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Standard Guide for Modeling the Colorimetric Properties of a CRT-Type Visual Display Unit[1]

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INTRODUCTION

This guide provides directions and mathematical models for deriving the relationship between digital settings in a computer-controlled visual display unit and the resulting photometric and colorimetric output of the display unit. The accurate determination of this relationship is critical to the goal of accurate, device-independent color simulation on a visual display unit.

1. Scope

1.1 This guide is intended for use in establishing the operating characteristics of a visual display unit (VDU), such as a cathode ray tube (CRT). Those characteristics define the relationship between the digital information supplied by a computer, which defines an image, and the resulting spectral radiant exitance and CIE tristimulus values. The mathematical description of this relationship can be used to provide a nearby device-independent model for the accurate display of color and colored images on the VDU. The CIE tristimulus values referred to here are those calculated from the CIE 1931 2° standard colorimetric (photopic) observer.

1.2 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.3 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E284 Terminology of Appearance

E1336 Test Method for Obtaining Colorimetric Data From a Visual Display Unit by Spectroradiometry

E1455 Practice for Obtaining Colorimetric Data from a Visual Display Unit Using Tristimulus Colorimeters

3. Terminology

3.1 Definitions of appearance terms in Terminology E284 are applicable to this guide.

3.2 *Acronyms:*

3.2.1 *CRT, n*—an abbreviation for the term cathode ray tube, a device for projecting a stream of electrons onto a phosphor-coated screen in such a way as to display characters and graphics.

3.2.2 *DAC, n*—an abbreviation for the term digital to analog converter, a device for accepting a digital computer bit pattern and translating it into an analog voltage of a prescribed value.

3.2.3 *LUT, n*—an abbreviation for the term look up table, a process in which input and output values are mapped in an *n*-dimensional table such that, for a given input value, the appropriate output value is "looked-up" from the table.

[1] This guide is under the jurisdiction of ASTM Committee E12 on Color and Appearance and is the direct responsibility of Subcommittee E12.06 on Display, Imaging and Imaging Colorimetry.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

3.2.4 *VDU, n*—an abbreviation for the term visual display unit, a device interfaced to a computer for displaying text and graphics.

3.2.4.1 *Discussion*—A CRT is one type of VDU.

4. Summary of Guide

4.1 Every color stimulus generated on a VDU is realized by the linear (additive) superposition of the spectral power distribution of three primaries. Test Method E1336 describes how to measure the spectral power distributions and reduce them to CIE tristimulus values. Practice E1455 describes how to measure the CIE tristimulus values of the primaries directly. An exact characterization of the VDU would require measurement of the spectral power distribution at all possible combinations of primary settings. Modern, computer-controlled VDUs will provide 256 or more levels of each of the three primaries. This results in more than 16 777 000 unique settings, which is far too many combinations to be measured practically (see Note 1). Instead, a characteristic function relating the radiant output of the screen to the digital inputs from the computer must be derived. Procedures are outlined for deriving a characteristic function for a computer-controlled VDU, using a minimum number of spectral radiometric measurements while maintaining near optimum accuracy. Examples of deriving and testing such models are given in Appendix X1.

NOTE 1—Different primary settings do not necessarily produce perceptibly different colors. For VDUs with a large number (for example, 16 777 000) of different primary settings, the number of perceptibly different colors will be less than the number of primary settings.

5. Significance and Use

5.1 The color displayed on a VDU is an important aspect of the reproduction of colored images. The VDU is often used as the design, edit, and approval medium. Images are placed into the computer by some sort of capture device, such as a camera or scanner, modified by the computer operator, and sent on to a printer or color separation generator, or even to a paint dispenser or textile dyer. The color of the final product is to have some well-defined relationship to the original. The most common medium for establishing the relationship between input, edit, and output color (device-independent color space) is the CIE tristimulus space. This guide identifies the procedures for deriving a model that relates the digital computer settings of a VDU to the CIE tristimulus values of the colored light emitted by the primaries.

6. Models

6.1 The models are based on eight basic assumptions. First, at each pixel location on the VDU, the radiant exitance (emitted light per unit area) attributable to one primary type (red, green, or blue) is invariant with the radiant exitances of the other primary types. Second, the radiance exitance at one spatial location is invariant with the radiant exitance at other spatial locations. Third, the relative spectral radiant exitance of a primary is invariant with excitation level. Fourth, there is no inter-reflection of light between pixel locations. Fifth, the output of the digital-to-analog conversion process is linear. Sixth, there is no ambient glare (flare) from the screen into the observer's eyes. Seventh, the refresh rate of the image is rapid enough to produce temporal fusion (no noticeable flicker) for the normal observer. Eighth, the pixel pitch is fine enough to produce spatial fusion for the normal observer. Each of the eight basic assumptions should be tested and either verified, noted, or corrected before deriving a characteristic model.

6.1.1 Assumption 1, independence of the primaries, is tested by measuring the radiometric output at several levels, as described by Cowan and Rowell.[3] If the departures are small, they may be neglected or a LUT correction applied. If the departures are significant and maximum reproduction accuracy is required, only a full table look-up method can be used to create the RGB to XYZ transform.

6.1.2 Assumption 2, spatial invariance, can be tested by measuring the center of a dark display and then repeating the measurements with pixels near the edge of the display illuminated fully. The display may have to be considered unusable for critical applications if this assumption is not met. The amount of spectral variance will be a function of both position and intensity of both the area of interest and the integrated area of pollution. While such models can be derived, they may be too complex to justify their use.

6.1.3 Assumption 3, level invariance, is tested by measuring the chromaticity of a primary at several different levels. It should be noted that care must be taken to maintain the signal to noise value of the color measuring instrument as the luminance of the primary is reduced. As the signal level of a colorimeter approaches the optical/electrical zero, the apparent chromaticity approaches that of neutral black.

6.1.4 Assumption 4, absence of inter-reflections, is often violated on CRT-type displays without high efficiency antireflection (HEA) coatings on the face plate gloss. This is detected in the same manner as spatial invariance. Again, models for this can be derived, but the complexity may not be worth the effort.

6.1.5 Assumption 5, linearity of the DAC, can be tested with a calibrated, high-precision oscilloscope. A doubling of the digital counts should produce a doubling of the output signal. It should be noted that RS-170 voltage levels are from −0.286 V to +0.714 V with the range from 0 V to 0.714 V being used for signal level and 0 V to −0.286 V being used for synchronization during the blanking interval on a CRT-type display. Other types of visual display units may have their own unique voltage ranges as well. In general, the setting of the drive voltage requires the simultaneous alignment of many operational parameters, the specification of which are beyond the scope of this guide. It is assumed that the signal generator and the receiver are adjusted to be within their unique operational specifications before the linearity test is performed.

6.1.6 Assumption 6, ambient glare, can be tested with a telephotometer, measuring the luminance and chroma of each primary in a dark and ambient environment. If the two readings

[3] Cowan, W. B., and Rowell, N., "On the Gun Independence and Phosphor Constancy of Colour Video Monitors," *Color Research and Application*, Vol 11, 1986, pp. S35–S38.