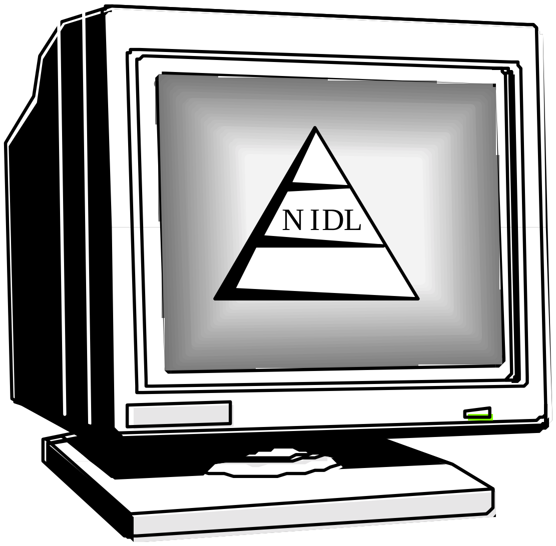

The Viewsonic VP181 is an award-winning, widely used 18.1 inch diagonal LCD color monitor. It was the first 18 inch flat panel monitor to incorporate digital, analog and video inputs in one display. The VP181 pivots to either landscape or portrait modes for full page viewing. NIDL evaluated this monitor both for its static and motion video display for an IEC workstation for image analysis and geospatial information. NIDL certifies the Viewsonic VP181 color LCD monitor as being suitable for monoscopic viewing for an IEC workstation, and rates this monitor an “A” in the monoscopic mode. It easily passed all the IEC Working Group monoscopic specifications, and the contrast modulation is outstanding. Its native resolution is 1280 x 1024 pixels and is capable of scaling from 640 x 480 to 1600 x 1200 pixels. The maximum vertical refresh rate is 75 Hz so it cannot meet the 120 Hz refresh rate needed for flicker-free 3D sequential stereo viewing; NIDL rates its stereo performance as “F”. Imagery analysts at some locations use their CRT color monitors only in the monoscopic mode. So, for this class of users, the Viewsonic LCD monitor should reduce space on the user’s desk, reduce heat to the office surroundings, while presenting an excellent image. The price is $2,880.

ViewSonic VP181
5 x 4 Aspect Ratio, 18.1 Viewable
Color LCD ViewPanel

National Information Display Laboratory

P. O. Box 8619
Princeton, NJ 08543-8619
Tel: (609) 951-0150
Fax: (609) 734-2313
e-mail: nidl@nidl.org

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NIDL IEC Monitor Certification Report

The ViewSonic VP181 Color LCD Monitor

FINAL GRADES
Monoscopic Mode: A
Stereoscopic Mode: F; LCD Monitor cannot do stereo at 120 Hz

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 Viewsonic VP181 is an award-winning, widely used 18.1 inch diagonal LCD color monitor. It was the first 18 inch flat panel monitor to incorporate digital, analog and video inputs in one display. A picture in picture overlay is achievable with composite video input from a DVD or VCR running live while working on other analog applications on a PC. The VP181 pivots to either landscape or portrait modes for full page viewing. NIDL evaluated this monitor both for its static and motion video display for an IEC workstation for image analysis and geospatial information. NIDL certifies the Viewsonic VP181 color LCD monitor as being suitable for monoscopic viewing for an IEC workstation, and rates this monitor an “A” in the monoscopic mode. It easily passed all the IEC Working Group monoscopic specifications, and the contrast modulation is outstanding. Its native resolution is 1280 x 1024 pixels and is capable of scaling from 640 x 480 to 1600 x 1200 pixels. The maximum vertical refresh rate is 75 Hz so it cannot meet the 120 Hz refresh rate needed for flicker-free 3D sequential stereo viewing; NIDL rates its stereo performance as “F”. Imagery analysts at some locations use their CRT color monitors only in the monoscopic mode. So, for this class of users, the Viewsonic LCD monitor should reduce space on the user’s desk, reduce heat to the office surroundings, while presenting an excellent image. The price is $2,880.

One result that is especially noteworthy is the very high contrast modulation compared to a color CRT monitor. Further, moiré is neither present nor a problem in a LCD monitor. In another example, an LCD monitor at the Naval Oceanographic Office was preferred to a CRT monitor when used with an electronic light table to zoom in to pixelate the image to distinguish the boundary between two adjacent features. Finally, in a previous test of a grayscale dpiX 5 megapixel LCD monitor in an office light ambient, three of seven NIMA image analysts preferred the LCD to a comparable resolution CRT monitor. NIDL also has evaluated the 18 inch Sun and the 20 inch NEC 2010 LCD monitors and will report on these. These three monitors represent “best of class” LCD monitors as of early 2000. The Sun LCD monitor was preferred by image analysts at the Naval Oceanographic Office, Warfighting Support Center. The NEC 2010 is widely used within the DoD. The NAVO image analysts preferred the 20 inch size, but objected to a subtle vertical line structure.

It should be noted that for pixelated displays such as LCDs, FEDs, and PDPs, image distortions (straightness, linearity) defy measurement and serve more as a confirmation of the test equipment rather than the display. These measurements are presented in this report to complete the comparison with other displays (CRTs, projectors).

We demonstrated NTSC video color bars, and also moving images from a DVD movie. Our tests showed that a CRT still has faster response for motion compared to a LCD. SECAM, PAL, and NTSC composite video signals can be input from a SVHS video recorder or directly from a composite video source into the Viewsonic VP181 LCD monitor. An alternative flat panel display for motion video is the 20 inch Sharp Electronics LC-20A2U LCD flat panel monitor. It has a built-in 181 channel tuner, a screen brightness over 100 fL, a 200:1 contrast ratio (23 dB), and a backlight rated for 60,000 hours. The list price is $5,999. Their web address is www.sharp-usa.com.

The VP181 monitor is also capable of digital through a DFP (digital flat panel) input port as well as the analog input signal. To input the digital signal, we purchased a Hercules 3D Prophet II GTS 64 MB driver card having a DVI output port for our PC AGP slot. To connect the DVI port on the display driver to the DFP port on the Viewsonic LCD, we purchased a converter from Viewsonic. The VP181 LCD and the Hercules driver card have some incompatibilities according to Viewsonic so we did not obtain a really good image. When everything works correctly, all digital signal handling should give a cleaner signal and perhaps better colors. The VP181 monitor also has a USB port to support a camera or scanner, and has built-in stereo speakers.

A newer monitor, the 18.1 inch Viewsonic VG181 LCD monitor has both DVI digital and VGA analog inputs. Thus, a DVI digital signal can be input directly from a DVI display driver card without the need for a DFP converter plug. In addition, the DVI connector is mechanically more robust. For digital applications, this would be the preferred monitor over the VP181. NIDL expects to test this monitor in the future.

The Viewsonic website is www.viewsonic.com. The site also includes Nokia monitors, now that they are a part of Viewsonic.

Evaluation Datasheet
ViewSonic 18.1 inch Color LCD Monitor

Mode	**IEC Requirement**	**Measured Performance**	**Compliance**
MONOSCOPIC			
Addressability	1024 x 1024 min.	1280 x 1024	Pass
Dynamic Range	24.7dB	25.9 dB	Pass
Luminance (Lmin)	0.1 fL min. ± 4%	0.15 fL	Pass
Luminance (Lmax)	30 fL, min	59.6fL	Pass
Uniformity (Lmax)	20% max.	13.7%	Pass
Halation	3.5% max.	3.75% ± 0.3	Pass
Color Temp	6500 to 9300 K	7119 K	Pass
Reflectance	Not specified	4.7%	Pass
Bit Depth	8-bit± 5 counts	8-bit	Pass
Step Response	No visible ringing	Clean	Pass
Uniformity (Chromaticity)	0.010 delta u'v' max. ± 0.005 Δ u'v'	<0.008 delta u'v'	Pass
Pixel aspect ratio	Square H = V± 6%	11.05 H x 11.02 V (mils)	Pass
Screen size, viewable diagonal	17.5 to 24 inches ± 2 mm	18.1 ins.	Pass
Cm, Zone A, 7.6"	25% min.	86%	Pass
Cm, Zone A, 9.1"	25% min.	86%	Pass
Cm, Zone B	20% min.	85%	Pass
Pixel density	72 ppi min.	91 ppi	Pass
Straightness	0.5% max ± 0.05 mm	0.03%	Pass
Linearity	1.0% max ± 0.05 mm	0.07%	Pass
Jitter	2 ± 2 mils max.	0.09 mils	Pass
Swim, Drift	5 ± 2 mils max.	0.07 mils	Pass
Warm-up time, Lmin to +/- 50%	30 mins. Max ± 0.5 minute	<5 mins.	Pass
Warm-up time, Lmin to +/- 10%	60 mins. Max ± 0.5 minute	<5 mins.	Pass
Refresh	72 ±1 Hz min. 60 ±1 Hz absolute minimum	Set to 60Hz for tests; monitor was run at 75 Hz from computer for images	Pass
STEREOSCOPIC		LCD cannot do sequential stereo at 120 Hz	
Addressability	1024 x 1024 min.		
Lmin	Not specified		
Lmax	6 fL min ± 4%		
Dynamic range	17.7 dB min		
Uniformity (Chromaticity)	0.02 delta u'v' max ± 0.005 Δ u'v'		
Refresh rate	60 Hz per eye, min		
Extinction Ratio	15:1 min		

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 ViewSonic VP181 color LCD 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: Monochrome CRT 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.*

