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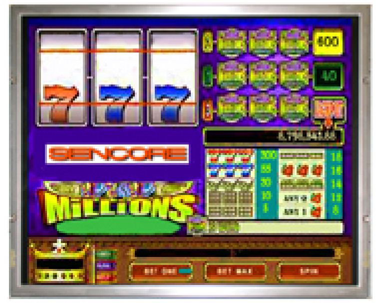
tech tips

Understanding Color Display Calibration

Understanding how we perceive color, and how electronics create color helps produce consistent displays.



All color video display devices share one critical calibration: color balance. This is true whether the device displays standard NTSC signals, standard computer-format signals, proprietary high resolution signals or HDTV signals. To display the most ac-curate colors, every video display's color balance must be adjusted to match the color balance of the signal source. This exact balance of red, green, and blue to make exactly the right color of white and neutral grays in the picture (often called White Balance) must be correct in both low brightness and high brightness parts of the picture. To understand how we see, specify and measure this color balance, let's review some basics of light and color.

Human Sight Characteristics

Light is electromagnetic energy within a narrow range of frequencies that are higher frequency than microwaves, but lower frequency than x-rays. If seen by itself, each different frequency, or wavelength, of light energy is perceived by the human eye/ brain as a different, fully saturated, color. In a certain respect, the eye/brain acts like a tuned, high frequency radio receiver. (see Figure 1).

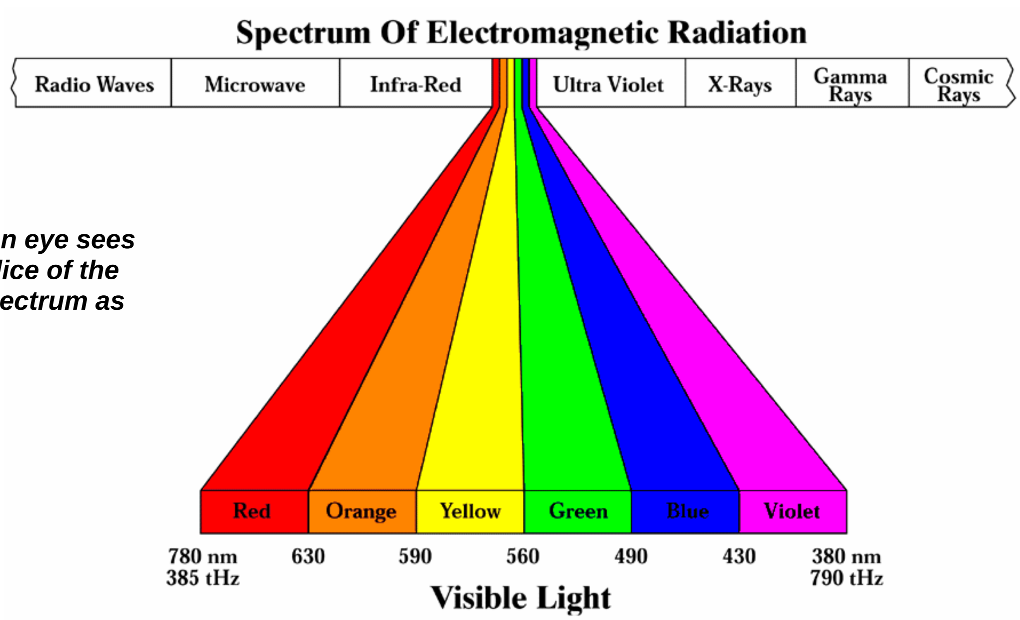


Figure 1. The human eye sees energy in a small slice of the electromagnetic spectrum as visible light.

Three characteristics define the way the human eye/brain sees light that is either radiated from or reflected off an object.

• **Brightness:** The eye sees the total amount of light energy radiated or reflected by an object, in comparison to other light sources or lighted objects in the field of view, as the brightness of the object.

• **Saturation:** A single frequency of light, at any energy level, is seen as a fully saturated, vivid color. The saturation of that color decreases as any other light frequency, or any combination of light frequencies, is added to the original light. If equal energy of all visible light frequencies is added together, the result is zero saturation, pure white light.

