17.2: Wide Aspect FPM with Calibrated High Information Content Display

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Abstract

Each year the Society awards the Display of the Year Award to several display devices that exhibit leading edge technology or innovative solutions to an information display need. The following paper provides a summary of the Silicon Graphics 1600SW™ Flat Panel Monitor, the recipient of the 1999 Silver Display of the Year award presented in May 2000. Addressing the explosion of computer graphics usage makes the need for accurate image reproduction obvious. The SGI 1600SW can change its spectral emission characteristics through the use of an embedded measuring device and independent color temperature control. Its optical features, white balance adjustment, the ergonomics of its wide aspect ratio and high information content display, and the development of its digital interface will be described.

1. Introduction

The 1600SW is a color active matrix LCD monitor incorporating amorphous silicon Thin Film Transistors (TFTs). The resolution of the panel is 1600 x 1024 pixels x RGB with 8-bits of gray scale capable of displaying 16.7M true colors without frame rate modulation. The monitor is composed of two main mechanical parts: Display and Tower (Figure 1). The Display's case includes the TFT module, graphic interface, and power management printed circuit assemblies (PCAs). The Tower connects to the Display assembly through a friction hinge mechanism to provide tilt and elevation adjustment for desktop use and is removable for wall mounting. The front panel of the monitor houses a power button and a status LED while the rear contains inputs for a calibration sensor device, DC power, and interface cable.

Figure 1. Silicon Graphics 1600SW flat panel monitor.

Commerce on the World Wide Web, medical imaging, graphics, and electronic publishing have placed a high demand on displays for accurate color reproduction. Many applications require color evaluation as part of their basic, "mission critical" function. Designers must be able to trust that the colors displayed on multiple monitors will faithfully resemble the final output without resorting to expensive proofing solutions [2]. Unless all these displays can be characterized and calibrated alike, full color management cannot be achieved.

SGI has tried to provide the tools to manage this task. The 1600SW flat panel monitor has the ability to adjust the display color temperature by precisely modifying the spectral emission characteristics of its backlight. With its embedded measurement device and software, the panel can be set to a known standard state. Colorimetric data and manufacturing information from the panel are input to an onboard memory location as references for the calibration application. Combined with its high contrast ratio and a lower native response curve, the 1600SW can simulate a broad range of visual environments. Ergonomically, its 16:10 SuperWide™ format and high pixel density provide extra real estate to allow the user access to more visual information.

2. Background

2.1 Technology Issues

In late 1997 when the SGI panel began development, CRTs and most flat panel monitors used an analog method to transfer image information from a CPU [1]. Problems could occur in data sampling and clocking as a result of poor timing synchronization causing misalignment of the screen image from frame to frame.

Solutions were being developed well suited to the spatially fixed format of flat panel monitors; i.e., a digital interface to a digital display. The industry was considering two types of these protocols: National Semiconductor had already introduced its Low Voltage Differential Signal (LVDS) interface while Silicon Image was promoting Transition Minimized Differential Signal (TMDS) [3]. Even though digital monitors scored higher user acceptance ratings, there were as yet no standards for graphics controllers.

Flat panels sizes at that time were mainly SVGA 12.1" to 14.5" XGA screens with the dominance of 15" XGA awaiting the completion of next-generation production lines. While these monitors could display very bright text and images, they suffered several disadvantages that kept them from being chosen over CRTs by color professionals: consistency at all viewing angles, high color saturation, and a way to match multiple screens.

Drivers for these panels commonly had only 6-bits of grayscale resolution which placed limits on the color palette. Color gamuts for monitors were in the mid-50 percent area, only slightly above the 40+ percent range for less saturated laptop displays which had to bow to battery conservation issues.

2.2 Historical Overview

Visual solutions for SGI's technical users required "no compromise," affordably priced high-information content FPMs with bright, fast, stable, and highly contrasted images. SGI partnered with the Advanced Display (ADI) subsidiary of Mitsubishi Electric with whom two previous display programs had been developed. Their Generation 2.5 line, which could normally fit only a single 17" SXGA panel per motherglass, was reconfigured to support two 17.3" 16:10 aspect panels. This layout represented a premium value for ADI's motherglass over a 4-up array of notebook panels.

The necessity of choosing a technology that was scalable to higher data rates while reliable across manufacturing processes made the selection of a digital interface a strategic imperative. During 1997, extensive testing and evaluation of National's LVDS technology indicated that a dual-channel implementation would be able to provide rates up to 130Mhz. An upgrade to OpenLDI the following year would increase the rate to 224Mhz. With limited Digital Out on desktop PCs, SGI bundled the capability with its monitor by partnering with NumberNine Visual Technology in the development of digital PCI and AGP graphics cards.

