The Samsung 240T, 24 inch, 1920 x 1200 pixel LCD color monitor ($5511) is the first LCD that has the capability for both digital and analog addressing at the full 1920 x 1200 addressability. NIDL reports here results on extensive digital and analog testing. We found that digital addressing improves the sharpness of visually observed SMPTE test patterns, of measured profiles of a single pixel wide line, and of Briggs patterns. This improvement is achieved in part by eliminating a spurious extra part of a pixel (phantom) observed in analog mode. We achieved 1920 x 1200 digital addressing by using an Elsa Synergy III graphics card in the single head mode with a single DVI channel by decreasing the vertical refresh rate to 52 Hz. Images look excellent with no flicker at this lower refresh rate. At 1920 x 1200 digital addressability, Briggs scores are 16, 38, 59 and 71 for the Delta-1, Delta-3, Delta-7 and Delta-15 contrast ratio targets, compared to 12, 34, 55 and 58 in the analog mode. The constancy of illumination in an LCD display allows the vertical refresh rate to be reduced to 52 Hz without observable flicker; the geometrical arrangement of the backlight, however, can lead to a somewhat higher luminance non-uniformity (23.4% versus 20% IEC requirement for CRT monitors). Luminance rise time in digital mode averages 13 ms compared to 20 ms in analog mode. The Samsung 240T LCD easily surpassed the IEC specifications for luminance, contrast ratio, halation, CCT, reflectance, tonal transfer curve, uniformity of chromaticity, pixel aspect ratio, contrast modulation, jitter/swim/drift, and warm-up time. NIDL rates the 240T a "B" in a monoscopic mode and therefore certifies it as an acceptable color monitor in a dual head IEC workstation. Also, it could be used as the main task monitor for a non-stereo mode color workstation, as is utilized at NAVO WSC. It cannot replace a CRT where a stereoscopic-mode capable color monitor is required.

Evaluation of the Samsung 240T Analog and Digital, 24-Inch Diagonal 1920 x 1200 Pixel LCD Color Monitor

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Abstract

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CONTENTS

NIDL IEC Monitor Certification Report

The Samsung 240T LCD Color Monitor

FINAL GRADES
Monoscopic Mode: B
Stereoscopic Mode: F

A=Substantially exceeds IEC Requirements; B= Meets IEC Requirements; C=Nearly meets IEC Requirements; F=Fails to meet IEC Requirements in a substantial way

The Samsung 240T, 24 inch, 1920 x 1200 pixel LCD color monitor ($5511) is the first LCD that has the capability for both digital and analog addressing at the full 1920 x 1200 addressability. NIDL reports here results on extensive digital and analog testing. We found that digital addressing improves the sharpness of visually observed SMPTE test patterns, of measured profiles of a single pixel wide line, and of Briggs patterns. This improvement is achieved in part by eliminating a spurious extra part of a pixel (phantom) observed in analog mode. We achieved 1920 x 1200 digital addressing by using an Elsa Synergy III graphics card in the single head mode with a single DVI channel by decreasing the vertical refresh rate to 52 Hz. Images look excellent with no flicker at this lower refresh rate. At 1920 x 1200 digital addressability, Briggs scores are 16, 38, 59 and 71 for the Delta-1, Delta-3, Delta-7 and Delta-15 contrast ratio targets, compared to 12, 34, 55 and 58 in the analog mode. The constancy of illumination in an LCD display allows the vertical refresh rate to be reduced to 52 Hz without observable flicker; the geometrical arrangement of the backlight, however, can lead to a somewhat higher luminance non-uniformity (23.4% versus 20% IEC requirement for CRT monitors). Luminance rise time in digital mode averages 13 ms compared to 20 ms in analog mode. The Samsung 240T LCD easily surpassed the IEC specifications for luminance, contrast ratio, halation, CCT, reflectance, tonal transfer curve, uniformity of chromaticity, pixel aspect ratio, contrast modulation, jitter/swim/drift, and warm-up time. NIDL rates the 240T a "B" in a monoscopic mode and therefore certifies it as an acceptable color monitor in a dual head IEC workstation. Also, it could be used as the main task monitor for a non-stereo mode color workstation, as is utilized at NAVO WSC. It cannot replace a CRT where a stereoscopic-mode capable color monitor is required.

Background
A number of NIMA and DoD sites use the 24-inch Sony color GDM-FW900/W900 monitor in the monoscopic-mode administrative screen (IEC workstation format) or as the monoscopic-mode NAVO task screen (Naval Oceanographic Office, Warfighting Support Center). NIDL identified and purchased the Samsung 240T, 24-inch color 1920 x 1200 pixel LCD monitor as a potential replacement having a smaller footprint for both of these applications, and also for its capability to do digital as well as analog addressing. We evaluated the Samsung monitor with reference to the NIMA IEC Working Group specifications for a color monitor operating in the monoscopic mode so we could compare it to the 24-inch Sony CRT monitor that NIDL had evaluated previously.

LCD monitors are different from CRT monitors in a number of ways. First, the pixel structure is fixed by the semiconductor-like fabrication process. A CRT monitor has no fixed pixel structure, rather it can be programmed to a wide range of pixel sizes; its limitation may be the size of the closest spacing of the openings in the shadow mask. For this reason, the fixed-pixel Samsung 240T LCD monitor is not as robust as the variable-resolution Sony FW900 CRT monitor for accommodating a wide range of input signal timing formats and addressabilities.

Second, the LCD is a light valve that either passes or blocks light from the backlight to the RGB color triads. A CRT generates its own light from the interaction of the three electron beams with the red, blue, and green phosphors. The method of generating the light influences the perception of flicker to the viewer. For a CRT monitor, the IEC specification is for a minimum of 72 Hz to minimize flicker. A LCD monitor in contrast has a back light always on, so that the vertical refresh rate can probably go to 52 Hz or less per eye before flicker becomes noticeable. Thus, a LCD monitor operating at 60 Hz should pass the IEC specification for vertical refresh rate.

<u>Luminance Uniformity</u>
The LCD backlight structure can also influence the uniformity. Edge lighting or serpentine fluorescent tubes can lead to larger variations in luminance than are measured for CRT monitors. For this reason, the Samsung 240T monitor failed the IEC luminance uniformity specification by 3.4 percentage points.

<u>Viewing Angle</u>
The effective viewing cone angle for the Samsung 240T LCD monitor is limited to approximately ±20 degrees from the perpendicular to the LCD screen in the vertical and horizontal directions. This is based on a measurement whereby the maximum contrast ratio of 350:1 (25.9dB) does not vary by more than a factor of 2 (3dB) based on luminance viewing cone measurements of Lmax (level 255) and Lmin (level 000). This LCD monitor did not exhibit grayscale inversion with viewing angle.

<u>Briggs Scores</u>
Briggs BTP #4 test patterns were displayed on the Samsung 240T LCD monitor in both analog and digital formats. The Briggs scores for the analog-addressed LCD are not quite as good as for the Sony FW900 CRT monitor as shown in the table below. The LCD Briggs scores for the digital-addressed LCD are marginally better than for the analog-addressed CRT monitor.

Table 1. Summary of Average Briggs Scores

Briggs Target	Analog 24-in. Sony 1920 x 1080	Analog Samsung 240T 1920 x 1080	Digital Samsung 240T 1920 x 1200	Digital Samsung 240T 1280 x 1024	Analog Samsung 240T 1280 x 1024
Delta-1	10	12	16	16	11
Delta-3	40	34	38	38	33
Delta-7	57	55	59	59	55
Delta-15	62	58	71	71	71

The Samsung 240T LCD 1920 x 1200 analog format Briggs scores were only slightly less than obtained for the Sony FW900 CRT monitor.

The 1280 x 1024 format was displayed on the Samsung 240T LCD monitor in both analog and digital modes.   LCD analog mode Briggs scores were slightly less than obtained for the 1280 x 1024 digital mode.

The 1920 x 1200 format was displayed on the Samsung 240T LCD monitor in digital mode using a single DVI channel by reducing the blanking period to 10% and by reducing the refresh rate to only 52 Hz.   The resulting Briggs scores were the same as obtained for the 1280 x 1024 x 60Hz digital mode.

Defective Pixels, Lmin Uniformity and Mura
We observed very few defective pixels. One in a million white pixels were stuck on, and a dust particle extended across two adjacent pixels. Black Luminance (Lmin = 0.1 fL) sampled at 240 points (20 x 12 grid) varied across the screen by up to 41%. Mura was slightly visible on a full black (Lmin) screen, but probably will not interfere with image analyst or geospatial specialist usage.

Analog Addressing
The Samsung 240T LCD monitor was evaluated principally in the 1920 x 1200 pixel format through the analog HD15 input signal connector driven by a laboratory grade programmable test pattern generator (Quantum Data Fox 8701 400 MHz). The normal mode is user selected using front panel controls for one-to-one pixel mapping and is preferred for image analysis because this mode results in little or no aliasing and produces the highest image quality.   The Matrox Millenium G450 PC graphics card also displayed the 1920 x 1200 pixel format equally as well as the Quantum Data Fox 8701 generator.

Video signal timing formats were computed using the VESA GTF spreadsheet. NIDL computed GTF timings for the GDM-FW900 CRT monitor and the Samsung SyncMaster 240T monitors. These timings were inputted to NIDL's Quantum Data 8701programmable test pattern generator used for testing.   The timing formats for the Sony 24 inch GDM-FW900 and the Samsung SyncMaster 240T monitors shown in Table 2 differ in that the manufacturer recommended refresh rate for the Sony GDM-FW900 CRT monitor is 75 Hz compared to 60 Hz for the Samsung 240T LCD monitor.   The higher refresh rate is necessary to avoid flicker on the CRT.

Table 2. Analog timing formats for Samsung LCD and Sony FW900 CRT monitors

	Samsung 240T LCD monitor at 1920 x 1200 @ 60 Hz		Sony FW900 CRT monitor at 1920 x 1200 @ 75 Hz	
Maximum Pixel Rate	193.156 MHz	5.1772 ns	246.59 MHz	4.0553 ns
Resolution	1920 Horiz	1200 Vert	1920 Horiz	1200 Vert
H Sync	208 Pix	1.077 us	208 Pix	0.844 us
H Back Porch	336 Pix	1.74 us	352 Pix	1.427 us
H Active	1920 Pix	9.94 us	1920 Pix	7.786 us
H Front Porch	128 Pix	0.663 us	144 Pix	0.584 us
H Blank	672 Pix	3.479 us	704 Pix	2.855 us
H Total	74.520 kHz	13.419 us	93.975 kHz	10.641 us
V Sync	3 H	40.258 us	3 H	31.923 us
V Back Porch	38 H	509.930 us	49 H	521.415 us
V Active	1200 H	16103 us	1200 H	12769 us
V Front Porch	1 H	13.419 us	1 H	10.641 us
V Blank	42 H	564 us	53 H	564 us
V Total	60 Hz	16.667 ms	75 Hz	13.333 ms

Below are results of testing the various formats using the Sun Microsystems workstation with a Creator3D graphics card, and using a PC workstation with a Matrox Millenium G450 graphics card driving the Samsung 240T 1920x1200 24-inch and 210T 1600x1200 21-inch LCD monitors. Except where the horizontal pixel count exceeded 1600, both monitors behaved the same.

Table 3. Results of Analog Signal Inputs

Creator3D Graphics Card and Sun Microsystems Ultra 60 Unix Workstation	Matrox Millenium G450 Graphics Card and 366 MHz Pentium PC with Windows 2000
Formats that display well for both the 240T and on the 210T:	
	1600x1200x60, 1600x1200x65, 1600x1200x70
1280x1024x60, 1280x1024x76	1280x1024x60, 1280x1024x75
1152x900x66, 1152x900x76	1152x864x60, 1152x864x75
1024x768x60, 1024x768x77	1024x768x60, 1024x768x85
640x480x60	800x600x56, 800x600x85
	640x480x60, 640x480x85
Formats that display well for the 240T but not for the 210T:	
1920x1080x72, 1920x1080x76	1920x1200x60
Formats that do not display properly on either the 240T or the 210T:	
1920x1200x70, 1920x1200x75	1920x1200x65
1600x1280x76	
1600x1000x66, 1600x1000x76	1600x1024x60, 1600x1024x76
1440x900x76	
1280x1024x67, 1280x1024x85	
1280x800x76	
1024x800x84	
640x480x60i	
Available formats not tested:	
960x680x108s, 960x680x112s	
768x575x50i	

Alternative analog formats were also attempted including 1920 x 1080 pixels, 1600 x 1200 pixels, 1600 x 1024 pixels, and 1280 x 1024 pixels generated using a variety of video signal

sources. Sources included programmable test pattern generators from Quantum Data (400 MHz Model 8701 Fox and 360 MHz Model 802G with analog and DVI output) and computer graphics cards (Matrox G450 dual-head, Evans & Sutherland Tornado with stereo output, Hercules 3D Prophet II with DVI output, and Sun Microsystems Creator 3D). The 1600 x 1200 pixel format used for some IEC workstations is 4:3 aspect ratio and would be more efficiently displayed on the 21-inch Samsung 210T LCD monitor with 1600 x 1200 pixel native resolution. NIDL has scheduled an evaluation of the 210T LCD monitor.   Of the formats tested, the 1600 x 1024 format was problematic for the Samsung 240T LCD monitor regardless of the signal source. The 1600 x 1024 format displays as intended only in the two expanded modes that result in pixel aliasing in the horizontal direction.

Video Artifacts
When the Samsung 240T LCD monitor was driven in 1920 x 1200 format using analog input signals, a phantom low-luminance subpixel shown in Figure 1 was observed at trailing object edges, vertical lines and even single pixels. This artifact effectively degrades peak luminance and contrast modulation for the analog input signals with 1200-line formats. This artifact did not occur for the digital (DVI) input signal operation, nor did this artifact occur for lower-resolution analog formats (1280 x 1024 or less). This artifact was also observed on the 210T 21-inch LCD monitor when driven in analog mode at 1600 x 1200 addressability.
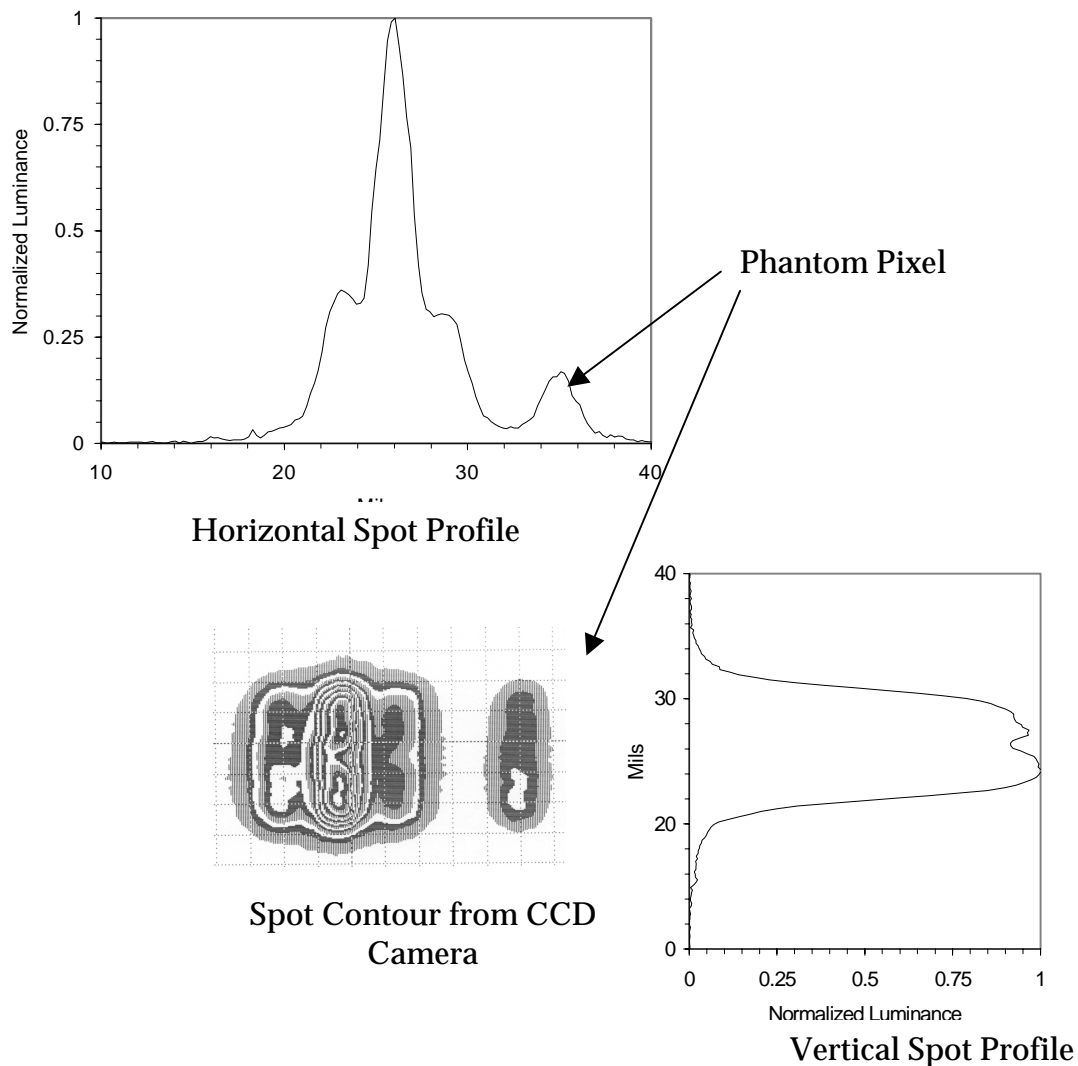
Figure 1. Phantom low-luminance subpixel observed at trailing object edges, vertical lines and even single pixels on the Samsung 210T and 240T LCD monitors in 1200-line analog modes.

Even with the phantom pixel artifact, the Samsung 240T LCD monitor produces very accurate one-to-one pixel mapping between the analog input signal and the fixed pixels on the screen, thus eliminating Moiré patterns that are exhibited by most color displays that use shadowmask or aperture grille CRTs such as the Sony FW900 monitor.

Digital Addressing
Samsung, the monitor manufacturer, was not surprised by our reporting of the appearance of the phantom pixel in analog mode, but offered the following suggestion: utilize digital addressing to eliminate the phantom pixel artifact. NIDL found that this LCD monitor can be addressed at the same 1920 x 1200 pixels using digital DVI as well as analog addressing. Ordinarily, a digital DVI interface is limited to 1280 x 1024 pixel addressability at a 60 Hz vertical refresh rate. We were able, with much assistance from Samsung, to achieve digital addressing at 1920 x 1200 with a single digital DVI interface by using the Elsa Synergy III graphics card recommended by Samsung.

According to the Samsung representative, the Elsa Synergy III PC graphics card uses a reduced total blanking time of less than 10% and reduces the vertical refresh rate to 52 Hz, enabling the 1920 x 1200 pixel format to be transmitted digitally using a single DVI channel. The pixel rate for this timing format is only 134 MHz, well within the 165 MHz limit for single-DVI. NIDL demonstrated this approach on the 240T LCD monitor and successfully eliminated the phantom pixel even at the full 1920 x 1200 native resolution. Images look great, and are free of flicker at 52 Hz.

Per instructions from Samsung, we found that the 240T LCD monitor works beautifully in 1920 x 1200 DVI mode after we boot up the PC with only the DVI connector of the Elsa Synergy III graphics card attached to the 240T, and the analog cable disconnected. The 240T on-screen display reported scan frequencies of 63.4 kHz horizontal x 51.8 Hz vertical. Further, digital addressing in the 1920 x 1200 DVI mode eliminates "phantom pixels" that we had seen in the 1920 x 1200 analog mode. The Synergy III is a dual monitor card but at 1920 X 1200 it is used as a single head video card. NIDL tried each of the available lower addressabilities of the Elsa Synergy III graphics card with the following results:

Table 4. Results of Digital Signal Inputs using the Elsa Synergy III Graphics Card

Elsa Synergy III Graphics Card and Pentium PC with Windows 98
Formats that display well in "normal" one-to-one pixel mapping mode on the 240T:
1920 x 1200 x 51.8 Hz
1600 x 1200
1280 x 1024, 1280 x 960
1024 x 768
800 x 600
640 x 480
Formats that display well for the 240T in "expanded" mode only (note that we are not recommending use of "expanded" modes because of the reduced resolution caused by pixel aliasing):
1600x1024, 1600x900
1360x768
1280x768, 1280 x 720
1152x864
848x480
Formats that do not display properly on the 240T in any mode:
1920x1080

While digital input operation is generally considered advantageous over analog mode, a potential disadvantage of the digital input signal operation is that only the front panel brightness control is

available in DVI mode. The contrast control is active only in analog mode. This means that Lmin and Lmax cannot be adjusted independently in digital mode.   Also, the color temperature controls are active only in analog mode, so color temperature cannot be adjusted in digital mode. With the brightness control adjusted to achieve Lmin = 0.1 fL, Lmax was measured to be 55 fL with a CCT of 5745 K (CIE x = 0.3263, y = 0.3593) which lies 0.017 u'v' units outside the IEC limits (6500 K to 9300 K). Each of the digital addressabilities available on the Elsa Synergy III graphics card were tested. The results are listed in Table 2.

According to Samsung's technical representative, the capability to exceed 1280 x 1024 digital addressability through the graphics card DVI port required a modification to the EDID file within the 240T monitor. The modified EDID file allows the monitor to communicate new detailed timing data to the graphics card allowing the graphics card to display the native mode of the monitor digitally (1920 x 1200).

The Elsa technical representative is Mike Fiato, (408) 961-4636, mike.fiato@elsa.com.   The Samsung technical representative is Jim Muta, (949) 975-7000 x7067.   The Samsung sales representative is Kim London, Corporate Sales Manager, Samsung Electronics America, Office (973) 586-9750, Fax (973) 586-9751, Pager (800) 973-9190, www.samsungmonitor.com. All were most cooperative with NIDL.

Evaluation Datasheet
Samsung 240T 24-Inch LCD Monitor, Analog and Digital

Mode	IEC Requirement	Measured Performance	Compliance
MONOSCOPIC			
Addressability	1024 x 1024 min.	1920 x 1200	pass
Dynamic Range	24.8 dB	25.9 dB, 25.5 dB [1]	pass
Contrast Ratio	300:1	393:1, 355:1 [1]	pass
Luminance (Lmin)	0.1 fL min ± 4%	0.1 fL	pass
Luminance (Lmax), Analog	30 fL ± 4%	39.3 fL, 35.7 fL [1]	pass
Digital		55 fL at 5745 K	
Reflectance	Not specified	5.1 %	
Uniformity (Lmin black)			
240-point Sampled	Not specified	41 %	
Uniformity (Lmax white)			
9-point Sampled	20% max.	23.4 %	pass
	30% absolute threshold		
240-point Sampled	Not specified	30.3 %	
Uniformity (Chromaticity)			
9-point Sampled	0.010 ± 0.005 delta u'v' max.	0.002 delta u'v'	pass
240-point Sampled	Not specified	0.008 delta u'v'	
Mura	Not specified	Some present	
Halation	3.5% max.	0.13%	pass
Correlated Color Temp	6500K to 9300K	6107 K as tested at 39.3 fL	pass
		6669 K verified at 35.7 fL [1]	
Distance from Daylight Locus	0.010 delta u'v' max.	0.015 delta u'v' as tested	
		0.009 delta u'v' verified [1]	pass
Color Tracking	No specification	0.043 delta u'v' (3.9 fL to 39 fL)	
Color Gamut Area	No specification	19% of CIE area	
		(Sony FW900 CRT is 27%)	
Bit Depth	8-bit ± 5 counts	8-bit	pass
Step Response, Analog	No visible ringing	Phantom trailing edge pixel	fail analog
Step Response, Digital	No visible ringing	Clean - Digital	pass digital
Pixel aspect ratio	Square, H = V ± 6%	H = V+ 0.2%	pass
Pixel density	72 ppi min.	94 ppi	pass
Phosphor-to-pixel spacing	1.0 max.	1.0 (No Moiré observed)	Pass
Screen size, viewable diagonal	17.5 to 24 inches ± 2 mm	24.043 inches	pass
Cm, Zone A, 7.6 inch diameter	25% min.	77 %	pass
40% circle, 11.5 in. dia.	25% min.	77 %	pass
Cm, Zone B	20% min.	75 %	pass
Straightness	0.5% max ± 0.05 mm	Not Measured	pass
Linearity	1.0% max ± 0.05 mm	Not Measured	pass
Jitter	2 ± 2 mils max.	0.45 mils [4]	pass
Swim, Drift	5 ± 2 mils max.	0.50 / 0.42 mils	pass
Warm-up time, Lmin to +/- 50%	30 ± 0.5 minutes max.	1 min.	pass
Warm-up time, Lmin to +/- 10%	60 ± 0.5 minutes max.	10 mins.	pass
Refresh	72 ±1 Hz min.	Set to 60 Hz analog, 52 Hz digital	pass [2]
	60 ±1 Hz absolute minimum	LCD exhibits no flicker	

Briggs Scores			
1920 x 1200, Analog	No specification	Delta-1 = 12, Delta-3 = 34 Delta-7 = 55, Delta-15 = 58	
1920 x 1200, Digital	No specification	Delta-1 = 16, Delta-3 = 38 Delta-7 = 59, Delta-15 = 71	
1280 x 1024, Analog	No specification	Delta-1 = 11, Delta-3 = 33 Delta-7 = 55, Delta-15 = 71	
1280 x 1024, Digital	No specification	Delta-1 = 16, Delta-3 = 38 Delta-7 = 59, Delta-15 = 71	
Viewing Angle	No specification	±20 degrees	
Rise Time Analog	No specification	20 ms	
Digital	No specification	13 ms	
Fall Time Analog	No specification	18 ms	
Digital	No specification	18 ms	
STEREOSCOPIC	1024 x 1024 x 120Hz	Not Measured [3]	fail
AMBIENT LIGHTING			
Dynamic Range 22 dB (158:1)	No specification	<2 fc	
Dynamic Range17.8 dB (60:1)	No specification	11 fc	

(1) CCT values within the IEC required range could only be obtained for slightly lower values of Lmax, i.e., 35.7 fL.

(2) No flicker is perceived at 60 Hz refresh as tested.

(3) LCD cannot achieve 120 Hz refresh rate required for stereo.   (4) 1 mil = 0.001 inch

Section I INTRODUCTION

The National Information Display Laboratory (NIDL) was established in 1990 to bring together technology providers - commercial and academic leaders in advanced display hardware, softcopy information processing tools, and information collaboration and communications techniques - with government users. The Sarnoff Corporation in Princeton, New Jersey, a world research leader in high-definition digital TV, advanced displays, computing and electronics, hosts the NIDL.

The present study evaluates a production unit of the Samsung 240T, Color LCD high-resolution display monitor. This report is intended for both technical users, such as system integrators, monitor designers, and monitor evaluators, and non-technical users, such as image analysts, software developers, or other users unfamiliar with detailed monitor technology.