• **Hue:** For any combination of light energy other than pure white, the dominant perceived frequency of the combined light energy is known as the hue of the light.

Light Measurement

To specify different amounts and combinations of light energy, we would like to measure light in a way that corresponds closely to the way we see light. In the video display industry, two types of measurement units are used to measure light and relate it to the human sight characteristics. These two measurement units are luminance and chromaticity.

• **Luminance** is a type of light measurement closely related to the human sight characteristic of brightness. The U.S. measurement unit of luminance-foot-lambert-specifies the number of lumens of light energy emitted from each square foot of a light source, such as a video display, or reflected off a solid object. (Footcandles, on the other hand, are a measurement unit of illuminance, the light falling on an object.)

• **Chromaticity** is a type of light measurement related to the human sight characteristics of hue and saturation. This combined method of chromaticity measurement was developed by the C.I.E. (International Commission on Illumination) in 1931 and is used by the video industry for all display color measurements. The C.I.E. developed a chromaticity diagram which graphically depicts the relationship between the hue and saturation of light sources.

The C.I.E. Chromaticity Diagram (Figure 2) plots the pure spectral colors (hues) around the curved border (380-780 nm). The results of mixing any of

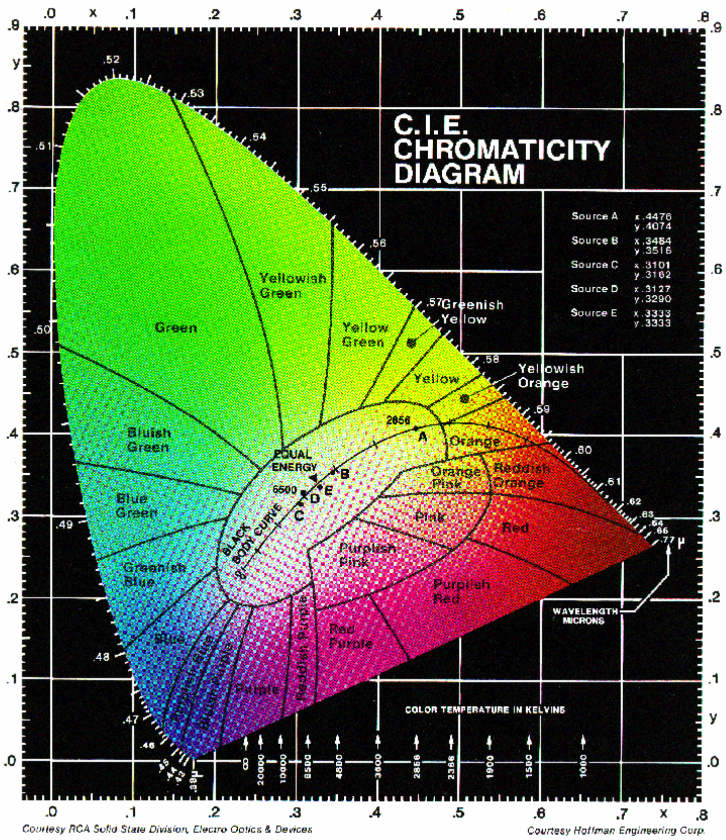


Figure 2. The 1931 C.I.E. Chromaticity Diagram provides a convenient tool for easily specifying the hue and saturation of any visible color.

these fully saturated spectral colors are shown at the base and interior of the diagram. Any visible color can be specified by the x coordinate and the y coordinate position of that color on the diagram.

White Reference

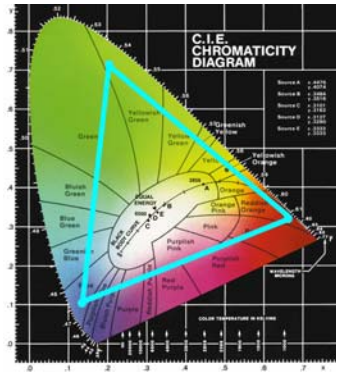
The C.I.E. coordinate pair of x = 0.333, y = 0.333 (E) specifies the white light produced by mixing equal light energy of all wavelengths (zero saturation). The color of any point immediately surrounding the equal energy white point would also appear white, if seen by itself with no other color reference.