2.3 Market Relevance

The 1600SW FPM design is about maximizing information content. The success of many financial institutions is often linked to the amount of information available to their traders and analysts who work in compact and crowded environments. As SXGA resolution was predicted to dominate the market, SGI's "SXGA-Wide" format would offer significant differentiation and utility in applications requiring finely rendered text and graphics.

Also, in a publishing workflow, a design is created and proofs are sent to another location for editing and review. Historically, the likelihood of the first generation of proofs being acceptable was less than 20%. The SGI display system promotes what is known as Remote Digital Soft Proofing that would allow art directors to bypass costly overnight deliveries to meet publication deadlines.

3. Technical Discussion

3.1 Product Design

3.1.1 Wide Aspect Ratio

With its 110-dpi resolution and SuperWide format, the 1600SW accommodates two full 8½-inch by 11-inch pages side-by-side, with room left over for control panels and icons. Beyond these evident benefits, SGI elected a wide aspect design because it creates a machine interface more closely aligned with the human cerebral cortex's tendency to "read" information in a horizontal direction. We owe this phenomenon to our ancestors living on the prehistoric African plains where the ability to scan the mainly horizontal vistas of their surroundings often meant the difference between life and death for these early humans. This basic survival skill became hardwired into the human cerebral cortex.

3.1.2 Monitor Architecture

As shown in Figure 2, the Glue logic PCA links the LCD control board to the host CPU through Philips Inter-Integrated Circuit (I^2C) and dual LVDS channels. All power management and color management functions are implemented in the Glue logic board and adjustments are done via I^2C commands from the host computer. Backlighting is supplied by 2 pairs of dual cold cathode fluorescent (CCF) tubes located along the top and bottom edges of a light pipe assembly. Each CCF pair contains a proprietary, narrow-emission band phosphor mixture for user adjustment of the display's white balance.

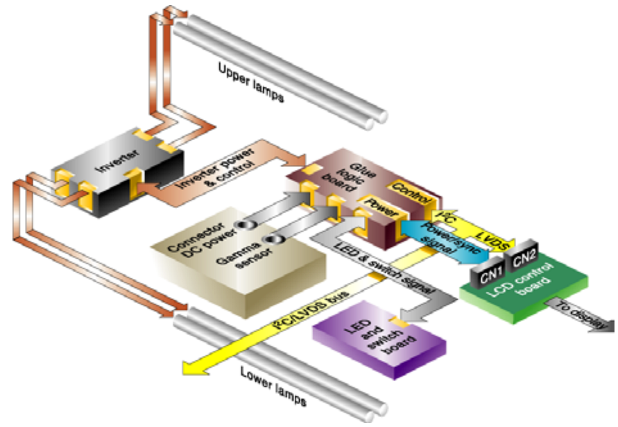

Figure 2. 1600SW block diagram.

3.1.3 Colorimetric Profile

The SGI monitor complies with the Display Data Channel standard, Version 2.0 level B (DDC2B), which defines the communications channel between the display and host system and transmits an Extended Display Identification Data (EDID) structure. Encoded within the display's onboard memory are its serial number, date of manufacture, and parameters such as display size, power management, gamma, and timing. These data are accessible to the user either directly from the CPU or over a local or wide area network. Additionally, SGI's flat panels are individually characterized at the factory and their colorimetry profiles are stored within the onboard memory of each monitor.

3.2 Technical Discriminators

3.2.1 Adjustable White Balance

Unique to the SGI 1600SW, a separate system is used to adjust the panel's white balance from 5000°K to 7000°K that works by adjusting the color temperature of the backlight without reducing the dynamic range of the gray scale levels for any of the color primaries. This provides a new dimension of color control for graphic arts, multimedia, and film production applications that rely upon color temperatures referenced to a specific color locus. Driven by on-screen controls or the color calibration application, this utility adheres closely to the Daylight White locus (Figure 3).

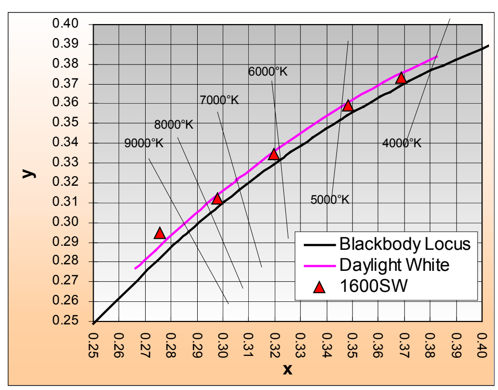

Figure 3. The 1600SW's color temperature range adheres closely to the Daylight White locus.

