USING PROFESSIONAL PLASMA DISPLAYS AS EVALUATION-GRADE VIDEO MONITORS

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Nearly a decade into the 21st century, we're seeing a paradigm shift in electronic imaging. The cathode ray-tube (CRT), for many decades the only choice for viewing video content, is on the endangered list. And there are several display technologies jockeying to replace it in the professional arena, but it's not yet clear which has the upper hand.

The CRT, which was developed in the early part of the 20th century, evolved over time into a bedrock imaging technology for broadcasters, film studios and production companies, and even computer graphic artists. CRTs, which are emissive devices, offered several advantages – excellent dynamic range, high linearity, rich, saturated colors, and high resolution.

Unfortunately, CRT monitors also brought along mass and weight issues, plus a permanent link between resolution and brightness. For viewing of fine image detail, small electron beam spot sizes were required and these resulted in dimmer pictures after calibration.

Still, the professional CRT became entrenched in color correction suites, film transfer houses, mobile production vans, and animation houses. The standardization of monitor color gamuts in the 1980s for NTSC and PAL video production ensured a greater degree of consistency from the production company to the viewer. Improvements in CRT design resulted in even finer pixel pitches, opening the doors to higher resolution.

A SEA CHANGE

But things were changing in the world of electronic imaging. During the 1990s, manufacturers began moving away from small assembly-line models to large-scale semiconductor "fabbing" of new display technologies, including plasma display panels and liquid-crystal displays. Both these and other nascent fixed-pixel imaging technologies finally severed the troublesome link between resolution and brightness.

Now, it was possible to have extremely bright displays and high resolution at the same time. Mass fabrication and the increased importance of the consumer TV marketplace led to dramatic drops in retail prices during the first five years of this century as flat-panel TV screens grew even larger.

Today, it is possible to buy a 50-inch consumer HDTV using plasma or LCD technology for well under $2,000. The manufacturing of professional CRTs has effectively ended, as those companies have shifted resources into flat panel displays, and continue to chase after the consumer HDTV business.

While this is good news for the home viewer, it's problematic for the video and film professional that is faced with the prospect of junking older professional CRT monitors and replacing them with something new – but what? Plasma monitors? LCD monitors? Or one of the new, emerging display technologies, like Field Emission Devices (FEDs) and Organic Light-Emitting Diodes (OLEDs)?

THE BASICS

What exactly is an evaluation monitor? In the simplest terms, an evaluation monitor is one that stays within close tolerances for performance, can be calibrated to specific brightness levels and color temperatures, has a color gamut equal to 100% of the largest standard video color spaces (NTSC for analog video, and ITU BT.709 for digital video), and exhibits consistent gamma performance while tracking input voltages from black (0 or 7.5 IRE) to white (100 IRE).[1]

[1] The Society of Motion Picture and Television Engineers (SMPTE) is currently developing new standards for fixed-pixel display technologies to be used as evaluation monitors.

Let's now examine each of the critical imaging parameters in more detail, and how they apply to an evaluation-grade monitor.

Grayscale and dynamic range: The CRT was the standard for years because it behaved just as a well-designed tube amplifier ought to. Small changes in input voltages resulted in corresponding steps in luminance values, a linear response that correlated to the signals being captured by tube video cameras, and later, solid-state cameras using charge-coupled devices (CCDs).

The range from video "black" to full white on CRT monitors (i.e. dynamic range) was not extreme, but wide enough to evaluate electronic images for broadcast and transfer to recorded media. A well-designed monitor with black levels measuring .2 nits (.06 foot-Lamberts) and peak whites at 100 nits (29 ft-L) exhibited a contrast ratio of 500:1, more than adequate for everyday work.

A calibrated CRT monitor could also reproduce a specific gamma curve accurately, to match standard gammas used with live video content and filmed content transferred to video. This monitor might not be blazingly bright, but its light output was sufficient to be viewed under controlled ambient lighting.

