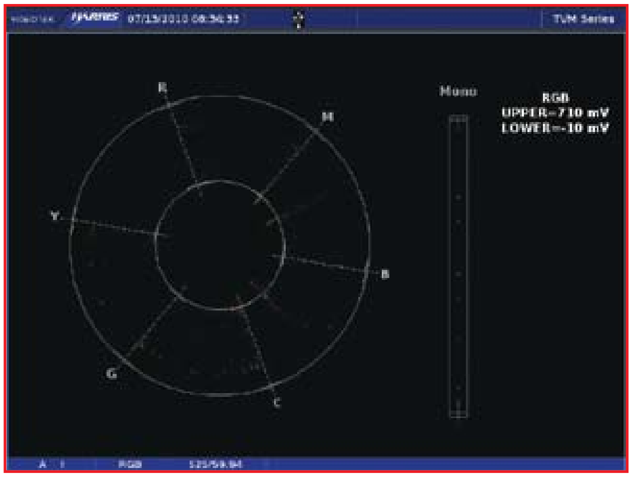
When signals are manipulated in color difference format, it is possible to produce illegal combinations that, when de-matrixed, would produce R, G or B components that are illegal (outside the legal 0 to 700 mV range).

Operational or creative adjustments in, for instance, a color correction or graphics suite, may produce acceptable viewing results on the monitors. However, if these have caused the signals' RGB limits to be exceeded and are therefore illegal, they will be clipped or compressed at later stages and may produce visibly detectable color errors.

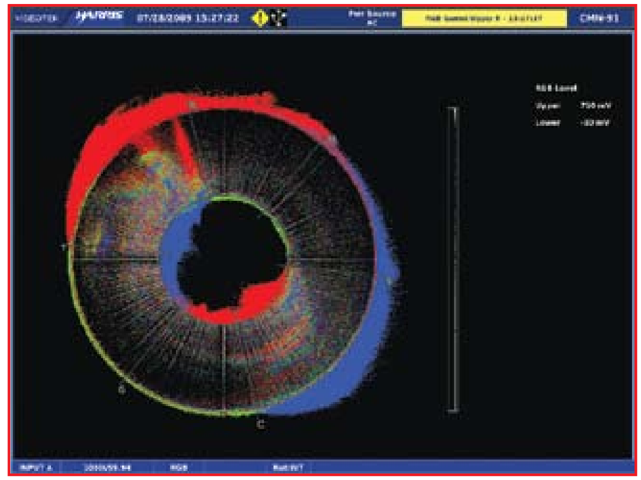
An example is shown in the second pair of waveforms below, where a color bar signal in color difference format has been increased in gain (amplitude). This may at first appear perfectly acceptable, but in fact, it produces an illegal RGB signal that, as described previously, will be distorted in subsequent downstream processing. In principle, there should be no illegal combinations in a video signal; however, experience has shown that small tolerances can be permitted, similar to those allowed for RGB signals.

Gamut Monitoring

Monitoring and adjustment of color gamut using conventional waveform monitors and vectorscopes are virtually impossible due to the composition of their displays. The vectorscope only displays a polar diagram of the phase and amplitude of the chrominance content of the video signal, while the waveform monitor shows only the amplitude of the video signal as a voltage per unit of time. Neither type of device was designed to monitor color gamut, and even the combined use of both displays does not add any value for this purpose. What is required is a display that has been specifically designed for for color gamut monitoring and adjustment.



Color Bar Signal



Live Video Signal

The patented Videotek® Digital Gamut Iris Display is extremely intuitive and designed specifically for this purpose. It can be used for signals of various component or even composite formats. Similar in appearance to the familiar vectorscope display, the Digital Gamut Iris Display maps color space information into a circular diagram using vector position coordinates. Since the Gamut Iris Display is produced digitally, the plot of the gamut information is extremely accurate and consistent. The color space indications are electronically generated traces placed into the polar display using their corresponding luminance and chrominance sample values.

The Digital Gamut Iris Display shows inner and outer boundary circles representing the minimum and maximum gamut excursions for the signal format under test.

Gamut displays illustrate which colors are causing illegal excursions and whether these are above or below the legal limits. The input signal is shown as an encoded display with gamut alarms when illegal elements are detected. The displays show RGB and composite video limits. Vector excursion marks are displayed in the gamut displays, and the excursion marks help to visualize the minimum/maximum value of a 100 percent color bar signal. The outer circle (the upper gamut alarm limit) represents the highest allowable amplitude in standard composite units (i.e., IRE for NTSC and mV for PAL). The inner circle (the lower gamut alarm limit) represents the lowest-allowable amplitude. The rings turn red when the alarm is enabled and the values exceed the threshold setting. For even more detailed inspection and adjustment, the gamut display can also be used in line-select mode.

Additionally, when "Gamut Highlighting" is selected in the "Picture Setup" menu, a grid pattern appears over the picture display highlighting gamut errors. This makes life much easier for less-technical operators.

Furthermore, the fact that the scales of the Digital Gamut Iris Display change color upon detection of color space violation opens up applications for new and non-technical users. As a go/no-go indication, most users can be trained in a matter of minutes to monitor color space gamut violations. And the experienced engineer will be pleased that determining gamut parameters is so simple. The display indicates the actual hue of the area violating the color space, so no guesswork is needed.

