

Journal of the

SOCIETY FOR INFORMATION DISPLAY

1995

Volume 3

Special Section

Selected papers from the 1995 SID International Symposium

**December
Number 4**

Content categories for this issue:

Field-emission displays
Helmet-mounted displays
Liquid-crystal displays
Novel materials
Projection displays
Three-dimensional displays/virtual reality
Human factors
Standards and measurements

Index

Previously published as
Proceedings of the Society for Information Display

SID
SOCIETY FOR INFORMATION DISPLAY

Table of Contents

SELECTED PAPERS FROM THE 1995 SID INTERNATIONAL SYMPOSIUM

FIELD-EMISSION DISPLAYS

- 147 Electron-stimulated surface reactions between residual vacuum gas and ZnS field-emission phosphors
J. Sebastian *et al.*,
University of Florida

HELMET-MOUNTED DISPLAYS

- 151 Helmet-mounted display with dual resolution
A. Fernie, CAE
Electronics, Canada

LIQUID-CRYSTAL DISPLAYS

- 155 Axially symmetric aligned microcell (ASM) mode: Electro-optical characteristics of new display mode with excellent wide-viewing angle
N. Yamada *et al.*,
Sharp Corp., Japan
- 159 Holographic reflective LCD
A. G. Chen *et al.*, Motorola
Corporate Manufacturing Research
Center
- 165 Dynamic drive for bistable reflective cholesteric displays: A rapid addressing scheme
X.-Y. Huang *et al.*,
Liquid Crystal Institute
- 169 Brighter backlights using highly scattered optical-transmission polymer
A. Horibe *et al.*,
Keio University, Japan
- 173 Viewing-angle-enhancement system for LCDs
S. Zimmerman *et al.*,
AlliedSignal, Inc.
- 177 AMLCD with integrated drivers made with a-Si TFTs
H. Lebrun, Thomson-LCD, France
- 181 High-efficiency color microdisplays
P. Alvelda, MIT
- 185 Molecular architectures in thin plastic films by *in-situ* photopolymerization of reactive liquid crystals
D. J. Broer, Philips Research
Laboratories, The Netherlands

continued . . .

Membership in the Society for Information Display is open to qualified individuals active or interested in any area of information display technology or use. Membership includes subscriptions to the *Journal of the SID, Information Display*, and member's chapter publications and newsletters; members are admitted to Society functions at reduced rates. Individual membership costs \$55/year. For further information, including reduced fees for student members and the benefits of Sustaining Membership, contact the International Office.

Subscriptions for non-members are \$100/year (\$110/year outside North America). Single copies are \$25; consult the International Office for availability of back issues. Copies of the *Symposium Digests* are available from the International Office; price varies with the year. Subscriptions to *Information Display* are available gratis to qualified individuals; contact the Managing Editor for information.

Editorial content of Society publications is the responsibility of the

individual authors; the Society does not endorse any opinions or products presented in its publications unless such endorsement is explicitly stated.

Copyright © 1995 The Society for Information Display. Copying of material in this *Journal* for internal or personal use, beyond the fair-use provisions granted by US Copyright Law, is subject to the payment of copying fees to the Copyright Clearance Center (CCC), 27 Congress St., Salem, MA 01970. The fee and article code number are listed at the bottom of the first page of each paper. All other copying of any material in this *Journal* without the specific permission of the Society is prohibited.

Journal of SID (ISSN 1071-0922) is published four times a year by the Society for Information Display. See above for subscription prices. **POSTMASTER:** Send address changes to *Journal of the SID*, 1526 Brookhollow Dr., Suite 82, Santa Ana, CA 92705-5421.

Table of Contents (Continued)

PROJECTION DISPLAYS

- 191 Ultrahigh-intensity short-arc long-life lamp system
E. Schnedler, *Philips Research Laboratories, Germany*; H. v. Wijngaarde, *Philips Lighting B.V., The Netherlands*
- 195 An optically active diffractive device for a high-efficiency light valve
P. J. Bos, *Liquid Crystal Institute*; B. Smith *et al.*, *Florida Atlantic University*
- 199 Picture quality in large-screen projectors using the Digital Micromirror Device
B. R. Critchley *et al.*, *Rank Brimar Ltd., U.K.*; R. O. Gale and M. Burton, *Texas Instruments*