It would seem logical that equal-energy white (E) would be used as the standard color of white for video display systems. However, since a more bluish white appears brighter, the C.I.E. coordinate pair of x = 0.313, y = 0.329 (C.I.E. standard illuminant D65) is the white "color" which was chosen as the standard white reference for all video and computer display systems. This allows displays to appear brighter without producing additional light energy output, yet doesn't shift the color of white enough to be detrimental to color accuracy.

White from Red, Green, Blue

On the C.I.E. chromaticity diagram, if any three color points are chosen, the area included by the connecting triangle represents the range of colors that are able to be produced by mixing the three chosen colors. The three points are known as the primary colors. The connecting triangle encloses the full range of colors (gamut) which is able to be produced by a display that produces mixtures of those colors of red, green, and blue light.

Figure 3. A triangle formed by any three colors encloses all the colors able to be formed by mixing the three colors.



The Eye: A Tristimulus Device

The human eye sees light through rod- and cone-type light receptors (Figure 4). Red, green and blue cone type receptors that give us color vision. The rod receptors give us black-and-white vision, especially in small detail and low light.

Each of the red, green, and blue cone receptors has a different response to different colors (frequencies) of light. The average response of the human eye receptors to light across the visible spectrum is shown by the Standard Observer Response graph, developed by the International Commission on Illumination (C.I.E.) (Figure 5).

We call this tristimulus vision because there are three types of receptors that individually send information to our brain and allow us to perceive different colors for the different mixtures of light energy within the visible spectrum.

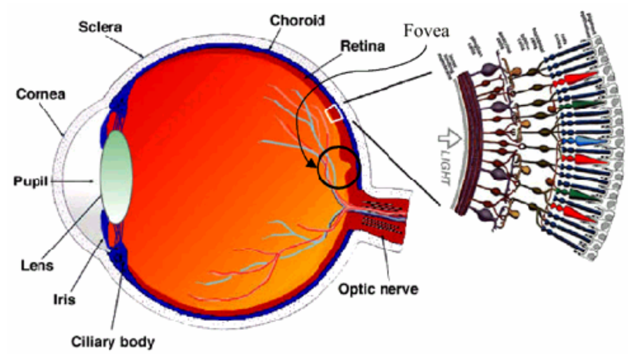


Figure 4. Three types of cone receptors in our eye provide response to light in the red, green and blue portions of the visible spectrum.

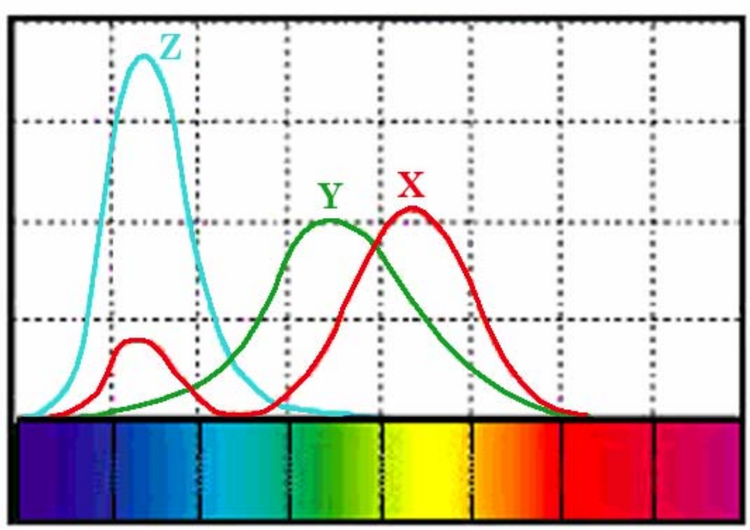


Figure 5. The C.I.E. Standard Observer Response graph shows the relative sensitivity of each type cone at different light frequencies.