The IEC requirements, procedures and calibrations used in the measurements are detailed in the following:

- *NIDL Publication No. 0201099-091*, *Request for Evaluation Monitors for the National Imagery & Mapping Agency (NIMA) Integrated Exploitation Capability (IEC)*, August 25, 1999.

Two companion documents that describe how the measurements are made are available from the NIDL and the Defense Technology Information Center at http://www.dtic.mil:

- *NIDL Publication No. 171795-036 Display Monitor Measurement Methods under Discussion by EIA (Electronic Industries Association) Committee JT-20 Part 1: CRT Color Monitor Performance Draft Version 2.0. (ADA353605)*
- *NIDL Publication No. 171795-037 Display Monitor Measurement Methods under Discussion by EIA (Electronic Industries Association) Committee JT-20 Part 2: Color CRT Monitor Performance Draft Version 2.0. (ADA341357)*

Other procedures are found in a recently approved standard available from the Video Electronics Standards Association (VESA) at http://www.vesa.org:

- *VESA Flat Panel Display Measurements Standard, Version 1.0, May 15, 1998.*
- *VESA Flat Panel Display Measurements Standard, Version 2.0, June 1, 2001.*

The IEC workstation provides the capability to display image and other geospatial data on either monochrome or color monitors, or a combination of both. Either of these monitors may be required to support stereoscopic viewing. Selection and configuration of these monitors will be made in accordance with mission needs for each site. NIMA users will select from monitors included on the NIMA-approved Certified Monitor List compiled by the NIDL. The color and monochrome, monoscopic and stereoscopic, monitor requirements are listed in the Evaluation Datasheet.

I.1. Manufacturer's Specifications for the Samsung 240T LCD Color Monitor

Manufacturer:	**Samsung**	**Model Name:**	**240T**
Model Code:	**PC24PBSS**	**Color Display Unit Type:**	**PC24PB**
Location:	**Suwon, Korea (SEC)**	**Manufacture Date:**	**January 2001**
Scan Code:	**PC24H4UR100110B**		

Please see Samsung web page for a description of the 240T LCD monitor at: www.samsungmonitor.com . Features shown on the current Samsung web page may reflect improvements in luminance and contrast over those listed below.

Features for the 240T
- **Viewable image size**   **24 inch**
- **Contrast ratio**   **450:1**
- **Interface**   **Analog/digital**
- **Max/native resolution**   **1920 x 1200 pixels**
- **Luminance**   **230 candelas/m2**
- **Viewing angle**   **170 degrees H and V**
- **Horizontal frequency**   **30-93 kHz analog, 30-81 KHz digital**
- **Special features**   **Digital @ 1920x1200, HDTV 1920x1080i, S-video**
- **Switchable aspect ratio**   **16:10, 5:4, 4:3**
- **Picture-in-picture**

Samsung specifications for their 240T LCD monitor

- **Panel type**   **Amorphous silicon thin film transistor**
- **Panel size**   **24 inch**
- **Pixel pitch**   **0.270 mm**
- **Vertical rate**   **56-85 Hz**
- **Bandwidth**   **200 MHz**
- **Color**   **16.7 million**
- **Input connectors**   **15 pin D-sub, DVI-D, S-video, RCA cable**
- **Video level**   **0.7 V peak to peak analog, TMDS digital**
- **Power on**   **95 W (max)**
- **Weight**   **30.4 pounds**
- **Warranty**   **3 years parts, 3 years labor, 3 years backlight**

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I.2. Initial Monitor Set Up

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5, p 5.

All measurements will be made with the display commanded through a laboratory grade programmable test pattern generator. The system will be operated in at least a 24 bit mode (as opposed to a lesser or pseudo-color mode) for color and at least 8 bits for monochrome. As a first step, refresh rate should be measured and verified to be at least 72 Hz. The screen should then be commanded to full addressability and Lmin set to 0.1 fL. Lmax should be measured at screen center with color temperature between D65 and D93 allowable and any operator adjustment of gain allowable. If a value >35fL is not achieved (>30 fL for color), addressability should be lowered. For a nominal 1200 by 1600 addressability, addressability should be lowered to 1280 by 1024 or to 1024 by 1024. For a nominal 2048 by 2560 addressability, addressabilities of 1200 x 1600 and 1024 x 1024 can be evaluated if the desired Lmax is not achieved at full addressability.

I.3. Equipment

Reference: CRT Color Monitor Performance, Draft Version 2.0 Section 2.0, page 3.

The procedures described in this report should be carried out in a darkened environment such that the stray luminance diffusely reflected by the screen in the absence of electron-beam excitation is less than 0.003 cd/m^2 (1mfL).

Instruments used in these measurements included:
•   Quantum Data 8701 400 MHz programmable test pattern signal generator
•   Quantum Data 802G 360 MHz programmable test pattern signal generator with analog and digital (DVI) outputs
•   Photo Research SpectraScan PR-650 spectroradiometer
•   Photo Research SpectraScan PR-704 spectroradiometer
•   Minolta LS-100 Photometer
•   Minolta CA-100 Colorimeter
•   Graseby S370 Illuminance Meter
•   Microvision Superspot 100 Display Characterization System which included OM-1 optic module (Two Dimensional photodiode linear array device, projected element size at screen set to 1.3 mils with photopic filter), OM-5 optic module (Two Dimensional CCD linear array device, projected element size at screen set to 0.2 mils with photopic filter) and Spotseeker 4-Axis Positioner.
•   Microvision SS200 Display Characterization System which included SS220 optic module (collimated optics on motorized goniometer, fiberoptically coupled to an Ocean Optics sprectrometer) and Spotseeker 4-Axis Positioner.

Computers used in these measurements included:
•   Sun Microsystems Ultra 60 workstation with dual 360 MHz processors and creator 3D graphics card for displaying Briggs targets.
•   Pentium PC with Hercules 3D Prophet II GTS 64MB graphics card with Analog and Digital (DVI) outputs for evaluating digital input signal mode.
•   Pentium PC with Elsa Synergy III graphics card with Analog and Digital (DVI) outputs for evaluating digital input signal mode.

Stereoscopic-mode measurements were not attempted due to the limited refresh rate.

Section II PHOTOMETRIC MEASUREMENTS

II.1. Dynamic Range and Screen Reflectance

References: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.6, p 6.

VESA Flat Panel Display Measurements Standard, Version 1.0, May 15, 199, Section 308-1.

Full screen white-to-black contrast ratio measured in 1920 x 1200 format is CR = 393 (25.9 dB dynamic range) in a dark room with Lmax set to 39.3 fL and Lmin set to 0.1 fL. It decreases to under 158:1 (22 dB), the absolute threshold for IEC, in 3 fc diffuse ambient illumination incident on the screen. The Samsung 240T LCD screen reflectance is 5.1%, equal to or lower than CRT color and grayscale monitors.

Objective: Measure the photometric output (luminance vs. input command level) at Lmax and Lmin in both dark room and illuminated ambient conditions.

Equipment: Photometer, Integrating Hemisphere Light Source or equivalent

Procedure: Luminance at center of screen is measured for input counts of 0 and Max Count. Test targets are full screen (flat fields) where full screen is defined addressability. Set Lmin to 0.1 fL. For color monitors, set color temperature between D_{65} to D_{93}. Measure Lmax.

This procedure applies when intended ambient light level measured at the display is 2fc or less. For conditions of higher ambient light level, Lmin and Lmax should be measured at some nominal intended ambient light level (e.g., 18-20 fc for normal office lighting with no shielding). This requires use of a remote spot photometer following procedures outlined in reference 2, paragraph 308-2. This will at best be only an approximation since specular reflections will not be captured. A Lmin > 0.1 fL may be required to meet grayscale visibility requirements.

According to the VESA directed hemispherical reflectance (DHR) measurement method, total combined reflections due to specular, haze and diffuse components of reflection arising from uniform diffuse illumination are simultaneously quantified as a fraction of the reflectance of a perfect white diffuse reflector using the set up depicted in figure II.1-1. Total reflectance was calculated from measured luminances reflected by the screen (display turned off) when uniformly illuminated by an integrating hemisphere simulated using a polystyrene icebox. Luminance is measured using a spot photometer with 1° measurement field and an illuminance sensor as depicted in Figure II.1-1. The measured values and calculated reflectances are given in Table II.1-1.

Use or disclosure of data on this sheet is subject to the restrictions on the cover and title of this report.

Data: Contrast ratio is a linear expression of Lmax to Lmin. Dynamic range expresses
               the contrast ratio in log units, dB, which correlates more closely with the
               sensitivity of the human vision system.

               Define contrast ratio by: CR = Lmax/Lmin

               Define dynamic range by: DR = 10log(Lmax/Lmin)

- Top View -
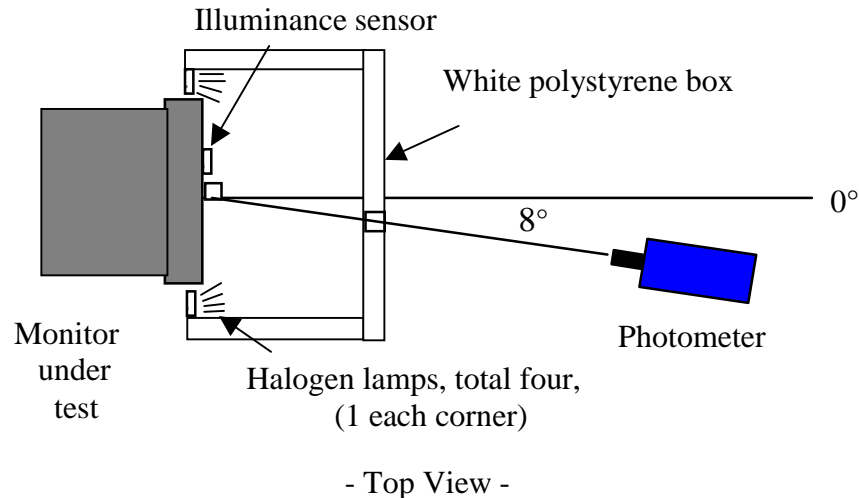
Figure II.1-1. Test setup according to VESA FPDM procedures for measuring
total reflectance of screen.

Table II.1-1. Directed Hemispherical Reflectance of Faceplate
VESA ambient contrast illuminance source (polystyrene box)

Ambient Illuminance	19.0 fc
Reflected Luminance	0.96 fL
Faceplate Reflectance	5.1 %

Ambient dynamic ranges of full screen white-to-black given in Table II.1-2 were computed for
various levels of diffuse ambient lighting using the measured value for DHR and the darkroom
dynamic range measurements. Full screen white-to-black contrast ratio decreases from 393:1
(25.9 dB dynamic range) in a dark room to CR > 158:1 (22 dB, the absolute threshold dynamic
range for IEC) in 3 fc diffuse ambient illumination.

Table II.1-2.Dynamic Range in Dark and Illuminated Rooms

Effect of ambient lighting on dynamic range is calculated by multiplying the measured LCD screen reflectivity times the ambient illumination measured at the LCD screen in foot candles added to the minimum screen luminance, Lmin.

Ambient Illumination	Contrast Ratio	Dynamic Range		Ambient Illumination	Contrast Ratio	Dynamic Range	
0 fc (Dark Room)	393	25.9	dB	11 fc	61	17.8	dB
1 fc	261	24.2	dB	12 fc	56	17.5	dB
2 fc	196	22.9	dB	13 fc	53	17.2	dB
3 fc	157	21.9	dB	14 fc	49	16.9	dB
4 fc	131	21.2	dB	15 fc	47	16.7	dB
5 fc	112	20.5	dB	16 fc	44	16.4	dB
6 fc	98	19.9	dB	17 fc	42	16.2	dB
7 fc	87	19.4	dB	18 fc	40	16.0	dB
8 fc	79	19.0	dB	19 fc	38	15.8	dB
9 fc	72	18.5	dB	20 fc	36	15.6	dB
10 fc	66	18.2	dB	21 fc	35	15.4	dB

II.2. Maximum White Luminance (Lmax)

References: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.2, p 6.

The highest luminance for Lmax was 39.4fL measured at screen center in 1920 x 1200 x 60Hz format for analog addressing.   Lmax was 55 fL for the digitally-addressed 1920 x 1200 x 52 Hz format, and cannot be user-adjusted with the front panel contrast control.

Objective: Measure the maximum output display luminance.

Equipment: Photometer

Procedure: See dynamic range. Use the value of Lmax defined for the Dynamic Range measurement.

Data: The maximum output display luminance, Lmax, and associated CIE x, y chromaticity coordinates (CIE 1976) were measured using a hand-held spectroradiometer (Photo Research PR-650). The correlated color temperature (CCT) computed from the measured CIE x, y chromaticity coordinates was slightly outside the range specified by IEC (6500K and 9300K).

Table II.2-1. Maximum Luminance and Color

Color and luminance (in fL) for Full screen at 100% Lmax taken at screen center.

Format	CCT	CIE x	CIE y	Luminance
1920 x 1200	6107 K	0.318	0.355	39.4 fL

II.3. Uniformity of White Luminance (Lmax) and Color

Reference: CRT Color Monitor Performance, Draft Version 2.0, Section 4.4, p. 28.
VESA FPDM Version 2.0, Section 306-1, p 118.

Maximum white luminance (Lmax) sampled at 9 points on the screen varied by up to 23.4% across the screen, within the 30% absolute maximum threshold for IEC. Chromaticity variations were less than 0.002 delta u'v' units meeting the IEC specification.

Because of the periodic nature of the back light, additional measurements were made at 240 points to determine the variation more completely.   These measurements showed greater variability in luminance and chromaticity coordinates than did the 9 point measurements. Luminance (Lmax) sampled at 240 points (20 x 12 grid) varied across the screen by up to 30.3%. Chromaticity coordinates varied by up to 0.008 delta u'v' units.

Objective: Measure the variability of luminance and chromaticity coordinates of the white point at 100% Lmax only and as a function of spatial position. Variability of luminance impacts the total number of discriminable gray steps.

Equipment: • Video generator
                • Photometer
                • Spectroradiometer or Colorimeter

Test Pattern: Full screen flat field with visible edges at L_{min} as shown in Figure II.3-1.
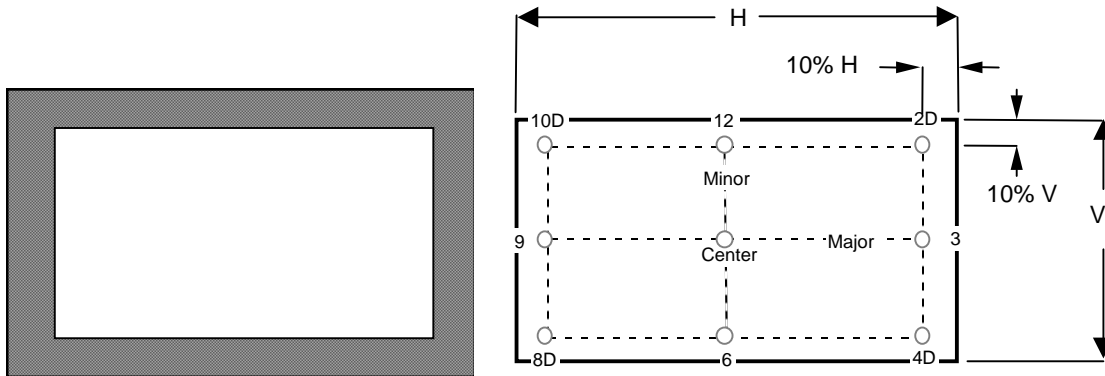
Full Screen Flat Field test pattern.
Figure II.3-1

Nine screen test locations.
Figure II.3-2

Procedure: Investigate the temporal variation of luminance and the white point as a function of intensity by displaying a full flat field shown in Figure II.3-1 for video input count levels corresponding L_{max}.   Measure the luminance and C.I.E. color coordinates at center screen.

Investigate the temporal variation of luminance and the white point as a function of spatial position by repeating these measurements at each of the locations depicted in Figure II.3-2. Define color uniformity in terms of delta u´v´.

Data: Tabulate the luminance and 1931 C.I.E. chromaticity coordinates (x, y) or correlated color temperature of the white point at each of the nine locations depicted in Figure II.3-2. Additionally, note the location of any additional points that are measured along with the corresponding luminance values.

Table II.3-1.   9-point Sampled Spatial Uniformity of Luminance and Color
Color and luminance (in fL) for Full screen at 100% Lmax taken at nine screen positions.

1920 x 1200

POSITION	CCT	CIE x	CIE y	L, fL
center	6111	0.318	0.354	39.3
2	6254	0.315	0.352	31.6
3	6111	0.318	0.354	37.8
4	6163	0.317	0.352	32.1
6	6111	0.318	0.354	31.0
8	6159	0.317	0.353	31.0
9	6111	0.318	0.354	36.1
10	6204	0.316	0.353	30.1
12	6163	0.317	0.352	31.3

```
10       12       2
                       Key to clock
9     CENTER    3     positions used
                       in the tables
8        6       4
```

1920 x 1200

Full screen at 100% Lmax

Luminance [fL] vs. Left, Center, Right — Top, Center, Bottom

Full screen at 100% Lmax

Delta u'v' vs. Left, Center, Right — Top, Center, Bottom
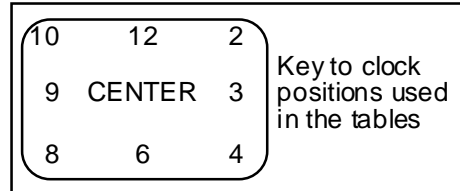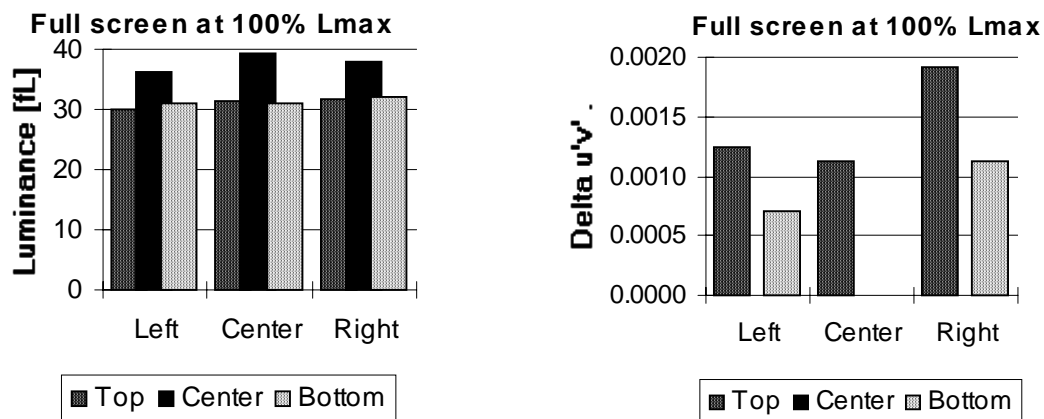
Fig.II.3-3. 9-Point (3 x 3 grid) Sampled Spatial Uniformity of Luminance and Chromaticity. (Delta u'v' of 0.004 is just visible.)

Left Half of Screen.   **Right Half of Screen**
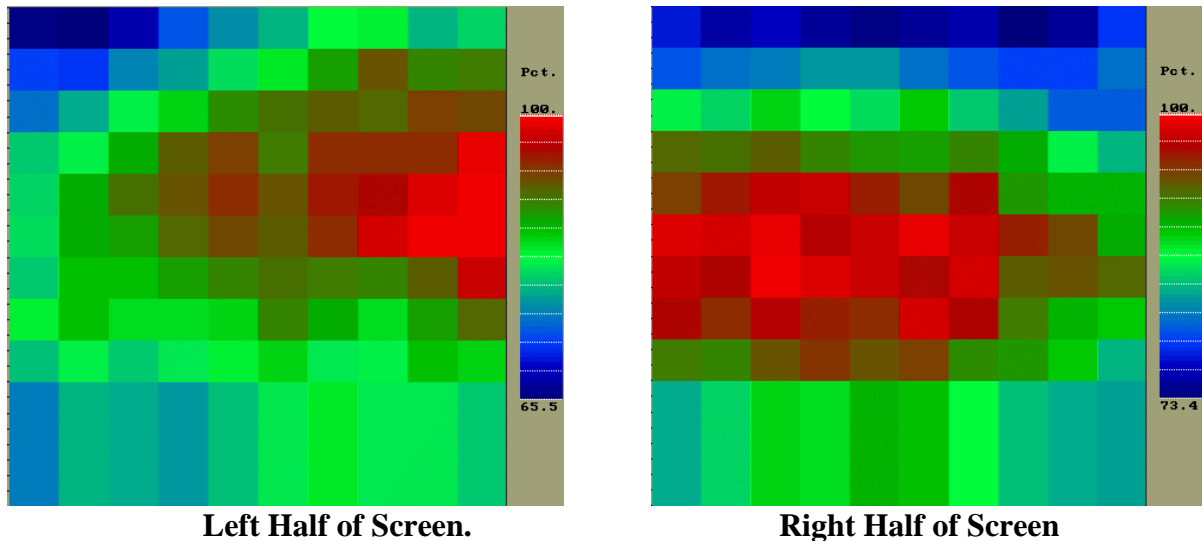
Figure.II.3-4. 240-Point (20 x 12 grid) Sampled Spatial Uniformity of Luminance of White at Lmax. (Left and right halves of the screen were measured separately due to limited length of x-y translation stage.) Luminance varied across the screen by up to 24.0% on the left side and up to 30.3% on the right side. Chromaticity coordinates varied by up to 0.008 delta u'v'.

II.4. Halation

Reference: CRT Color Monitor Performance, Draft Version 2.0 Section 4.6, page 48.

> *Halation was 0.13% on a small black patch surrounded by a large full white area and is nearly 30 times lower than the IEC specification for the maximum value.*

Objective: Measure the contribution of halation to contrast degradation. Halation is a phenomenon in which the luminance of a given region of the screen is increased by contributions from surrounding areas caused by light scattering within the phosphor layer and internal reflections inside the glass faceplate.   The mechanisms that give rise to halation, and its detailed non-monotonic dependence on the distance along the screen between the source of illumination and the region being measured have been described by E. B. Gindele and S.L. Shaffer.   The measurements specified below determine the percentage of light that is piped into the dark areas as a function of the extent of the surrounding light areas.

Equipment: •   Photometer
                          •   Video generator

Test Pattern:

Figure II.4-1 *Test pattern for measuring halation.*

Procedure: Note: The halation measurements require changing the setting of the BRIGHTNESS control and will perturb the values of L_{max} and L_{min} that are established during the initial monitor set-up. The halation measurements should therefore be made either first, before the monitor setup, or last, after all other photometric measurements have been completed.
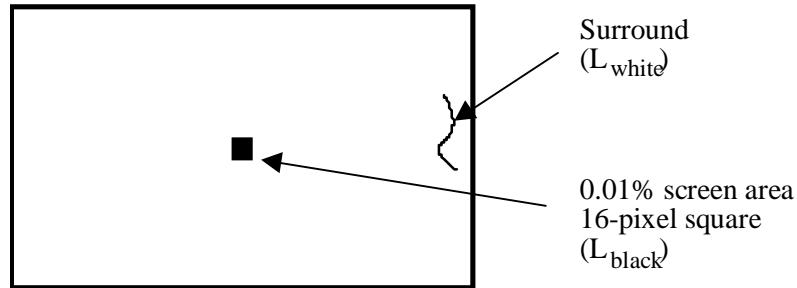
Determine halation by measuring the luminance of a small square displayed at L_{black} (essentially zero) and at L_{white} when surrounded by a much larger square displayed at L_{white} (approximately 75% L_{max}).

Establish L_{black} by setting the display to cutoff. To set the display to cut-off, display a flat field using video input count level zero, and use a photometer to monitor the luminance at center screen. Vary the BRIGHTNESS control until the CRT beam is visually cut off, and confirm that the corresponding luminance (L_{stray}) is essentially equal to zero. Fine tune the BRIGHTNESS control such that the CRT beam is just on the verge of being cut off. These measurements should be made with a photometer, which is sensitive at low light levels (below L_{min} of the display). Make no further adjustments or changes to the BRIGHTNESS control or the photometer measurement field.

Next, decrease the video input level to display a measured full-screen luminance of 75% L_{max} measured at screen center. Record this luminance (L_{white}).

The test target used in the halation measurements is a black (L_{black}) square patch of width equal to 0.01% of the area of addressable screen, the interior square as shown in Figure II.4-1. The interior square patch is enclosed in a white (L_{white}) background encompassing the remaining area of the image. The exterior surround will be displayed at 75% L_{max} using the input count level for L_{white} as determined above. The interior square will be displayed at input digital count level zero.

Care must be taken during the luminance measurement to ensure that the photometer's measurement field is less than one-half the size of the interior square and is accurately positioned not to extend beyond the boundary of the interior square. The photometer should be checked for light scattering or lens flare effects which allow light from the surround to enter the photosensor. A black card with aperture equal to the measurement field (one-half the size of the interior black

square) may be used to shield the photometer from the white exterior square while making measurements in the interior black square.

Analysis: Compute the percent halation for each test target configuration. Percent halation is defined as:

$$\% \text{ Halation } = L_{black} / (L_{white} - L_{black}) \times 100$$

Where, L_{black} = measured luminance of interior square displayed at L_{black} using input count level zero,

L_{white} = measured luminance of interior square displayed at L_{white} using input count level determined to produce a full screen luminance of 75% L_{max} .

Data: Table II.4-1 contains measured values of L_{black}, L_{white} and percentage halation.

Table II.4-1 Halation for 1920 x 1200 Addressability
Lmin was not set to cutoff. Instead, Lmin is subtracted from Lblack and Lwhite for calculating the halation.

	Reported Values
Lmin	0.106 fL
Lblack + Lmin	0.1557 fL
Lblack - Lmin	0.50 fL
Lwhite	37.45 fL
Lwhite - Lmin	37.34 fL
Halation	**0.13%**

II.5. Color Temperature

Reference: CRT Color Monitor Performance, Draft Version 2.0 Section 5.4, page 22.

With analog addressing, correlated color temperature (CCT) values within 0.010 delta u'v' units (the IEC limit) from the CIE Daylight Locus could be achieved at 35 fL, exceeding the minimum required Lmax value (30 fL). At the highest Lmax value, 39 fL, the CCT failed to meet the IEC specification. Therefore, NIDL recommends operation of the monitor between 30 and 35 fL so that CCT will be within 6500 to 9300K for analog addressing. Digital addressing produced an Lmax of 55 fL, but the CCT of the whitepoint (5745 K) failed to meet the IEC specification of 6500K to 9300K.

Objective: Insure measured screen white of a color monitor has a correlated color temperature (CCT) between 6500K and 9300K.

Equipment: Colorimeter

Procedure: Command screen to Lmax. Measure u'v' chromaticity coordinates (CIE 1976).