THREE-DIMENSIONAL DISPLAYS/VIRTUAL REALITY

- 203 Time-multiplexed three-dimensional video display
A. R. L. Travis *et al.*, *Cambridge University, U.K.*
- 207 Design factors in stereoscopic virtual-reality displays
M. Mon-Williams, *University of Reading, U.K.*; J. P. Wann and S. Rushton, *University of Edinburgh, Scotland*
- 211 Visual requirements for virtual-environment generation
R. V. Kenyon, *et al.*, *University of Illinois at Chicago*

HUMAN FACTORS

- 215 Visual suppression of one eye's view with dichoptic stimulation
R. Blake, *Vanderbilt University*

STANDARDS AND MEASUREMENTS

- 219 A survey of the components of display-measurement standards
E. E. Kelley *et al.*, *NIST*; M. D. Grote and D. J. Bechis, *National Information Display Laboratory*

REGULAR PAPERS

LIQUID-CRYSTAL DISPLAYS

- 223 Analytical models for a-Si and poly-Si TFTs for high-definition display technology
M. S. Shur *et al.*, *University of Virginia*; M. Hack, *Xerox PARC*
- 237 Quantitative comparison of LCD viewing-angle improvement brought about by various methods
M. Ishikawa *et al.*, *Toshiba Corp., Japan*
- 243 Reduction of reflectance in LCDs
M. Ishikawa *et al.*, *Toshiba Corp., Japan*
- 249 Moving-image enhancement on AMLCDs
S. Bitzakidis, *Philips Research Laboratories, U.K.*

INDEX

- 257 *Journal of the SID*, Vol. 3, 1995 and *Information Display*, Vol. 11, 1995

Journal of the SID

The quarterly *Journal of the SID* publishes original work dealing with the theory and practice of information display. Coverage includes hard and soft copy; the underlying chemistry, physics, physiology, and psychology; measurement techniques; and all aspects of the interaction between equipment and its users.

The Society also publishes *Symposium Digests*, containing extended abstracts of papers presented at the annual International Symposia, and the monthly magazine *Information Display*. We cooperate in publishing the digests of technical papers presented at the annual International Display Research Conferences. Information about all of these publications and meetings is available from the Society's international office.

Information on membership can be found with the Table of Contents. Detailed information for contributors is at the back of this issue. Full-length papers, brief communications, and letters are welcomed; they may be submitted to any of the Associate Editors or to the Editor.

Published as *Proceedings of the SID* from 1963 through 1991 (Volumes 1-32)

Editor

Alan Sobel, 633 Michigan Ave., Evanston, IL 60202, USA,
phone/fax 708/869-5607; 72020.3607@compuserve.com

Associate Editors

CRTs

Carlo Infante, CBI Technology Consultants
9433 North 87th Way, Scottsdale, AZ 85258
602/951-0808, fax - 6083; 71055.2241@compuserve.com

LCDs

Paul S. Drzaic, Raychem Corp., MS 123/6410
300 Constitution Drive, Menlo Park, CA 94025-1161, USA
415/361-5503, fax -5392, pdrzaic@raychem.com

Allan R. Kmetz

AT&T Bell Laboratories, 600 Mountain Ave., 2D-329,
Murray Hill, NJ 07974-0636, USA
908/582-6179, fax -2913, kmetz@allwise.att.com

Shunsuke Kobayashi

Faculty of Technology, Tokyo University of Agriculture & Technology,
2-24-16, Nakamachi, Koganei, Tokyo, 184 Japan
81-423-81-4221 ext. 515, fax 81-423-85-5395, koba@cc.tuat.ac.jp

Vision Science/Human Factors

David L. Post, Armstrong Laboratory, AL/CFHV
2255 H St., Rm. 300, Wright-Patterson AFB, OH 45433-7022, USA
513/255-7597, fax -8366, -9198; dpost@falcon.al.wpafb.af.mil

Plasma Displays

Shigeo Mikoshiba, Dept. of Electronics Engineering, University of Electro-
Communications, 1-5-1, Chofugaoka, Chofu-shi, Tokyo 182, Japan
phone/fax 81-424-83-3294, shigeo@langmuir.ee.uec.ac.jp

Heiju Uchiike, Electronics Dept., Hiroshima University
1-4-1 Kagamiyama, Higashi-Hiroshima, 724 Japan
81-824-22-7111 x3411; fax 81-824-22-7039

General

Gunter Baur, Fraunhofer-Institut für Angewandte Festkörperphysik
Tullastraße 72, D-7800 Freiburg i. Br., Germany
49-0761-5159-0; fax 49-761-5159-400