3.2.2 Colorlock Calibrator

The 1600SW ships with the ColorLock Sensor, an attachable calibration device with photopic responsivity for use with software applications installed on SGI workstations (see Figure 4). The sensor is optimized for extremely wide dynamic range operation, exhibits excellent linearity, and is stable over long periods. As core design parameters for compatibility with liquid crystal displays, SGI required the sensor to be responsive to the emission spectra of the backlight lamps, have a narrow measuring cone angle, and avoid placing any stress on the display glass.

Figure 4. Sensor attached during measurement; "Settings" calibration window.

The Sensor makes use of the embedded colorimetric profile data to calibrate the panel to which it is attached. Figure 4 also shows a dialog window by which the user can set the monitor to one of five standard presets or use sliders to adjust the display's color temperature, gamma, and brightness to a custom setting. This setting is formatted as an International Color Consortium (ICC) color-matching profile that can be saved, synchronized with an application such as PhotoShop, or electronically shared with a remote location to synchronize two or more monitors.

3.2.3 Optical Design Considerations

Successful color management in an LCD includes dealing with its off-axis viewing characteristics, which may be problematic. Light is retarded to a different refractive index (n), depending on the angle at which it passes through a twisted-nematic (TN) structure [6], and acquires a positive birefringence where nx = ny < nz.

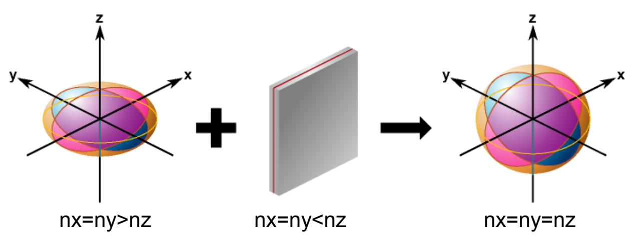

Figure 5. TN cell with biaxial stretched negative birefringence films for optical compensation.

At the time of the 1600SW's introduction, the leading counter-measure for this effect was to orient and address the liquid crystal molecules in an in-plane switching (IPS) mode [7]. However, response time ($T_r + T_f$) for IPS display devices is characteristically slower, around 50ms to 60ms [4, 5], than for twisted-nematic structures which can limit the LCD's ability to show artifact-free video. Also, IPS constructions had significantly reduced light transmission requiring much brighter backlights to remain at parity with their TN counterparts. To improve off-axis light distortions, maintain brightness, and keep response times below 40ms, the 1600SW was designed with a TN structure and negative birefringence optical compensation films (Figure 5).

3.3 Performance Evaluation Results

3.3.1 Native Gamma

The 1600SW monitor has a native gamma of 1.8 (Figure 6); this is lower than the 2.2 to 2.8 values for CRTs. Together with the 1600SW's 350:1 contrast ratio, it enhances viewability of shadow and mid-tone regions so that the panel can be used more effectively in relatively high-ambient illumination. For lower brightness levels, the ColorLock calibration system can be used to adjust the gamma from host-based graphics card lookup tables.

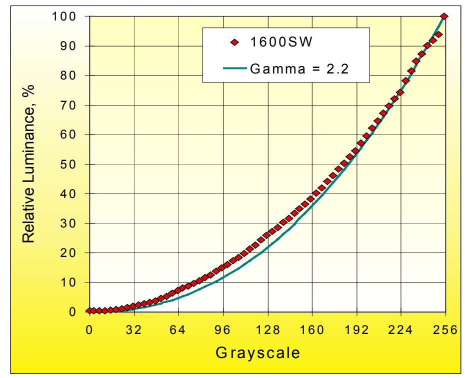

Figure 6. The 1600SW's native gamma response.

3.3.2 Color Gamut

The Silicon Graphics 1600SW is able to achieve an elevated gamut value with high-caliper color filters, offsetting the impact on luminous efficiency with special optical films and backlight structures. These films are selected for their performance reliability to ensure the display maintains its color space in all types of environmental and lighting situations. The 1600SW has a color reproduction gamut of 63 percent of the National Television System Committee (NTSC) standard. This was higher than that of other flat panel monitors at the time of its launch and equal to or better than many CRTs (see Figure 7).

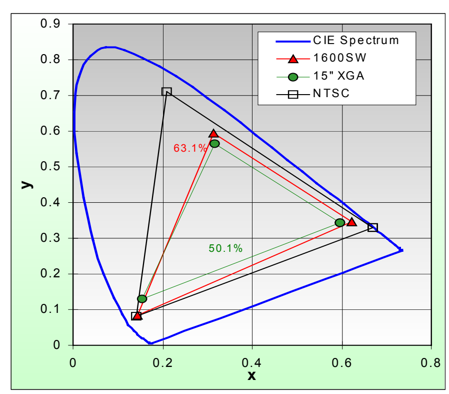

Figure 7. Color gamuts compared to NTSC standard.