Data: Coordinates of screen white should be within 0.01 Δu'v' of the corresponding CIE
                daylight, which is defined as follows: If the measured screen white has a CCT
                between 6500 and 9300 K, the corresponding daylight has the same CCT as the
                screen white. If the measured CCT is greater than 9300 K, the corresponding
                daylight is D93. If the measured CCT is less than 6500 K, the corresponding
                daylight is D65. The following equations were used to compute Δu'v' values
                listed in table II.5.1:

                1. Compute the correlated color temperature (CCT) associated with (x,y) by the
                   VESA/McCamy formula: $CCT = 437 \, n^3 + 3601 \, n^2 + 6831 \, n + 5517$,
                   where $n = (x-0.3320)/(0.1858 - y)$. [This is on p. 227 of the FPDM standard]

                2. If CCT < 6500, replace CCT by 6500. If CCT > 9300, replace CCT by 9300.

                4. Use formulas 5(3.3.4) and 6(3.3.4) in Wyszecki and Stiles (pp.145-146 second
                   edition) to compute the point (xd,yd) associated with CCT.
                   • First, define u = 1000/CCT.
                   • If CCT < 7000, then $xd = -4.6070 \, u^3 + 2.9678 \, u^2 + 0.09911 \, u +$
                   • 0.244063.
                   • If CCT > 7000, then $xd = -2.0064 \, u^3 + 1.9018 \, u^2 + 0.24748 \, u +$
                   • 0.237040.
                   • In either case, $yd = -3.000 \, xd^2 + 2.870 \, xd - 0.275$.

                5. Convert (x,y) and (xd,yd) to u'v' coordinates:
                   • (u',v') = (4x,9y)/(3 + 12y - 2x)
                   • (u'd,v'd) = (4xd,9yd)/(3 + 12yd - 2xd)

                6. Evaluate delta-u'v' between (u,v) and (ud,vd):
                   • delta-u'v' = $sqrt[(u' - u'd)^2 + (v' - v'd)^2]$.

                7. If delta-u'v' is greater than 0.01, display fails the test. Otherwise it passes the
                    test.

Correlated Color Temperature and Daylight Locus

Error bars denote delta u'v' = 0.010
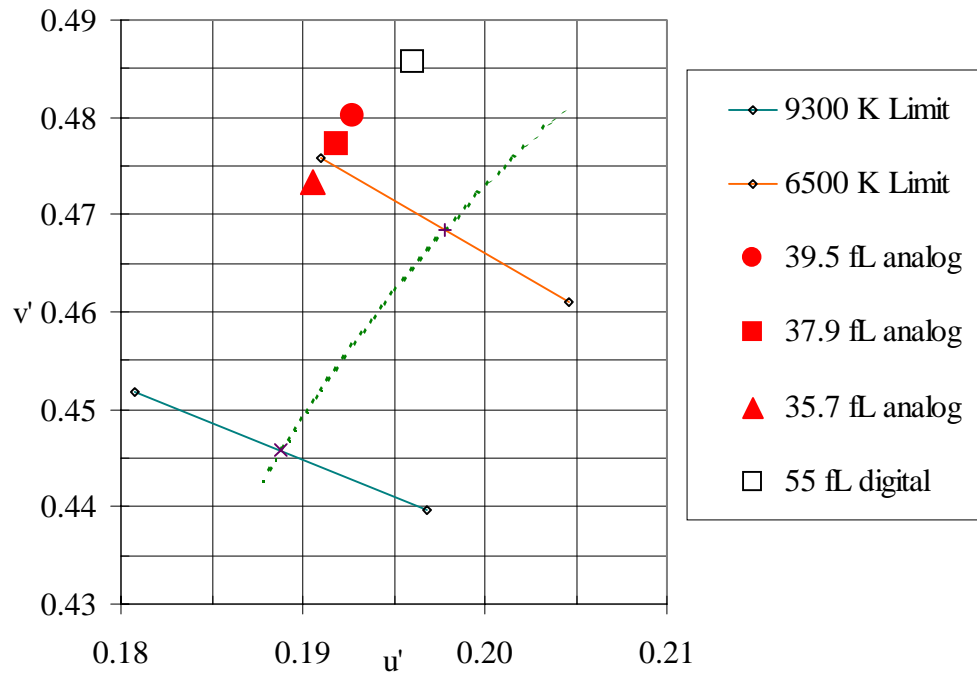
Figure II.5-1 *CCT of measured white points for analog and digital addressed luminance values 35.7 fL to 55 fL shown relative to the Daylight Locus.*

Table II.5-1 Δu'v' Distances between measured white point and CIE coordinate values from D_{65} to D_{93}.

	Analog Addressing			Digital Addressing
	39.3 fL (Level 255)	37.9 fL (Level 255)	35.7 fL (Level 255)	55 fL (Level 255)
CIE x	0.317	0.313	0.308	0.326
CIE y	0.351	0.346	0.340	0.359
CIE u'	0.193	0.192	0.191	0.196
CIE v'	0.480	0.477	0.473	0.486
CCT	6167	6379	6669	5745
delta u'v' from Daylight Locus	**0.013**	**0.011**	**0.009**	**0.017**

II.6. Bit Depth

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.6, p 6.

> *Monotonic increases in luminance were measured for each of the 256 input levels for 8 bits of gray scale for both analog and digital addressing. Neither black level clipping nor white level saturation was observed. Thus, this monitor has an excellent tonal transfer curve with substantially between 1 to 4 JNDs between each luminance step.*

Objective: Measure the number of bits of data that can be displayed as a function of the DAC and display software.

Equipment: Photometer

Test targets: Targets are four inch patches with command levels of all commandable levels; e.g., 256 for 8 bit display. Background is commanded to $0.5* ((0.7 *P)+0.3*n)$ where P = patch command level, n = number of command levels.

Procedure: Measure patch center for all patches with Lmin and Lmax as defined previously. Count number of monotonically increasing luminance levels. Use the NEMA/DICOM to define discriminable luminance differences. For color displays, measure white values.

Data: Define bit depth by $\log_2$ (number of discrete luminance levels)

The number of bits of data that can be displayed as a function of the input signal voltage level were verified through measurements of the luminance of white test targets displayed using a Quantum Data 8701 test pattern generator and a Minolta CA-100 colorimeter. Targets are n four-inch patches with command levels of all commandable levels; e.g., 256 for 8 bit display. Background is commanded to $0.5* ((0.7 *P)+0.3*n)$ where P = patch command level, n = number of command levels.   The NEMA/DICOM was used to define discriminable luminance differences in JNDs.

Figure II.6-1 shows the System Tonal Transfer curve at center screen as a function of input counts. Figure II.6-2 shows the perceptible differences between gray levels according to the NEMA/DICOM JND metric. The data for each of the 256 levels are listed in Tables II.6-1 and II.6-2. As a result of input from a member of the American Association of Physicists in Medicine Task Group 18 (AAPM TG#18), differences between adjacent gray levels are reported in tenths of JND units rather than whole JNDs.

Analog Addressing

Tonal Transfer Curve

Gray Level Step Sizes
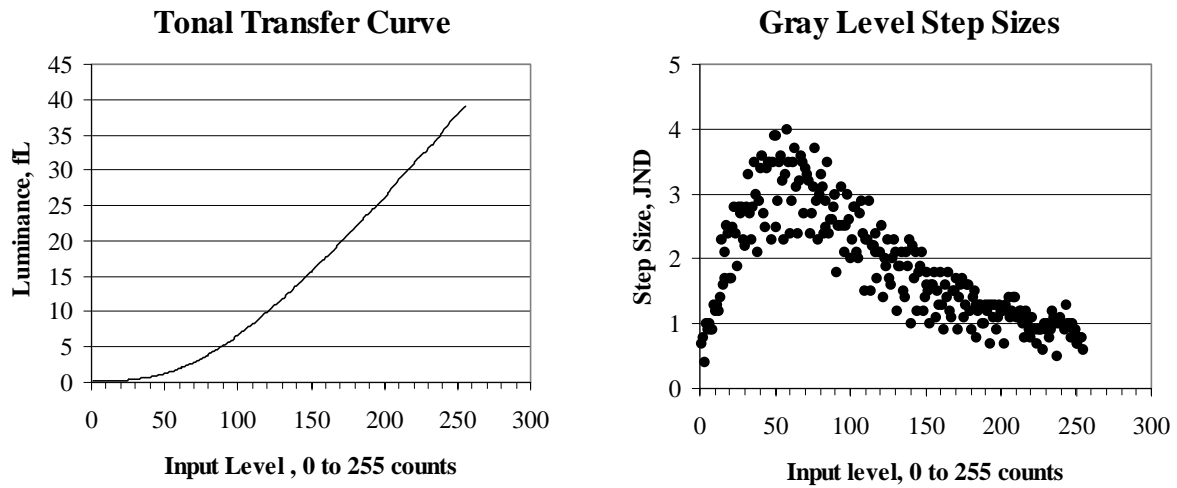
Figure II.6-1. System tonal transfer and perceptibility of gray level steps at center screen as a function of input counts for analog addressing in 1920 x 1200 x 60 Hz format.

Digital Addressing

Tonal Transfer Curve

Gray Level Step Sizes
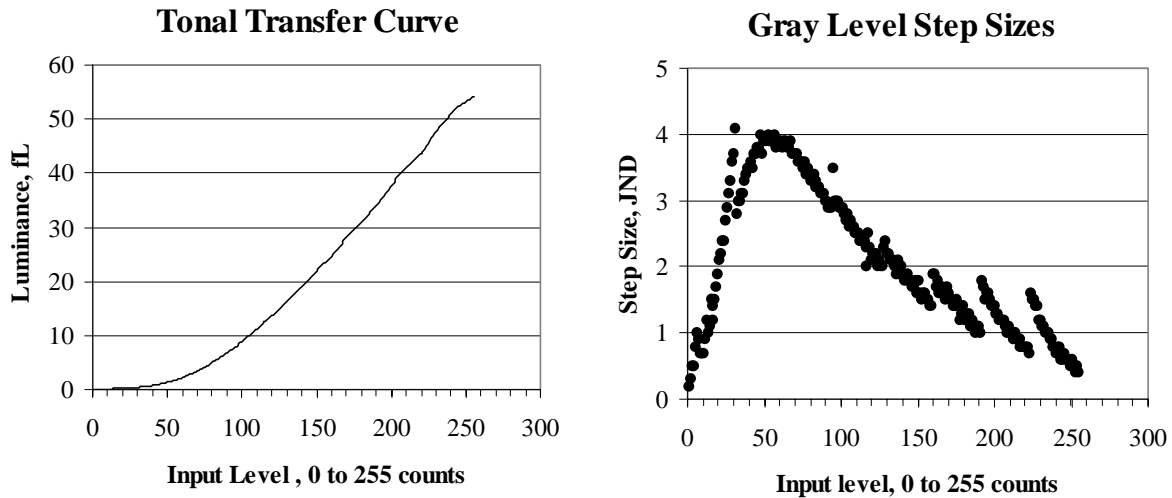
Figure II.6-2. System tonal transfer and perceptibility of gray level steps at center screen as a function of input counts for digital addressing in 1920 x 1200 x 52 Hz format. The periodic variation in luminance step sizes is not considered to significantly impact the analysts' ability to perform their tasks.

Digital Addressing

Partial Tonal Transfer Curve using Microsoft Powerpoint

— Meas. #1, Powerpoint, 26Nov2001
◆ Meas #2, Powerpoint, 26Nov2001

Partial Tonal Transfer Curve using PC Paintbrush Bitmaps

◇ Meas. #3, PC Paintbrush, 27Nov2001
■ Meas. #4, Powerpoint, 27Nov2001
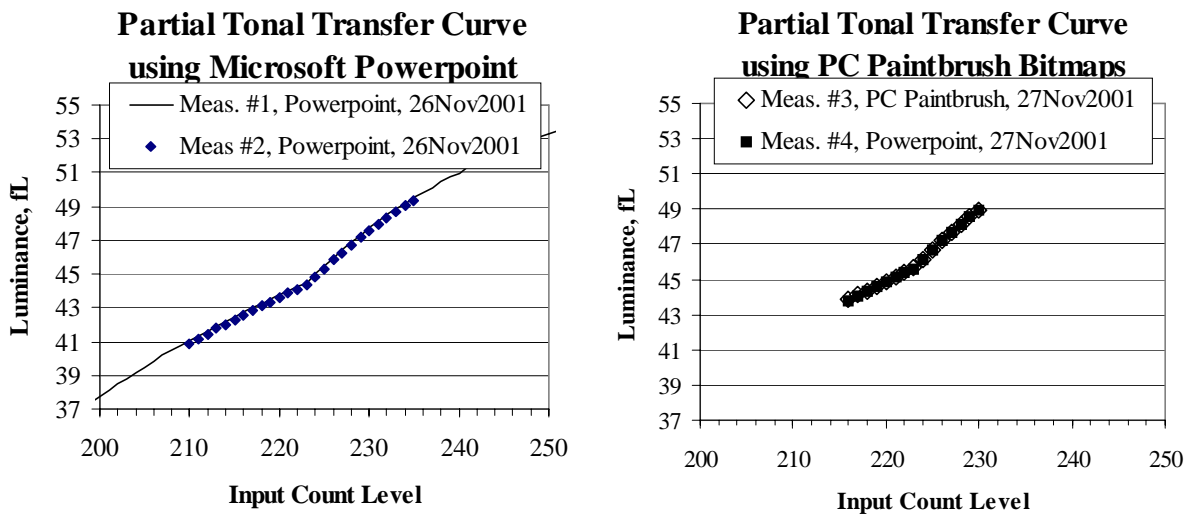
Figure II.6-3. Partial system tonal transfer curves of gray level steps at center screen as a function of input counts for digital addressing in 1920 x 1200 x 52 Hz format using Microsoft Powerpoint Slides compared to bitmap images displayed using PC Paintbrush. The kink near input count level 223 persists for both imaging software applications, so this artifact is likely a characteristic of either the Elsa Synergy III DVI graphics card or the Samsung 240T LCD monitor.

Table II.6-1. System Tonal Transfer at center screen for analog input counts 000 to 127.

Background	Target	L, fL	Diff, fL	Diff, JND	Background	Target	L, fL	Diff, fL	Diff, JND
38	0	0.111	0	0.0	61	64	2.281	0.083	3.1
39	1	0.114	0.003	0.7	61	65	2.348	0.067	2.4
39	2	0.117	0.003	0.8	62	66	2.441	0.093	3.2
39	3	0.119	0.002	0.4	62	67	2.547	0.106	3.6
40	4	0.123	0.004	1.0	62	68	2.654	0.107	3.5
40	5	0.127	0.004	0.9	63	69	2.738	0.084	2.7
41	6	0.131	0.004	1.0	63	70	2.847	0.109	3.4
41	7	0.135	0.004	0.9	63	71	2.954	0.107	3.3
41	8	0.139	0.004	0.9	64	72	3.065	0.111	3.2
42	9	0.145	0.006	1.3	64	73	3.146	0.081	2.4
42	10	0.151	0.006	1.2	64	74	3.243	0.097	2.7
42	11	0.157	0.006	1.3	65	75	3.353	0.11	3.1
43	12	0.163	0.006	1.2	65	76	3.494	0.141	3.7
43	13	0.17	0.007	1.4	65	77	3.603	0.109	2.9
43	14	0.182	0.012	2.3	66	78	3.694	0.091	2.3
44	15	0.191	0.009	1.6	66	79	3.812	0.118	3.0
44	16	0.2	0.009	1.7	66	80	3.947	0.135	3.3
44	17	0.212	0.012	2.1	67	81	4.079	0.132	3.1
45	18	0.227	0.015	2.5	67	82	4.182	0.103	2.4
45	19	0.242	0.015	2.4	67	83	4.293	0.111	2.5
45	20	0.253	0.011	1.7	68	84	4.419	0.126	2.9
46	21	0.264	0.011	1.7	68	85	4.582	0.163	3.5
46	22	0.281	0.017	2.5	69	86	4.693	0.111	2.4
46	23	0.301	0.02	2.8	69	87	4.819	0.126	2.6
47	24	0.319	0.018	2.4	69	88	4.946	0.127	2.6
47	25	0.333	0.014	1.9	70	89	5.084	0.138	2.8
48	26	0.355	0.022	2.8	70	90	5.236	0.152	3.0
48	27	0.377	0.022	2.7	70	91	5.332	0.096	1.8
48	28	0.401	0.024	2.8	71	92	5.464	0.132	2.5
49	29	0.421	0.02	2.3	71	93	5.598	0.134	2.5
49	30	0.441	0.02	2.2	71	94	5.77	0.172	3.1
49	31	0.467	0.026	2.8	72	95	5.91	0.14	2.5
50	32	0.499	0.032	3.3	72	96	6.03	0.12	2.1
50	33	0.526	0.027	2.7	72	97	6.176	0.146	2.5
50	34	0.55	0.024	2.3	73	98	6.354	0.178	3.0
51	35	0.581	0.031	2.8	73	99	6.511	0.157	2.6
51	36	0.62	0.039	3.5	73	100	6.631	0.12	2.0
51	37	0.654	0.034	3.0	74	101	6.777	0.146	2.3
52	38	0.68	0.026	2.1	74	102	6.952	0.175	2.8
52	39	0.715	0.035	2.9	74	103	7.136	0.184	2.8
52	40	0.759	0.044	3.4	75	104	7.276	0.14	2.1
53	41	0.806	0.047	3.6	75	105	7.413	0.137	2.0
53	42	0.843	0.037	2.7	76	106	7.597	0.184	2.7
53	43	0.879	0.036	2.5	76	107	7.799	0.202	2.9
54	44	0.929	0.05	3.4	76	108	7.968	0.169	2.4
54	45	0.981	0.052	3.5	77	109	8.076	0.108	1.5
55	46	1.036	0.055	3.5	77	110	8.248	0.172	2.3
55	47	1.073	0.037	2.3	77	111	8.423	0.175	2.3
55	48	1.132	0.059	3.5	78	112	8.639	0.216	2.9
56	49	1.199	0.067	3.9	78	113	8.753	0.114	1.5
56	50	1.269	0.07	3.9	78	114	8.931	0.178	2.2
56	51	1.317	0.048	2.5	79	115	9.103	0.172	2.2
57	52	1.372	0.055	2.9	79	116	9.299	0.196	2.4
57	53	1.441	0.069	3.5	79	117	9.468	0.169	2.1
57	54	1.514	0.073	3.6	80	118	9.608	0.14	1.7
58	55	1.582	0.068	3.2	80	119	9.786	0.178	2.1
58	56	1.63	0.048	2.3	80	120	9.967	0.181	2.1
58	57	1.703	0.073	3.3	81	121	10.19	0.223	2.5
59	58	1.795	0.092	4.0	81	122	10.31	0.12	1.4
59	59	1.878	0.083	3.5	81	123	10.49	0.18	2.0
59	60	1.936	0.058	2.4	82	124	10.66	0.17	1.9
60	61	2.008	0.072	2.9	82	125	10.87	0.21	2.3
60	62	2.099	0.091	3.5	83	126	11.03	0.16	1.7
60	63	2.198	0.099	3.7	83	127	11.18	0.15	1.6

Table II.6-2. System Tonal Transfer at center screen for analog input counts 128 to 255.

Background	Target	L, fL	Diff, fL	Diff, JND	Background	Target	L, fL	Diff, fL	Diff, JND
83	128	11.38	0.2	2.0	106	192	24.48	0.23	1.3
84	129	11.6	0.22	2.3	106	193	24.62	0.14	0.7
84	130	11.81	0.21	2.1	106	194	24.86	0.24	1.3
84	131	11.93	0.12	1.2	107	195	25.07	0.21	1.1
85	132	12.12	0.19	1.9	107	196	25.32	0.25	1.3
85	133	12.31	0.19	1.9	107	197	25.48	0.16	0.9
85	134	12.53	0.22	2.1	108	198	25.7	0.22	1.1
86	135	12.69	0.16	1.5	108	199	25.96	0.26	1.3
86	136	12.84	0.15	1.4	108	200	26.2	0.24	1.2
86	137	13.06	0.22	2.1	109	201	26.43	0.23	1.2
87	138	13.27	0.21	1.9	109	202	26.58	0.15	0.7
87	139	13.52	0.25	2.3	109	203	26.84	0.26	1.3
87	140	13.64	0.12	1.0	110	204	27.08	0.24	1.2
88	141	13.88	0.24	2.2	110	205	27.36	0.28	1.4
88	142	14.08	0.2	1.7	111	206	27.58	0.22	1.1
88	143	14.32	0.24	2.1	111	207	27.84	0.26	1.2
89	144	14.47	0.15	1.2	111	208	28.14	0.3	1.4
89	145	14.68	0.21	1.8	112	209	28.42	0.28	1.4
90	146	14.91	0.23	1.9	112	210	28.67	0.25	1.1
90	147	15.16	0.25	2.1	112	211	28.89	0.22	1.1
90	148	15.31	0.15	1.2	113	212	29.15	0.26	1.2
91	149	15.48	0.17	1.4	113	213	29.42	0.27	1.2
91	150	15.69	0.21	1.6	113	214	29.65	0.23	1.0
91	151	15.91	0.22	1.8	114	215	29.83	0.18	0.8
92	152	16.11	0.2	1.5	114	216	30.06	0.23	1.1
92	153	16.24	0.13	1.0	114	217	30.33	0.27	1.2
92	154	16.45	0.21	1.6	115	218	30.57	0.24	1.0
93	155	16.66	0.21	1.6	115	219	30.76	0.19	0.9
93	156	16.9	0.24	1.8	115	220	30.94	0.18	0.8
93	157	17.05	0.15	1.1	116	221	31.2	0.26	1.1
94	158	17.25	0.2	1.5	116	222	31.42	0.22	0.9
94	159	17.44	0.19	1.3	116	223	31.63	0.21	0.9
94	160	17.68	0.24	1.8	117	224	31.79	0.16	0.7
95	161	17.87	0.19	1.3	117	225	31.99	0.2	0.9
95	162	18	0.13	0.9	118	226	32.22	0.23	0.9
95	163	18.22	0.22	1.6	118	227	32.43	0.21	0.9
96	164	18.43	0.21	1.4	118	228	32.57	0.14	0.6
96	165	18.69	0.26	1.8	119	229	32.81	0.24	1.0
97	166	18.87	0.18	1.2	119	230	33.04	0.23	0.9
97	167	19.03	0.16	1.1	119	231	33.27	0.23	1.0
97	168	19.25	0.22	1.5	120	232	33.48	0.21	0.8
98	169	19.48	0.23	1.5	120	233	33.68	0.2	0.9
98	170	19.74	0.26	1.7	120	234	34	0.32	1.2
98	171	19.88	0.14	0.9	121	235	34.26	0.26	1.1
99	172	20.11	0.23	1.4	121	236	34.51	0.25	1.0
99	173	20.35	0.24	1.6	121	237	34.64	0.13	0.5
99	174	20.62	0.27	1.7	122	238	34.91	0.27	1.0
100	175	20.81	0.19	1.1	122	239	35.18	0.27	1.1
100	176	21.02	0.21	1.3	122	240	35.43	0.25	1.0
100	177	21.28	0.26	1.6	123	241	35.7	0.27	1.0
101	178	21.54	0.26	1.6	123	242	35.94	0.24	0.9
101	179	21.74	0.2	1.2	123	243	36.28	0.34	1.3
101	180	21.9	0.16	0.9	124	244	36.54	0.26	1.0
102	181	22.13	0.23	1.4	124	245	36.81	0.27	1.0
102	182	22.38	0.25	1.5	125	246	37.04	0.23	0.8
102	183	22.61	0.23	1.3	125	247	37.3	0.26	1.0
103	184	22.75	0.14	0.8	125	248	37.54	0.24	0.9
103	185	22.97	0.22	1.2	126	249	37.78	0.24	0.9
104	186	23.2	0.23	1.3	126	250	37.97	0.19	0.7
104	187	23.43	0.23	1.3	126	251	38.18	0.21	0.7
104	188	23.61	0.18	1.0	127	252	38.41	0.23	0.8
105	189	23.78	0.17	1.0	127	253	38.62	0.21	0.8
105	190	24.03	0.25	1.3	127	254	38.85	0.23	0.8
105	191	24.25	0.22	1.2	128	255	39.01	0.16	0.6

Table II.6-3. System Tonal Transfer at center screen for digital input counts 000 to 127.

Background	Target	L, fL	Diff, fL	Diff, JND	Background	Target	L, fL	Diff, fL	Diff, JND
38	0	0.104	0	0.0	61	64	2.689	0.118	3.9
39	1	0.105	0.001	0.2	61	65	2.812	0.123	3.8
39	2	0.106	0.001	0.3	62	66	2.936	0.124	3.8
39	3	0.108	0.002	0.5	62	67	3.068	0.132	3.9
40	4	0.11	0.002	0.5	62	68	3.196	0.128	3.7
40	5	0.113	0.003	0.8	63	69	3.33	0.134	3.7
41	6	0.117	0.004	1.0	63	70	3.467	0.137	3.7
41	7	0.121	0.004	0.9	63	71	3.607	0.14	3.7
41	8	0.124	0.003	0.7	64	72	3.751	0.144	3.6
42	9	0.127	0.003	0.7	64	73	3.896	0.145	3.6
42	10	0.13	0.003	0.7	64	74	4.045	0.149	3.6
42	11	0.134	0.004	0.9	65	75	4.197	0.152	3.5
43	12	0.139	0.005	1.2	65	76	4.352	0.155	3.6
43	13	0.144	0.005	1.0	65	77	4.509	0.157	3.4
43	14	0.149	0.005	1.1	66	78	4.67	0.161	3.5
44	15	0.156	0.007	1.5	66	79	4.833	0.163	3.4
44	16	0.162	0.006	1.2	66	80	4.994	0.161	3.3
44	17	0.169	0.007	1.4	67	81	5.161	0.167	3.3
45	18	0.177	0.008	1.5	67	82	5.335	0.174	3.4
45	19	0.186	0.009	1.7	67	83	5.51	0.175	3.3
45	20	0.196	0.01	1.9	68	84	5.685	0.175	3.2
46	21	0.208	0.012	2.1	68	85	5.864	0.179	3.2
46	22	0.221	0.013	2.2	69	86	6.044	0.18	3.2
46	23	0.236	0.015	2.4	69	87	6.226	0.182	3.1
47	24	0.251	0.015	2.4	69	88	6.409	0.183	3.1
47	25	0.269	0.018	2.7	70	89	6.599	0.19	3.1
48	26	0.289	0.02	2.9	70	90	6.786	0.187	3.0
48	27	0.311	0.022	3.1	70	91	6.979	0.193	3.0
48	28	0.336	0.025	3.3	71	92	7.171	0.192	2.9
49	29	0.365	0.029	3.6	71	93	7.367	0.196	2.9
49	30	0.396	0.031	3.7	71	94	7.565	0.198	2.9
49	31	0.432	0.036	4.1	72	95	7.807	0.242	3.5
50	32	0.458	0.026	2.8	72	96	8.018	0.211	3.0
50	33	0.486	0.028	3.0	72	97	8.239	0.221	3.0
50	34	0.516	0.03	3.0	73	98	8.464	0.225	3.0
51	35	0.548	0.032	3.1	73	99	8.689	0.225	2.9
51	36	0.582	0.034	3.1	73	100	8.914	0.225	2.9
51	37	0.619	0.037	3.3	74	101	9.147	0.233	2.9
52	38	0.658	0.039	3.4	74	102	9.369	0.222	2.8
52	39	0.7	0.042	3.5	74	103	9.598	0.229	2.7
52	40	0.744	0.044	3.5	75	104	9.829	0.231	2.8
53	41	0.791	0.047	3.6	75	105	10.06	0.231	2.6
53	42	0.84	0.049	3.5	76	106	10.29	0.23	2.7
53	43	0.892	0.052	3.7	76	107	10.53	0.24	2.6
54	44	0.947	0.055	3.7	76	108	10.76	0.23	2.6
54	45	1.005	0.058	3.8	77	109	11	0.24	2.5
55	46	1.065	0.06	3.8	77	110	11.23	0.23	2.5
55	47	1.132	0.067	4.0	77	111	11.47	0.24	2.5
55	48	1.196	0.064	3.7	78	112	11.71	0.24	2.4
56	49	1.266	0.07	3.9	78	113	11.95	0.24	2.4
56	50	1.339	0.073	3.9	78	114	12.19	0.24	2.4
56	51	1.415	0.076	3.9	79	115	12.44	0.25	2.4
57	52	1.493	0.078	3.9	79	116	12.68	0.24	2.3
57	53	1.576	0.083	4.0	79	117	12.89	0.21	2.0
57	54	1.661	0.085	3.9	80	118	13.16	0.27	2.5
58	55	1.75	0.089	3.9	80	119	13.41	0.25	2.3
58	56	1.841	0.091	3.9	80	120	13.65	0.24	2.1
58	57	1.936	0.095	4.0	81	121	13.9	0.25	2.2
59	58	2.033	0.097	3.8	81	122	14.15	0.25	2.2
59	59	2.134	0.101	3.9	81	123	14.4	0.25	2.2
59	60	2.237	0.103	3.9	82	124	14.64	0.24	2.0
60	61	2.345	0.108	3.9	82	125	14.89	0.25	2.1
60	62	2.456	0.111	3.8	83	126	15.14	0.25	2.0
60	63	2.571	0.115	3.9	83	127	15.39	0.25	2.0

Table II.6-4. System Tonal Transfer at center screen for digital input counts 128 to 255.

