7-01: Plotting the Course of the Next VESA Flat Panel Display Measurements Standard

Edward F. Kelley *
National Institute of Standards and Technology, Boulder, CO 80305
Phone: 303-497-4599 E-Mail: kelley@nist.gov

1. Abstract

The Display Metrology Committee of the Video Electronics Standards Association is developing the next *Flat Panel Display Measurements Standard*. The document's philosophy and the standard's acceptance are reviewed. New directions will be reviewed, including more diagnostics, robust reflection measurements and their scaling, motion artifacts, and robustness of the measurement.

2. Introduction

The Flat Panel Display Measurements Standard (FPDM) is distributed by the Video Electronics Standard Association (VESA) and is the production of the Display Metrology Committee (DMC) within VESA. [1] In this paper, we review the history of the FPDM, the philosophy behind the document, how it has been received by the industry, its problems, and where it is going in the next version.

3. History

In a review of existing display standards, it was found that many committees and organizations seemed reluctant to fully specify the methods required to make the measurements they desired. [2] This is understandable because of the amount of space that would be required to detail such measurements. Another assumption that permeated some of the display industry is that display measurements are simple and without subtle complications, which is not true, in general. The FPDM is therefore an attempt to fill the hole that exists in many display standards: to provide guidance in display metrology that other standards committees will not want to spend the time documenting. The FPDM has influenced display standards in the SAE (Society of Automotive Engineers), CIE (Commission Internationale de l'Eclairage [International Commission on Illumination]), and ISO (International Organization for Standardization). Currently ISO is employing parts of the FPDM in its new ergonomic collection of standards.

4. Philosophy

In general, the whole point of the FPDM is to provide a metrology foundation for specification language and display characterization. We want manufacturers who make quality displays to be able to brag about them using a bedrock foundation of good measurement methods. We want those who use displays in a product to be able to clearly specify the performance they need, and then be able to measure their purchases with agreed-upon methods of measurement. There is, therefore, a dual goal of defining the measurement method with a unique name and providing for robust and reproducible methods. Some of the other goals in preparing the document are provided below.

Easy to Use and Self-Contained: Much of what created the FPDM came about from the desire to make a standards document easy to use. We were not confined by document templates and organizational document construction rules, so we attempted to do whatever we could to clearly identify each section and measurement as well as making all measurements complete and self-contained as much as possible within one or two pages (if possible). A variety of fonts is used to distinguish different sections. A numbering system is employed that is easy to remember and avoids the "see Section 3.14.7.9.12.7.2.4" numbering that is easy to lose track of and where 3.14 > 3.5. Other features that make this standards document a departure from the usual are: Icons are employed, large page numbers are on each side of the page, running section headers and numbers—even icons in the headers and footers are supplied to assist with the speed of using the document. There is a deliberate redundancy in the document so that the need to page back and forth across the document is minimized, yet too much redundancy can cause the reader to miss important details. For example, the setup conditions in each measurement are often much the same, so these were reduced to icons, and only the special setup conditions for each measurement are described, in general.

Accommodating: Ergonomics and vision-science issues are avoided. For example, we avoided saying how much contrast is needed for a specific task, or how much white luminance is required for a given condition. A number of people have wanted such things in the FPDM. However, the FPDM is a measurement-methods document. We don't care what the results are, we just care that they are measured correctly. Unfortunately, some have misinterpreted the examples provided in the document thinking that they represent expected values to observe. This is not the case! The examples provide the user with results of sample calculations. They are not—in any way—intended to represent typical or desired values to be obtained.

There are a few measurements that contain thresholds (e.g., 303–7). These thresholds can be used, but their use is not required. Other thresholds may be more appropriate for a given task than the ones suggested. We often state in the document that all interested parties should agree on any deviations from the specified measurement conditions. For example, suppose a company incorporating displays in its product needs to use a threshold other than that specified in 303-7 Resolution from Contrast Modulation. Both that company and the manufacturer supplying the displays need to agree on the threshold to be used before the measurements will be made. If this agreement were not made, then it would be assumed that the thresholds specified would be applicable.

Extensible—A Buffet: The FPDM is a compendium of measurement methods for displays. It is like a buffet where you

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view the many offerings and select what you wish to consume. With the FPDM you can select the measurements that you need to make. There may be several methods to make similar measurements, and these can each produce different results. To avoid confusion, each measurement is given a unique name and number. For example, the general contrast measurement to always be made is a full-screen contrast measurement where the contrast is the luminance ratio between full-screen white and full-screen black. This is called 302-3 Darkroom Contrast Ratio of Full Screen. There are other useful measures of contrast also included, such as 303-1 Line Contrast Ratio, 304-1 Luminance and Contrast Ratio of Centered Box, 304-2 Centered Box On-Off Contrast Ratio, 304-3 Transverse Contrast Ratio of Box, 304-9 Checkerboard Contrast Ratio, 304-10 Highlight Contrast, etc. The document requires that full-screen darkroom contrasts always be measured and reported (for applicable technologies); any other contrast metric that is used must be clearly identified with its proper name in any reporting documentation.