Tristimulus Measuring Devices

Tristimulus color measurement devices are called colorimeters (Figure 6). This type of device works similar to the human eye. Three filtered light sensors receive light from the source to be measured. The filter for each light sensor allows only a certain amount of each color of light to reach the sensor. The response of each of the three filters is designed to mimic the response of one of the types of cones in the average human eye.

The measurement information from each of the three light sensors is the same as the information from each of the three types of cones in the eye, only in electronic-signal form. This information allows us to compute a different measurement result for the different mixtures of light energy within the visible spectrum, in a way that duplicates the response of the human eye/brain combination. To accurately predict the response of the human eye to a combination of light energy at different frequencies, a tristimulus color measurement device must "see" light exactly the same way the human eye sees light, as documented by the C.I.E. Standard Observer Response graph.

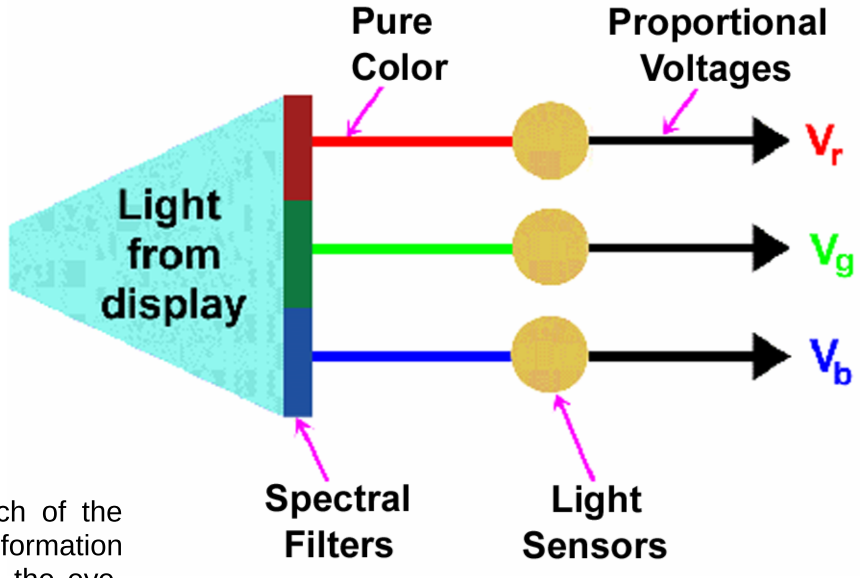


Figure 6. The three light sensors in a colorimeter receive filtered light with responses equal to that of the human eye.

Display Technology Challenges

Each of today's new display types - plasma, LCD, DLP, LCOS, D-ILA, etc. - produces light energy with a spectral power distribution (SPD) that is usually quite different from the average spectrum produced by CRTs. This is a change from working only with direct-view CRTs, because all CRT phosphor sets produced strong peaks of light and low levels of light at pretty much the same color frequencies. Some of the new display types produce strong peaks of light at color frequencies where CRTs produce very little light. Each of the new display types can still produce a standard color of white by adjusting the relative balance of colors in the red, green, and blue portions of the spectrum (Figure 7).

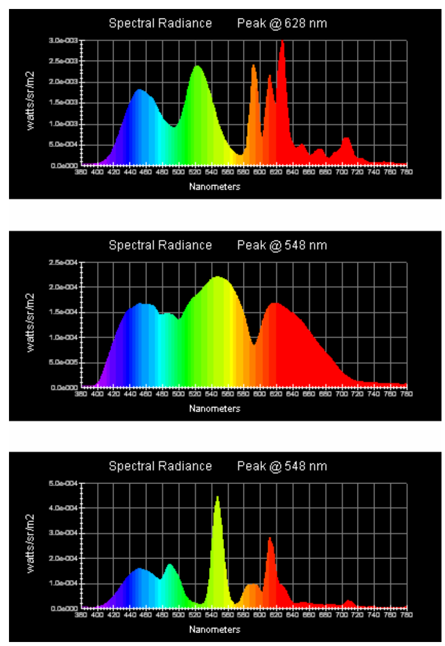


Figure 7. Different display technologies each have a unique spectral power distribution (SPD). (Courtesy Joe Kane Productions)

Because the new technology displays may produce strong peaks of light at just about any color frequency, it is now critical that a colorimeter's optical filters must accurately duplicate the CIE standard observer response at all color frequencies, not just at the particular frequencies at which direct-view CRTs produce high light output. Its three color sensors must see light over the entire visible spectrum with the identical amplitude response as the three color sensors of our eye (Figure 8).