Background	Target	L, fL	Diff, fL	Diff, JND	Background	Target	L, fL	Diff, fL	Diff, JND
83	128	15.68	0.29	2.3	106	192	34.56	0.44	1.8
84	129	15.98	0.3	2.4	106	193	34.99	0.43	1.7
84	130	16.27	0.29	2.2	106	194	35.4	0.41	1.5
84	131	16.55	0.28	2.2	107	195	35.81	0.41	1.6
85	132	16.84	0.29	2.1	107	196	36.22	0.41	1.6
85	133	17.12	0.28	2.1	107	197	36.63	0.41	1.5
85	134	17.41	0.29	2.1	108	198	37.01	0.38	1.4
86	135	17.68	0.27	2.0	108	199	37.39	0.38	1.4
86	136	17.96	0.28	1.9	108	200	37.77	0.38	1.4
86	137	18.25	0.29	2.1	109	201	38.12	0.35	1.3
87	138	18.53	0.28	1.9	109	202	38.47	0.35	1.3
87	139	18.82	0.29	2.0	109	203	38.82	0.35	1.2
87	140	19.1	0.28	1.9	110	204	39.17	0.35	1.2
88	141	19.38	0.28	1.8	110	205	39.49	0.32	1.2
88	142	19.66	0.28	1.8	111	206	39.84	0.35	1.2
88	143	19.95	0.29	1.9	111	207	40.16	0.32	1.1
89	144	20.23	0.28	1.8	111	208	40.45	0.29	1.0
89	145	20.51	0.28	1.8	112	209	40.77	0.32	1.1
90	146	20.78	0.27	1.7	112	210	41.07	0.3	1.0
90	147	21.07	0.29	1.7	112	211	41.36	0.29	1.0
90	148	21.35	0.28	1.8	113	212	41.65	0.29	0.9
91	149	21.63	0.28	1.6	113	213	41.94	0.29	1.0
91	150	21.9	0.27	1.6	113	214	42.2	0.26	0.9
91	151	22.2	0.3	1.8	114	215	42.5	0.3	0.9
92	152	22.47	0.27	1.6	114	216	42.76	0.26	0.9
92	153	22.74	0.27	1.5	114	217	43.02	0.26	0.8
92	154	23.02	0.28	1.6	115	218	43.25	0.23	0.8
93	155	23.29	0.27	1.6	115	219	43.51	0.26	0.8
93	156	23.56	0.27	1.5	115	220	43.75	0.24	0.8
93	157	23.83	0.27	1.5	116	221	44.01	0.26	0.8
94	158	24.09	0.26	1.4	116	222	44.25	0.24	0.8
94	159	24.36	0.27	1.4	116	223	44.48	0.23	0.7
94	160	24.7	0.34	1.9	117	224	45.01	0.53	1.6
95	161	25.06	0.36	1.9	117	225	45.5	0.49	1.5
95	162	25.4	0.34	1.7	118	226	45.97	0.47	1.5
95	163	25.75	0.35	1.8	118	227	46.45	0.48	1.4
96	164	26.06	0.31	1.6	118	228	46.9	0.45	1.4
96	165	26.39	0.33	1.7	119	229	47.31	0.41	1.2
97	166	26.73	0.34	1.7	119	230	47.72	0.41	1.2
97	167	27.05	0.32	1.6	119	231	48.1	0.38	1.1
97	168	27.37	0.32	1.5	120	232	48.48	0.38	1.1
98	169	27.72	0.35	1.7	120	233	48.83	0.35	1.0
98	170	28.04	0.32	1.6	120	234	49.18	0.35	1.0
98	171	28.37	0.33	1.5	121	235	49.5	0.32	1.0
99	172	28.68	0.31	1.5	121	236	49.83	0.33	0.9
99	173	28.99	0.31	1.4	121	237	50.14	0.31	0.9
99	174	29.3	0.31	1.4	122	238	50.43	0.29	0.8
100	175	29.62	0.32	1.5	122	239	50.73	0.3	0.8
100	176	29.92	0.3	1.4	122	240	50.99	0.26	0.7
100	177	30.21	0.29	1.2	123	241	51.28	0.29	0.8
101	178	30.5	0.29	1.3	123	242	51.54	0.26	0.8
101	179	30.82	0.32	1.4	123	243	51.78	0.24	0.6
101	180	31.08	0.26	1.2	124	244	52.01	0.23	0.6
102	181	31.38	0.3	1.3	124	245	52.26	0.25	0.7
102	182	31.67	0.29	1.2	125	246	52.48	0.22	0.6
102	183	31.96	0.29	1.2	125	247	52.71	0.23	0.6
103	184	32.25	0.29	1.3	125	248	52.92	0.21	0.6
103	185	32.51	0.26	1.1	126	249	53.12	0.2	0.5
104	186	32.81	0.3	1.2	126	250	53.32	0.2	0.6
104	187	33.07	0.26	1.1	126	251	53.53	0.21	0.5
104	188	33.33	0.26	1.0	127	252	53.7	0.17	0.5
105	189	33.59	0.26	1.1	127	253	53.88	0.18	0.4
105	190	33.86	0.27	1.1	127	254	54.04	0.16	0.5
105	191	34.12	0.26	1.0	128	255	54.23	0.19	0.4

II.8. Luminance Step Response

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.8, p 7.

When the Samsung 240T LCD monitor was driven in 1920 x 1200 format using analog input signals, a phantom low-luminance subpixel was observed at trailing object edges, vertical lines and even single pixels. This artifact was not observed for digital (DVI) addressabilities and was not observed for analog addressabilities 1280 x 1024 pixels or less.

Objective: Determine the presence of artifacts caused by undershoot or overshoot.

Equipment: Test targets, SMPTE Test Pattern RP-133-1991, 2-D CCD array

Procedure: Display a center box 15% of screen size at input count levels corresponding to 25%, 50%, 75%, and 100% of Lmax with a surround of count level 0. Repeat using SMPTE Test pattern
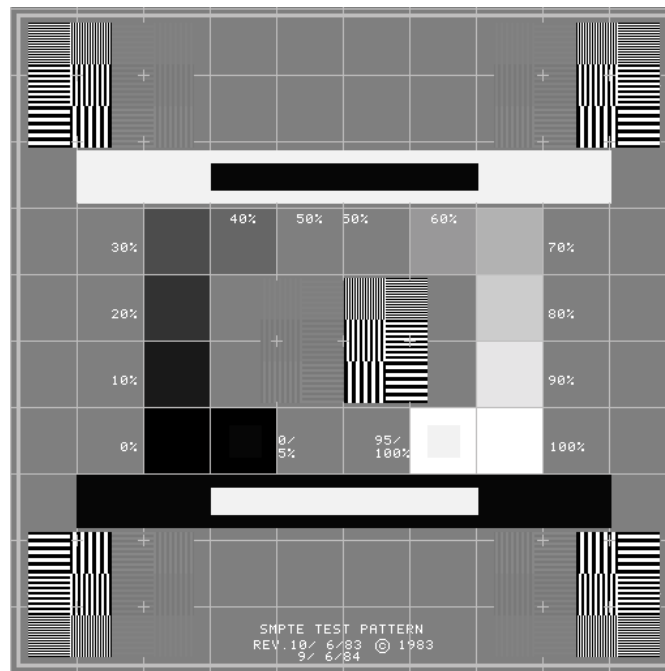
Figure II.8-1. SMPTE Test Pattern.

Data: Define pass by absence of noticeable ringing, undershoot, overshoot, or streaking.

The test pattern shown in Figure II.8-1 was used in the visual evaluation of the monitor. This test pattern is defined in SMPTE Recommended Practice RP-133-1986 published by the Society of Motion Picture and Television Engineers (SMPTE) for medical imaging applications. Referring to the large white-in-black and black-in-white horizontal bars contained in the test pattern, RP133-1986, paragraph 2.7 states " These areas of maximum contrast facilitate detection of

mid-band streaking (poor low-frequency response), video amplifier ringing or overshoot, deflection interference, and halo."

When the Samsung 240T LCD monitor was driven in 1920 x 1200 format using analog input signals, a phantom low-luminance subpixel illustrated in Figure II.8-2 was observed at trailing object edges, vertical lines and even single pixels. This artifact did not occur for the digital (DVI) input signal operation, nor did this artifact occur for lower-resolution analog formats (1280 x 1024 or less). This artifact was also observed on the Samsung 210T 21-inch LCD monitor when driven in analog mode at 1600 x 1200 pixels.

Horizontal Spot Profile

Spot Contour from CCD Camera

Vertical Spot Profile
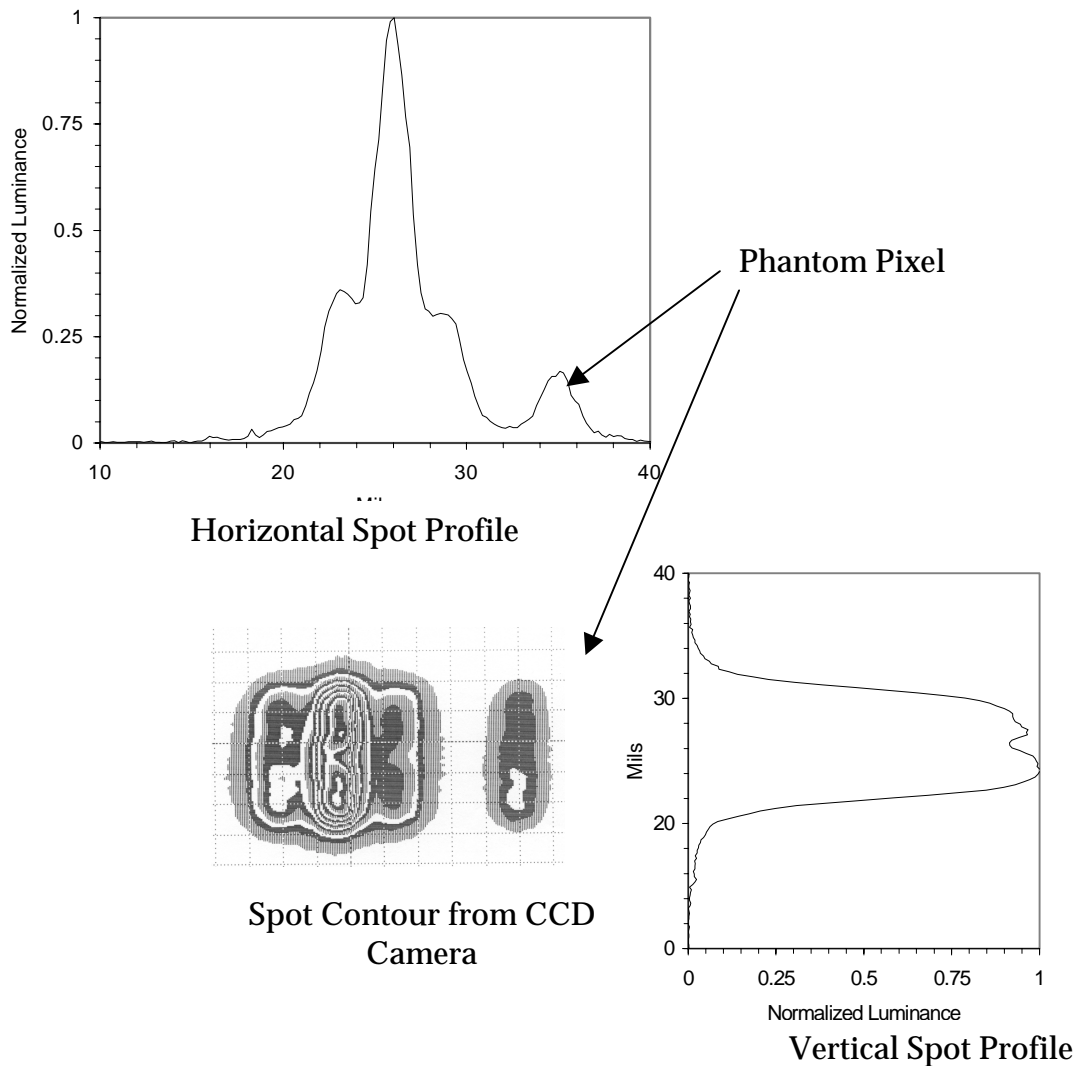
Figure II.8-2. Phantom low-luminance subpixel observed at trailing object edges, vertical lines and even single pixels on the Samsung 210T and 240T LCD monitors in 1200-line analog modes.

Samsung, the monitor manufacturer, was not surprised by our reporting of the appearance of the phantom pixel, but offered the following suggestion: utilize digital addressing at a reduced vertical refresh rate to comply with the maximum 165 MHz pixel rate limitation of the DVI digital input signal.   NIDL demonstrated this approach on the 240T LCD monitor and successfully eliminated the phantom pixel even at the full 1920 x 1200 native resolution of the 240T.

II.9. Addressability

Reference: CRT Color Monitor Performance, Draft Version 2.0, Section 6.1, page 67.

This monitor properly displayed all addressed pixels for the 1920 H x 1200 V analog and digital formats.   NIDL tested this format as Lockheed Martin stated that the 24 inch Sony CRT monitor in the IEC IA workstation uses this addressability.

Objective: Define the number of addressable pixels in the horizontal and vertical
                dimension; confirm that stated number of pixels is displayed.

Equipment: Programmable video signal generator.
                Test pattern with pixels lit on first and last addressable rows and columns
                and on two diagonal lines beginning at upper left and lower right; H & V
                grill patterns 1-on/1-off.

Procedure: The number of addressed pixels were programmed into the Quantum Data
                8701 test pattern generator for 73 Hz minimum for monoscopic mode and
                120 Hz minimum for stereoscopic mode, where possible. All perimeter
                lines were confirmed to be visible, with no irregular jaggies on diagonals
                and, for monochrome monitors, no strongly visible Moiré on grilles.

Data: If tests passed, number of pixels in horizontal and vertical dimension. If
                test fails, addressability unknown.

Table II.9-1. Results of Analog Signal Inputs

Creator3D Graphics Card and Sun Microsystems Ultra 60 Unix Workstation	Matrox Millenium G450 Graphics Card and 366 MHz Pentium PC with Windows 2000
Formats that display well for both the 240T and on the 210T:	
	1600x1200x60, 1600x1200x65, 1600x1200x70
1280x1024x60, 1280x1024x76	1280x1024x60, 1280x1024x75
1152x900x66, 1152x900x76	1152x864x60, 1152x864x75
1024x768x60, 1024x768x77	1024x768x60, 1024x768x85
640x480x60	800x600x56, 800x600x85
	640x480x60, 640x480x85
Formats that display well for the 240T but not for the 210T:	
1920x1080x72, 1920x1080x76	1920x1200x60
Formats that do not display properly on either the 240T or the 210T:	
1920x1200x70, 1920x1200x75	1920x1200x65
1600x1280x76	
1600x1000x66, 1600x1000x76	1600x1024x60, 1600x1024x76
1440x900x76	
1280x1024x67, 1280x1024x85	
1280x800x76	
1024x800x84	
640x480x60i	
Available formats not tested:	
960x680x108s, 960x680x112s	
768x575x50i	

Table II.9-2. Results of Digital Signal Inputs using the Elsa Synergy III Graphics Card

Elsa Synergy III Graphics Card and Pentium PC with Windows 98
Formats that display well in "normal" one-to-one pixel mapping mode on the 240T:
1920 x 1200 x 51.8 Hz
1600 x 1200
1280 x 1024, 1280 x 960
1024 x 768
800 x 600
640 x 480
Formats that display well for the 240T in "expanded" mode only (note that we are not recommending use of "expanded" modes because of the reduced resolution caused by pixel aliasing):
1600 x 1024, 1600 x 900
1360 x 768
1280 x768, 1280 x 720
1152 x 864
848 x 480
Formats that do not display properly on the 240T in any mode:
1920 x 1080

II.10.   Pixel Aspect Ratio

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.10, p 8.

Pixel aspect ratio is 1:1 for an addressability of 1920 x 1200 pixels and passes the IEC specification.

Objective: Characterize aspect ratio of pixels.

Equipment: Test target, measuring tape with at least 1/16th inch increments

Procedure: Display box of 400 x 400 pixels at input count corresponding to 50% Lmax and background of 0. Measure horizontal and vertical dimension.

Alternatively, divide number of addressable pixels by the total image size to obtain nominal pixel spacings in horizontal and vertical directions.

Data: Define pass if H= V± 6% for pixel density <100 ppi and ± 10% for pixel density > 100 ppi.

Table II.11-1. Pixel Aspect Ratio
Monoscopic Mode

	1920 x 1200 Full Screen
H x V Image Size (inches)	20.4 x 12.724
H x V Pixel Spacing (mils)	10.625 x 10.603
H x V Pixel Aspect Ratio	H = V + 0.2%

II.11.   Screen Size (Viewable Active Image)

Reference: VESA Flat Panel Display Measurements Standard, Version 1.0, May 15, 1998, Section 501-1.

Image size as tested in monoscopic mode (1920 x 1200) was 24.043 inches in diagonal.

Objective: Measure beam position on the CRT/LCD display to quantify width and height of active image size visible by the user (excludes any overscanned portion of an image).

Equipment: • Video generator
• Spatially calibrated CCD or photodiode array optic module
• Calibrated X-Y translation stage

Test Pattern: Use the three-line grille patterns in Figure II.11-1 for vertical and horizontal lines each 1-pixel wide. Lines in test pattern are displayed at

100% L_{max} must be positioned along the top, bottom, and side edges of the addressable screen, as well as along both the vertical and horizontal centerlines (major and minor axes).
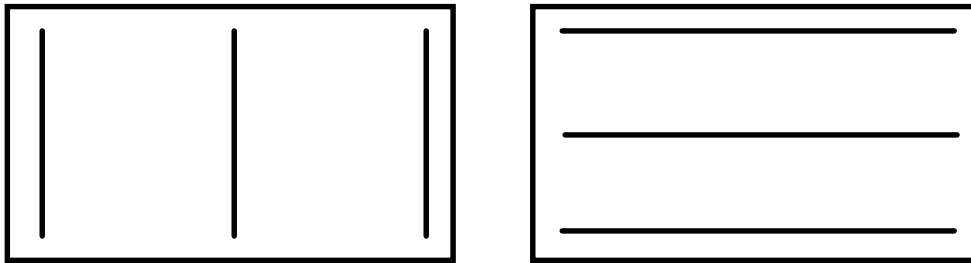
1-pixel-wide lines displayed at 100% L_{max}
Figure II.11-1 Three-line grille test patterns.

Procedure: Use diode optic module to locate center of line profiles in conjunction with calibrated X-Y translation to measure screen x, y coordinates of lines at the ends of the major and minor axes.

Data: Compute the image width defined as the average length of the horizontal lines along the top, bottom and major axis of the screen. Similarly, compute the image height defined as the average length of the vertical lines along the left side, right side, and minor axis of the screen. Compute the diagonal screen size as the square root of the sum of the squares of the width and height.

Table II.11-1. Image Size

	Monoscopic Mode
Addressability (H x V)	1920 x 1200
H x V Image Size (inches)	20.4 x 12.724
Diagonal Image Size (inches)	24.043

II.12.   Contrast Modulation

Reference: CRT Color Monitor Performance, Draft Version 2.0, Section 5.2, page 57.

Contrast modulation (Cm) for 1-on/1-off grille patterns displayed at 50% Lmax analog-addressed 1920 x 1200 format exceeded Cm = 77% in Zone A, and exceeded Cm = 75% in Zone B.   These values exceed the IEC specification for contrast modulation in Zones A and B.

In analog mode, a phantom low-luminance subpixel was observed in the luminance profile of vertical 1-pixel-ON/1-pixel-OFF grille patterns displayed at 1920 x 1200 pixel format. The artifact was not observed in analog addressing for 1280 x 1024 pixels or less. The artifact was not observed at all in digital addressing.

Objective: Quantify contrast modulation as a function of screen position.

Equipment: • Video generator
               • Spatially calibrated CCD or photodiode array optic module
               • Photometer with linearized response

Procedure: The maximum video modulation frequency for the 1024 x 1024 format
               was examined using horizontal and vertical grille test patterns consisting
               of alternating lines with 1 pixel on, 1 pixel off. Contrast modulation was
               measured in both horizontal and vertical directions at screen center and at
               eight peripheral screen positions. The measurements should be along the
               horizontal and vertical axes and along the diagonal from these axes. Use
               edge measurements no more than 10% of screen size in from border of
               active screen. The input signal level was set so that 1-line-on/1-line-off
               horizontal grille patterns produced a screen area-luminance of 25% of
               maximum level, Lmax.

               Zone A is defined as a 24 degree subtended circle from a viewing distance
               of 18 inches (7.6 inch circle). Zone B is the remainder of the display. Use
               edge measurements no more than 10% of screen size in from border of
               active screen area to define Cm for Zone B (remaining area outside center
               circle). Determine Cm at eight points on circumference of circle by
               interpolating between center and display edge measurements to define Cm
               for Zone A. If measurements exceed the threshold, do not make any more
               measurements. If one or more measurements fail the threshold, make eight
               additional measurements at the edge (but wholly within) the defined circle.

Data: Values of vertical and horizontal Cm for Zone A and Zone B are given in Table II.12-1. The contrast modulation, Cm, is reported (the defining equation is given below) for the 1-on/1-off grille patterns. The modulation greatly exceeds the IEC specification for equal to or greater than 25% in Zone A, and equal to or greater than 20% in Zone B.

$$C_m = \frac{L_{peak} - L_{valley}}{L_{peak} + L_{valley}}$$

Table II.12-1. Contrast Modulation
Corrected for lens flare and Zone Interpolation

Zone A = 7.6-inch diameter circle for 24-degree subtended angle at 18-inch viewing distance

	Left		Minor						Right	
	H-grille	V-grille	H-grille	V-grille	H-grille	V-grille	H-grille	V-grille	H-grille	V-grille
Top	89%	75%			88%	77%			91%	76%
			90%	77%	89%	78%	90%	78%		
Major	90%	77%	90%	78%	90%	79%	89%	79%	88%	80%
			91%	79%	87%	78%	89%	79%		
Bottom	94%	78%			86%	78%			88%	78%

Zone A = 11.5-inch diameter circle for 40% area

	Left		Minor						Right	
	H-grille	V-grille	H-grille	V-grille	H-grille	V-grille	H-grille	V-grille	H-grille	V-grille
Top	89%	75%			88%	77%			91%	76%
			89%	77%	88%	77%	90%	77%		
Major	90%	77%	90%	78%	90%	79%	89%	80%	88%	80%
			92%	78%	86%	78%	89%	78%		
Bottom	94%	78%			86%	78%			88%	78%

1280 x 1024 Digital
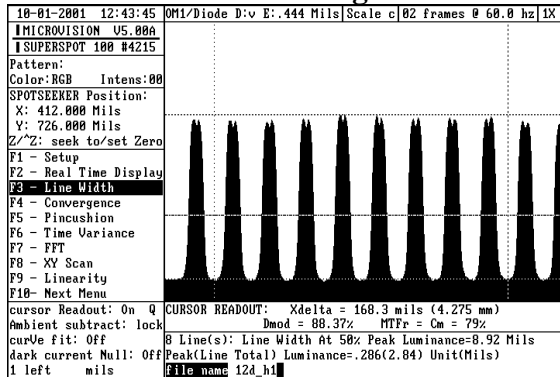
1-On/1-Off H-grille   1-On/1-Off V-grille
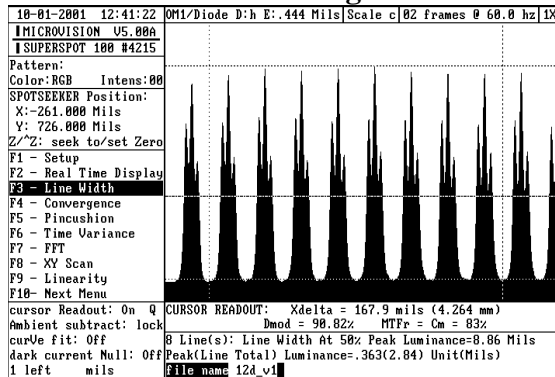
1280 x 1024 Analog
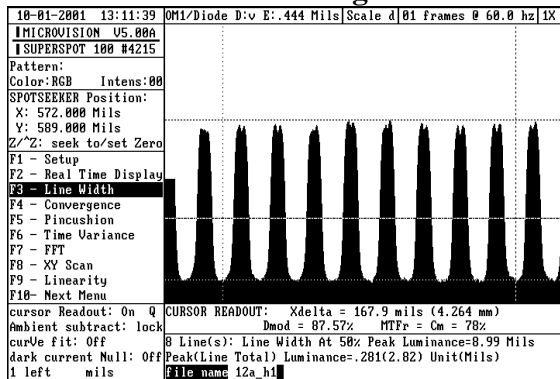
1-On/1-Off H-grille   1-On/1-Off V-grille
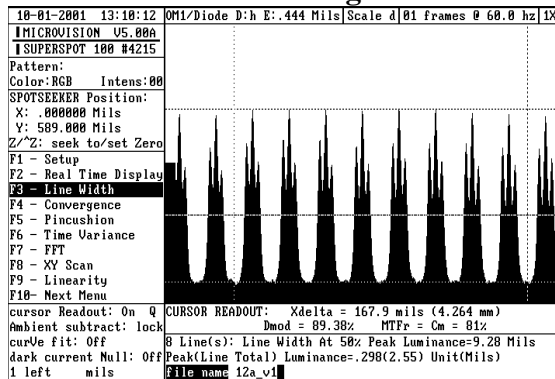
1920 x 1200 Analog

1-On/1-Off H-grille   1-On/1-Off V-grille
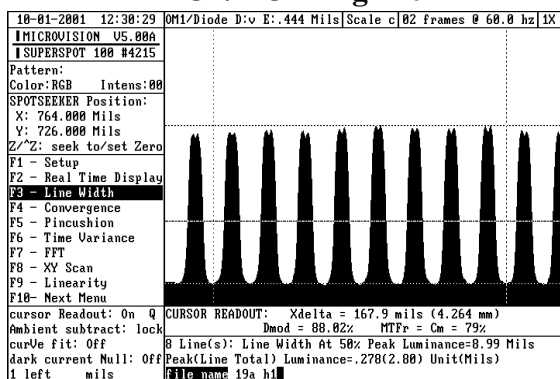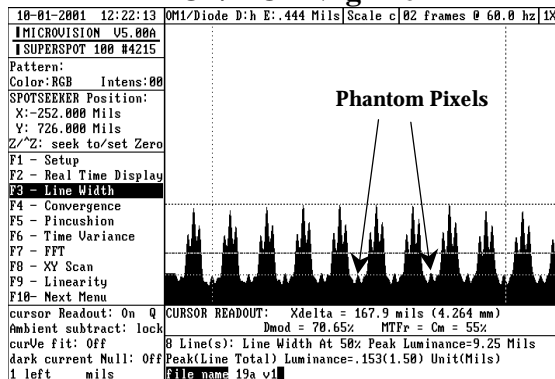
Phantom Pixels

Figure II.12-1. The 1280 x 1024 pixel format displayed nearly perfectly in both digital and analog modes. A phantom low-luminance subpixel was observed in the luminance profile corresponding to the OFF pixels indicated by arrows in the figure showing vertical 1-pixel-ON/1-pixel-OFF grille patterns displayed at 1920 x 1200 pixel format. This artifact effectively degrades contrast modulation for the analog input signals with 1200-line formats for which one-to-one pixel mapping between the input video signal and the actual pixels on the screen cannot be precisely achieved by this monitor.