3.3.3 Off-axis Color Stability

The color filters used in the construction of the 1600SW are of the stable pigment type. After exposure to environmental stress conditions such as 60°C, 90%RH for 200 hours and 85°C for 500 hours, the resultant color shift, given by ΔE*, is less than 1.5. Also, Figure 8 shows the –80°/+80° chromatic change of the RGB primary colors in the horizontal and vertical directions.

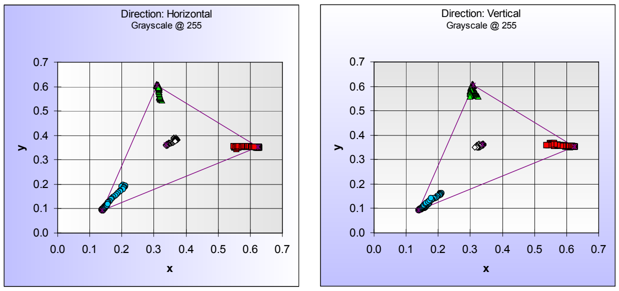

Figure 8. Off-axis colorimetric uniformity.

4.0 Status Update

4.1 Recent Developments

To support customers with a wide variety of video cards wishing to connect to the standard Digital Video Interface (DVI) and make full use of the 1600SW's resolution, SGI recently released the Silicon Graphics MultiLink™. This adapter box (Figure 9) uses a DVI-I input connector to accept component RGB analog, Digital Flat Panel (DFP), and TMDS digital signals and outputs an LVDS digital signal to drive the 1600SW. An on-screen display (OSD) may be operated by using the five buttons mounted in the top of the case to make further refinements to the display image.

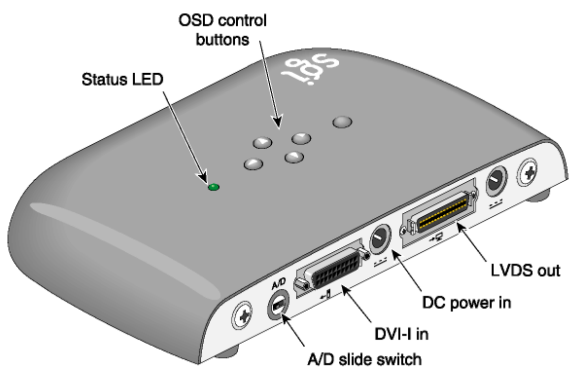

Figure 9. The Silicon Graphics MultiLink adapter.

Non-native timing modes run on MultiLink through an operation known as scaling that adapts the input graphics timing format into one that the 1600SW supports without loss of image quality. MultiLink scales all standard VESA 60Hz timing modes, as well as HDTV 720P, up to the native resolution of the 1600SW. A slider switch on the rear I/O panel selects the active interface and relevant data in MultiLink's EDID structure (DDC2B protocol).

4.2 Future Development Plans

SGI will continue to refine the electronic imaging tools its offers to the graphics artist and content creator. An important step will be to provide an API utility for adjustable white balance backlight control that will be portable across Macs and PCs for the various graphics card vendors that support our flat panels (see Figure 10).

The next generation ColorLock application will be platform independent, reside in the host CPU, and work with either flat panels or CRTs. The Sensor will be calibrated at the factory so as to measure the absolute luminance of a panel and will communicate with the host over RS232 or USB serial lines. Its optical elements will allow non-contact measurement of and gamma correction for reflected ambient lighting (veiling glare).

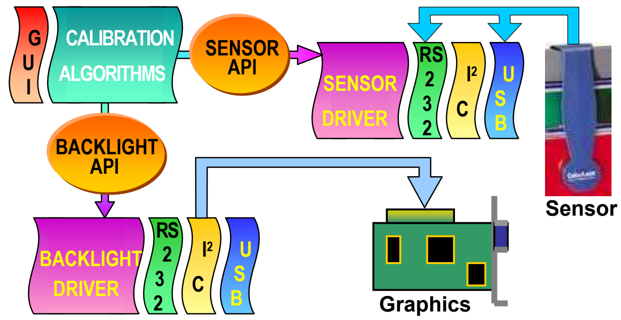

Figure 10. Next generation ColorLock with serial interface and cross-platform backlight control utility.

5. Conclusion

Color has become a critical part of both a company's and a product's identity. The monitor described incorporates unique solutions to maintain a standardized, consistent image quality. The Silicon Graphics 1600SW represents the best design possible with technology available at the time of its launch. It enables the user to simulate and manage viewing environments that were simply not possible before its introduction.

6. Acknowledgements

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