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 The ViewSonic VP181 Color LCD Monitor

ViewSonic's Specifications

According to ViewSonic, the specifications for the ViewSonic VP181 monitor are:

LCD ViewPanel®	**Type**	TFT active matrix SXGA LCD (16.7 million colors)
	Display Area	18.1" diagonal viewable area
	Contrast Ratio	300:1 contrast ratio (typical)
	Viewing Angle	160° horizontal, 160° vertical
	Light Source	Long life, 50,000 hrs. (typical)
	Response Time	50ms (typical)
	Brightness	235 cd/m2 (typical)(68.6 fL)
	Glass Surface	Anti-glare coat
ANALOG INPUT	**Video**	RGB Analog
	Sync	H/V separate (TTL)
	Frequency	F_h:30-95kHz, F_v:50-75Hz
DIGITAL INPUT	**Format**	VESA, DFP compliant, DVI with optional adapter*
COMPOSITE VIDEO		NTSC, PAL SECAM, HDTV
AUDIO	Speakers	Two 2-watt (located in base)
	Microphones	Pass through
COMPATIBILITY	**PC**	VGA up to 1600 x 1280 non-interlaced
	Mac®*	Power Mac™ up to 1600 x 1200
CONNECTOR BASE	**USB**	4/Downstrean, 1 upstream
	Analog RGB	15-pin mini D-sub X 2
	Digital Output	DFP output to head
	Composite video	RCA x 1, SVHS x 1
	Power	DC in, DC to head
	Audio	2 stereo mini (3.5mm) jacks for audio in, 1 mike in, 1 mike out
	Security	Kensington security port
CONNECTOR HEAD	**USB**	2/downstrean, 1 upstream
	Power	DC in
	Digital RGB	2 VESA DFB MDR 20 receptacle
POWER		AC 90-264V 50/60Hz (auto switch), 50W (typical
USER CONTROLS	**Basic (base)**	On/off, mute, Vol+/-, 1, down, up, 2
DISPLAY AREA	**Factory Setting**	359mm (H) x 287mm (V)
	OnView®	Advanced image and sound controls
DIMENSIONS	**Physical**	444.7mm (W) x 458.8mm (H) x 238.9mm (D) (17.5" x 18.1" x 9.4")
WEIGHT	**Net**	11Kg (24.2 lbs.)
OTHER		DDC1, DDC2B, PC 99 compliant, GTF
REGULATIONS		UL, DHHS, FCC-B, EPA Energy Star-,DOC-B, CE,CSA, CB, C-UL, NOM, MPR-II, TCO, TUV/GS,CCIB, S-MARK, ISO 13406-2, NEMKO, SEMKO, DEMKO, FIMKO, BCIQ, C-Tick
POWER MANAGEMENT		Meets Energy Star®, VESA® DPMS™, and TCO standards
WARRANTY		Three year limited warranty on parts labor and back light 48 hour Express Exchange® Service option available

*** NIDL ordered the optional Viewsonic DVI to DFP adapter for the Hercules 64 MB Prophet II DVI driver card to work with the LCD monitor for digital addressing.**

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 1600 by 1200 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: Monochrome CRT 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 903 250 MHz programmable test pattern signal generator
- 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) and Spotseeker 4-Axis Positioner
- Microvision SuperSpot 220 with LCD Goniometer

Stereoscopic-mode measurements were attempted using the following commercially-available stereo products:

- 21SX NuVision LCD shutter panel with passive polarized eyewear
- StereoGraphics CE-3 CrystalEyes 3 eyewear and the ENT infrared emitter.

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 dynamic range in a dark room in 1280 x 1024 format is 25.9 dB. It is more than 23 dB (the absolute threshold for IEC) in 3 fc diffuse ambient illumination.

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.

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

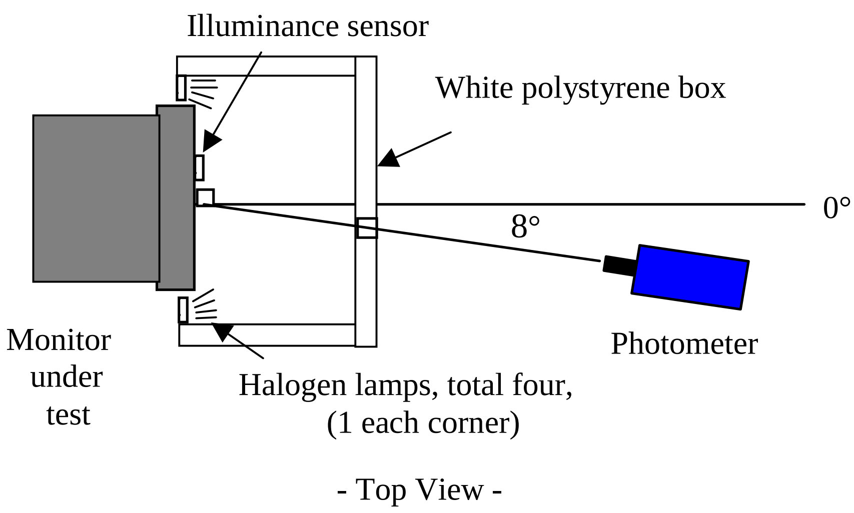


Figure II.1-1. Test setup according to VESA FPDM procedures for measuring total reflectance of screen.

Table II.1-1. Directed Hemispherical Reflectance of Faceplate

VESA ambient contrast illuminance source (polystyrene box)

Ambient Illuminance	21.1 fc
Reflected Luminance	0.98 fL
Faceplate Reflectance	4.7 %

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 dynamic range decreases from 25.9 dB in a dark room to 23.1 dB (the absolute threshold 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 CRT faceplate reflectivity times the ambient illumination measured at the CRT in foot candles added to the minimum screen luminance, Lmin, where Lmin = 0.146 fL.

Ambient Illumination	**Displayed Addressable Format 1280 x 1024**
0 fc (Dark Room)	25.9 dB
1 fc	24.7 dB
2 fc	23.8 dB
3 fc	23.1 dB
4 fc	22.5 dB
5 fc	21.9 dB
6 fc	21.4 dB
7 fc	21.0 dB
8 fc	20.6 dB
9 fc	20.2 dB
10 fc	19.9 dB

II.2. Maximum Luminance (Lmax)

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

The highest luminance for Lmax was 59.6 fL measured at screen center in 1280 x 1024 format.

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 colorimeter (Minolta CA-100). The correlated color temperature (CCT) computed from the measured CIE x, y chromaticity coordinates was within 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
1280 x 1024	7119	0.302	0.331	59.6

II.3. Luminance (Lmax) and Color Uniformity

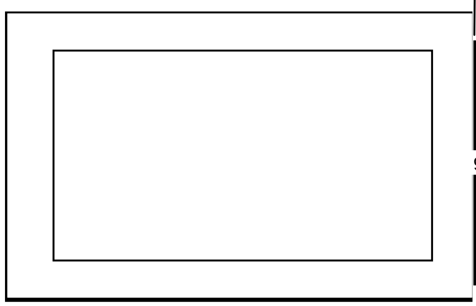
Reference: Monochrome CRT Monitor Performance, Draft Version 2.0, Section 4.4, p. 28.

Maximum luminance (Lmax) varied up to 13.7% across the screen. Chromaticity variations were less than 0.008 delta u'v' units.

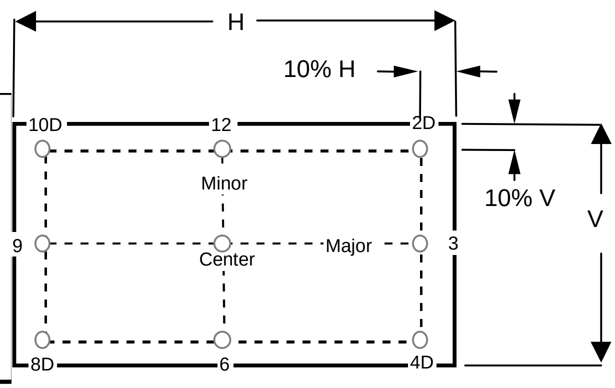
Objective: Measure the variability of luminance and chromaticity coordinates of the white point at 100% Lmax only and as a function of spatial position. Variability of luminance impacts the total number of discriminable gray steps.

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 Δ u´v´.

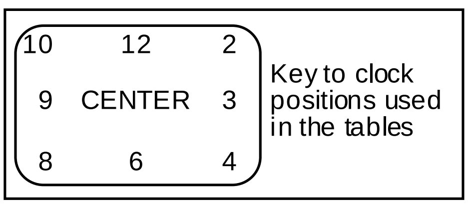
Data: Tabulate the luminance and 1931 C.I.E. chromaticity coordinates (x, y) or correlated color temperature of the white point at each of the nine locations depicted in Figure II.3-2. Additionally, note the location of any additional points that are measured along with the corresponding luminance values.

Table II.3-1.Spatial Uniformity of Luminance and Color

Color and luminance (in fL) for Full screen taken at nine screen positions.