II.13.   Pixel Density

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.13, p 9.

Pixel density was 94 H x 94 V pixels per inch (ppi) as tested for the 1920 x 1200-line format.

Objective: Characterize density of image pixels

Equipment: Measuring tape with at least 1/16 inch increments

Procedure: Measure H&V dimension of active image window and divide by vertical and horizontal addressability

Data: Define horizontal and vertical pixel density in terms of pixels per inch

Table II.13-1. Pixel-Density

	Monoscopic Mode
H x V Addressability, Pixels	1920 x 1200
H x V Image Size, Inches	20.4 x 12.724
H x V Pixel Density, ppi	94 x 94

II.15.   Straightness

The Samsung 240T LCD monitor is a pixelated flat panel display which is inherently straight and free of geometric distortions such as pincushion and nonlinearity normally associated with other display technologies such as raster-scanned CRT monitors and projectors.

II.16.   Refresh Rate

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.16, p 9.

In analog mode, vertical refresh rate for the 1920 x 1200 monoscopic format was set to 60 Hz limited by the display. In digital mode, vertical refresh rate for the 1920 x 1200 monoscopic format was set to 52 Hz limited by the DVI single-channel bandwidth. No flicker is observed for either of the 60 Hz or 52 Hz refresh rates for this LCD monitor.

Objective: Define vertical and horizontal refresh rates.

Equipment: Programmable video signal generator.

Procedure: The refresh rates were programmed into the Quantum Data 8701 test pattern generator for 72 Hz minimum for monoscopic mode and 120 Hz minimum for stereoscopic mode, where possible.

Data: Report refresh rates in Hz.

Table II.16-1 Refresh Rates as Tested

	Monoscopic Mode	
Addressability	1920 x 1200	
Addressing Mode	Analog	Digital
Vertical Scan	60 Hz	52 Hz

II.17.   Extinction Ratio

Extinction ratio measurement is not applicable because the Samsung 240T LCD monitor cannot be run in stereoscopic mode.

II.18.   Linearity

The Samsung 240T LCD is a pixelated flat panel display which is inherently straight and free of geometric distortions such as pincushion and nonlinearity normally associated with other display technologies such as raster-scanned CRT monitors and projectors.

II.19.   Jitter/Swim/Drift

Reference: CRT Color Monitor Performance, Draft Version 2.0 Section 6.4, p 80.

Maximum jitter, swim, and drift were less than 0.45 mils, 0.50 mils and 0.42 mils, respectively, smaller by factors of 5 or more than required by the IEC specification.

Objective: Measure amplitude and frequency of variations in beam spot position of the CRT display. Quantify the effects of perceptible time varying raster distortions: jitter, swim, and drift. The perceptibility of changes in the position of an image depend upon the amplitude and frequency of the motions which can be caused by imprecise control electronics or external magnetic fields.

Equipment: • Video generator
                • Spatially calibrated CCD or photodiode array optic module
                • Calibrated X-Y translation stage

Test Pattern: Use the three-line grille patterns in Figure II.19-1 for vertical and horizontal lines each 1-pixel wide. Lines in test pattern must be positioned along the top, bottom, and side edges of the addressable screen, as well as along both the vertical and horizontal centerlines (major and minor axes).
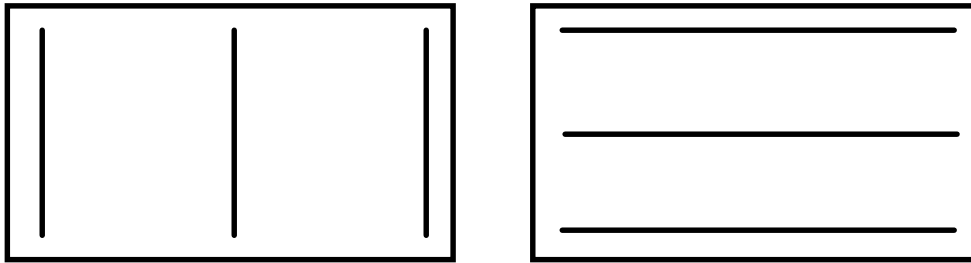
V-grille for measuring horizontal motion   H-grille for measuring vertical motion

1-pixel wide lines

Three-line grille test patterns.
Figure II.19-1

Procedure: With the monitor set up for intended scanning rates, measure vertical and horizontal line jitter (0.01 to 2 seconds), swim (2 to 60 seconds) and drift (over 60 seconds) over a 2.5 minute duration as displayed using grille video test patterns. Generate a histogram of raster variance with time. The measurement interval must be equal to a single field period.

Optionally, for multi-sync monitors measure jitter over the specified range of scanning rates. Some monitors running vertical scan rates other than AC line frequency may exhibit increased jitter.

Measure and report instrumentation motion by viewing Ronchi ruling or illuminated razor edge mounted to the top of the display. It may be necessary to mount both the optics and the monitor on a vibration damped surface to reduce vibrations.

Data: Tabulate motion as a function of time in x-direction at top-left corner screen location. Repeat for variance in y-direction. Tabulate maximum motions (in mils) with display input count level corresponding to L_{max} for jitter (0.01 to 2 seconds), swim (2 to 60 seconds) and drift (over 60 seconds) over a 2.5 minute duration. The data are presented in Table II.19-1. Both the monitor and the Microvision equipment sit on a vibration-damped aluminum-slab measurement bench.

Table II.19-1. Jitter/Swim/Drift
Maximum motions in mils.
Time scales: Jitter 2 sec., Swim 10 sec., and Drift 60 sec.
Signal Generator: Quantum Data FOX 8701

Screen Position		**H-lines**	**V-lines**
10D corner			
	Jitter	0.181	0.631
	Swim	0.201	0.697
	Drift	0.184	0.72
Black Tape			
	Jitter	0.192	0.186
	Swim	0.23	0.197
	Drift	0.388	0.301
Less Tape Motion			
	Jitter	-0.01	0.45
	Swim	-0.03	0.50
	Drift	-0.20	0.42

II.20. Warm-up Period

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.20, p. 10.

> *A 10-minute warm-up was necessary for luminance stability of Lmin = 0.1 fL +/- 10%. This is a factor of 6 shorter than required by the IEC specification.*

Objective: Define warm-up period

Equipment: Photometer, test target (full screen 0 count)

Procedure: Turn monitor off for three-hour period. Turn monitor on and measure center of screen luminance (Lmin as defined in Dynamic range measurement) at 1-minute intervals for first five minutes and five minute intervals thereafter. Discontinue when three successive measurements are ± 10% of Lmin.

Data: Pass if Lmin within ± 50% in 30 minutes and ±10% in 60 minutes.

The luminance of the screen (commanded to the minimum input level, 0 for Lmin) was monitored for 120 minutes after a cold start. Measurements were taken every minute. Figure II.20-1 shows the in graphical form. The black luminance remains very stable after 30 minutes.

Warm Up Characteristic for Lmin
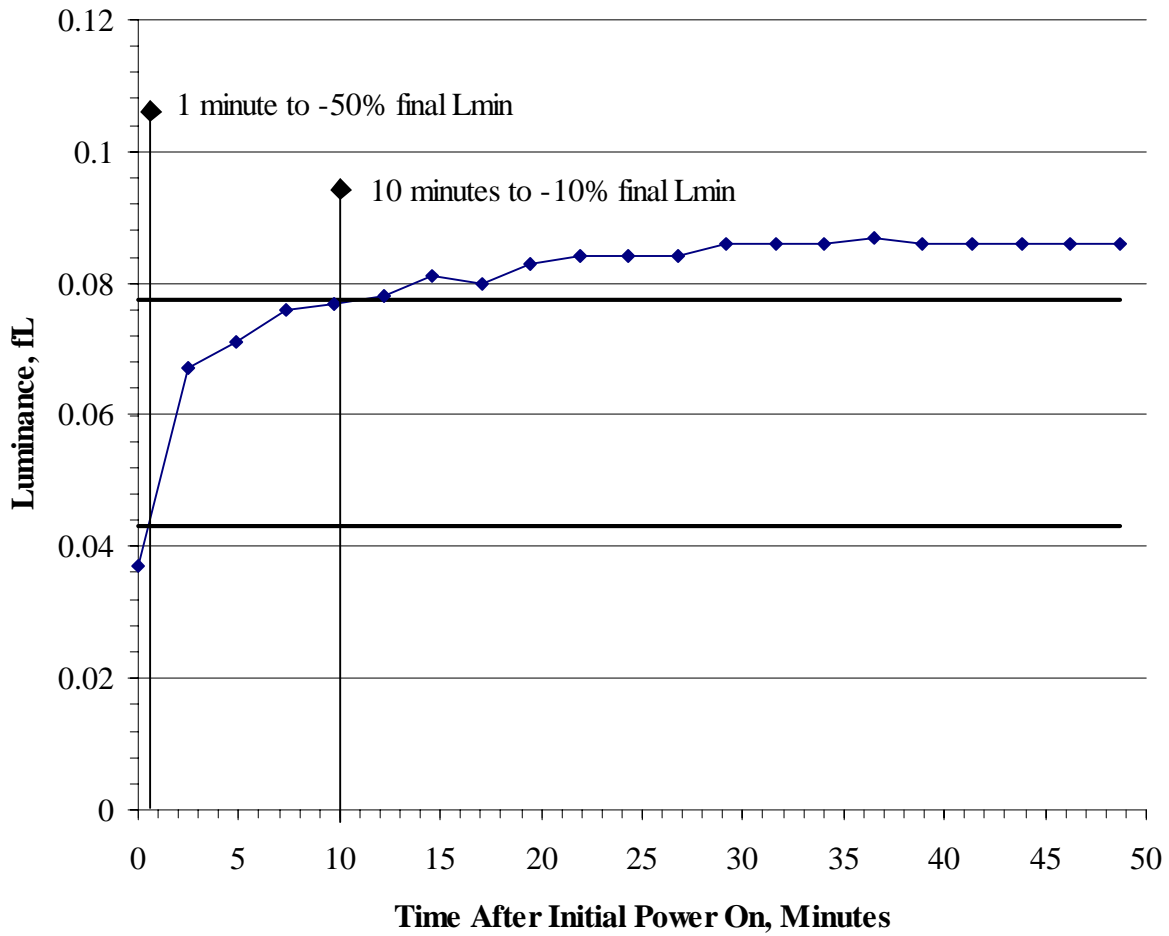
Figure II.20.1. Luminance (fL) as a function of time (in minutes) from a cold start with
an input count of 0.

II. 21. Briggs Scores

*Reference: SofTrak User's Guidelines and Reference Manual Version 3.0, NIDL, Sept.
          1994, page 3.*

Briggs BTP #4 test patterns were displayed on the Samsung 240T LCD monitor in both analog and digital formats.

- *The 1920 x 1200 format was displayed on the Samsung 240T LCD monitor in digital mode using a single DVI channel by reducing the blanking period to 10% and by reducing the refresh rate to only 52 Hz. The resulting Briggs scores averaged 16, 38, 59, and 71 for the Delta-1, Delta-3, Delta-7 and Delta-15 contrast ratio targets sets, respectively. These scores were the same as obtained for the 1280 x 1024 digital mode.*

- *The Samsung 240T LCD 1920 x 1200 analog format Briggs scores averaged 12, 34, 55, and 58 for the Delta-1, Delta-3, Delta-7 and Delta-15 contrast ratio targets sets, respectively. These scores were only slightly less than obtained for the Sony FW900 CRT monitor: 10, 40, 57, and 62 for Delta-1, Delta-3, Delta-7 and Delta-15, respectively.*

- *The 1280 x 1024 format was displayed on the Samsung 240T LCD monitor in both analog and digital modes. LCD analog mode Briggs scores averaged 11, 33, 55, and 71 for the Delta-1, Delta-3, Delta-7 and Delta-15 contrast ratio targets sets, respectively. These scores were slightly less than obtained for the 1280 x 1024 digital mode: 16, 38, 59, and 71 for Delta-1, Delta-3, Delta-7 and Delta-15, respectively.*

- *The Briggs scores for the analog-addressed LCD are not quite as good as for the Sony FW900 CRT monitor. The LCD Briggs scores for the digital-addressed LCD are marginally better than for the analog-addressed CRT monitor.*

The Briggs series of test targets were developed to visually evaluate the image quality of grayscale monitors. Three NIDL observers selected the maximum scores for each target set displayed on both the Samsung 240T color LCD and Sony FW900 color CRT monitors. The operating and environmental conditions were identical (a very low light level room) to ensure a level-playing-field comparison between the LCD and CRT monitors. In accordance with Briggs procedures, magnifying devices were used when deemed by the observer to be advantageous in achieving higher scores.

The Sony 24 inch CRT and the Samsung 24 inch LCD were both run at 1920 x 1080 addressability and driven in analog mode using a Sun Microsystems Ultra 60 workstation with Creator 3D graphics card.

The Samsung 24 inch LCD was also run at 1280 x 1024 addressability and driven digitally using a Quantum Data 802G programmable test pattern generator with DVI output for comparison with Briggs scores obtained using analog input signals. An Elsa Synergy III PC graphics card was used to display the full 1920 x 1200 native addressability at 52 Hz refresh using a single DVI channel. No flicker was observed at the 52 Hz refresh rate.

Briggs score results are summarized below in Table II.21-1. The Sony FW900 CRT analog Briggs scores are marginally better than for the analog-addressed Samsung 240T LCD monitor. The Briggs scores for the digital addressing are marginally better than for the analog addressing. Detailed results are presented in Tables II.21-2 through II.21-4 and shown graphically in Figures II.21.3 through II.21.5.

Table II.21-1. Summary of Average Briggs Scores

	Analog RGB			Digital DVI	
Video Source	Sun Microsystems Ultra 60 Creator 3D Graphics Card			Quantum Data 802G	Elsa Synergy III
Monitor	24-in. Color CRT Sony FW900	24-in. Color LCD Samsung 240T			
Pixel Format	1920 x 1080 x 60 Hz	1920 x 1080 x 60 Hz	1280 x 1024 x 60Hz	1280 x 1024 x 60Hz	1920 x 1200 x 52Hz
Briggs Target					
Delta-1	10	12	11	16	16
Delta-3	40	34	33	38	38
Delta-7	57	55	55	59	59
Delta-15	62	58	71	71	71
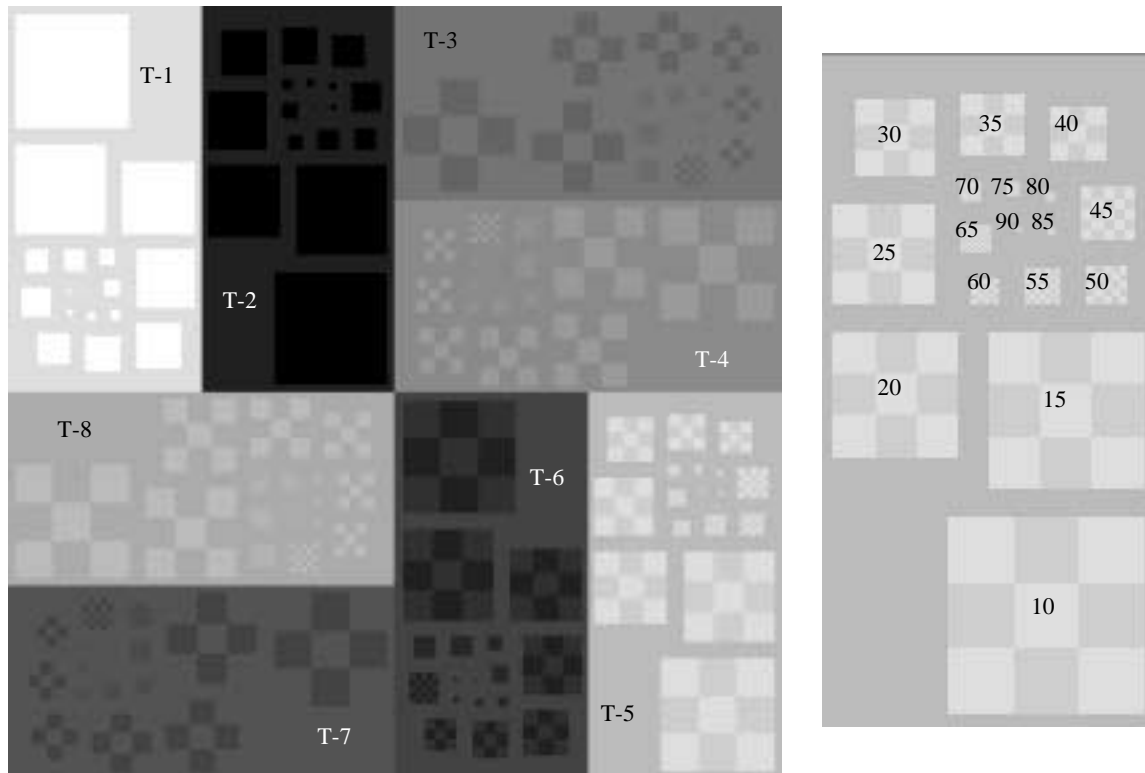
Figure II.21.1. Briggs BPT#4 Test Patterns comprised of 8 targets labeled T-1 through T-8. A series of 17 checkerboards is contained within each of the 8 targets. Each checkerboard is assigned a score value ranging from 10 to 90. Higher scores are assigned to smaller checkerboards.
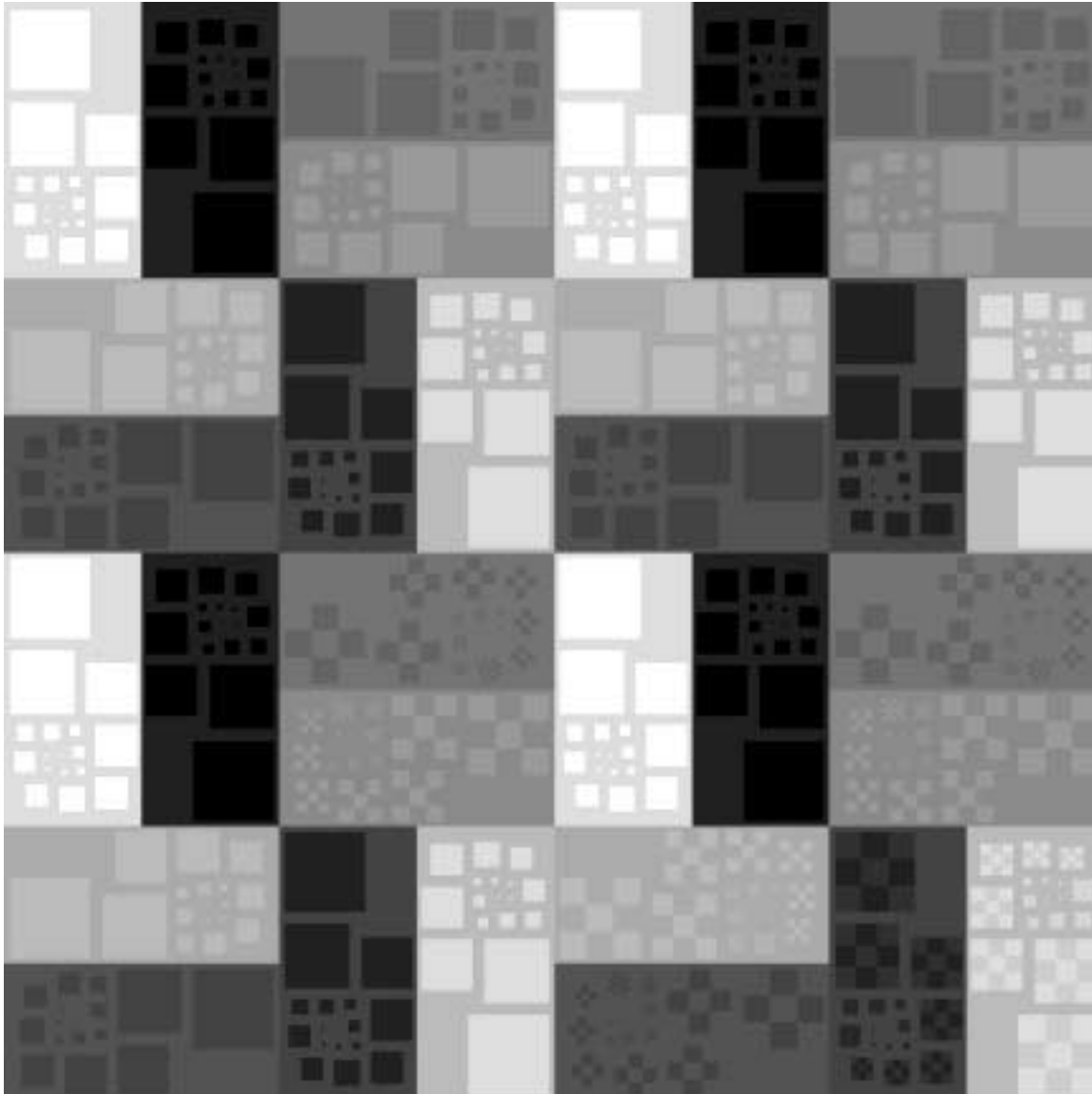
Figure II.21.2. 1024 x 1024 mosaic comprised of four 512 x 512 Briggs BPT#4 Test Patterns. The upper left quadrant contains the set of 8 Briggs targets with command contrast of delta 1. The upper right quadrant contains command contrast of delta 3. Delta 7 targets are in the lower left quadrant and delta 15 targets are in the lower right.