Equally important, a professional CRT monitor would be expected to track a specific color temperature value from black to white and all steps in between. This track could vary only by a small amount – say, 250 Kelvin – to be considered for critical color and exposure correction, where larger changes in white point values create noticeable color shifts in subtle, pastel color shades and flesh tones. (Figure 1)

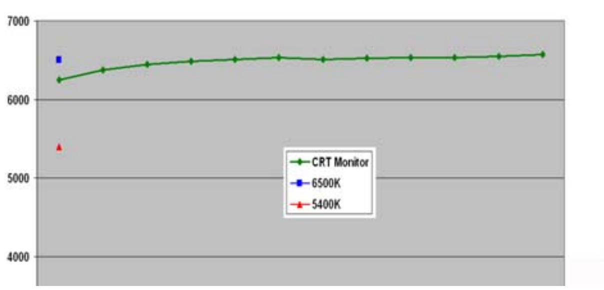

Figure 1. Typical grayscale track for evaluation CRT monitor.

Support for standard color spaces: Professional CRTs were manufactured to the SMPTE-C standard gamut, which closely matches the NTSC standard and slightly exceeds the EBU (PAL/SECAM) standard. Any limitations on the reproduction of certain color shades were due to the maximum saturated levels of red, green, and blue phosphor compounds used in these monitors.

While coverage of SMPTE-C and BT.709 color spaces isn't difficult to accomplish with a CRT, coverage of new, extended color gamuts such as *xv*YCC and the digital cinema P3 minimum standard gamut is problematic for CRT phosphor imaging. At best, a well-designed CRT monitor could expect to cover about 60% - 70% of these wider spaces, which typically push deeper into the green section of the 1931 CIE "tongue" color diagram. (Figure 2)

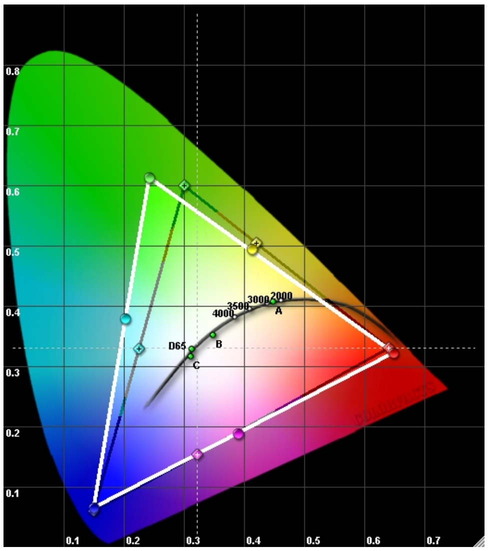

Figure 2. A typical color gamut for an evaluation-grade CRT monitor, referenced to BT.709 coordinates.

Picture Resolution: At the heyday of CRT monitors, high definition video was in its infancy, and most video production was done at standard definition resolutions like 720x480 (NTSC) and 720x576 (PAL). Because of the link between spot size and resolution, the highest resolution achieved by the best CRT monitors capped out at 1100 lines – about half of what was needed to show 1920x1080 HD content.

Frame Rate Support: CRTs are raster-scanning displays, and have an easy time showing both interlaced and progressive-scan video content. Support for standard rates included 29.97 Hz (30 frame video), 50 Hz, and 59.94 Hz (60 frame video). Professional monitors added support for 24-frame and 25-frame playback when viewing content shot film-style, or transferred from film to video for editing and image manipulation. Some CRTs could scan at even faster rates to support playback from workstations at 70 and 72 Hz.

THE CANDIDATES

As mentioned earlier, there are several candidates to replace CRT technology for evaluation-grade monitors. They fall into one of three categories – transmissive (light shuttering), emissive (burst), and reflective.

Transmissive imaging: The leading contender here is the liquid-crystal display, or LCD. LCDs use liquid-crystal compounds that align with changes in voltage to pass or block light from a constant-operation or modulated backlight. If the backlight uses a constant light source, such as a cold-cathode fluorescent lamp (CCFL), then red, green, and blue microfilters are applied to the front surface of each pixel to obtain full RGB color. (Figure 3)

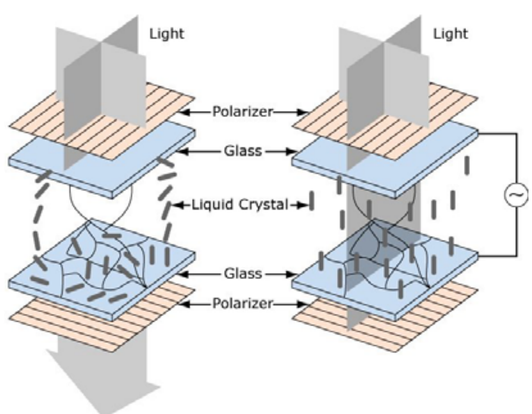

Figure 9. Cross section of a typical LCD pixel, showing the LC alignment process and light shuttering effect.