1280 x 1024

POSITION	CCT	CIE x	CIE y	L, fL
center	7119	0.302	0.331	59.6
2	7029	0.302	0.336	51.7
3	7051	0.302	0.334	53.4
4	7209	0.299	0.335	51.4
6	7234	0.299	0.333	53.3
8	6908	0.304	0.337	52.7
9	6864	0.305	0.336	55.3
10	7247	0.299	0.332	54.0
12	7365	0.297	0.332	54.6



1280 x 1024

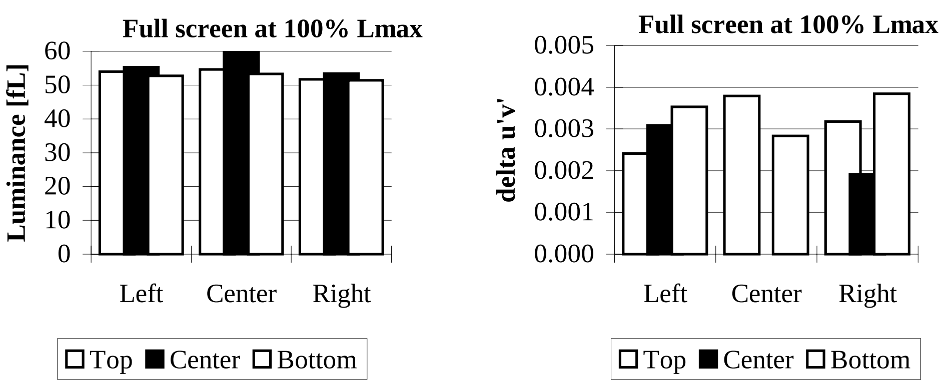


Fig.II.3-3. Spatial Uniformity of Luminance and Chromaticity. (Delta u'v' of 0.004 is just visible.)

II.4. Halation

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

Halation was 3.75 % +/- 0.3% on a small black patch surrounded by a large full white area.

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:

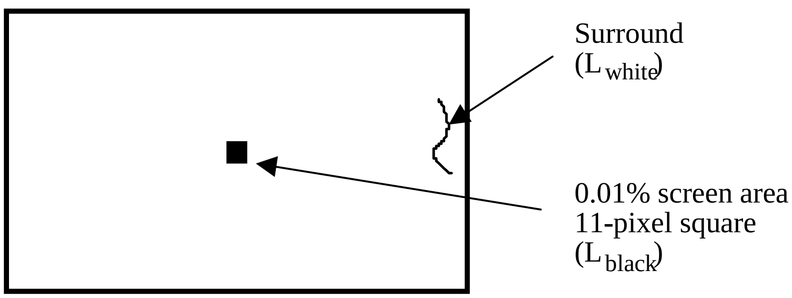


Figure II.4-1 *Test pattern for measuring halation.*

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 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 1280 x 1024 Addressability

	Reported Values	Range for 4% uncertainty
Lblack	1.55 fL ± 4%	1.488 fL to 1.612 fL
Lwhite	41.36 fL ± 4%	39.7 fL to 40.0fL
Halation	3.75% ± 0.3%	3.46 % to 4.06%

II.5. Color Temperature

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

The CCT of the measured white point lies within the boundaries accepted by IEC.

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.

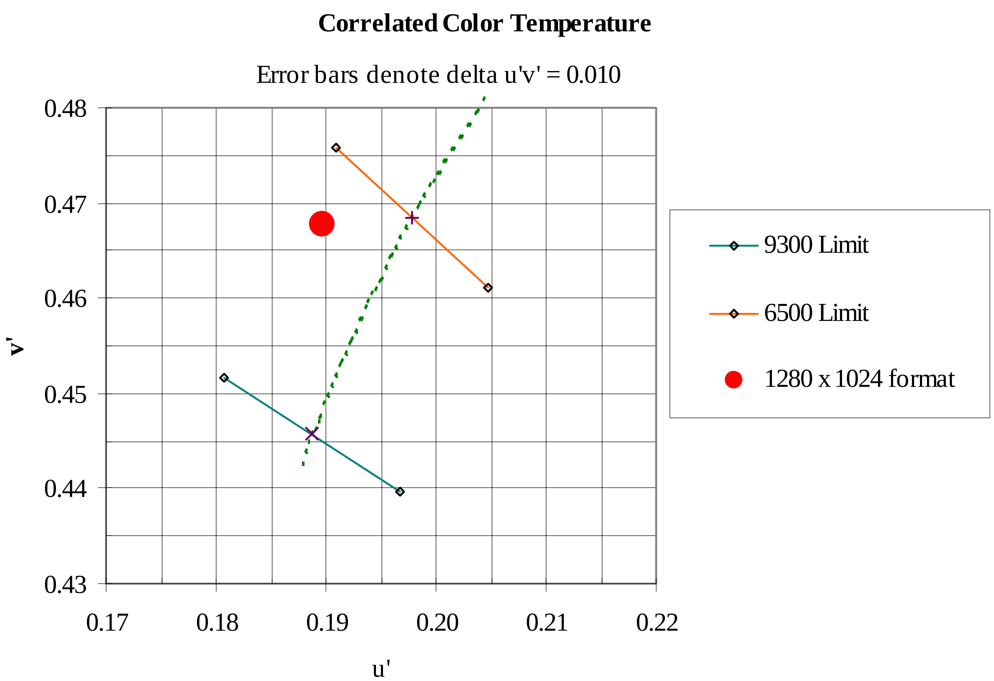


Figure II.5-1 *CCTs of measured whitepoints are within the boundaries required by IEC.*

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

	1280 x 1024
CIE x	0.302
CIE y	0.331
CIE u'	0.190
CIE v'	0.468
CCT	7086
delta u'v'	0.008

II.6. Bit Depth

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

Positive increases in luminance were measured for each of the 256 input levels for 8 bits of gray scale. Neither black level clipping nor white level saturation was observed.

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 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.

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 model 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 model 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. The data for each of the 256 levels are listed in Tables II.6-1 and II.6-2.

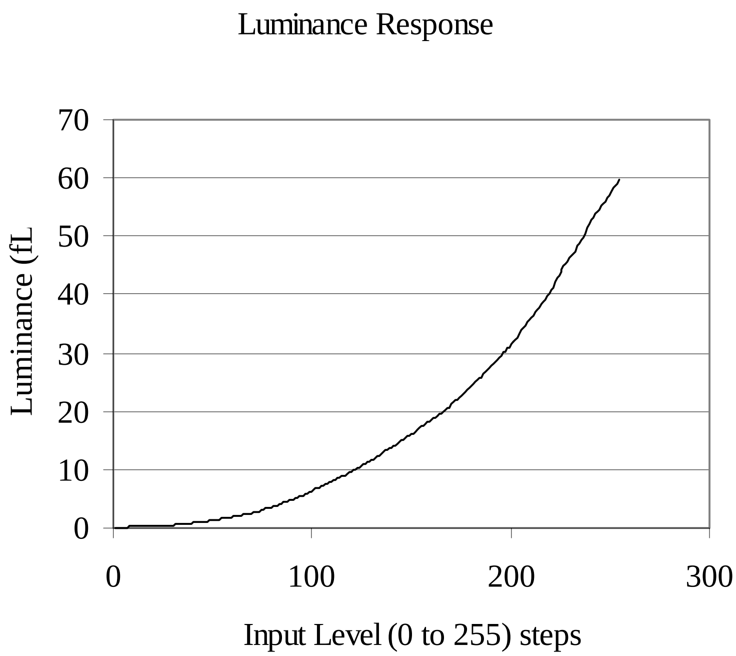


Figure II.6-1. System Tonal Transfer at center screen as a function of input counts.

Table II.6-1. System Tonal Transfer at center screen as a function of input counts. Target levels 000 to 127.

Back Ground	Target	L, fL	Diff, fL	Diff, JND
38	0	0.158		2
39	1	0.16	0.00	3
39	2	0.16	0.00	2
39	3	0.16	0.00	3
40	4	0.16	0.00	2
40	5	0.16	0.00	3
41	6	0.17	0.00	3
41	7	0.17	0.00	2
41	8	0.18	0.01	3
42	9	0.18	0.01	2
42	10	0.19	0.00	3
42	11	0.19	0.01	3
43	12	0.20	0.01	2
43	13	0.21	0.01	3
43	14	0.22	0.01	3
44	15	0.23	0.02	3
44	16	0.25	0.01	2
44	17	0.26	0.01	3
45	18	0.27	0.01	3
45	19	0.29	0.02	2
45	20	0.30	0.02	3
46	21	0.32	0.01	3
46	22	0.33	0.02	2
46	23	0.35	0.02	3
47	24	0.37	0.02	2
47	25	0.39	0.02	3
48	26	0.41	0.02	3
48	27	0.431	0.02	2
48	28	0.457	0.03	3
49	29	0.481	0.02	2
49	30	0.507	0.03	3
49	31	0.544	0.04	3
50	32	0.597	0.05	2
50	33	0.635	0.04	3
50	34	0.67	0.04	2
51	35	0.703	0.03	3
51	36	0.743	0.04	2
51	37	0.784	0.04	3
52	38	0.817	0.03	2
52	39	0.85	0.03	3
52	40	0.891	0.04	2
53	41	0.926	0.04	3
53	42	0.966	0.04	2
53	43	1.007	0.04	3
54	44	1.046	0.04	2
54	45	1.091	0.04	2
55	46	1.134	0.04	3
55	47	1.171	0.04	3
55	48	1.219	0.05	2
56	49	1.302	0.08	3
56	50	1.375	0.07	2
56	51	1.431	0.06	3
57	52	1.482	0.05	2
57	53	1.532	0.05	2
57	54	1.587	0.05	3
58	55	1.634	0.05	2
58	56	1.683	0.05	2
58	57	1.745	0.06	3
59	58	1.804	0.06	2
59	59	1.857	0.05	2
59	60	1.915	0.06	3
60	61	1.973	0.06	2
60	62	2.051	0.08	2
60	63	2.122	0.07	2