Table II.21-2. CRT and LCD Briggs Scores for 1920 x 1080 Analog Addressing
Using Sun MicroSystems Creator 3D Graphics

1920 x 1080 Analog Mode, Creator3D

Target	Sony FW900 24-in. CRT Monitor				Samsung 240T 24-in. LCD Monitor			
	Observer 1	Observer 2	Observer 3	Average	Observer 1	Observer 2	Observer 3	Average
Delta-1	Sony FW900 CRT, Creator 3D, average score = 10				Samsung 240T LCD, Creator 3D, average score = 12			
T-2 Dark	4	4	4	4	4	4	4	4
T-6	4	30	4	13	15	35	40	30
T-7	4	20	4	9	10	45	35	30
T-3	10	50	4	21	4	50	4	19
T-4	10	45	4	20	4	4	4	4
T-8	4	4	4	4	4	4	4	4
T-5	4	4	4	4	4	4	4	4
T-1 Bright	4	4	4	4	4	4	4	4
			Average	10			Average	12
Delta-3	Sony FW900 CRT, average score = 40				Samsung 240T LCD, average score = 34			
T-2 Dark	4	10	4	6	4	4	20	9
T-6	55	60	55	57	50	60	50	53
T-7	40	60	55	52	45	50	50	48
T-3	50	60	55	55	50	50	60	53
T-4	40	60	50	50	45	50	50	48
T-8	40	55	55	50	35	50	40	42
T-5	45	50	40	45	10	20	15	15
T-1 Bright	4	15	4	8	10	4	4	6
			Average	40			Average	34
Delta-7	Sony FW900 CRT, average score = 57				Samsung 240T LCD, average score = 55			
T-2 Dark	60	55	45	53	60	50	60	57
T-6	65	60	60	62	65	60	60	62
T-7	60	60	60	60	60	60	60	60
T-3	60	60	60	60	50	60	60	57
T-4	50	60	60	57	50	60	60	57
T-8	50	60	60	57	45	50	55	50
T-5	60	60	60	60	45	50	45	47
T-1 Bright	50	50	50	50	50	45	50	48
			Average	57			Average	55
Delta-15	Sony FW900 CRT, average score = 62				Samsung 240T LCD, average score = 58			
T-2 Dark	55	60	60	58	50	60	60	57
T-6	60	60	60	60	60	60	60	60
T-7	60	60	60	60	60	60	60	60
T-3	50	90	60	67	60	60	60	60
T-4	50	90	60	67	50	60	60	57
T-8	60	90	60	70	60	60	60	60
T-5	50	60	60	57	60	60	60	60
T-1 Bright	50	60	60	57	50	50	50	50
			Average	62			Average	58

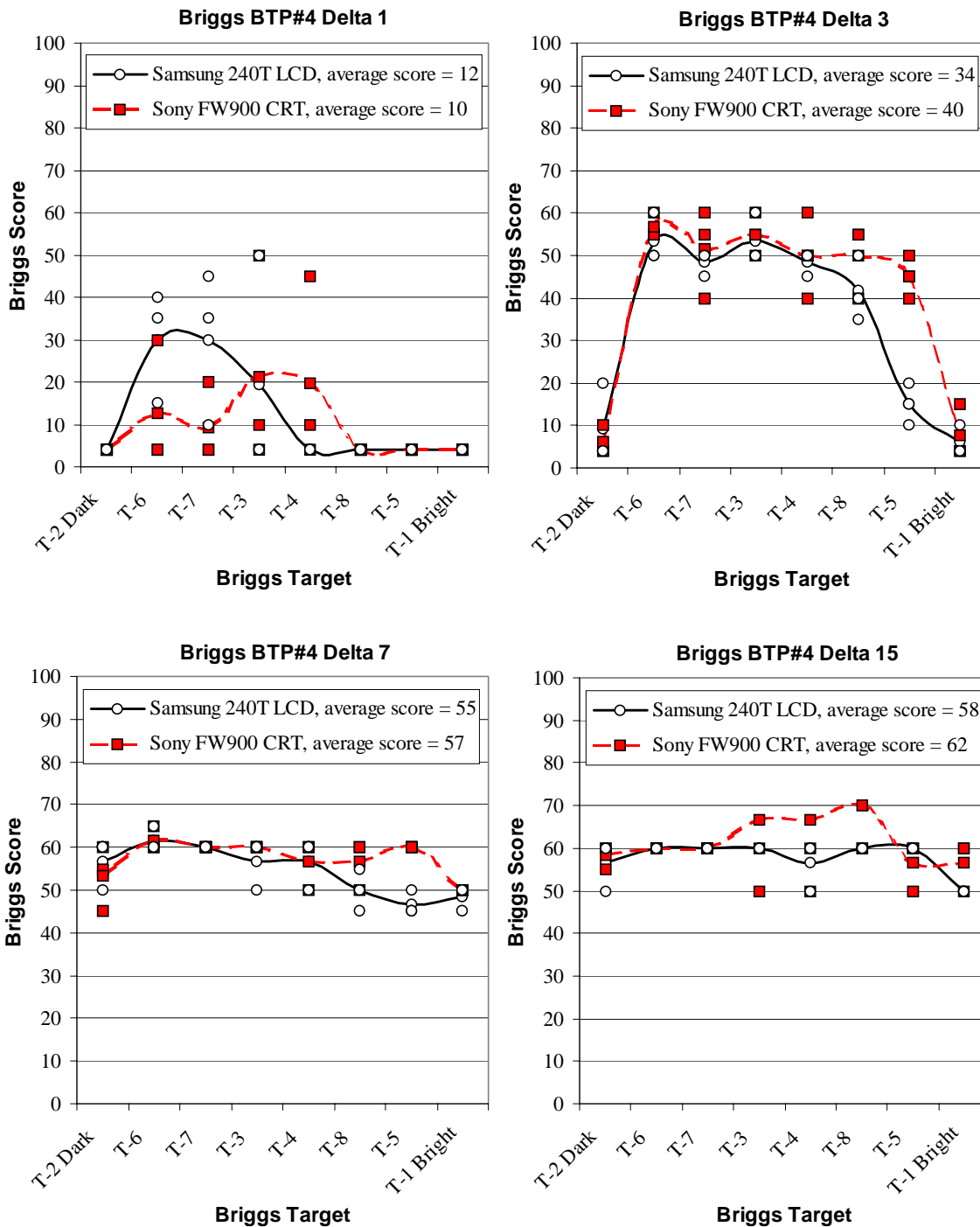## CRT and LCD Briggs Scores for 1920 x 1080 Analog Addressing

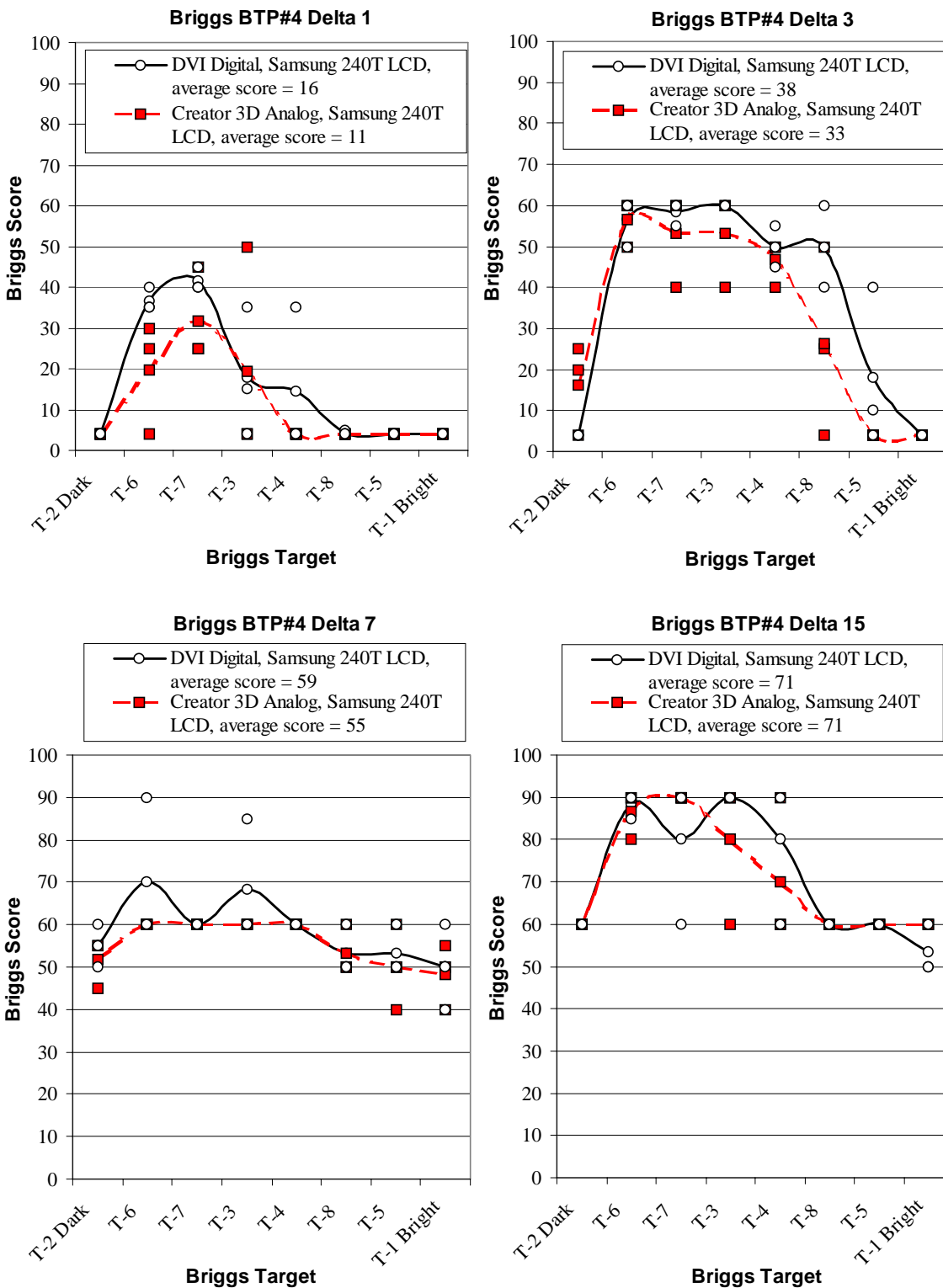**Figure II.21.3.** Briggs scores for delta-1, delta-3, delta-7, and delta-15 contrast ratios on BPT#4 test pattern for the Samsung 240T color LCD compared to the Sony 24 inch FW900 flat face color CRT monitor. Each of these data points represents an individual score by each of three NIDL observers. The solid line shows the average score for each target, T-1 through T-8.

Table II.21-3. LCD Briggs Scores for 1280 x 1024 Digital Using Quantum Data 802G Test Generator and Analog Addressing Using Sun MicroSystems Creator 3D Graphics

1280 x 1024 x 60 Hz
Samsung 240T 24-in. LCD Monitor

Target	Creator 3D Analog Mode				Digital Mode, Quantum Data 802G			
	Observer 1	Observer 2	Observer 3	Average	Observer 1	Observer 2	Observer 3	Average
Delta-1	Creator 3D Analog, Samsung 240T LCD, average score = 11				DVI Digital, Samsung 240T LCD, average score = 16			
T-2 Dark	4	4	4	4	4	4	4	4
T-6	4	30	25	20	35	35	40	37
T-7	25	45	25	32	40	45	40	42
T-3	4	50	4	19	35	15	4	18
T-4	4	4	4	4	35	4	4	14
T-8	4	4	4	4	5	4	4	4
T-5	4	4	4	4	4	4	4	4
T-1 Bright	4	4	4	4	4	4	4	4
			Average	11			Average	16
Delta-3	Creator 3D Analog, Samsung 240T LCD, average score = 33				DVI Digital, Samsung 240T LCD, average score = 38			
T-2 Dark	25	20	4	16	4	4	4	4
T-6	50	60	60	57	50	60	60	57
T-7	40	60	60	53	55	60	60	58
T-3	40	60	60	53	60	60	60	60
T-4	40	50	50	47	50	55	45	50
T-8	4	50	25	26	40	50	60	50
T-5	4	4	4	4	40	10	4	18
T-1 Bright	4	4	4	4	4	4	4	4
			Average	33			Average	38
Delta-7	Creator 3D Analog, Samsung 240T LCD, average score = 55				DVI Digital, Samsung 240T LCD, average score = 59			
T-2 Dark	45	55	55	52	60	55	50	55
T-6	60	60	60	60	60	90	60	70
T-7	60	60	60	60	60	60	60	60
T-3	60	60	60	60	60	60	85	68
T-4	60	60	60	60	60	60	60	60
T-8	50	50	60	53	50	50	60	53
T-5	40	50	60	50	50	50	60	53
T-1 Bright	40	50	55	48	40	50	60	50
			Average	55			Average	59
Delta-15	Creator 3D Analog, Samsung 240T LCD, average score = 71				DVI Digital, Samsung 240T LCD, average score = 71			
T-2 Dark	60	60	60	60	60	60	60	60
T-6	90	90	80	87	90	90	85	88
T-7	90	90	90	90	60	90	90	80
T-3	60	90	90	80	90	90	90	90
T-4	60	60	90	70	60	90	90	80
T-8	60	60	60	60	60	60	60	60
T-5	60	60	60	60	60	60	60	60
T-1 Bright	60	60	60	60	50	50	60	53
			Average	71			Average	71

LCD Briggs Scores for 1280 x 1024 Digital and Analog Addressing
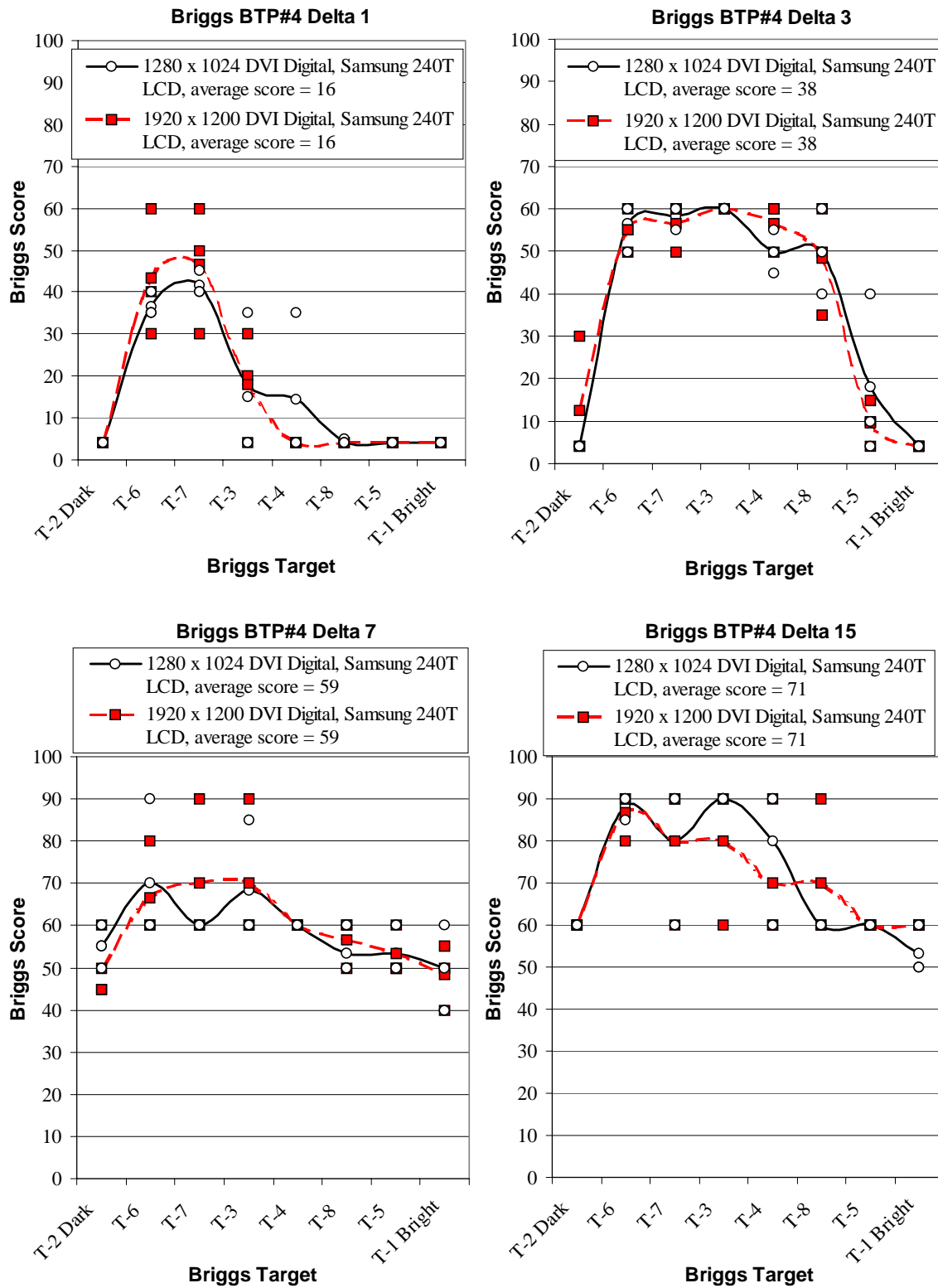

Figure II.21.4. Briggs scores for delta-1, delta-3, delta-7, and delta-15 contrast ratios on BPT#4 test pattern for the Samsung 240T color LCD driven digitally compared to the same LCD monitor driven in analog mode. Each of these data points represents an

individual score by each of three NIDL observers. The solid line shows the average score
for each target, T-1 through T-8.

Table II.21-4. LCD Briggs Scores for 1280 x 1024 x 60 Hz Digital Using Quantum Data 802G Test Generator and 1920 x 1200 x 52 Hz Digital Using Elsa Synergy III PC Graphics Card

Samsung 240T 24-in. LCD Monitor

Digital Mode, 1280 x 1024 x 60 Hz Quantum Data 802G Test Generator				Digital Mode, 1920 x 1200 x 52 Hz Elsa Synergy III PC Graphics Card			
Observer 1	Observer 2	Observer 3	Average	Observer 1	Observer 2	Observer 3	Average
1280 x 1024 DVI Digital, Samsung 240T LCD, average score = 1				1920 x 1200 DVI Digital, Samsung 240T LCD, average score =			
4	4	4	4	4	4	4	4
35	35	40	37	30	40	60	43
40	45	40	42	30	50	60	47
35	15	4	18	30	20	4	18
35	4	4	14	4	4	4	4
5	4	4	4	4	4	4	4
4	4	4	4	4	4	4	4
4	4	4	4	4	4	4	4
		Average	15.9			Average	16.0
1280 x 1024 DVI Digital, Samsung 240T LCD, average score = 3				1920 x 1200 DVI Digital, Samsung 240T LCD, average score =			
4	4	4	4	4	4	30	13
50	60	60	57	50	60	55	55
55	60	60	58	50	60	60	57
60	60	60	60	60	60	60	60
50	55	45	50	50	60	60	57
40	50	60	50	35	50	60	48
40	10	4	18	10	4	15	10
4	4	4	4	4	4	4	4
		Average	37.6			Average	37.9
1280 x 1024 DVI Digital, Samsung 240T LCD, average score = 5				1920 x 1200 DVI Digital, Samsung 240T LCD, average score =			
60	55	50	55	45	45	60	50
60	90	60	70	60	60	80	67
60	60	60	60	60	60	90	70
60	60	85	68	60	60	90	70
60	60	60	60	60	60	60	60
50	50	60	53	50	60	60	57
50	50	60	53	50	50	60	53
40	50	60	50	40	50	55	48
		Average	58.8			Average	59.4
1280 x 1024 DVI Digital, Samsung 240T LCD, average score = 7				1920 x 1200 DVI Digital, Samsung 240T LCD, average score =			
60	60	60	60	60	60	60	60
90	90	85	88	90	90	80	87
60	90	90	80	60	90	90	80
90	90	90	90	60	90	90	80
60	90	90	80	60	60	90	70
60	60	60	60	60	60	90	70
60	60	60	60	60	60	60	60
50	50	60	53	60	60	60	60
		Average	71.5			Average	70.8

LCD Briggs Scores for 1280 x 1024 x 60 Hz and 1920 x 1200 x 52 Hz
Single-DVI Digital Addressing

Figure II.21.5. Briggs scores for delta-1, delta-3, delta-7, and delta-15 contrast ratios on BPT#4 test pattern for the Samsung 240T color LCD driven digitally in 1280 x 1024 x 60 Hz mode compared to the same LCD monitor driven in 1920 x 1200 x 52 Hz mode. Each of these data points represents an individual score by each of three NIDL observers. The solid line shows the average score for each target, T-1 through T-8.

II. 22. Pixel Defects

Reference: VESA FPDM Version 2.0, Section 303-6, p70.

> *We observed very few defective pixels. One in a million white pixels were stuck on, and a dust particle extended across two adjacent pixels.*

The Samsung 240T LCD monitor had very few deflective pixels. While viewing a full white (Lmax) screen, internal dust particles were observed extending across two adjacent pixels. While viewing a full black (Lmin) screen, three pixels were observed to be "stuck white" (1.3×10^{-4} %).   Locations of these deflects are illustrated in Figure II.22-1.
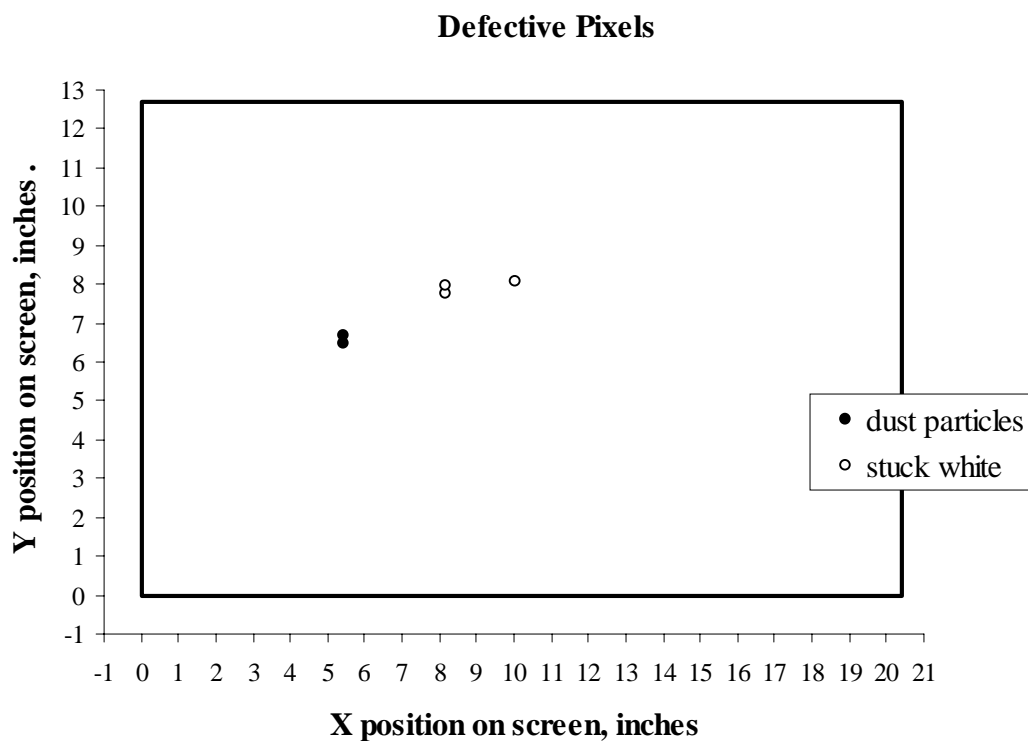
Figure II.22-1. Locations of pixel deflects observed on the Samsung 240T LCD monitor.

II. 23. Black Luminance (Lmin) Uniformity and Mura

Reference: *VESA FPDM Version 2.0, Section and 303-8, p78, and Section 306, p115.*

Black luminance (Lmin = 0.1 fL) sampled at 240 points (20 x 12 grid) varied across the screen by up to 41% (0.067 to 0.104 fL). Mura was slightly visible on a full black (Lmin) screen, but probably will not interfere with image analyst or geospatial specialist usage. There is no IEC specification for uniformity of black.

According to the VESA FPDM Version 2.0 standard, mura is a Japanese term meaning *nonuniformity* including any imperfections that interfere with the uniformity of the displayed luminance such as a mottled appearance or bright or dark spots that may be objectionable. Such imperfections are on the scale of from a few pixels in size to usually less than 20 % of the screen diagonal.

Figure II.23-1. Photograph of black full screen at Lmin showing luminance nonuniformities and mura on the Samsung 240T LCD monitor.
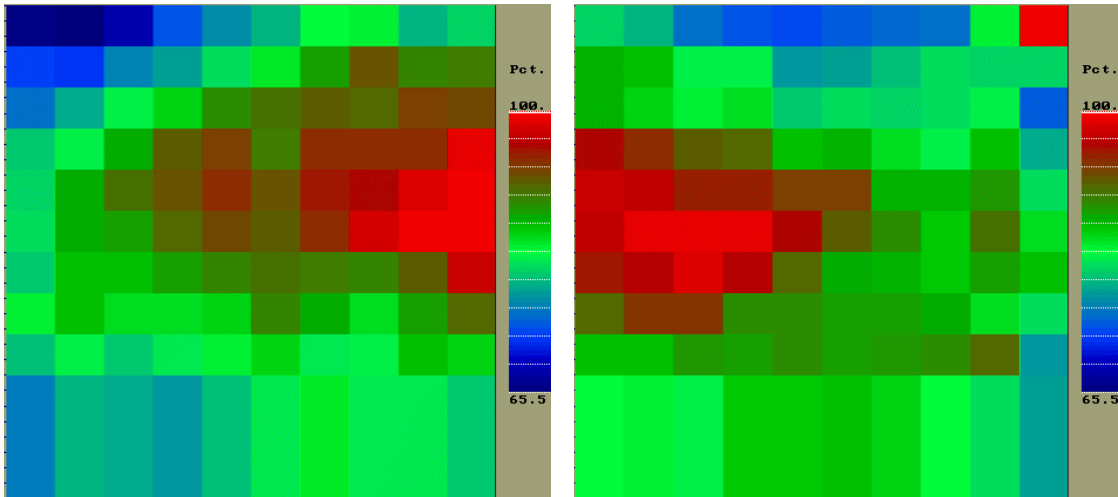
Figure II.23-2. 240-Point (20 x 12 grid) Sampled Spatial Uniformity of Luminance of Black at Lmin. (Left and right halves of the screen were measured separately due to limited length of x-y translation stage.) Luminance of Lmin varied across the screen by up to 41% (0.104 fL and center, 0.067 fL at edge).

II. 24. Viewing Angle

Reference: VESA FPDM Flat Panel Display Measurements, Sections 307-1,2, page 106.

> *This LCD monitor did not exhibit grayscale inversion with viewing angle.*
>
> *The effective viewing cone angle for the Samsung 240T LCD monitor is approximately ±20 degrees from the perpendicular to the LCD screen in the vertical and horizontal directions. NIDL defines the viewing angle as that angle for which the maximum contrast ratio decreases by a factor of 2 (3dB). This is much smaller than the ±85 degrees viewing angle claimed in the manufacturer's description of their monitor.*

Luminance of full screen gray levels was measured at screen center as a function of horizontal viewing angle with vertical angle set perpendicular to the screen, and as a function of vertical viewing angle with horizontal angle set perpendicular to the screen. The luminance data are plotted in Figures II.24-2 through II.24-13. From this data, threshold viewing cone angles where contrast ratio (CR = Lmax/Lmin) decreases by a factor of two from 350:1 to 175:1 were determined using linear interpolation.

Viewing angle for LCD monitors using the criterion of only a factor of 2 reduction in contrast ratio is approximately ±20 degrees. This is much smaller than the 170-degree (±85 degrees) viewing angle claimed in the manufacturer's description of their monitor. Thus the IA and GI should maintain their head position within ±20 degrees of the perpendicular to the LCD screen. An exception may be to use the change in contrast with viewing angle to make a subtle feature more prominent. Care must be taken when a second viewer is looking over the analyst's shoulder so that the point of interest is not obscured. It will be noted from the accompanying figures that the CRT monitor shows less variation in contrast ratio with viewing angle than does the LCD monitor.