If a modulated light source is used, the light source can also generate color (red, green, and blue light-emitting diodes). Or, white LEDs can be used in combination with the discrete color microfilters just described. Modulated light sources are unique in that they can be used for local area dimming to improve contrast from scene to scene.

Emissive imaging: Plasma display panels are the leader in this category. Plasma pixels, which contain a mixture of neon and xenon gases, emit ultraviolet light when electricity is discharged through them. The burst of UV light in turn stimulates red, green, and blue phosphors to glow. By design, plasma pixels are capable of local area dimming, and also switch at very high speeds. (Figure 4)

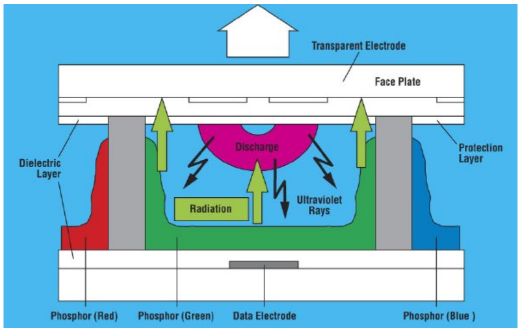

Figure 4. Cross section of a plasma pixel.

Because plasma monitors function as high-speed switching displays and provide only two operating states (on and off), they create grayscale images by using a pulse-width modulation (PWM) technique. The luminance level of the image is determined by the ratio of “on” cycles to “off” cycles within a specific time interval. (Figure 5)

Figure 5. Using pulse-width modulation to create grayscale values.

New flat panel emissive technologies such as FEDs and OLEDs are also classified as emissive displays. In the case of FEDs, their operation is very similar to that of a CRT, with low-voltage scanning from one emitter (cathode) to another, producing an electron beam that is amplified by a high anode voltage. The anode current is small (milliamperes).

OLEDs work just like other semiconductor devices, with a flow of electrons from anode to cathode at voltages as low as 3 volts and with high current. The flow of electrons generates photons, and the organic film layer produces the desired color. Both OLEDs and FEDs are still in their infancy, and not ready for mass production in larger screen sizes.

Reflective imaging: Two technologies are popular here, and are used for front and rear projection monitors only. The first is Digital Light Processing (DLP®), which modulates a beam of light through the action of thousands of tiny mirrors switching on and off at a high rate of speed. DLP also uses pulse-width modulation to create grayscale images.

The micromirror device is a monochromatic light modulator, so color is added by using either a sequential color wheel or a bandpass filter with three separate light modulators.

The other reflective technology is liquid crystal on silicon (LCoS). LCoS panels behave just like LCDs, except that their liquid crystals typically align in a vertical mode to pass or block light, which is then reflected back from the device at a right angle to the incident light from the illuminating source. LCDs have an analog response to changes in driving voltages and create color from discrete red, green, and blue light filtered by dichroics.

PLASMA VS. LCD IMAGING

The clear majority of evaluation-grade monitor applications call for direct-view displays. Presently, only plasma and LCD monitors are currently available in sufficient quantities, resolutions, and screen sizes to be considered for direct-view monitors. Both have their strengths and weaknesses. Both are available in different screen sizes, although the choices for plasma are not as expansive. And both have achieved 2K (at least 1920x1080) native pixel resolution.

A case can be made that, despite the preponderance of LCD monitors currently offered for sale, plasma is a better choice for many production, post-production, and monitoring applications. Let's review its advantages.

CRT emulation: Like the CRT, plasma uses an emissive (burst) color imaging process. It exhibits excellent black levels, a wide dynamic range, sufficient brightness for evaluation and grading environments, high color saturation, a wide color gamut, and excellent linearity in tracking a given white point.

LCD monitors, on the other hand, are challenged to produce low black levels while using conventional CCFL backlights. Also, CCFLs exhibit uneven spectral characteristics – that is, they tend to spike in greenish-blue energy, with reduced response in reds, oranges, and yellows. Color correction can be applied to compensate for this unequal chromatic energy, and compensating filters can improve spectral response, too.