Back Ground	Target	L, fL	Diff, fL	Diff, JND
61	64	2.173	0.05	2
61	65	2.253	0.08	3
62	66	2.369	0.116	2
62	67	2.463	0.094	3
62	68	2.542	0.079	2
63	69	2.569	0.027	2
63	70	2.672	0.103	2
63	71	2.755	0.083	2
64	72	2.834	0.079	2
64	73	2.904	0.07	3
64	74	2.992	0.088	2
65	75	3.097	0.105	2
65	76	3.178	0.081	2
65	77	3.275	0.097	3
66	78	3.359	0.084	2
66	79	3.464	0.105	2
66	80	3.578	0.114	2
67	81	3.675	0.097	2
67	82	3.768	0.093	2
67	83	3.911	0.143	3
68	84	4.092	0.181	2
68	85	4.217	0.125	2
69	86	4.334	0.117	2
69	87	4.442	0.108	2
69	88	4.576	0.134	2
70	89	4.681	0.105	2
70	90	4.789	0.108	2
70	91	4.935	0.146	2
71	92	5.094	0.159	2
71	93	5.213	0.119	2
71	94	5.367	0.154	2
72	95	5.481	0.114	2
72	96	5.627	0.146	2
72	97	5.802	0.175	2
73	98	5.948	0.146	2
73	99	6.068	0.12	2
73	100	6.272	0.204	2
74	101	6.535	0.263	2
74	102	6.716	0.181	2
74	103	6.873	0.157	2
75	104	6.996	0.123	2
75	105	7.162	0.166	2
76	106	7.294	0.132	2
76	107	7.425	0.131	2
76	108	7.612	0.187	2
77	109	7.775	0.163	2
77	110	7.939	0.164	1
77	111	8.099	0.16	2
78	112	8.277	0.178	2
78	113	8.423	0.146	2
78	114	8.636	0.213	2
79	115	8.791	0.155	2
79	116	8.916	0.125	2
79	117	9.062	0.146	2
80	118	9.278	0.216	2
80	119	9.497	0.219	2
80	120	9.704	0.207	1
81	121	9.865	0.161	2
81	122	10.08	0.215	2
81	123	10.26	0.18	2
82	124	10.43	0.17	1
82	125	10.58	0.15	2
83	126	10.82	0.24	2
83	127	11.04	0.22	2

Table II.6-2. System Tonal Transfer at center screen as a function of input counts
Target levels 128 to 255.

Back ground	Target	L, fL	Diff, fL	Diff, JND
83	128	11.26	0.22	1
84	129	11.42	0.16	2
84	130	11.6	0.18	2
84	131	11.82	0.22	2
85	132	12.07	0.25	2
85	133	12.21	0.14	1
85	134	12.49	0.28	2
86	135	12.74	0.25	2
86	136	13.08	0.34	2
86	137	13.24	0.16	1
87	138	13.46	0.22	2
87	139	13.67	0.21	2
87	140	13.89	0.22	1
88	141	14.09	0.2	2
88	142	14.22	0.13	2
88	143	14.47	0.25	1
89	144	14.74	0.27	2
89	145	14.96	0.22	2
90	146	15.21	0.25	2
90	147	15.41	0.2	1
90	148	15.64	0.23	2
91	149	15.82	0.18	1
91	150	16.05	0.23	2
91	151	16.25	0.2	1
92	152	16.52	0.27	2
92	153	16.88	0.36	2
92	154	17.11	0.23	1
93	155	17.36	0.25	2
93	156	17.63	0.27	2
93	157	17.84	0.21	1
94	158	18.08	0.24	2
94	159	18.22	0.14	1
94	160	18.52	0.3	2
95	161	18.76	0.24	1
95	162	19.01	0.25	2
95	163	19.23	0.22	1
96	164	19.44	0.21	2
96	165	19.67	0.23	1
97	166	19.95	0.28	2
97	167	20.22	0.27	2
97	168	20.42	0.2	1
98	169	20.73	0.31	2
98	170	21.23	0.5	1
98	171	21.52	0.29	2
99	172	21.88	0.36	1
99	173	22.08	0.2	2
99	174	22.45	0.37	1
100	175	22.72	0.27	2
100	176	23.02	0.3	1
100	177	23.32	0.3	1
101	178	23.69	0.37	2
101	179	24	0.31	2
101	180	24.37	0.37	1
102	181	24.62	0.25	1
102	182	24.96	0.34	2
102	183	25.29	0.33	1
103	184	25.67	0.38	1
103	185	25.89	0.22	2
104	186	26.29	0.4	1
104	187	26.78	0.49	2
104	188	27.16	0.38	1
105	189	27.51	0.35	2
105	190	27.85	0.34	1
105	191	28.28	0.43	1

Back ground	Target	L, fL	Diff, fL	Diff, JND
106	192	28.61	0.33	2
106	193	28.93	0.32	1
106	194	29.24	0.31	1
107	195	29.62	0.38	2
107	196	30.03	0.41	1
107	197	30.35	0.32	2
108	198	30.73	0.38	1
108	199	31.05	0.32	1
108	200	31.46	0.41	1
109	201	31.78	0.32	2
109	202	32.17	0.39	1
109	203	32.75	0.58	1
110	204	33.45	0.7	2
110	205	33.91	0.46	1
111	206	34.35	0.44	1
111	207	34.79	0.44	2
111	208	35.26	0.47	1
112	209	35.72	0.46	1
112	210	36.13	0.41	1
112	211	36.48	0.35	2
113	212	36.98	0.5	1
113	213	37.39	0.41	1
113	214	37.85	0.46	1
114	215	38.32	0.47	2
114	216	38.64	0.32	1
114	217	39.14	0.5	1
115	218	39.72	0.58	2
115	219	40.16	0.44	1
115	220	40.77	0.61	0
116	221	41.33	0.56	1
116	222	42.19	0.86	2
116	223	42.76	0.57	1
117	224	43.4	0.64	1
117	225	43.91	0.51	1
118	226	44.42	0.51	2
118	227	44.86	0.44	1
118	228	45.21	0.35	1
119	229	45.77	0.56	2
119	230	46.29	0.52	1
119	231	46.76	0.47	1
120	232	47.17	0.41	2
120	233	47.52	0.35	1
120	234	48.22	0.7	1
121	235	48.83	0.61	2
121	236	49.33	0.5	0
121	237	49.91	0.58	1
122	238	50.61	0.7	1
122	239	51.63	1.02	1
122	240	52.19	0.56	2
123	241	52.71	0.52	1
123	242	53.21	0.5	1
123	243	53.79	0.58	1
124	244	54.29	0.5	2
124	245	54.52	0.23	1
125	246	55.1	0.58	1
125	247	55.66	0.56	1
125	248	56.01	0.35	1
126	249	56.51	0.5	1
126	250	57.03	0.52	0
126	251	57.61	0.58	2
127	252	58.2	0.59	1
127	253	58.72	0.52	1
127	254	59.02	0.3	1
128	255	59.69	0.67	1

II.8. Luminance Step Response

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

No video artifacts were observed.

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

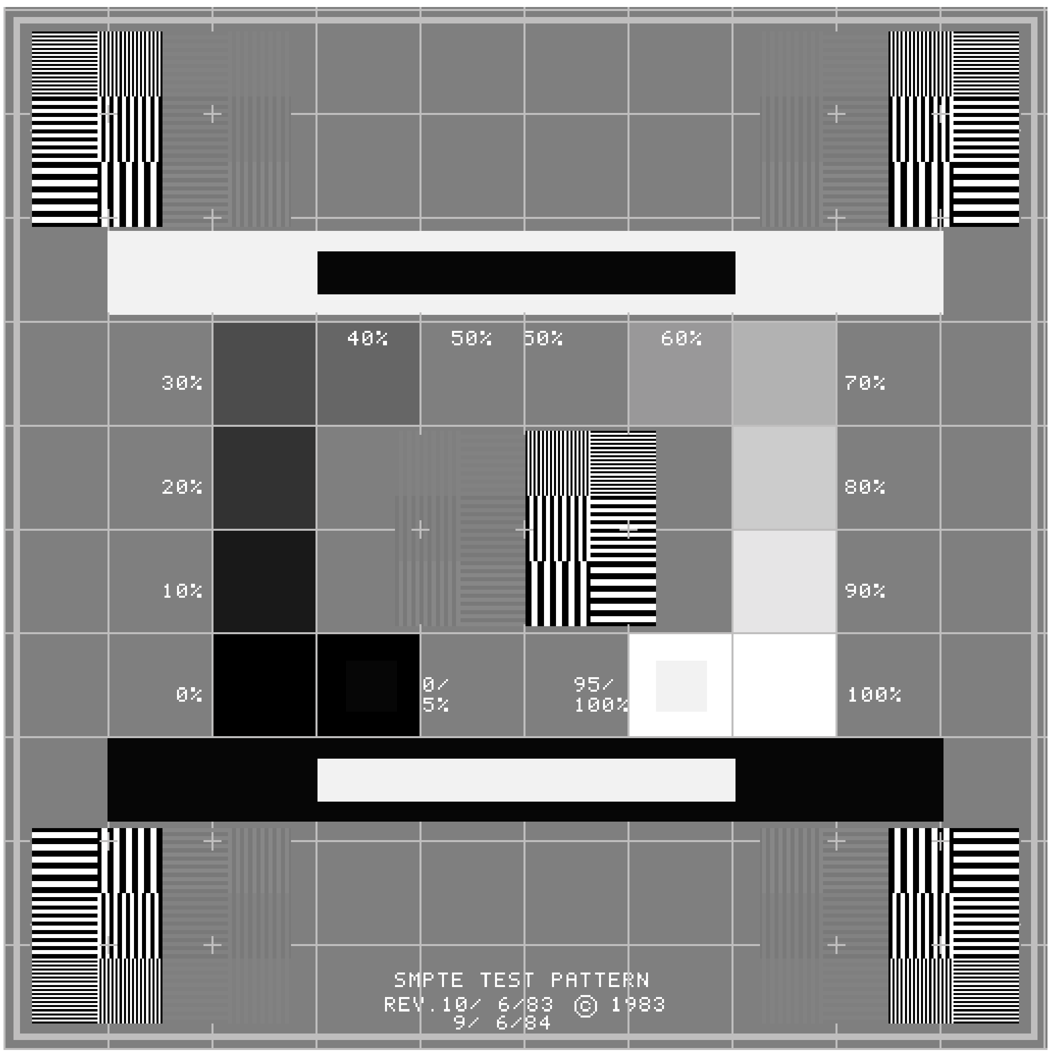


Figure II.8-1. SMPTE Test Pattern.