The Samsung 240T LCD monitor did not exhibit grayscale inversion with viewing angle. Grayscale inversion can occur on many other LCDs as shown in Figure II.24.1 taken from VESA FPDM.
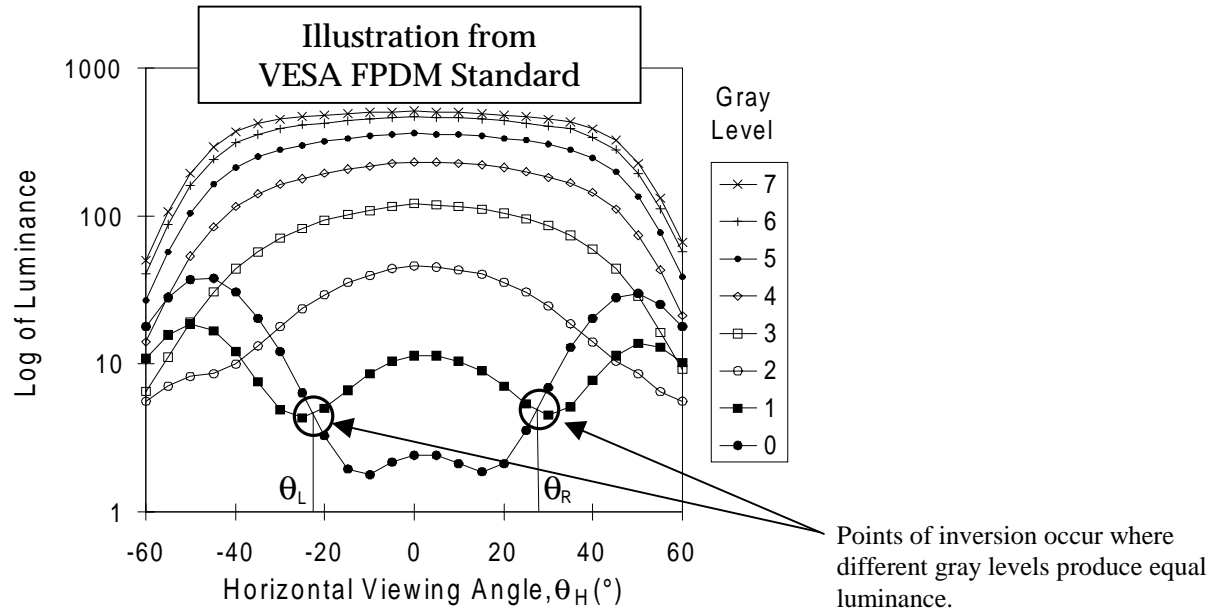
Figure II.24.1. Example of Gray Scale Inversion. Points of inversion occur where different gray levels produce equal luminance as indicated in the plot.
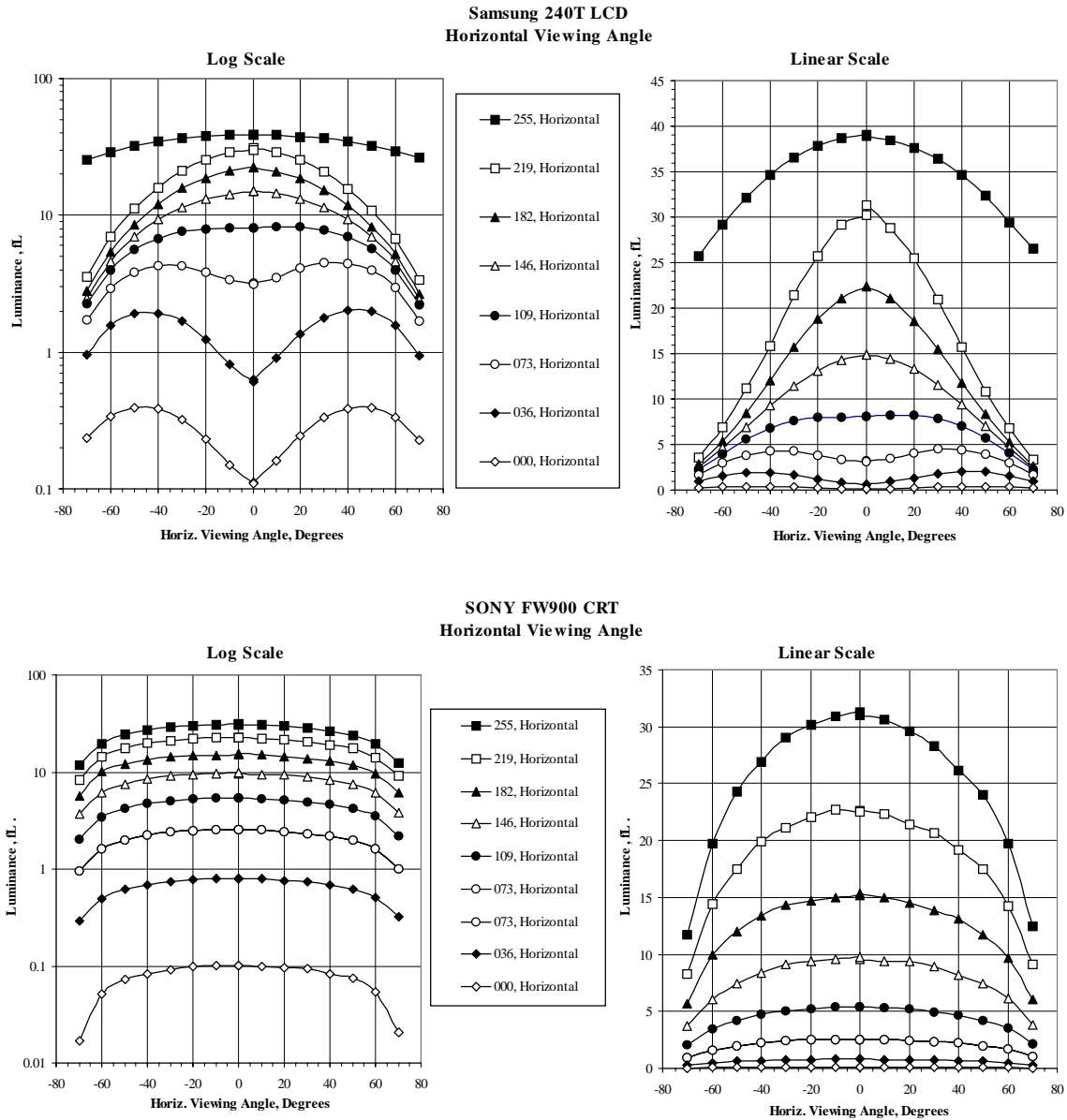
Samsung 240T LCD
Horizontal Viewing Angle

Figure II.24.2. Horizontal Viewing Angle for the Samsung 240T LCD monitor compared to the Sony FW900 flat face CRT monitor with luminance units shown on both logarithmic and linear scales.
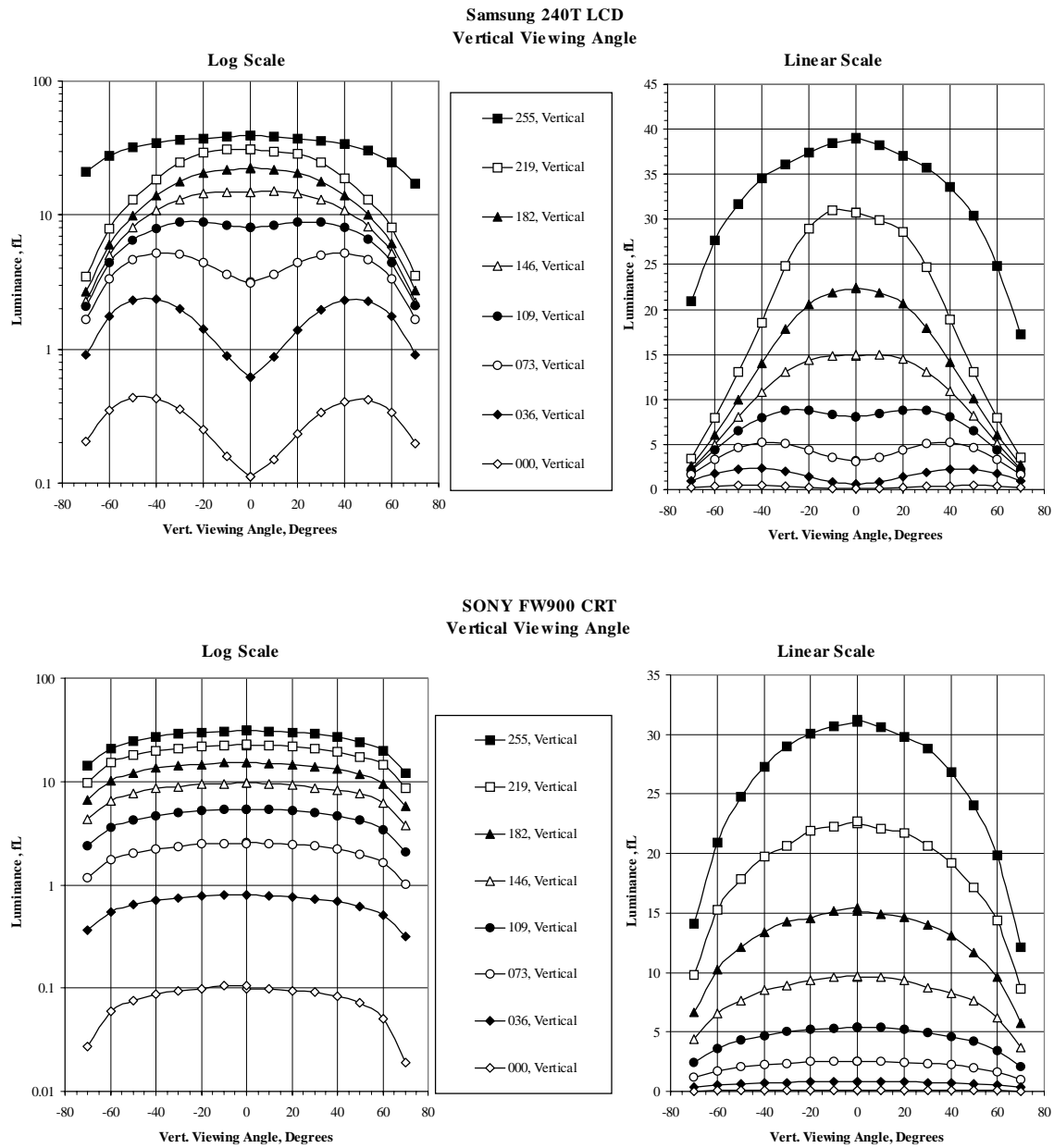
Figure II.24.3. Vertical Viewing Angle for the Samsung 240T LCD monitor compared to the Sony FW900 flat face CRT monitor with luminance units shown on both logarithmic and linear scales.

Samsung 240T LCD
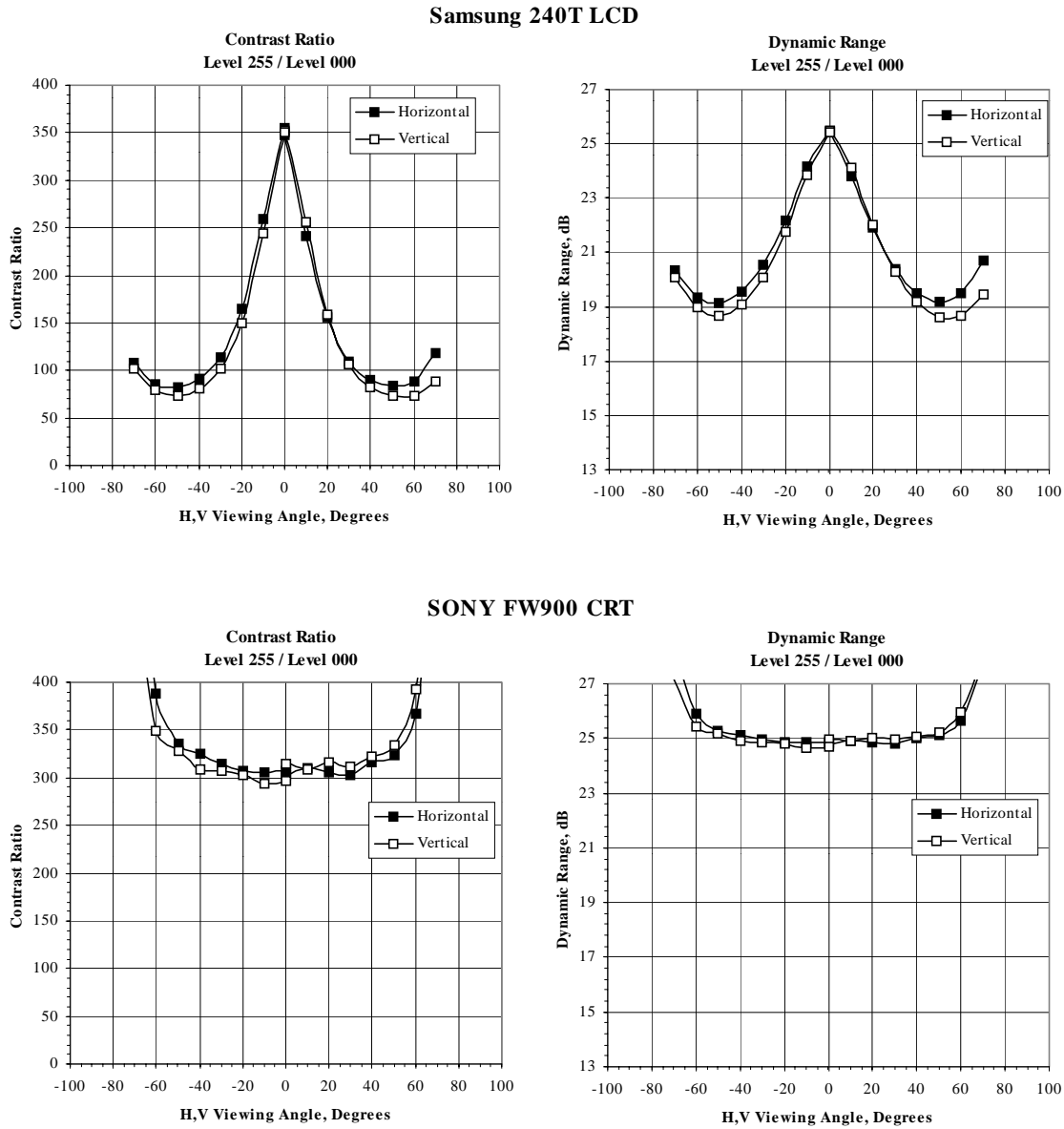
SONY FW900 CRT

Figure II.24.4. Vertical and Horizontal Viewing Angle for Contrast Ratio and Dynamic Range for the Samsung 240T LCD monitor compared to the Sony FW900 flat face CRT monitor.

Samsung 240T LCD
Chromaticity Viewing Angle
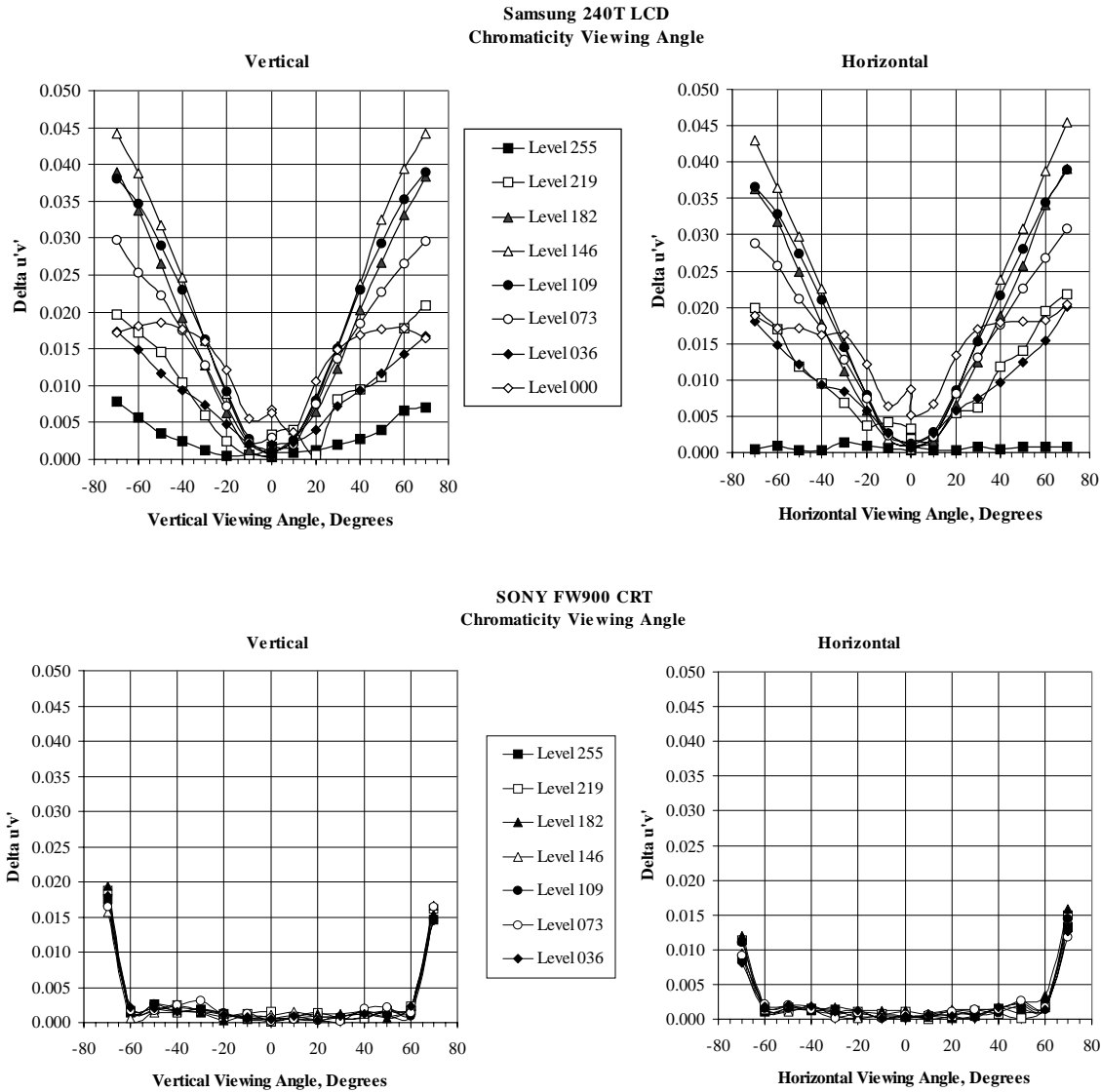
Figure II.24.5. Vertical and Horizontal Viewing Angle for Chromaticity of 8 gray levels for the Samsung 240T LCD monitor compared to the Sony FW900 flat face CRT monitor.

Samsung 240T LCD Level 255   **Sony FW900 CRT Level 255**
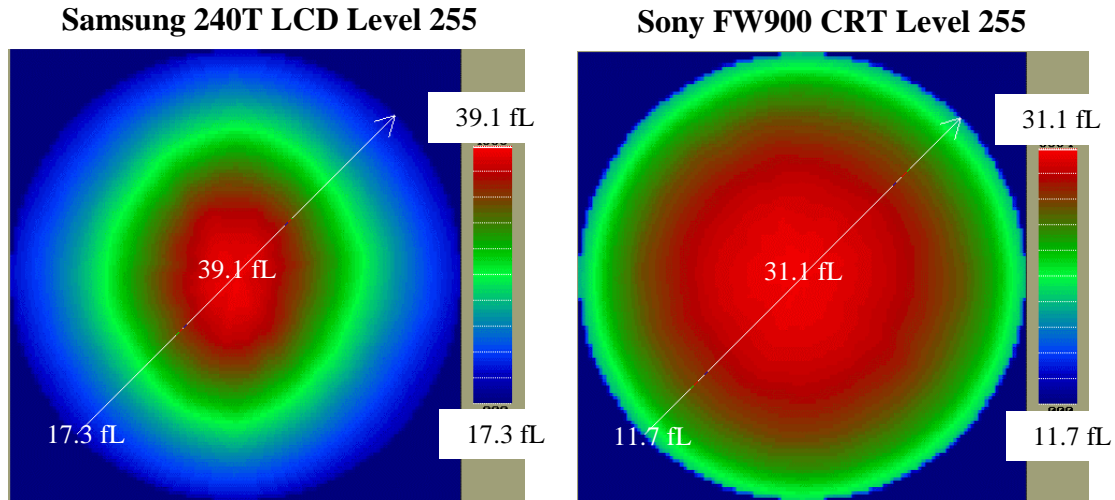
Figure II.24.6. Viewing Cone Luminance of Lmax (level 255). The center of the plot is perpendicular to the screen. The edge of the circle is 70 degrees off perpendicular.
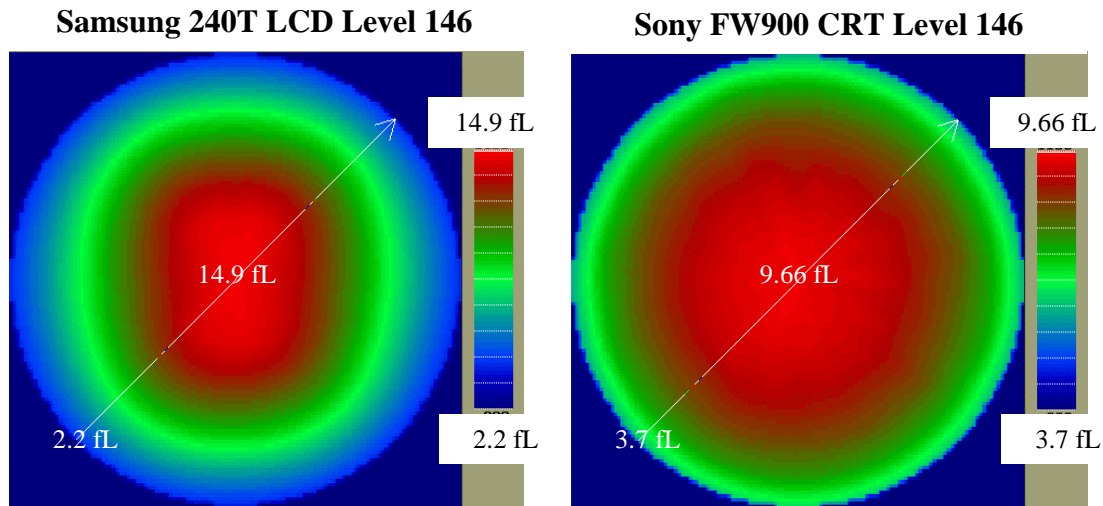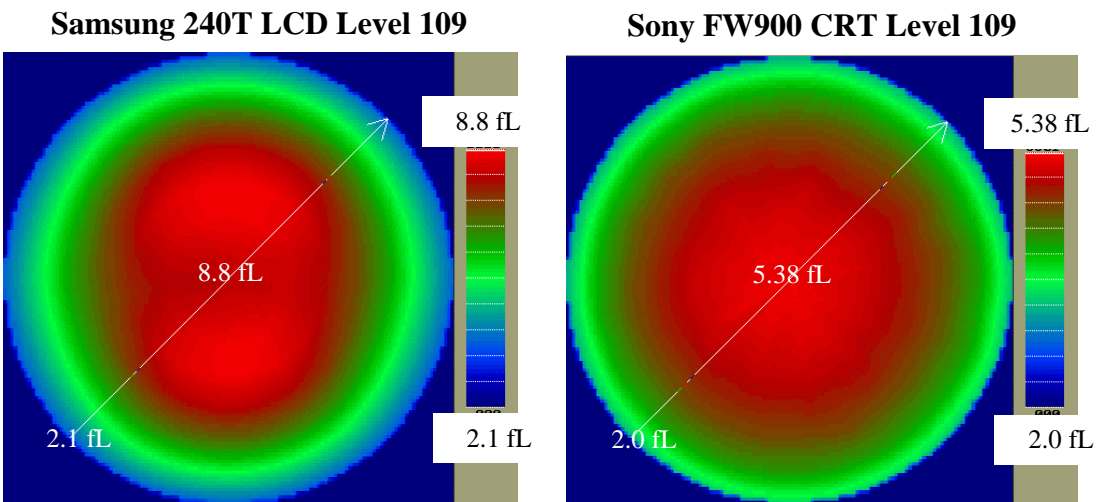
Samsung 240T LCD Level 219   **Sony FW900 CRT Level 219**
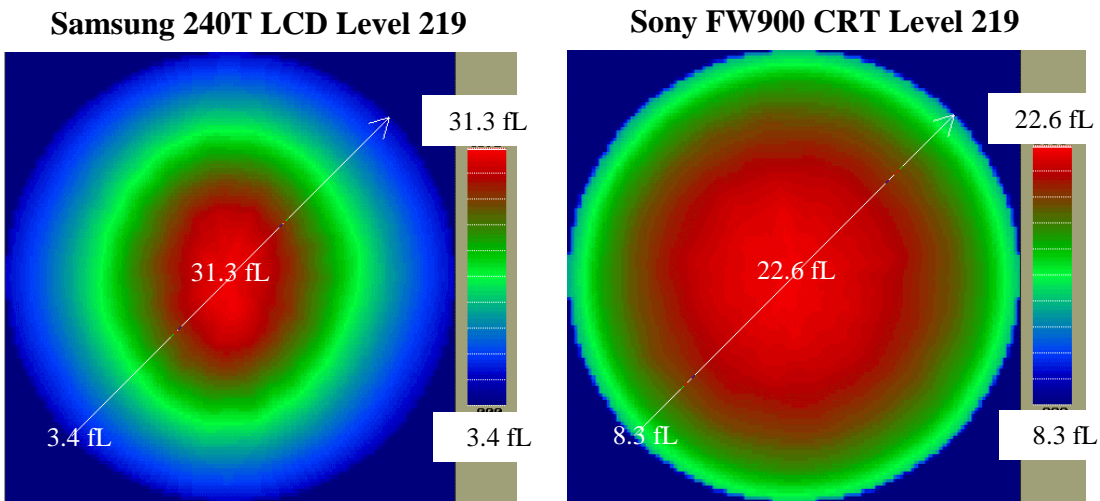
Figure II.24.7. Viewing Cone Luminance of gray level 219. The center of the plot is perpendicular to the screen. The edge of the circle is 70 degrees off perpendicular.
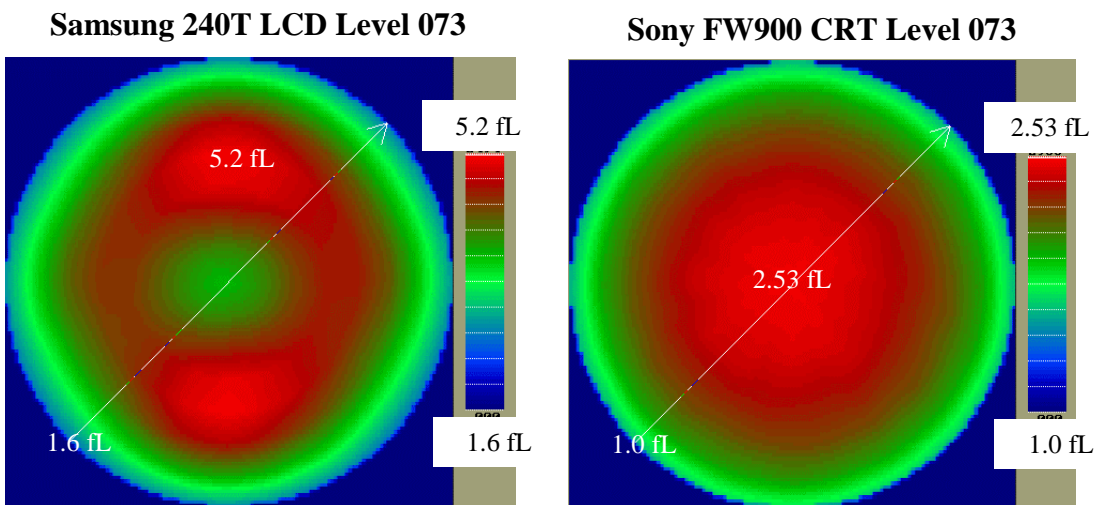
Samsung 240T LCD Level 182   **Sony FW900 CRT Level 182**
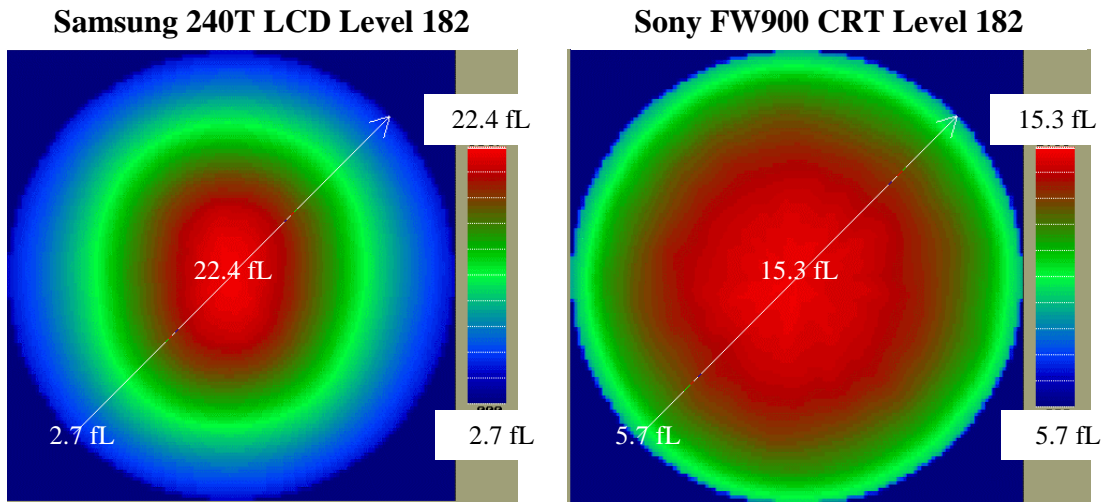
Figure II.24.8. Viewing Cone Luminance of gray level 182. The center of the plot is perpendicular to the screen. The edge of the circle is 70 degrees off perpendicular.