A better solution is to employ LEDs as LCD backlights, improving both color shading and black levels. But there are drawbacks here, such as the added cost to the backlight and the associated electronics to modulate individual LEDs and groups of LEDs. LED clusters can also produce a visible "halo" artifact. Finally, there is also a power consumption premium associated with LED backlights, not a minor issue in an era of increased awareness of energy savings.

Viewing angles: LCD monitors are further impaired by narrower viewing angles than plasma monitors. With a plasma display, the viewer is looking directly at the source of light, while LCD displays must modulate a backlight that has already passed through one polarizing filter. The second polarizing filter further attenuates light output and results in a narrower viewing angle for full brightness and contrast. As a result, image brightness drops off quickly as the viewer moves away from the LCD monitor's center axis, and a color shift (usually towards magenta) is often observed.

Dynamic range and gamma response: Both plasma and LCD monitors are capable of producing extremely bright images. In fact, LCD monitors are often twice as bright as plasma monitors before calibration. However, that extra brightness comes at a price, and that is an S-curve gamma response that flattens low-level detail and crushes high luminance values. Such a response is ill suited to the evaluation monitor environment. (Figure 5a-b)

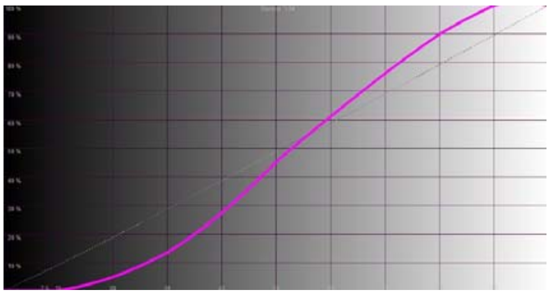

Figure 5a. Gamma response of a CCFL-equipped professional LCD monitor, operating in its factory "Cinema" preset mode.

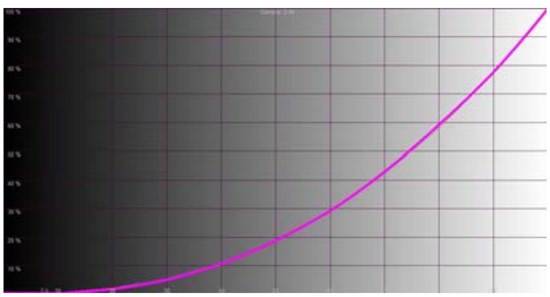

Figure 5b. Gamma response from the same monitor after recalibration to maximum brightness of 115 nits.

In fact, many LCD monitors only exhibit a linear gamma response at much lower brightness levels, typically below 130 nits – a level easily achieved by plasma monitors[2], which also exhibit consistent gamma response in this range. (Figure 6)

It should also be mentioned that evaluation-grade monitors are typically used under controlled lighting conditions where a full-white brightness reading of 100 nits (29 foot-Lamberts) is sufficient for everyday work.

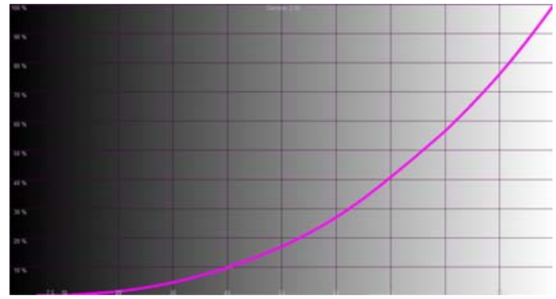

Figure 6. Gamma response of a professional plasma monitor set to peak SA brightness of 120 nits.

Contrast: In terms of contrast performance, the limiting factor is typically the level of black. A professional plasma monitor will easily achieve black levels at or below .15 nits (.04 ft-L) after calibration.

In contrast, black level measurements for professional LCD monitors range from a low of .26 nits (.076 ft-L) for monitors equipped with LED backlights to .4 nits (.12 ft-L) for conventional CCFL backlights.[3]

Given a practical peak white setting of 120 nits for best gamma response and dynamic range using either plasma or LCD technology, the resulting contrast ratios would be 800:1 for the plasma monitor, 462:1 for the LED-equipped LCD monitor, and 300:1 for the CCFL-equipped LCD monitor. These numbers reveal an almost a 2:1 advantage in contrast performance for plasma display technology.