Managing Editor

Jay Morreale, Palisades Institute for Research Services, Inc.
201 Varick St., Suite 1006, New York, NY 10014, USA
212/620-3371, fax -3379; 70762.1757@compuserve.com

The Society for Information Display

Executive Officers

President	A. I. Lakatos	Regional Vice-President, Americas T. J. Nelson	Treasurer	A. C. Lowe
President-Elect	W. E. Howard	Regional Vice-President, Asia	Secretary	A. Silzars
		Regional Vice-President, Europe		
		J. N. Perbet		

Directors

Bay Area	H. Sherman	Greater Dayton	R. Holmes	Minneapolis/St. Paul	V. Born
Beijing	S. Ding	Japan	A. Iwamoto	New England	W. A. Hamilton
Belarus	A. Smirnov	Korea	C. Lee	San Diego	R. Ruff
Canada	V. Angelo	Los Angeles	D. Pinsky	Taipei	C. C. Shiu
Delaware Valley	J. Parker	Metropolitan Detroit	Z. Yaniv	UK/Ireland	N. Milward
France	F. Maurice	Mid-Atlantic	D. Ketchum	Immediate Past President	P. M. Heyman
		Mid-Europe	E. Lueder		

Publications Committee

Chairman

A. Silzars

International Office

Lauren Kinsey, Executive Administrator
1526 Brookhollow Drive, Suite 82,
Santa Ana, CA USA 92705-5421
714/545-1526, fax - 1547
email: socforinfodisplay@mcimail.com
www home page: <http://www.display.org/sid>

A survey of the components of display-measurement standards*

E. F. Kelley
G. R. Jones
P. A. Boynton
M. D. Grote
D. J. Bechis

Abstract — Several display standards are reviewed and distinctive elements are compared. With flat panel displays becoming more common and the CRT displays being so well established, the associated standards activities can be somewhat bewildering, even overwhelming. This paper attempts to identify complementary and inconsistent elements of related display standards.

Keywords — Display measurement, standards, standards organizations.

1 Introduction

The growing number and diversity of display applications and technologies and the growing interdependence of users and manufacturers of display devices are both driving a seemingly endless number of standards (1-5). Standards exist because they provide a commercial benefit. Users are assured a certain level of performance, equipment builders can adequately specify their display requirements, and display manufacturers can more easily sell their products.

In November 1994, a workshop was held at the National Institute of Standards and Technology which focused on display standards issues. A number of conclusions were reached: 1) Few companies can afford to follow all the display standards activities in the traditional time-consuming manner which may include costly travel. 2) Few of those working on standards are able to follow what other standards-making bodies are preparing. 3) It would be helpful if people could gain immediate access to all the work being done on display standards. 4) Many would welcome a workshop where display measurement standards were demonstrated in a laboratory. 5) The standards development process can be better implemented in a more timely manner to reduce overlap and inconsistencies. 6) Users of displays need a solid bedrock of measurement standards in order to pick the best display for their application. To successfully address these observations a compilation of existing display standards would be required.

2 Comparisons of display standards

In this paper we attempt to examine a number of display standards and compare their component parts. This is a first step in providing such a comparison and is not comprehensive in that

some display standards are not yet included. The listing of components of standards is found in the table as column headings. The standards reviewed are from the following organizations: ISO – International Standards Organization ANSI – American National Standards Institute; EIA – Electronics Industries Association; EC – International Electrotechnical Commission; VESA – Video Electronics Standards Association; SAE – Society of Automotive Engineers; MPR – from the Swedish National Board for Measurement and Testing; and standards from the US military.

There are several entries in the component columns of the table — the first two columns — which need explanation, although most entries will be self-explanatory to display technologists. Small area luminance includes character and individual dot or pixel luminances, whereas large area luminance integrates the luminance contributions over an area of the screen. Under Luminance and Colors the term “gamma” has historical origins with CRTs and refers to the electrooptic transfer function or power-law dependence of the luminance (or any color) upon voltage $L(V) \propto V^\gamma$, where γ is a constant typically near 2.3. Loading is the change in luminance of white as the area of the white changes, that is, the luminance can depend upon area $L(A)$. Under Line width, Positive refers to narrow black lines on white vs. Negative, white lines on black. MTF is the modulation transfer function, and MTFA is its area. Character modulation quantifies character generation contrast as with, for example, a one-on-two-off pixel arrangement. Raster modulation characterizes the visibility of separate raster lines using a full-field all-on uniform pattern. Small area linearity provides a metric for localized character misalignment, whereas large area linearity quantifies line separation uniformity about the screen. Defects, Spurious Illumination

*This is a contribution of the National Institute of Standards and Technology; not subject to copyright.