The format of the FPDM easily permits the addition of more measurement methods as they become available and tested. This contributes to the variety of the buffet. However, some have objected that doing this elevates bad measurement methods to the same level as good measurement methods. To avoid this problem, any questionable method or any method that has the potential for irreproducible results is clearly identified and appropriate warnings are included. The measurement methods are also extensible in that they can be modified to suit a specific measurement task provided all interested parties agree to the modification.

Adaptable: We avoided requiring specialized equipment and attempted to make the measurement methods as open as possible to a variety of measurement apparatus. A simple luminance meter (non-contact type) with a measurement field angle of 2° or less can perform many of the measurements specified. For more detailed work where the measurement field is much smaller, an array camera, narrow field-of-view luminance meter, or other instrumentation can be used to make the measurements. The measurements themselves are adaptable; that is, they can be changed to suit the purposes of the user, customer, and manufacturer so long that all interested parties are aware of any changes, the changes are explicitly presented in all documentation, and all agree to the changes.

Available: The DMC tried very hard to make the document widely available by keeping it inexpensive. At this writing, its cost remains under $40 (without shipping and handling). We all thank the VESA board of directors and management for making such a large document (322 pages) available for a reasonable cost. Because version 3.0 of the document will be even larger, we might anticipate a price increase.

Cartoons: The inclusion of tone-setting cartoons in a standards document is somewhat questionable. They started as a pressure relief valve for a joke and became a part of the document at the insistence of the committee members. However, they do sometimes serve a real purpose in exposing bad attitudes that we observed while preparing the document—attitudes that could not have been addressed in any other way. They are also fun in that they remind us of some of the humorous moments during our meetings that are assuredly repeated in many other standards meetings. Besides, they serve as a filler of the otherwise blank areas. We've received words of only appreciation for the cartoons from readers all over the world.

Appendix: There are two sections in the appendix of the document: A100 Metrology and A200 Technical Discussions. The Metrology Section is provided to alert users of some of the problems that can be encountered in making display measurements and how to avoid those problems. The Technical Discussion Section is intended to provide some background for the entire document. The system of units that we use to describe the light from displays is a difficult system to understand for most who are exposed to those units for the first time so some attempt is made to help the novice to become more familiar with those units.

5. Reception and Use

The best endorsement of a standard is its use in the industry. Both institutions and manufacturers have employed the FPMD to write specifications. A number of OEMs (original equipment manufacturers) have written specifications for ordering new displays based upon the FPDM measurement methods.

In general, we have received many glowing remarks from individuals in the display industry. Most like the document's completeness and attention to detail. People for whom English is not their native language appreciate the attempt to keep the sentence structure simple, using "we" and "you" in a natural way, thus avoiding the complicated constructions often found in technical writing.

The major display-measurement equipment manufacturers have incorporated the FPDM's measurements into their automated and robotic systems. A number of them include the FPDM document with their apparatus. The tutorial information in the appendix has also served such manufacturers well when they have had to discuss measurement problems with their customers; they can often point to the FPDM to resolve misunderstandings or correct their customers' expectations.

There have also been some understandable less-positive observations. Although some view the FPDM as a scientific document, they don't necessarily feel it is cookbook enough to be useful to the untrained technician. That is, some would welcome a numbered, step-by-step approach more than having the required information embedded in paragraphs. These are good points, and we will have to see if we can modify the document to accommodate such ideas without losing its technical clarity or without increasing its size excessively.

6. Future Directions

A number of additions and changes will be made to the next version of the FPDM (version 3.0):

1. Projection measurements and associated diagnostics for the illuminance meters. The use of SLETs (stray-light elimination tubes), projection masks, and line masks for making measurements of the intrinsic performance of a front projector despite ambient lighting in the room.
2. Measurements of rear projection using a SLET to reduce ambient light contributions.
3. Measurements of motion artifact.
4. Robust measurements of reflection and their combinations with scaling to sunlight and other levels.
5. More suggestions for grille measurement such as using tapered replica masks for veiling-glare compensation or using Ronchi rulings to characterize the veiling-glare performance of the detector.