Color Gamuts: Both plasma and LCD displays are capable of equaling CRT color gamuts. Plasma displays can even exceed SMPTE-C and BT.709 standard color spaces and cover a good portion of extended color spaces such as *xv*YCC and P3. LED-equipped LCD monitors expand the gamut colors seen from CCFL-equipped models, but at a substantial cost premium. (Figures 7a-b)

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[2] This is a small area full brightness measurement on a typical plasma monitor.

[3] Based on actual side-by-side tests by ROAM Consulting LLC under controlled ambient lighting conditions.

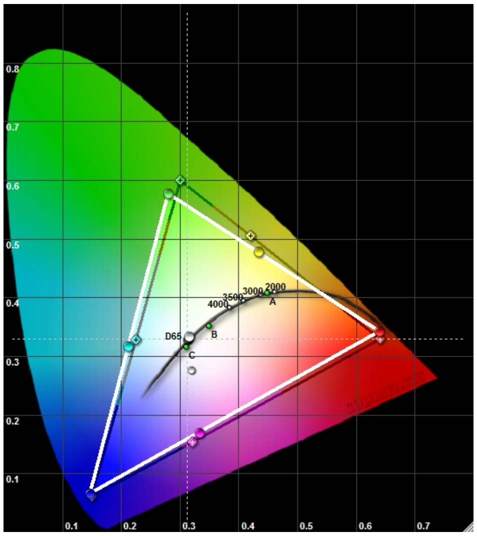

Figure 7a. The plotted color gamut for a professional 24-inch LCD monitor, using a CCFL backlight. Reference is the BT.709 color space (in black).

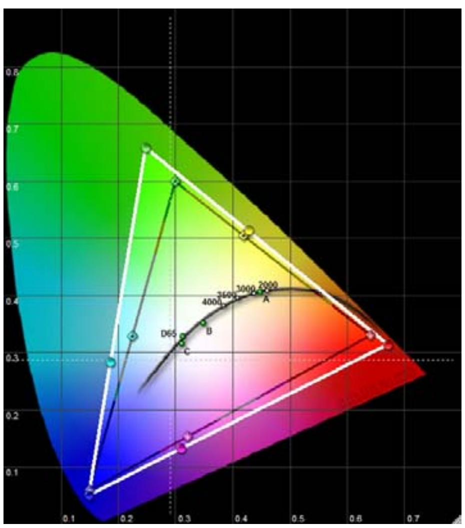

Figure 7b. The plotted color gamut for a 42-inch professional plasma monitor. Reference is the BT.709 color space (in black)

Color temperature and white balance: Tracking a given white point can be problematic for LCDs, particularly those equipped with CCFLs. Unless gamma corrected for each color channel, it's not unusual to see an LCD grayscale track vary by several hundred degrees from black to white.

On the other hand, plasma displays, even those intended for consumer use as HDTVs, typically track a consistent value of white after calibration from near black to 100% white. (Figures 8a-b)

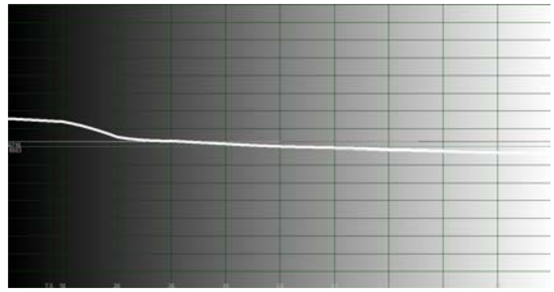
Figure 8a. Grayscale track for a professional LCD monitor using the factory Video setting. Center line reference is 6500 Kelvin.

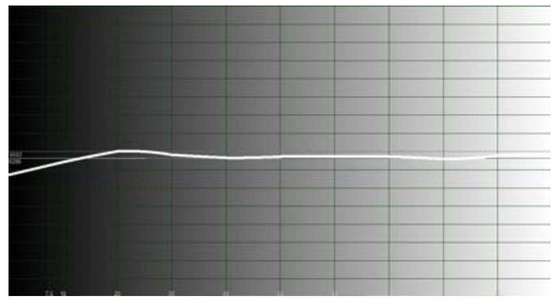
Figure 8b. Grayscale track for a professional plasma monitor using the factory Cinema/Warm setting. Center line reference is 6500 Kelvin.