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." None of these artifacts was observed in the ViewSonic VP181 LCD monitor, signifying good electrical performance of the video circuits.

II.9. Addressability

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

This monitor properly displayed all addressed pixels for the following tested format (HxV):

1280 x 1024 x 60 Hz.

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 and V grille patterns 1-pixel-on/1-pixel-off.

Procedure: The number of addressed pixels were programmed into the Quantum Data 8701 test pattern generator for 75 Hz for monoscopic mode and 110 Hz maximum addressable 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 Addressabilities Tested

Monoscopic Mode	Stereo Mode*
1280 x 1024	

* NIDL could not achieve stereoscopic mode at 100 Hz.

II.10. Pixel Aspect Ratio

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

Pixel aspect ratio is within 0.03%.

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.

	Monoscopic Mode
Addressability (H x V)	**1280 x 1024**
H x V Image Size (inches)	14.138 x 11.283
H x V Pixel Spacing (mils)	11.05 x 11.02
H x V Pixel Aspect Ratio	H = V + 0.03%

II.11. Screen Size (Viewable Active Image)

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

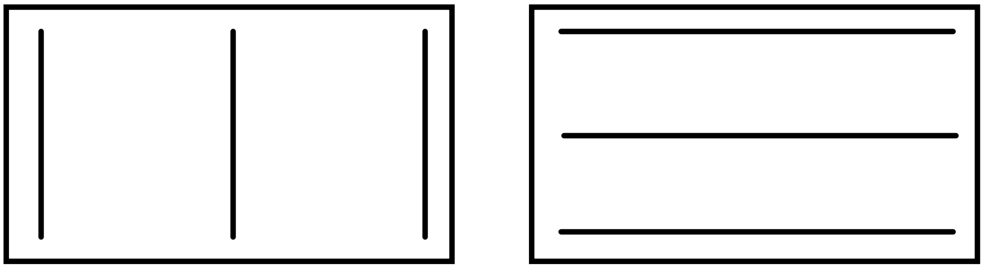
Image size as tested in monoscopic mode (1280 x1024) was 18.089 inches in diagonal.

Objective: Measure beam position on the 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 Modes
Addressability (H x V)	**1280 x 1024**
H x V Image Size (inches) Diagonal Image Size (inches)	14.138 x 11.283 18.089

II.12. Contrast Modulation

Reference: Monochrome CRT 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 exceeded Cm = 86% in Zone A of diameter 7.6 inches, and exceeded 86% for Zone A diameter of 9.79 inches (40% of image area). Cm exceeded 85% for zone B, significantly higher than for CRT monitors measured by NIDL.

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 each format 1280 x 1024 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.

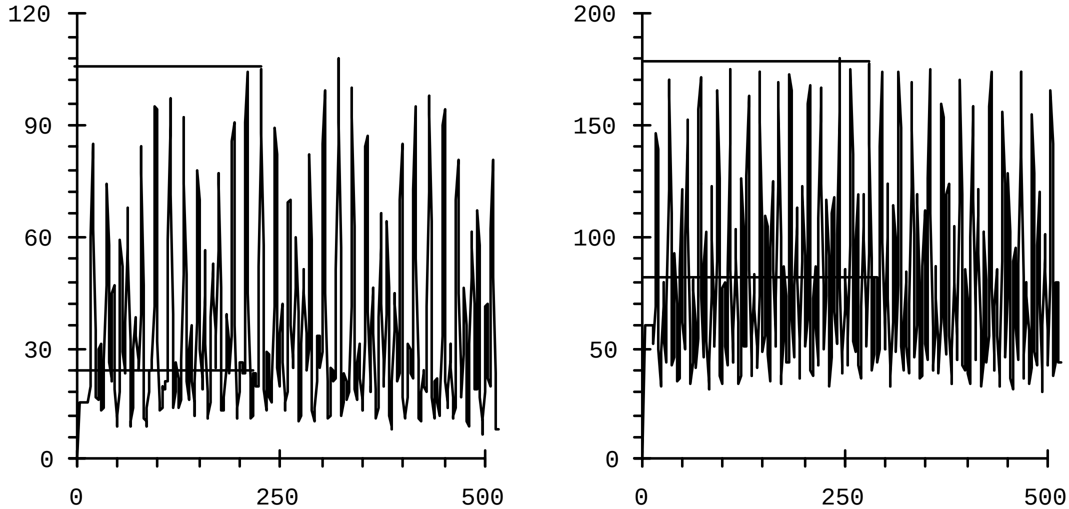
Zone A is defined as a 24 degree subtended circle from a viewing distance of 18 inches (7.6 inch circle). Zone B is the remainder of the display. Use edge measurements no more than 10% of screen size in from border of active screen area to define Cm for Zone B (remaining area outside center circle). 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 is equal to or greater than 86% in Zone A, and is equal to or greater than 85% in Zone B.

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

The sample contrast modulations shown in Figure II.12-1 for two different color CRTs are not fully realized because of the presence of moiré caused by aliasing between the image and the shadowmask. Because contrast modulation values are calculated for the maximum peak and minimum valley luminance levels as indicated in the sample data shown, they do not include the degrading effects of aliasing.

Moiré is neither present nor a problem in a LCD monitor.



Monitor A

Monitor B

$$Cm = \frac{105 - 24}{105 + 24} = 63\%$$

$$Cm = \frac{179 - 821}{179 + 821} = 37\%$$

Figure II.12-1. *Contrast modulation for sample luminance profiles (1 pixel at input level corresponding to 50% Lmax, 1 pixel at level 0 = Lmin) for CRT monitors exhibiting moiré due to aliasing.*

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

Zone A = 7.6-inch diameter circle for 24-degree subtended circle at 18-inches 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	88%	85%			90%	87%			90%	87%
			89%	86%	90%	87%	90%	87%		
Major	89%	87%	90%	87%	90%	87%	90%	87%	90%	87%
			90%	87%	90%	87%	91%	87%		
Bottom	90%	86%			90%	87%			91%	88%

Zone A = 9.79-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	88%	85%			90%	87%			90%	87%
			89%	86%	90%	87%	90%	87%		
Major	89%	87%	90%	87%	90%	87%	90%	87%	90%	87%
			90%	86%	90%	87%	91%	88%		
Bottom	90%	86%			90%	87%			91%	88%

	24 degrees		**40% Circular Area**	
Zone A dia.	**7.6**	**inches**	**9.01**	**inches**
Cm Zone A	**86%**	**min.**	**86%**	**min.**
Cm Zone B	**85%**	**min.**	**85%**	**min.**

II.13. Pixel Density

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

Pixel density was 91H x 91V pixels per inch (ppi) as tested for the 1280x 1024-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	**1280 x 1024**
H x V Image Size, Inches	14.138 x 11.28
H x V Pixel Density, ppi	91 x 91

II.14. Moiré

Reference: Request for Evaluation Monitors, NIDL Pub. 0201099-091, Section 5.14, p 9.

The ViewSonic VP181 LCD monitor shows no moiré. The color filter pitch and the pixel pitch are identical.

Objective: Determine lack of moiré.

Equipment Loupe with scale graduated in 0.001 inch or equivalent

Procedure Measure phosphor pitch in vertical and horizontal dimension at screen center. For aperture grille screens, vertical pitch will be 0. Define pixel size by 1/pixel density.

Data: Define value of phosphor: pixel spacing. Value <1 passes, but <0.6 preferred.

Table II.14-1. Phosphor-to-Pixel-Spacing Ratios

	Monoscopic Mode
Addressability	1280 x 1024
LCD color filter pitch	11.05 mils
Pixel Spacing	11.05mils
LCD color filter-to-Pixel-Spacing	1.0

II.15. Straightness

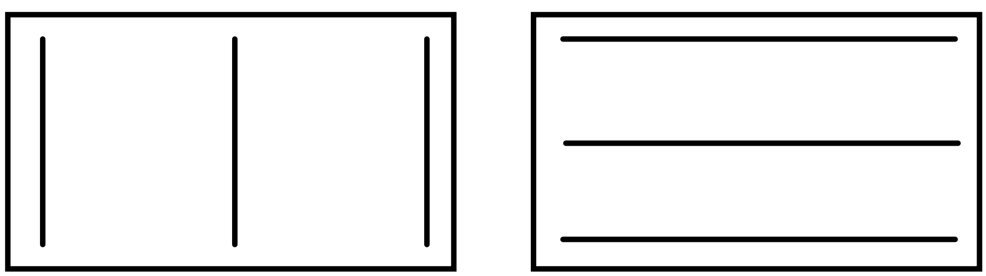
Reference: Monochrome CRT Monitor Performance, Draft Version 2.0, Section 6.1 Waviness, page 67.