6. Emphasis of the seriousness of veiling glare in making high-contrast measurements even more than we presently do.
7. Discussion of robustness in measurement apparatus.
8. Discussion of error propagation to include covariance situations.
9. Making the terminology compliant with the CIE.
10. Discussion of the use and calibration of array cameras and having reasonable expectations of their imaging results, particularly when veiling glare represents an important corruption to detailed scenes.
11. Use and calibration of white reflectance standards.
12. Use and calibration of neutral-density filters and their combination in stacking.
13. Use and calibration of black glasses and mirrors.
14. Testing of detector linearity.
15. New patterns:
    a. Complicated and busy patterns.
    b. Faces of multiple races and pigmentation.
    c. Gray-scale ends and detailed ramps
16. Response time with gray shades and colors.
17. More tutorials in the Technical Discussion Section such as:
    a. Discussion of BRDF (bidirectional reflectance distribution function) measurement methods.
    b. Image blur from finite gray-shade transition times.
    c. Perceptively equal gray-shade intervals.
    d. Transparent diffuser—luminance vs. illuminance.
18. Setup visual tests based upon the detection of the ends of the grayscale (5% and 95% and/or 3% and 97% gray levels). [3]
19. Diagnostics for head-mounted displays (HMDs) and near-eye displays (NEDs).

Patterns & Faces: Patterns employed for setup and testing of displays are now being generated using MATLAB® [4] software in any desired pixel array (we prefer the use of the term "pixel array" rather than "resolution" because "resolution" refers to what the eye can see and not necessarily the geometric configuration of the pixel surface). Work is underway to provide faces of several different races and pigmentation that can be used to evaluate display quality for imaging purposes. The human visual system is quite sensitive to facial detail changes, and some problems will be immediately obvious in a facial image that could go undetected in ramps, patterns, and even other types of natural images or scenes.

Robust Reflection Measurements: Special emphasis will be made to warn the reader of the importance of considering robust measurements of reflection in general. We (at NIST) are developing a MATLAB® computer program that permits us to calculate the reflectance of a display that has a three-component reflection characteristic—see Fig. 1. [5, 6] We will be able to show how many reflection-apparatus configurations are either robust or not for a very wide variety of apparatus and reflection properties—all this without requiring laboratory setups. Hopefully, the results of this modeling will help dispel some of the erroneous ideas about using—with impunity—a number of inappropriate source configurations to characterize reflection properties. It is very important for people to realize that the geometric configuration of the measurement apparatus can dramatically affect the reflection measurement result whenever there is a nontrivial haze component of reflection. [7] Although reflection properties seem so easy to measure to the eye, the eye is not a linear device. Because we use a linear detector for light measurements, very small deviations visible or not visible to the eye can be enormous deviations as measured by our linear instrumentation.

High-resolution measurements of the BRDF (bidirectional reflectance distribution function) are not a simple matter. A number of people have noted this difficulty. Attempts will be made to identify robust reflection measurement methods that provide some level of reflection characterization and that will be suitable for fast measurements in an industrial setting. Certainly, BRDF measurements are of great value, but reproducibility is hard to achieve without a great deal of effort, and few are willing to expend either the money or the time to make them correctly.

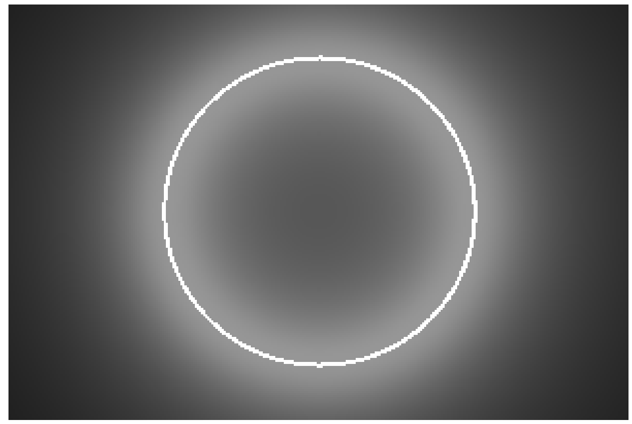

Fig. 1. *Ring-light reflection computer calculation with a three-component reflection model.*

Wiggle Room: We have been disappointed to learn that some have deliberately misinterpreted what we have intended. For example, regarding setting up the display, we offer guidelines "if not available from the manufacturer." Some have taken this as an allowance to make unreasonable setup adjustments that render the display virtually unusable, but do provide them with better specifications. Thus, in the next version, we will eliminate such wiggle room with a statement such as:

> Section 301-3 and, in particular, 301-3A discuss setting up the display for measurements. Also, find discussions in 301-1C, 301-3K, and A112 (especially A112-2). In any of these discussions, we sometimes refer to "manufacturer's specifications" (MS) and other ideas to guide the user in properly setting up the display. In referring to MS and associated setup procedures we mean the following: If the manufacturer describes or specifies how to set up the display for its intended use to provide the very best quality and most pleasing and useful image for the task at hand, then use the MS to set up the display. If the MS are not provided or are not suitable for the intended task then you should use the other suggestions presented in these sections. However, it is not permissible—and it violates the philosophy of this document—to adjust the display to extremes in order to get extreme measurement results if such adjustments make the display unsuitable, impractical, unreasonable for the intended task, or drives it to extremes beyond the anticipated production and/or distribution configuration. Calling for such extreme settings disqualifies the MS from being used to set up the display. The term MS or any other idea presented in these sections is not a license for anyone tweaking the display to an impractical state and

then obtaining measurement results for any public disclosure. That is, the display needs to look as good as it can for its intended task and not be configured with unrealistic settings that are used only to make the measurement results look good for competition or marketing purposes.

As an example, let's consider a display to be used in some kind of an office environment (see, for example, ISO 13406.2 Section 7.3 where it specifies that an office illuminance E incident upon a screen varies according to $E = E_0[1+\cos(\alpha)]$, where $E_0 = 250$ lx and α is the angle between the screen surface and the horizontal angle measured behind the screen): The display might be set up using the computer images that would be found to be of the best possible quality for the intended users, the intended information to be displayed, and the typical surround conditions. This is, to some extent, a subjective matter. However, it is not permissible to adjust such a display to extremes or to unrealistic levels where most people and any trained observer would not consider the display adjusted for office tasks. It would not be proper, for example, to derive a contrast metric based upon extreme measured quantities unless those extremes would normally be used for the intended task. For example, unscrupulous individuals might adjust the contrast and brightness (or other controls) for the brightest white (luminance L_w), readjust the controls to the darkest black (L_k), and then report a display contrast of $C = L_w/L_k$. Such a contrast would rarely be achieved during normal use of the display (unless this kind of adjustment is part of the task for which the display is used). Reporting such a contrast would be inappropriate for office use, because people don't routinely make and use such adjustments for office tasks.

At this point (FPDM2) all the measurements are specified for darkroom setup conditions, because a darkroom is the most reproducible setting in which the display can be measured. Whenever ambient lighting is employed, the exact geometric specification of that lighting is required to enable reproducible measurements, and most are not prepared to accurately reproduce such lighting conditions—it cannot be done casually. The geometry must be carefully reproduced or the results with ambient illumination will not be reproducible for all display types. To properly enable a rigorous setup in non-darkroom conditions, we may well have to exactly specify ambient conditions for setting up the display for office use, for daylight use, and for other ambient environments in such a way that the measurement results will be reproducible.

Conformance & Compliance: There has been some discussion regarding making a provision so that a manufacturer's documentation can reflect that their reported measurement results and quantities described have been obtained and documented according to the FPDM methods. This would provide some assurance that the reported numbers are realistic and that there are no hidden problems.

Your Contributions: The DMC is always sensitive to the needs and contributions from the industry. Those involved in display measurements and specifications are welcome to participate at several levels for the generation of the next document. Feel free to contact VESA at www.vesa.org, E-mail moderator@vesa.org, or contact the author.

7. Acknowledgements

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8. Referenece

[1] *Flat Panel Display Measurements Standard*, Video Electronics Standards Association, Version 2.0, 322 pp., June 1, 2001. Current chair of the DMC is Larry Liese, IBM, NC, and the author currently serves as the editor of the document.

[2] Edward F. Kelley, George R. Jones, Paul A. Boynton, Michael D. Grote, and Dennis J. Bechis. "A Survey of the Components of Display Measurement Standards." Journal of the of the Society for Information Display, Vol. 3, No. 4, pp. 219-222, December 1995.

[3] Private communications with Dr. R. Soneira.

[4] Any commercial item referred to in this paper is for the purpose of identification only. Such a reference does not imply a recommendation or endorsement by the National Institute of Standards and Technology, neither does it suggest suitability to task.

[5] E. F. Kelley, G. R. Jones, and T. A. Germer, "The Three Components of Reflection," Information Display, Vol. 14, No. 10, pp. 24-29, October 1998.

[6] E. F. Kelley, G. R. Jones, and T. A. Germer, "Display Reflectance Model Based on the BRDF," Displays, Vol. 19, No. 1, pp. 27-34, June 30, 1998.

[7] E. F. Kelley, "Sensitivity of Display Reflection Measurements to Apparatus Geometry," 2002-SID International Symposium Digest of Technical Papers, Society for Information Display, Boston, MA, pp. 140-143, May 19-24, 2002.