Motion rendering: The biggest drawback to LCD monitors is their inability to render detailed fast motion. Liquid crystal molecules have a specific transit time from one position to another, and a combination of a "sample and hold" error in the human brain and a motion lag artifact in LCD displays usually create a smeared presentation, which adds to normal camera-induced blur. (Figure 9)

To overcome this problem, LCD monitors must do one or both of two things. First, they need to refresh images at a faster speed than the native frame rate.

For example, fast motion presented at 60Hz must be refreshed twice as fast (120 Hz) with additional frames of interpolated motion and combined with a technique known as "partial black frame insertion" to create a shuttering effect, overcoming the "sample and hold" error and providing more motion detail.

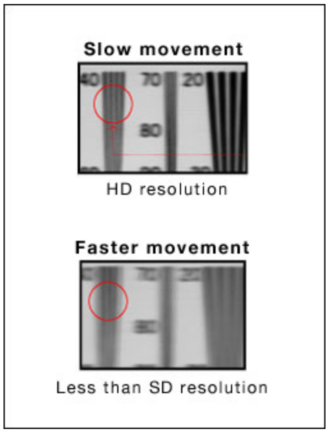

Figure 9. A moving resolution chart as displayed on a 120Hz LCD monitor at low speed (top) and high speed (bottom).

LCD monitors with 4x rates (240 Hz) and even 8x rates (480 Hz) have also been demonstrated as solutions for blurred motion artifacts. If the LCD monitor is to show active-shutter 3D content, then the actual frame rate needs to be double that of the motion correction rate to sequence the interpolated left eye – right eye information. (Pulsed LED backlights are better suited to the high switching speeds needed to correct motion blur and obviate the need for black frame insertion.)

On the other hand, plasma monitors use a high frame rate to begin with (typically 600 Hz) and have no issue with motion blur. The only limiting factor will be motion blurring introduced by the camera, or other image-capture devices. (Figure 10)

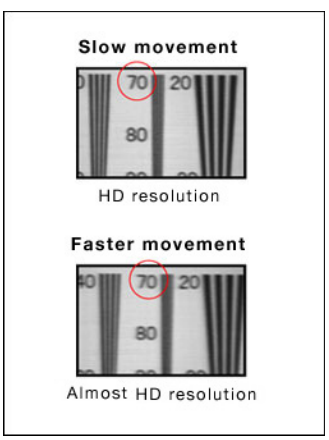

Figure 10. The same resolution chart as displayed on a standard plasma monitor at low (top) and high (bottom) speeds.

Active shutter 3D content is also much easier to show on plasma monitors, as is a combination of interpolated super-fast motion and 3D material. Plasma monitors can also handle lower frame rates with ease, doubling and tripling 24 and 25Hz frame rates used for video and film production.

THE FUTURE OF PLASMA

Although the number of companies that manufacture plasma displays is smaller than those manufacturing LCD displays, plasma technology is by no means passé. Steady improvements have been made in power consumption, with new “green” models shown in early 2009 that exceed the current 2 lumens/watt power efficiency levels for plasma. Prototype plasma monitors have also been shown with three times the luminous efficiency of current offerings, a number that would also realize significant power savings.

Research continues into improving the color phosphors used in plasmas, specifically to attain a higher saturation level for the green channel, and to cover more of the extended *xv*YCC and P3 color gamuts. New phosphor compounds are also being tested for faster decay, to improve rendering of 3D content and minimize left eye/right eye ghosting due to slow phosphor decay.

Additional improvements have been made to sub-field addressing for lower black levels and improved contrast ratios. At present, the maximum pixel resolution for professional plasma monitors remains at 1920x1080 pixels, but it is possible to go even higher – a 4K (4096x2160) 150-inch plasma monitor has been demonstrated, and is scheduled for commercial delivery in 2010.

In conclusion, plasma technology is now and will continue to be an excellent choice for many evaluation-grade monitor applications in the production and post-production of film and video content, as well as specialized applications like 3D imaging, computer graphics, and simulation.