Samsung 240T LCD Level 146   **Sony FW900 CRT Level 146**

Figure II.24.9. Viewing Cone Luminance of gray level 146. The center of the plot is perpendicular to the screen. The edge of the circle is 70 degrees off perpendicular.
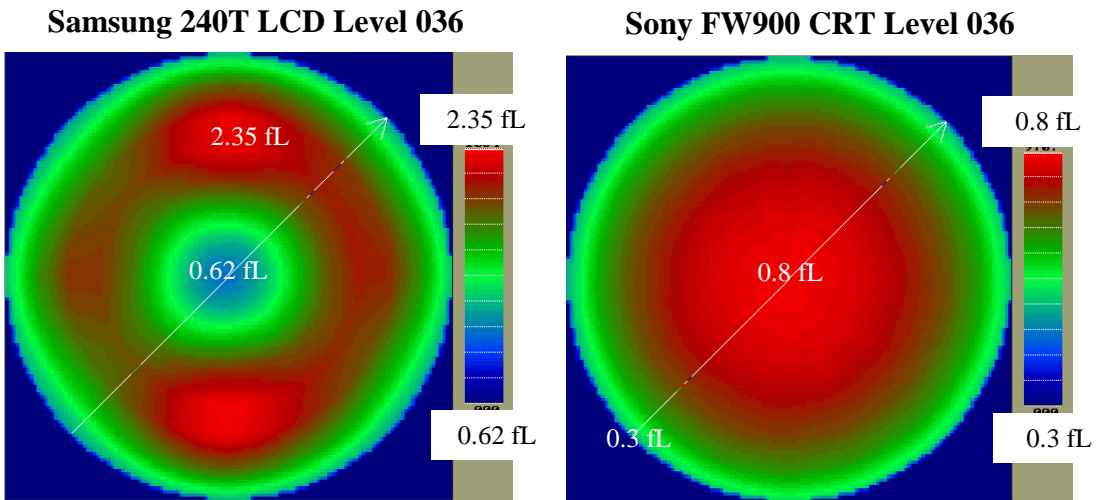
Samsung 240T LCD Level 109   **Sony FW900 CRT Level 109**

Figure II.24.10. Viewing Cone Luminance of gray level 109. The center of the plot is perpendicular to the screen. The edge of the circle is 70 degrees off perpendicular.
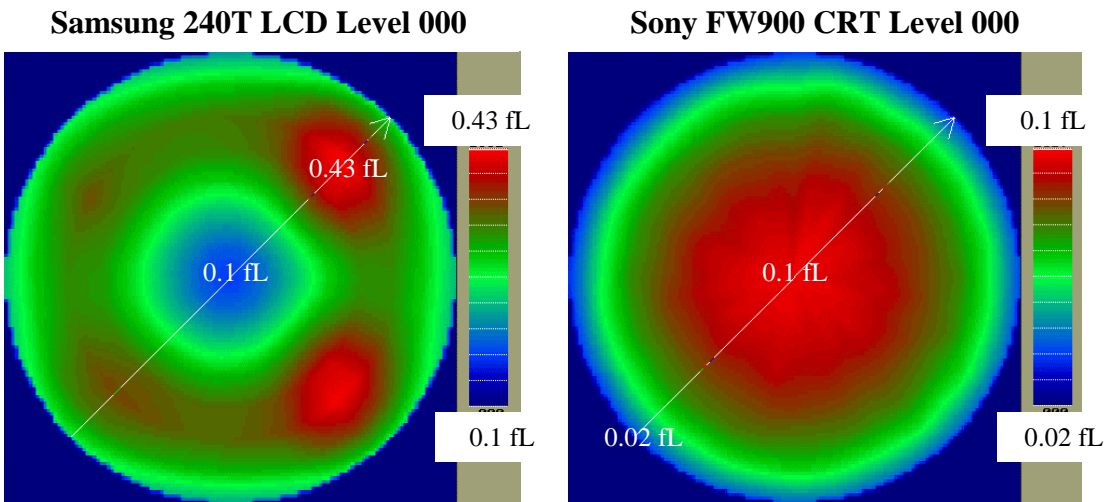
Samsung 240T LCD Level 073   **Sony FW900 CRT Level 073**

Figure II.24.11. Viewing Cone Luminance of gray level 073. The center of the plot is perpendicular to the screen. The edge of the circle is 70 degrees off perpendicular.

Samsung 240T LCD Level 036   **Sony FW900 CRT Level 036**

Figure II.24.12. Viewing Cone Luminance of gray level 036. The center of the plot is perpendicular to the screen. The edge of the circle is 70 degrees off perpendicular.

Samsung 240T LCD Level 000   **Sony FW900 CRT Level 000**

Figure II.24.13. Viewing Cone Luminance of Lmin (level 000). The center of the plot is perpendicular to the screen. The edge of the circle is 70 degrees off perpendicular.

II. 25. Color Gamut

Reference: VESA FPDM Version 2.0, Section 302-4A, p. 47.

> *The area bounded by the u'v' color coordinates of R, G, and B primaries of the Samsung 240T LCD monitor is 19% of the total CIE 1976 area. This compares to 27% for the Sony FW900 color CRT monitor.*

The color gamut metric is the area of the triangle subtended by the primaries (R,G,B) in the chromaticity space whose coordinates are (u', v').

The area bounded by CIE 1976 u'v' color coordinates of R, G, and B primaries is measured and compared to the total area accessible to the display. After multiplying by 100%, the gamut area of the display is computed as:

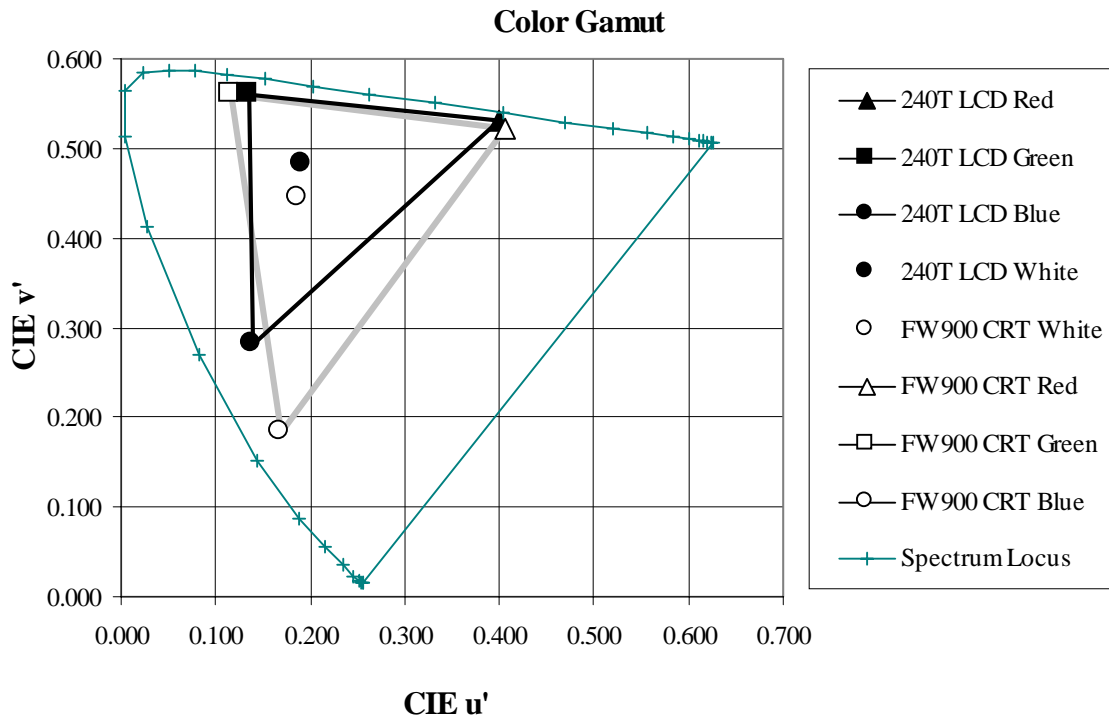$$\text{Gamut Area} = 256.1\ [(u'_r - u'_b)(v'_g - v'_b) - (u'_g - u'_b)(v'_r - v'_b)]$$

Figure II.25-1. CIE chromaticity coordinates and color gamut of the Samsung 240T LCD monitor compared to the Sony FW900 color CRT monitor.

Table II.25.1. CIE chromaticity coordinates and color gamut area of the Samsung 240T LCD monitor compared to a CRT monitor.

Samsung 240T LCD monitor						
	x	y	u'	v'	fL	CCT
White	0.318	0.355	0.192	0.482	39.4	6090
Red	0.607	0.358	0.399	0.530	9.17	
Green	0.314	0.579	0.135	0.559	24.2	
Blue	0.15	0.135	0.139	0.281	5.9	
Gamut Area	**19% of total area from 380 nm to 700 nm.**					

Sony FW900 CRT monitor						
	x	y	u'	v'	fL	CCT
White	0.31	0.348	0.189	0.478	31.4	9652
Red	0.602	0.344	0.406	0.523	7.77	
Green	0.28	0.599	0.116	0.560	22.3	
Blue	0.152	0.073	0.170	0.184	3.87	
Gamut Area	**27% of total area from 380 nm to 700 nm.**					

II. 26. Color Tracking

Reference: None

The whitepoint varied from 6107 K to 11274 K (0.043 delta u'v' units) among gray levels between Lmax (39.3 fL, level 255) and 10%Lmax (3.93fL, level 073). This is a measure of color tracking. There is no IEC specification for color tracking. We noted a much smaller shift for the Sony FW900 CRT than for the Samsung 240T LCD monitor.
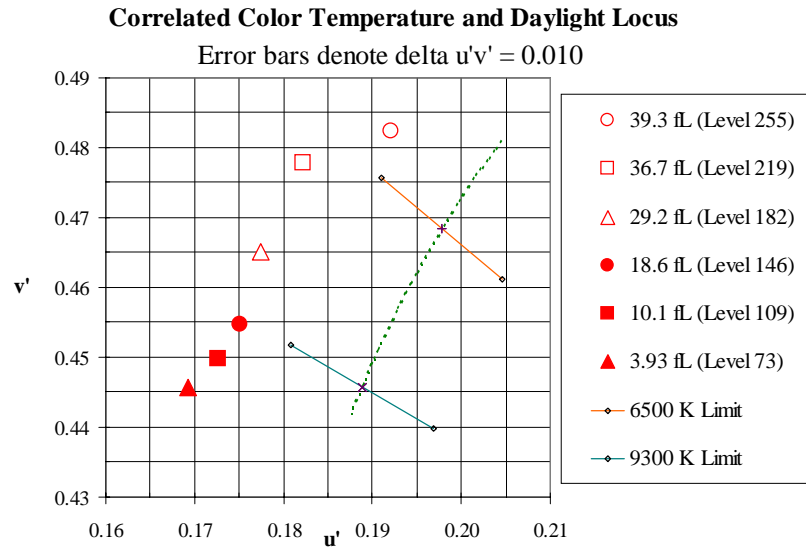

Figure II.26-1. CCT of measured white points for luminance values 3.93 fL to 39.3 fL shown relative to the Daylight Locus shown as a dotted line.
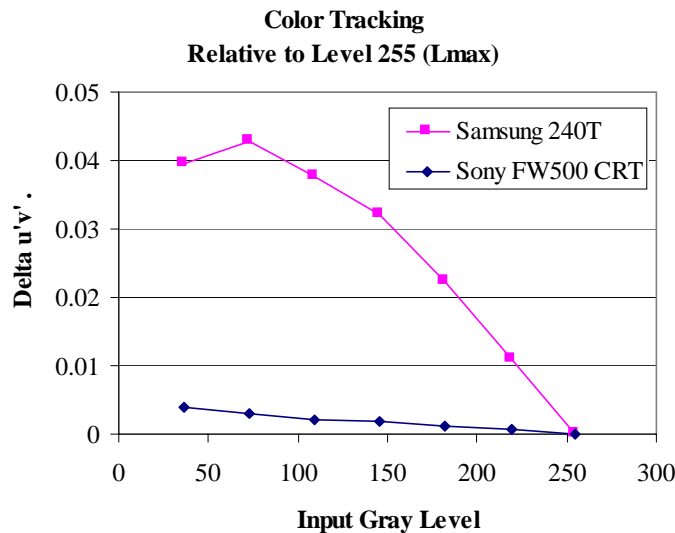

Figure II.26-2 Chromaticity shift of measured white points for 8 input levels shown relative to Lmax (Level 255) for the Samsung 240T LCD and Sony FW900 CRT monitors.

Table II.26-1 Δu'v' Distances between measured white point and
CIE coordinate values from D$_{65}$ to D$_{93}$.

	39.3 fL (Level 255)	36.7 fL (Level 219)	29.2 fL (Level 182)	18.6 fL (Level 146)	10.1 fL (Level 109)	3.93 fL (Level 73)
CIE x	0.318	0.301	0.284	0.273	0.266	0.259
CIE y	0.355	0.351	0.331	0.315	0.308	0.303
CIE u'	0.192	0.182	0.177	0.175	0.173	0.169
CIE v'	0.482	0.478	0.465	0.455	0.450	0.446
CCT	6107	6929	8184	9429	10326	11274
delta u'v' from Daylight Locus	0.015	0.020	0.018	0.016	0.017	0.019
delta u'v' relative to Level 255	0.000	0.011	0.022	0.032	0.038	0.043

II. 27. LCD Dynamic Response Time

Reference: VESA FPDM Version 2.0, Section 305-1, June 2001, pp 102-104.

Based on results of visual evaluations, response times of the Samsung 240T LCD monitor are approximately equivalent to other LCD displays evaluated by NIDL. But the response time for an LCD is much longer than for a CRT phosphor.

In analog mode, the Samsung 240T LCD monitor luminance rise and fall times average 20 ms and 18 ms, respectively, when switching between white and black states. Rise times in digital mode average only 13 ms, somewhat faster than for analog mode.

We visually compared the Samsung 240T LCD versus the ViewSonic VP181 LCD versus the Mitsubishi 2040u CRT for dynamic response to a moving target. The results are summarized in Table II.27-1 where it may be seen that objects on a CRT can be observed clearly for faster movement than with LCDs.

We measured the response times of the Samsung 240T LCD in both analog and digital modes using blinking white targets on black backgrounds. Blink rate was approximately 2 seconds on/ 2 seconds off. Targets included a small square box (4 mm x 4 mm), a horizontal line segment (4 mm in length), and a vertical line segment (4 mm in length). The results are summarized in Table II.27-2. Luminance response characteristics are plotted in Figures II.27-1 through II.27-4.

Table II.27-1. Results of the visual testing of moving cursor boxes.
(White on black and black on white)
C = Clearly viewable
B = Blur or smearing, not clearly visible

Quantum Data Model 903 Persistence Test Image [1]
For visual assessment of response time.

	/8	/7	/6	/5	/4	/3	/2	1X	2X	3X	4X	5X	6X	7X	8X
Samsung 240T LCD	C	C	C	C	C	C	B	B							
ViewSonic VP181 LCD	C	C	C	C	C	C	B	B							
Mitsubishi 2040u CRT	C	C	C	C	C	C	C	C	C	C	C	C			

(1) Explanation of Persistence as per Quantum Data Combined User's and Programmer's Manual for Model 801GC-ISA & 801 GR-ISA - Rev. A/31-Aug-95 Working with images pages 5-45 and 5-46. In the primary version, 15 small white boxes move back and forth between diagonal guide lines. The lines form 15 side-by-side tracks. The size of each box is scaled to the light meter box size set by the MSIZ system parameter. The box in the center track moves one scan line vertically and one pixel horizontally for each vertical frame of refresh. The seven boxes in the tracks to the right of the center track move 2, 3, 4, 5, 6, 7 and 8 pixels and lines per frame. These boxes are marked 2X through 8X at the bottom of the tracks. The seven boxes to the left of the center track move one scan line vertically and one pixel horizontally for every 2, 3, 4, 5, 6, 7 and 8 vertical frames of refresh. These boxes are marked /2 through /8 at the bottom of the tracks. In cases where the next move would cause the box to move beyond the end of the track, it immediately reverses and moves the correct distance in the opposite direction for the next frame. The secondary version draws a black image on a white background as pictured above. The phosphors on the face of most CRTs continue to glow for a short period of time after the electron beam has stopped energizing them. This phenomenon is called persistence. A certain amount of persistence is desirable in most application. It prevents a flickering of a displayed image that most users would find objectionable. On the other hand, a display with an overly long persistence (response) time causes moving objects to leave a blurred trail. A flickering in the slower moving boxes indicates that the combination of refresh rate and phosphor persistence is not suitable for long-term viewing. A fading tail left behind by the faster moving boxes indicates that the display may not be suitable for viewing animated images.

Table II.27-2. Results of the measured 10% to 90% rise and fall times of blinking cursor boxes and lines (White on black)

	Samsung 240T LCD			
	Analog Addressing		Digital Addressing	
Test Pattern	Rise Time (ms)	Fall Time (ms)	Rise Time (ms)	Fall Time (ms)
White Square	14	17	13	19
White Horizontal Line	15	18	13	17
White Vertical Line	32	18	12	18
Average	20	18	13	18

Risetime for White Square Box
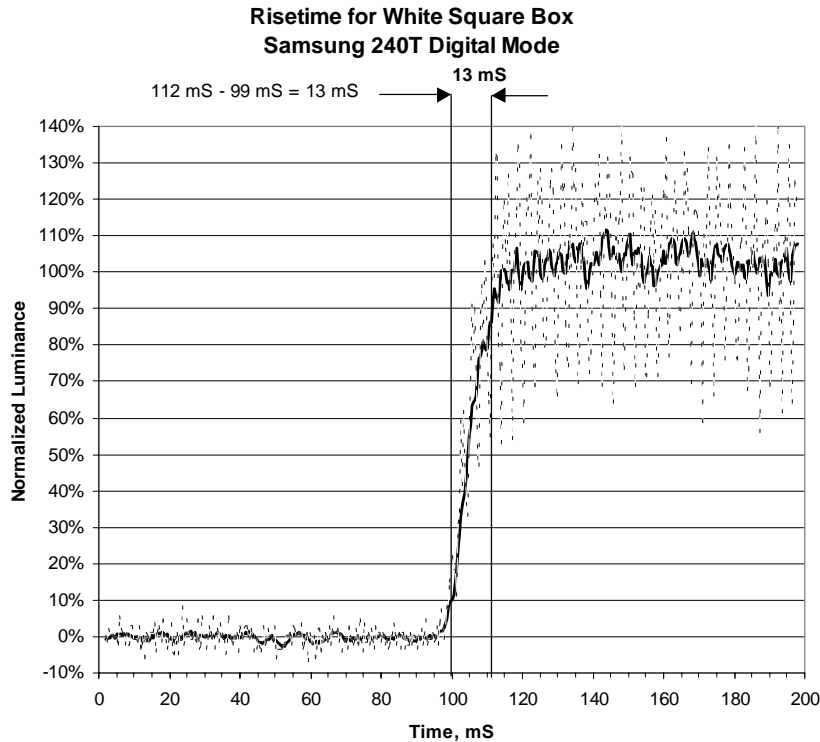**Samsung 240T Digital Mode**

Figure II.27-1. Digital luminance rise time response characteristic for a black (Lmin) to white (Lmax) transition. The bold curve represents the moving average of the raw measured data plotted in the dotted line.
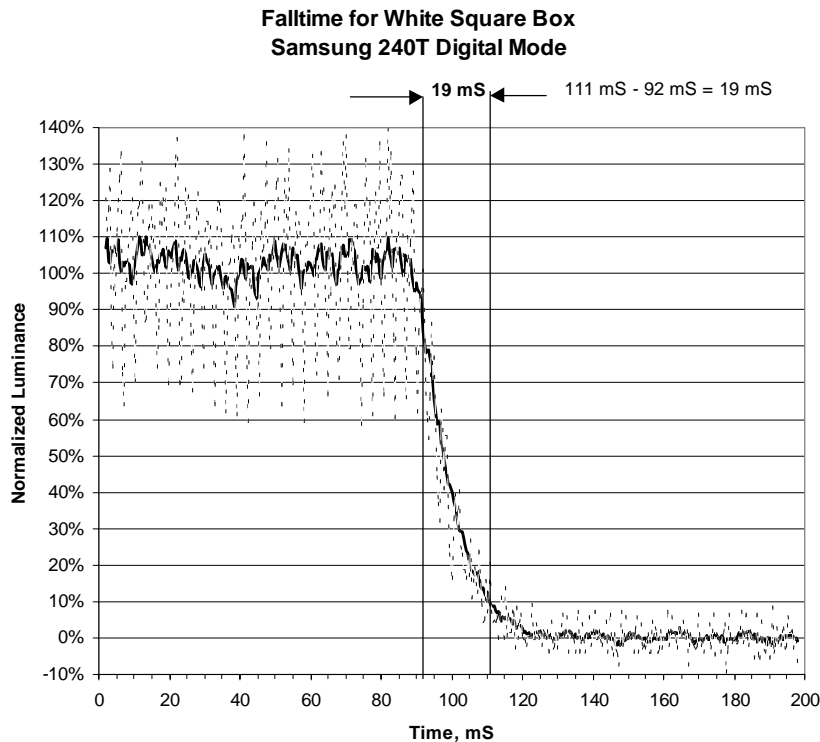
Falltime for White Square Box
Samsung 240T Digital Mode

Figure II.27-2. Digital luminance fall time response characteristic for a white (Lmax) to black (Lmin) transition. **The bold curve represents the moving average of the raw measured data plotted in the dotted line.**

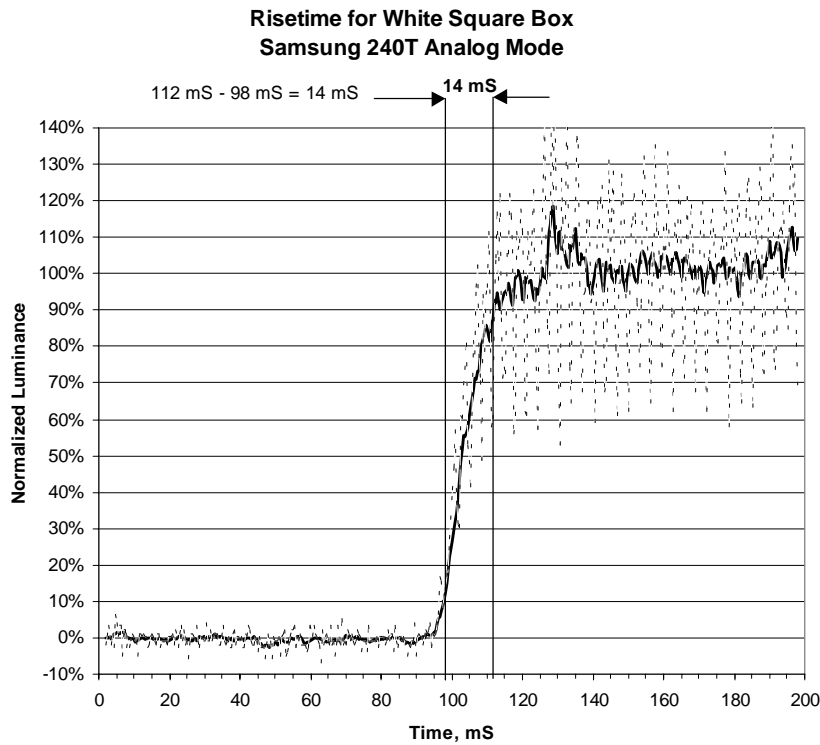**Risetime for White Square Box**
Samsung 240T Analog Mode

Figure II.27-3. Analog luminance rise time response characteristic for a black (Lmin) to white (Lmax) transition. The bold curve represents the moving average of the raw measured data plotted in the dotted line.
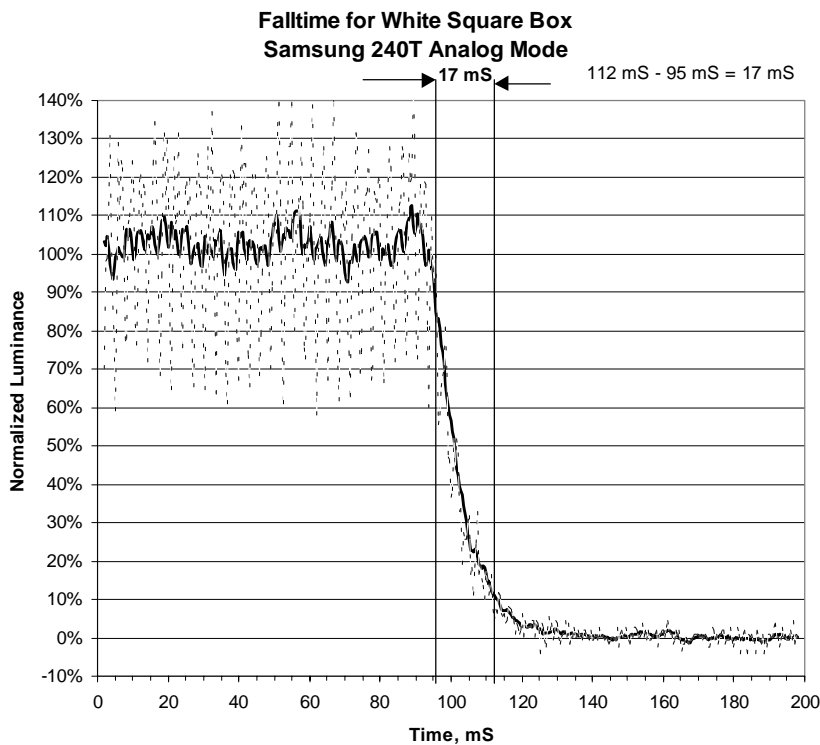
Falltime for White Square Box
Samsung 240T Analog Mode

Figure II.27-4. Analog luminance fall time response characteristic for a white (Lmax) to black (Lmin) transition. The bold curve represents the moving average of the raw measured data plotted in the dotted line.