Reprint of an invited paper presented at the 1995 SID International Symposium. Contrary to the *Journal's* usual practice, this paper has not been refereed or edited. The paper was invited and accepted by the SID '95 Program Committee. The papers in this special section were selected on the basis of the Symposium attendees' votes for best or most interesting papers.

E. F. Kelley, G. R. Jones, and P. A. Boynton are with the National Institute of Standards and Technology, Electricity Division, Electronics and Electrical Engineering Laboratory, Technology Administration, U.S. Department of Commerce, Bldg. 220, Rm. B344, Gaithersburg, MD 20899.

M. D. Grote and D. J. Bechis are with the National Information Display Laboratory, Princeton, NJ.

© Copyright 1995 Society for Information Display 1071-0922/95/0304-0219\$1.00

Display Standards Survey Summary Table

STANDARD ↓ COMPONENT →		ISO				ANSI		EIA		VESA (1)	NIDL (2)		SAE		MPR	Air Force	IEC
		9241		13406	HFS-100	IT7.215	TEB	TEP	Part 1 Mono.		Part 2 Color	ARP	ARP	1990:8	Air Force	SC 47C	
		Part 3	Part 7	Part 8	Draft 2	1988	1992	27				105	1782	4260	1990:10		87213A
Display Type	CRT	•	•	•		•		•	•	•	•	•		•	•		
	Flat panel				•								•	•	•	•	
	Projection						•										
Initial setup		•	•	•	•	•	•				•	•	•				
Colorimetric Attributes																	
Warm-up L(t)											•					•	
Luminance	Small area	•		•		•						•	•	•	•		
	Large area	•		•	•	•	•		105	•	•	•	•	•	•	•	
	No. of levels											•				•	
	Gamma									•	•	•					
White point	Small area			•		•								•			
	Large area			•	•	•			105-11-A	•	•	•	•	•	•	•	
Colors	Gamut			•	•	•										•	
	Default colors			•	•	•						•				•	
	Gamma									•	•	•					
Uniformity	Luminance	•			•	•	•			•	•	•	•	•	•	•	
	Chromaticity			•	•	•				•	•	•	•	•	•	•	
Contrast	Contrast ratio	•			•	•			105-10	•		•	•	•	•	•	
	Small area	•				•				•						•	
	Large area	•			•	•	•		105-10	•		•	•		•	•	
	with Ambient	•			•	•			105-10	•		•	•		•	•	
Loading L(A)											•						
Halation											•						
View angle					•								•	•	•		
Polarization													•				
Resolution																	
Resolution from addressability													•				
Resolution Addressability Ratio							•	•	105	•	•	•				•	
Line width	Mono. Negative	•			•	•			105-7-A	•	•	•	•	•	•	•	
	Mono. Positive	•			•	•		•				•			•		
	Color Negative	•				•		•	105-9	•		•	•		•		
	Color Positive	•															
Crosstalk													•				
Modulation	Monochrome						•		105-17		•			•	•		
	Color										•						
	Raster	•									•	•		•	•		
	MTF								105,-3,-8		•	•		•	•		
	MTFA					•								•	•		
	Character	•			•	•								•	•		
Convergence				•						•		•					

Display Standards Survey Summary Table - Continued

		ISO				ANSI		EIA		VESA	NIDL		SAE		MPR	Air Force	IEC
		9241			13406	HFS-100	IT7.215	TEB	TEP		Part 1	Part 2	ARP	ARP	1990:8	AFGS	SC 47C
		Part 3	Part 7	Part 8	Draft 2	1988	1992	27	105		Mono.	Color	1782	4260	1990:10	87213A	
Geometric Attributes																	
Linearity	Small area	•			•	•											
	Large area	•								•	•				•	•	
Waviness	Small area	•			•	•					•				•		
	Large area	•							105		•				•		
Size	Small area	•		•	•	•				•					•		
	Large area	•								•	•				•		
Orthogonality		•					•			•			•		•		
Tilt		•					•			•			•				
Trapezoid		•					•			•			•				
Reflection	Specular		•		•				105-13	•	•		•	•	•	•	•
	Diffuse		•		•				105-12		•		•	•	•	•	•
Fill factor		•			•												
Temporal Attributes																	
Stability	Jitter	•				•					•				•	•	
	Flicker	•			•	•					•				•	•	
Bandwidth								•									
Phosphor	Decay								105-14	•							
	Saturation								105-16								
Image retention														•			
Pixel response					•									•			•
Defects	Blemishes																
	Spurious Illum.								105								
	Pixel				•								•				
Degradation									105-15							•	
Physical Attributes (Other)					•										•		•
	Size									•						•	
	Weight									•						•	
	Tilt									•							
	Viewing area									•							
Display Environment		•	•	•	•	•				•			•			•	
Equipment	Specifications	•	•	•	•	•	•				•	•	•	•	•		
	Calibration	•	•	•	•	•	•				•	•	•	•	•		