Automated Correction

Legalizers are used to correct any illegal digital values ahead of conversion to other formats and are routinely used as a final precaution before signal distribution. One area where we see gamut signals causing problems is transmission via MPEG encoders.

Consider these two examples:

- A local broadcast station had the following problem: whenever a certain promotional spot aired, the signal would break up. The signal was on a secondary channel, but the encoder overload would cause the multiplexer to hiccup, affecting all of the programs in the transport. It was not possible to get the spot re-cut. When a legalizer was placed ahead of the encoder and set to limit the equivalent peak-to-peak chroma amplitude, the breakup ceased.
- A national sports league takes in feeds from all of the stadiums on game day. They then create a highlight reel from each stadium that is sent to all of the other stadiums via a fiber optic network. The league was having problems with occasional signal breakup on the return feeds. However, when legalizers were added ahead of the encoders, the disruptions ceased.

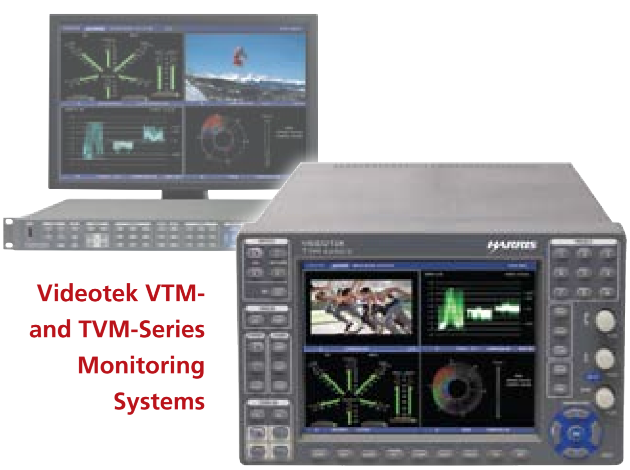
These examples illustrate that, however efficiently the QA processes of a production house are maintained using gamut monitoring, a legalizer downstream in the signal chain can be configured in “set and forget” operation to provide additional security. The legalizer can be an invaluable insurance device to prevent any illegal content escaping the facility and provide peace of mind.

How Our Products Help You

Monitoring

Videotek multiformat VTM-, TVM- and CMN-series products are the most advanced, versatile and intuitive HD/SD-SDI monitoring solutions available today. Incorporating 100 percent digital signal processing technology, they provide accurate, stable and user-customizable displays in quadrant or full-screen views. Signals may be examined in many ways depending on the parameters that need to be viewed, measured or adjusted. Gamut displays are available on all.

The new CMN Compact Monitor models (CMN-41 and CMN-91) are extremely lightweight and portable. Each provides a compact half-rack footprint of less than 7 inches depth, two HD/SD-SDI inputs with 3 Gb/s (1080p) capability, one AES input and metering for 16 channels of embedded audio. The short mounting depth of both CMN models integrates easily with today’s LCD monitors. And, with its portable case and battery mount options, the CMN-91 is perfectly suited for standalone field operation.



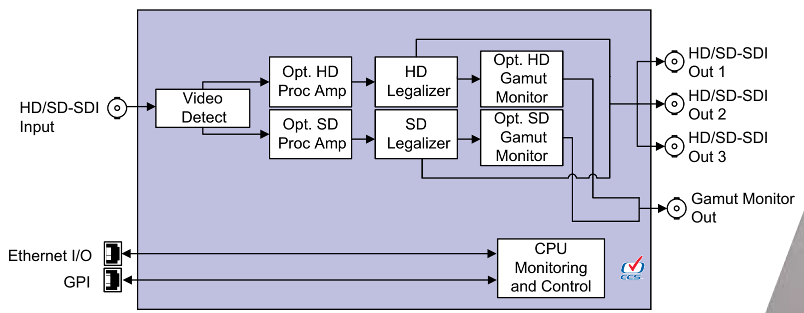
Videotek VTM- and TVM-Series Monitoring Systems

Videotek CMN Compact Monitoring Systems

Automated Legalizers

Harris manufactures a range of color correctors and legalizers, of which the Videotek DL-860 provides the most complete flexibility for legalization of HD-SDI or SD-SDI signals.

Optional HD-SDI/SD-SDI outputs are available on Videotek legalizer and monitoring products to provide picture monitor feeds with burned-in, on-screen gamut error indications. This is an extremely useful feature, both for less technical operators, as well as for trained engineering staff desiring more detailed analysis. It is also valuable as a training tool for illustrating gamut effects to new creative or engineering hires.



Conclusion

While digital video technology has enhanced creative possibilities beyond belief, it has also brought about issues that require technical competence to monitor and correct — as early in the production workflow as possible. As SD and HD content of multiple standards and formats is combined and manipulated in the production environment, it is essential to have access to quality assessment tools that have appropriate displays, depth of functionality and ease of use in order to produce fast, reliable results. The Videotek product range is continually being enhanced to deliver the latest in test and measurement technology to make life easier for technical and operational users alike.

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