Deviation from straightness did not exceed 0.03% of the total image height or width.

Objective: Measure beam position on the CRT display to quantify effects of waviness which causes nonlinearities within small areas of the display distorting nominally straight features in images, characters, and symbols.

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.15-1 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.15-1 Three-line grille test patterns.

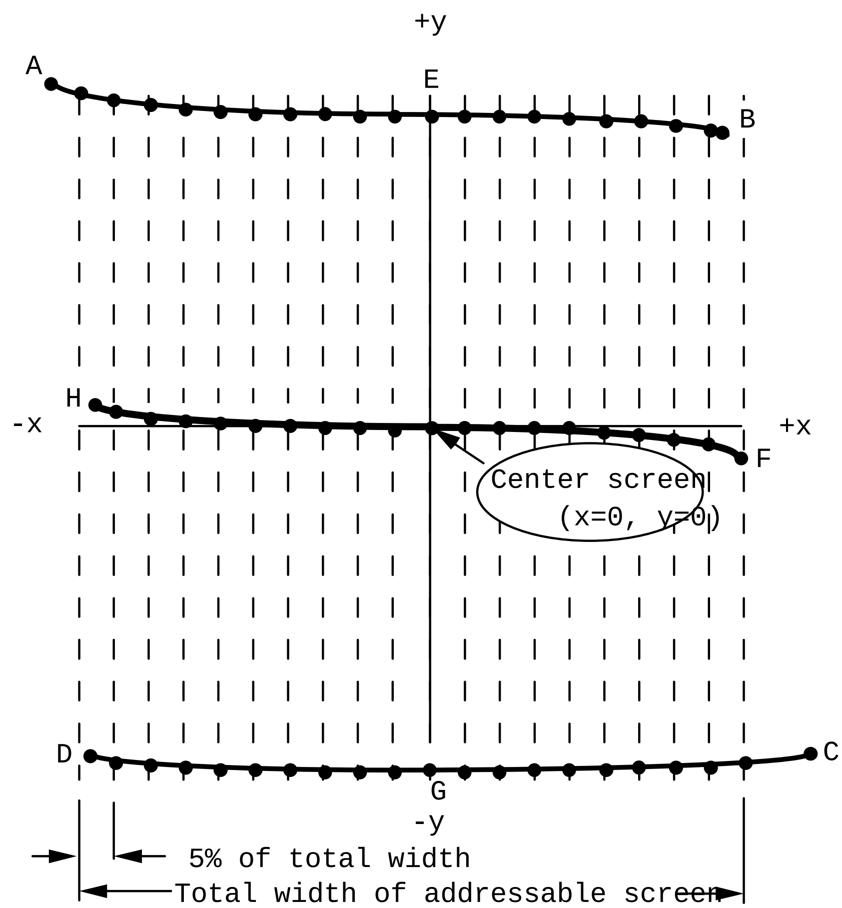


Figure II.15-2 Measurement locations for waviness along horizontal lines. Points A, B, C, D are extreme corner points of addressable screen. Points E, F, G, H are the endpoints of the axes.

Procedure: Use diode optic module to locate center of line profiles in conjunction with calibrated X-Y translation to measure screen x,y coordinates along the length of a nominally straight line. Measure x,y coordinates at 5% addressable screen intervals along the line. Position vertical lines in video to land at each of three (3) horizontal screen locations for determining waviness in the horizontal direction. Similarly, position horizontal lines in video to land at each of three (3) vertical screen locations for determining waviness in the vertical direction.

Data: Tabulate x,y positions at 5% addressable screen increments along nominally straight lines at top and bottom, major and minor axes, and left and right sides of the screen as shown in Table II.15-I. Figure II.15-3 shows the results in graphical form.

Table II.15-1. Straightness
Tabulated x,y positions at 5% addressable screen increments
along nominally straight lines.

Top		Bottom		Major		Minor		Left Side		Right Side	
x	y	x	y	x	y	x	y	x	y	x	y
-7070	5649	-7070	-5637	-7068	0	0	5649	-7070	5646	7073	5646
-6300	5649	-6300	-5637	-6300	0	0	5400	-7070	5400	7073	5400
-5600	5649	-5600	-5637	-5600	0	0	4800	-7070	4800	7073	4800
-4900	5649	-4900	-5637	-4900	0	0	4200	-7070	4200	7073	4200
-4200	5649	-4200	-5637	-4200	0	0	3600	-7070	3600	7073	3600
-3500	5649	-3500	-5637	-3500	0	0	3000	-7070	3000	7073	3000
-2800	5649	-2800	-5637	-2800	0	0	2400	-7070	2400	7073	2400
-2100	5649	-2100	-5637	-2100	0	0	1800	-7070	1800	7072	1800
-1400	5649	-1400	-5637	-1400	0	0	1200	-7070	1200	7072	1200
-700	5649	-700	-5637	-700	0	0	600	-7070	600	7072	600
0	5649	0	-5637	0	0	0	0	-7070	0	7072	0
700	5649	700	-5637	700	0	-1	-600	-7070	-600	7071	-600
1400	5649	1400	-5637	1400	0	-2	-1200	-7071	-1200	7070	-1200
2100	5649	2100	-5637	2100	0	-3	-1800	-7071	-1800	7070	-1800
2800	5649	2800	-5637	2800	0	-3	-2400	-7071	-2400	7070	-2400
3500	5649	3500	-5637	3500	0	-4	-3000	-7072	-3000	7069	-3000
4200	5649	4200	-5637	4200	0	-5	-3600	-7073	-3600	7067	-3600
4900	5649	4900	-5637	4900	0	-5	-4200	-7073	-4200	7066	-4200
5600	5649	5600	-5637	5600	0	-5	-4800	-7073	-4800	7066	-4800
6300	5649	6300	-5637	6300	0	-4	-5400	-7072	-5400	7067	-5400
7073	5649	7064	-5637	7070	0	-3	-5637	-7071	-5634	7065	-5637

1280 x 1024

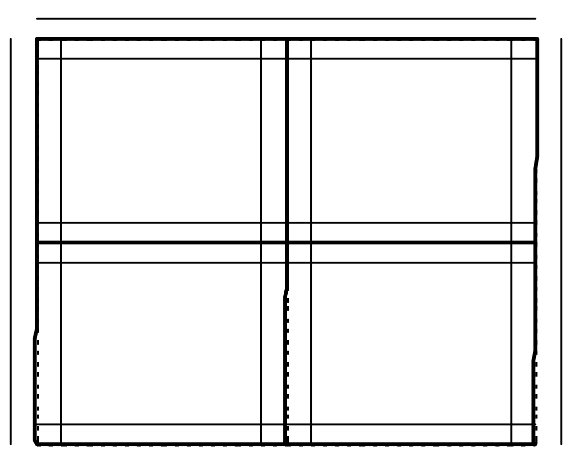


Figure II.15-3 Waviness of ViewSonic VP181 Color monitor in 1280 x 1024 mode. Departures from straight lines are exaggerated on a 10X scale. Error bars are +/- 0.5% of total screen size.

II.16. Refresh Rate

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

Vertical refresh rate for 1280 x 1024 format was set to 60 Hz, and not limited by the monitor. The LCD monitor cannot achieve the necessary 120 Hz refresh rate for stereo. It is limited to 75 Hz.

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 achievable.

Data: Report refresh rates in Hz.

Table II.16-1 Refresh Rates as Tested

	Monoscopic Mode	**Stereo Mode**
Addressability	**1280 x 1024**	
Vertical Scan Horizontal Scan	60 Hz 63.98 kHz	

* Manufacturer states 95 kHz maximum scan rate, thus, 120 Hz vertical scan rate is not achievable in stereo mode. Manufacturer states a maximum vertical refresh rate of 75 Hz.

II.17. Extinction Ratio

Due to a maximum vertical refresh rate at 75Hz, the Stereo tests were attempted but were not successful. The Stereo mode requires 120Hz or a minimum of 100Hz.

II.18. Linearity

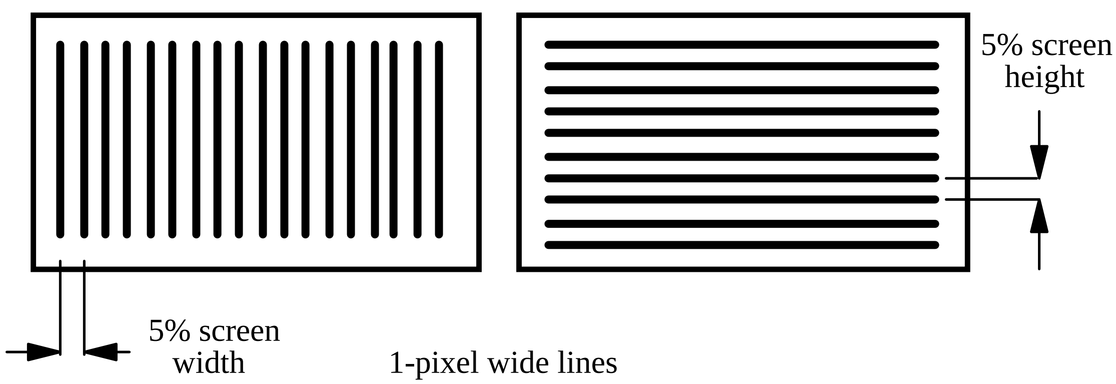
Reference: Monochrome CRT Monitor Performance, Draft Version 2.0, Section 6.2, page 73.