If a colorimeter uses optical filters that are accurate to the human-eye response at all frequencies of light, not just high output CRT frequencies, the instrument will accurately measure all displays of the past, present, and future, no matter what their SPD.

Displays can be made to have accurate colors. Also, adjacent displays can be made to produce the same accurate colors, whether they are multiple projection displays in the same facility, or the individual cubes of a video wall. Accurately measuring and calibrating the color of each display is the key to producing beautiful end results.

All-Display Color Analyzer

The Sencore CP5000/CP5001 'ColorPro' uses optical filters which are accurate to the C.I.E. standard observer response at all frequencies of light. This economical measurement system allows you to measure and calibrate any video display (LCD, DLP, Plasma, CRT, and any future technology). The 'ColorPro' gives you confidence that you've accurately aligned the video display to industry standards and made the display deliver its peak performance.

The continuously-updated 'ColorPro' readings provide display alignment capabilities not available with the single-shot readings provided by more expensive spectroradiometers (which are also very accurate). A user-friendly graphical interface speeds display calibration time with simple, easy to follow measurement screens that show you exactly what to adjust to obtain a perfect match to the industry standard white reference. Integrated software lets you store a display's calibration data and print a customized, easily understood calibration report.

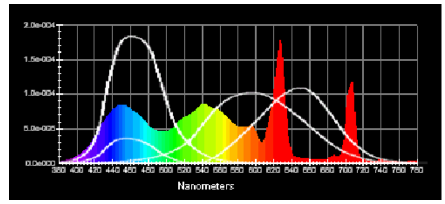


Figure 8. The response of a colorimeter's optical filters (white) needs to be accurate at all color frequencies to accurately measure light from any type of display.

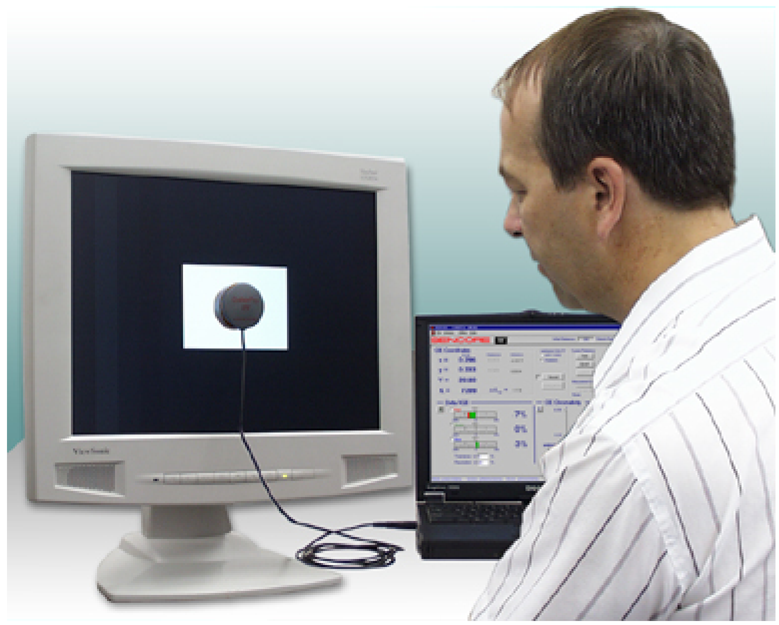


Figure 9. The CP5000 is a PC based All Display Color Analyzer. If you would like more information about the CP5000 'ColorPro', click on this link: http://www.sencore.com/products/cp5000.htm

Figure 10. The CP5001 is an All Display "Pocket PC" 'ColorPro' Color Analyzer. If you would like more information about the CP5001, click on this link: http://www.sencore.com/colorpro/index.htm

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