(1) VESA Standard: Display Specifications and Test Procedures.

(2) NIDL: Procedures for Evaluation and Reporting the Capabilities of High Performance Display Monitors for Imagery Applications.

refers to an unwanted background luminance which cannot be eliminated by brightness adjustments. For more details and identification of these measurements, refer to the standards documents.

3 Comments and observations

From the table it is evident that there is a great deal of overlap among the various display standards, yet the methods of measurements for the same measurand, or component of the standard, are not the same. In addition, one finds a wide range of detail describing precisely how any measurement is to be made and reported. Take, for example, the measurement of resolution.

Of the standards surveyed, measurement procedures for evaluating the resolution of a visual display involve luminance modulation or line-width measurements. There is some agreement among the standards that resolution measurements be performed in a darkened room with test patterns displayed at the maximum luminance. For color displays, resolution measurements of tricolor white are usually required, and line width is measured at the full-width-half-maximum of the luminance profile.

However, line-width measurement methods vary in several ways. Most standards specify line width to be measured across one-pixel wide lines, while others specify character stroke width to be measured across a variety of text characters of various pixel widths including "M," "H," and "m." Standards intended for testing stand-alone CRTs exclude video amplifier effects on line width by restricting the measurement to raster scan lines.

Luminance modulation methods also vary in several ways. While most require darkroom conditions, there is some disagreement among standards regarding ambient illumination and test patterns used for luminance modulation measurements. Most standards specify measuring luminance modulation across one-pixel-on/one-pixel-off grille patterns while others specify the use of text consisting of "MEME", "m", or "e" characters. A minority of standards specify using the shrinking raster method to determine resolution at specified levels of modulation. Other standards intended for stand-alone CRTs further restrict the

shrinking raster method to the measurement of raster scan lines, thereby, eliminating video amplifier effects.

Perhaps the greatest disparity among existing standards for measuring resolution is the variety of special techniques, or lack thereof, for analyzing the line width and luminance modulation profiles of a color shadowmask CRT. Methods include connecting the peaks of the luminance profile, numerically filtering the profile data, fitting the profile with a Gaussian curve, and using moving beam methods to eliminate shadowmask effects altogether. Inconsistencies among the various standard measurement methods produce differences in results which make a fair comparison of display resolution impossible.

Better communication between standards bodies should provide a more uniform consensus on measurement methods. With the current interest in electronic information transfer over networks, it is natural to ask if such standards activities can be coordinated electronically and not require the travel which presently makes participation so difficult. The traditional iterative meeting process seems too slow for the rapidly advancing display technologies. It may, indeed, be time to consider an electronic solution.

Improvements might be realized if a buffet of measurement standards existed from which manufacturers and users could pick and choose. Developing that set of measurement procedures that is unambiguous, that applies to multiple display technologies, and that is practical and cost-effective to utilize is one approach to establishing standards that would move the technology in a Positive direction.

References

- 1 Peter A. Keller and Roland Zavada, "A Survey of Display Standards Activities," *Information Display*, 5, No. 12, pp. 21-26, December 1989.
- 2 James C. Greeson, Jr., "Display Standards," *Information Display*, 6, No. 12, pp. 26-28, December 1990.
- 3 James C. Greeson, Jr., "Display Standards Update," *Information Display*, 7, No. 12, pp. 24-27, December 1991.
- 4 James C. Greeson, Jr., "Display Standards in Trouble," *Information Display*, 10, No. 12, pp. 24-27, December 1994.
- 5 William A. Rowe, "SID and the Issues in Global Standards," *Society for Information Display 1995 Display Manufacturing Technology Conference, Digest of Technical Papers*, Santa Ana, CA, pp. 27-28, 1995.