The maximum nonlinearity of the scan was 0.07% of full screen.

Objective: Measure the relation between the actual position of a pixel on the screen and the commanded position to quantify effects of raster nonlinearity. Nonlinearity of scan degrades the preservation of scale in images across the display.

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

Test Pattern: Use grille patterns of single-pixel horizontal lines and single-pixel vertical lines displayed at 100% L_{max}. Lines are equally spaced in addressable pixels. Spacing must be constant and equal to approximately 5% screen width and height to the nearest addressable pixel as shown in Figure II.18-1.



V-grille ***H-grille***

Figure II.18-1. *Grille patterns for measuring linearity*

Procedure: The linearity of the raster scan is determined by measuring the positions of lines on the screen. Vertical lines are measured for the horizontal scan, and horizontal lines for the vertical scan. Lines are commanded to 100% Lmax and are equally spaced in the time domain by pixel indexing on the video test pattern. Use optic module to locate center of line profiles in conjunction with x,y-translation stage to measure screen x,y coordinates of points where video pattern vertical lines intersect horizontal centerline of screen and where horizontal lines intersect vertical centerline of the CRT screen as shown in Figure II.18-2.

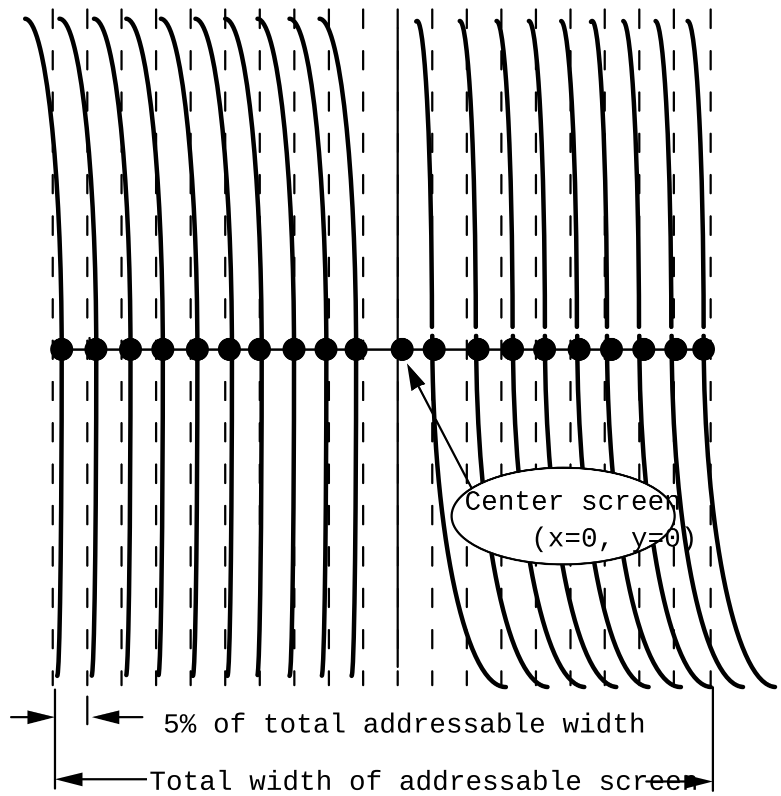


Figure II.18-2. *Measurement locations for horizontal linearity along the major axis of the display. Equal pixel spacings between vertical lines in the grille pattern are indicated by the dotted lines. The number of pixels per space is nominally equivalent to 5% of the addressable screen size.*

Data: Tabulate x, y positions of equally spaced lines (nominally 5% addressable screen apart) along major (horizontal centerline) and minor (vertical centerline) axes of the raster. If both scans were truly linear, the differences in the positions of adjacent lines would be a constant. The departures of these differences from constancy impact the absolute position of each pixel on the screen and are, then, the nonlinearity. The degree of nonlinearity may be different between left and right and between top and bottom. The maximum horizontal and vertical nonlinearities (referred to full screen size) are listed in table II.18-1. The complete measured data are listed in table II.18-2 and shown graphically in Figures II.18-3 and II.18-4.

Table II.18-1. Maximum Horizontal and Vertical Nonlinearities

Format	Left Side	Right Side	Top	Bottom
1280 x 1024	0.02%	0.07%	0.04%	0.05%

Table II.18-2. Horizontal and Vertical Nonlinearities Data

Vertical Lines x-Position (mils)		Horizontal lines y-Position (mils)	
Left Side	Right Side	Top	Bottom
-6957	6970	5624	-5626
-6263	6274	5060	-5064
-5568	5576	4496	-4500
-4872	4877	3932	-3937
-4176	4179	3369	-3375
-3480	3481	2807	-2813
-2784	2784	2245	-2251
-2088	2087	1684	-1689
-1392	1391	1122	-1126
-696	696	562	-562
0	0	0	0

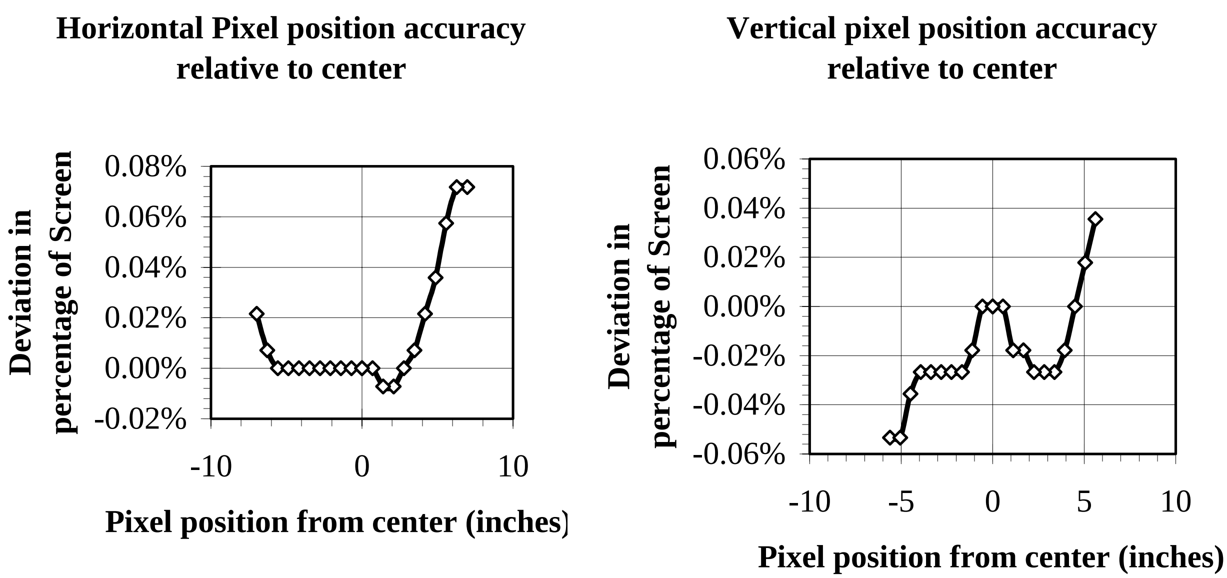


Figure. II.18-3 Horizontal and Vertical Linearity characteristics.

II.19. Jitter/Swim/Drift

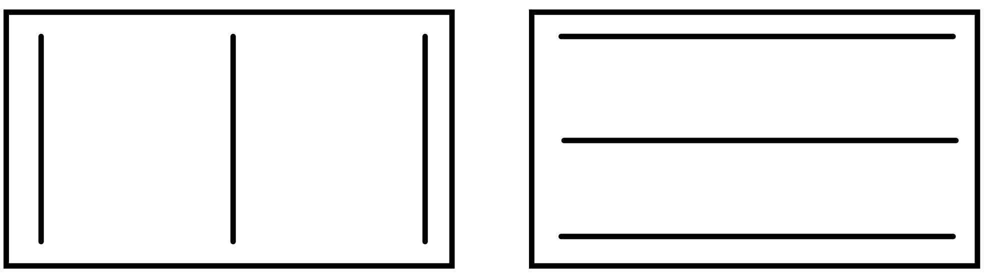
Reference: Monochrome CRT Monitor Performance, Draft Version 2.0 Section 6.4, p80.

Maximum jitter and swim/drift were 0.09 mils and .07 mils, respectively.

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 depends 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. The motion of the test bench was a factor of 10 times smaller than the CRT raster motion.

Table II.19-1. Jitter/Swim/Drift

Time scales: Jitter 2 sec., Swim 10 sec., and Drift 60 sec.

1280 x 1024 x 60hz

		H-lines	V-lines		
10D corner	Max Motions				
	Jitter	0.177	0.119		
	Swim	0.19	0.133		
	Drift	0.2	0.133		
Black Tape	Max Motions				
	Jitter	0.091	0.054		
	Swim	0.14	0.059		
	Drift	0.171	0.061		
Less Tape Motion				maximums	
	Jitter	0.09	0.07		0.09
	Swim	0.05	0.07		0.07
	Drift	0.03	0.07		0.07

II.20. Warm-up Period

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

Less than a 5 minute warm-up was necessary for luminance to be stable within 10% of Lmin = 0.146 fL

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 data for 1280 x 1024 format in graphical form. The luminance remains very stable after 53 minutes.

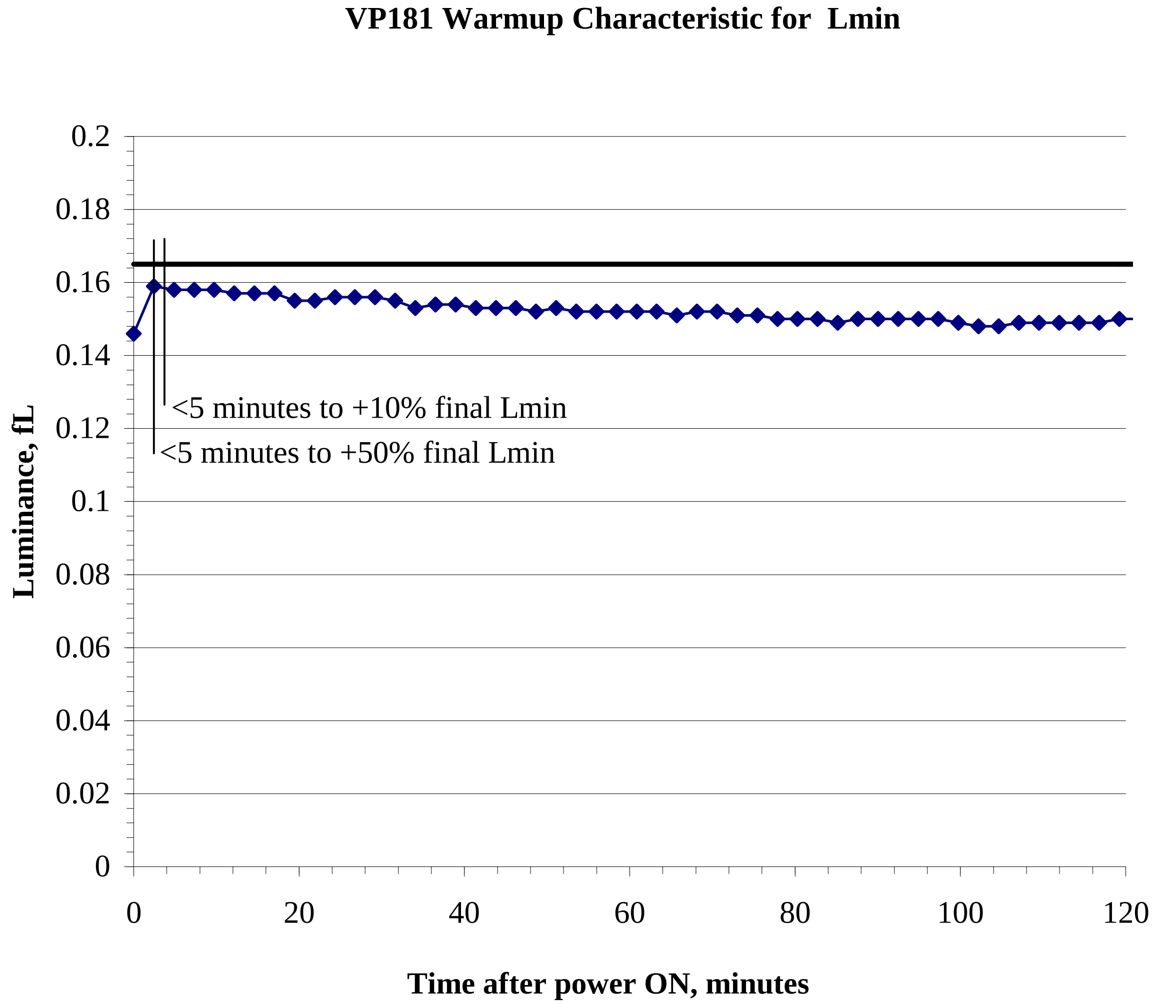


Figure II.20.1. Luminance (fL) as a function of time (in minutes) from a cold start with an input count of 0. (Note suppressed zero on luminance scale).

II.21. Viewing Cone Analysis

The following pictures are generated using the Goniometer/Microvision SS220 System. The view is of a cone of luminance at center screen over a viewing angle of ±50 degrees. The maximum luminance is uniform within about a ±12 degree viewing angle from the perpendicular. Outside of that viewing cone, the luminance drops off progressively with angle away from the perpendicular to the viewing surface.

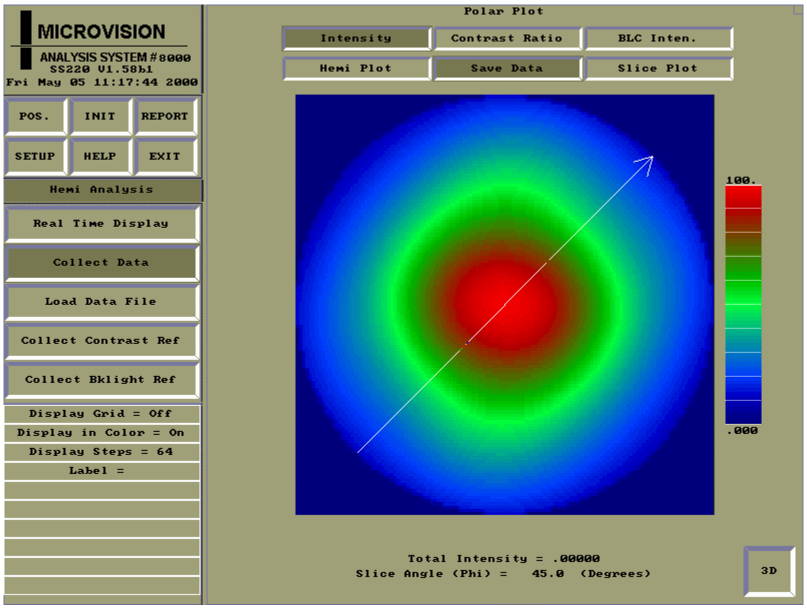


Figure II.21.1. Luminance set at 100% Lmax.

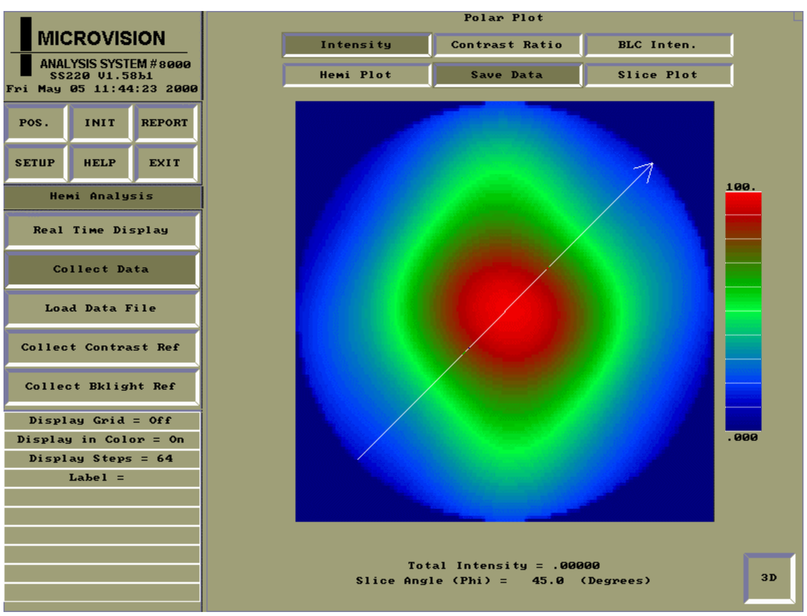


Figure II.21.1. Luminance set at 50% Lmax.

II.22. Monitor response to input signal motion test pattern.

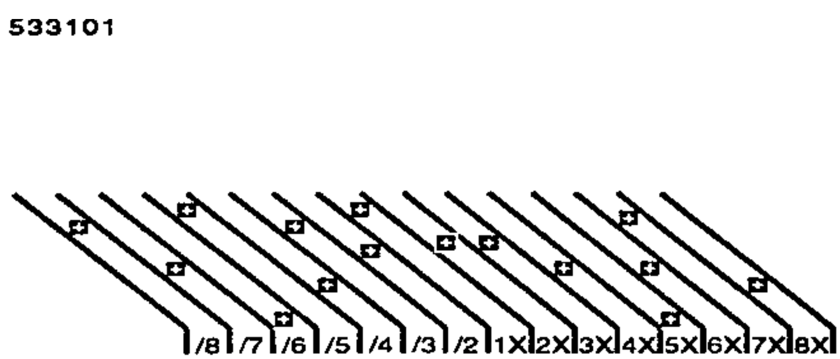
Test condition: 1280 x 1024 x 60 Hz

Results of the visual testing of moving cursor boxes
(White on Black and black on white)

ViewSonic VP181

/3 - Clear but flicker increases heavily towards 8X / viewable
/1 - Slight blur / viewable
1X - Slight blur / viewable
2X - Great blur / less than viewable
3X - through 8X Blurs heavily towards 8X / not viewable

For comparison, on a CRT monitor the 4X test pattern is clearly visible.



/8 /7 /6 /5 /4 /3 /2 1X 2X 3X 4X

Figure II.22.1. Quantum Data Persistence Test Image using the MicroVision SS200 to test the LCD response time and to compare it with a CRT monitor.

Description of motion artifacts*

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.

A continuously running counter appears in the upper left-hand corner of the image. The number shown is the number of vertical frame refreshes that have occurred since the generator was first powered up.

The secondary version draws a black image on a white background. As pictured above.

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.

*Explanation of motion artifacts 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.