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TECHNICAL REPORT

colour inside

Electronic display devices –
Part 2-3: Measurements of optical properties – Multi-colour test patterns

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Part 2-3: Measurements of optical properties – Multi-colour test patterns

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ELECTRONIC DISPLAY DEVICES –

Part 2-3: Measurements of optical properties – Multi-colour test patterns

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IEC TR 62977-2-3, which is a technical report, has been prepared by IEC technical committee 110: Electronic display devices.

The text of this technical report is based on the following documents:

Enquiry draft	Report on voting
110/781A/DTR	110/800A/RVDTR

Full information on the voting for the approval of this technical report can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 62977 series, published under the general title *Electronic display devices*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
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INTRODUCTION

Current display measurement standards mainly use simple test patterns to estimate the display performance. These test patterns would typically contain only one colour, or a colour with a black background. However, as recent research has shown, modern display electronics can be content-aware, and adjust the display rendering based on the input image content. Therefore, multi-colour test patterns that more closely simulate realistic image content are recommended in order to better represent the display performance.

This Technical Report discusses the impact of the display drive electronics and image processing on the display rendering behaviour, and reviews research results that demonstrate the need for multi-colour test patterns and average picture level loading considerations.

ELECTRONIC DISPLAY DEVICES –

Part 2-3: Measurements of optical properties – Multi-colour test patterns

1 Scope

This part of IEC 62977, which is a Technical Report, reviews the impact of test pattern colour content and image loading on the measured display's photometric and colorimetric performance. Experimental data for several display technologies is presented to demonstrate the need for using a broader range of colours in the test patterns, and measuring the display at an image loading level appropriate for the intended application.

2 Normative references

There are no normative references in this document.

3 Terms, definitions and abbreviated terms

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1 Terms and definitions

3.1.1
signal pixel
smallest encoded picture element in the input image

3.1.2
pre-gamma average picture level
average input level of all signal pixels relative to an equivalent white pixel driven by a digital RGB input

Note 1 to entry: Unless otherwise stated, the pre-gamma average picture level (APL) will simply be referred to as average picture level in this document.

Note 2 to entry: the APL will normally be expressed as a percentage, where a full white screen at maximum drive level would be 100 % APL.

3.2 Abbreviated terms

APL	average picture level
CIE	Commission Internationale de L'Eclairage (International Commission on Illumination)
LUT	look-up tables
OLED	organic light emitting diode
RGB	red, green, and blue
sRGB	standard RGB colour space as defined in IEC 61966-2-1
WRGB	white, red, green, and blue

4 Colour-managed displays

4.1 Legacy displays

Early displays had driven electronics that directly controlled the pixel elements. As illustrated in Figure 1, the independent drive electronics in these legacy displays resulted in a direct correlation between the input signal and the primary colour emitters. The direct link between input signals to pixel output meant that there was only one unique combination of R, G, and B that gave the desired colour. This simplified that calibration process which ensured that the display had proper colorimetric additive mixing. For example, equal input signal levels to the red, green, and blue channels would have created a proportional grey level. Standard colour spaces, such as the sRGB colour space (IEC 61966-2-1), utilize this additivity property. Current displays that strive to accurately reproduce the encoded colour information in this colour space also need to exhibit the additive mixing property.

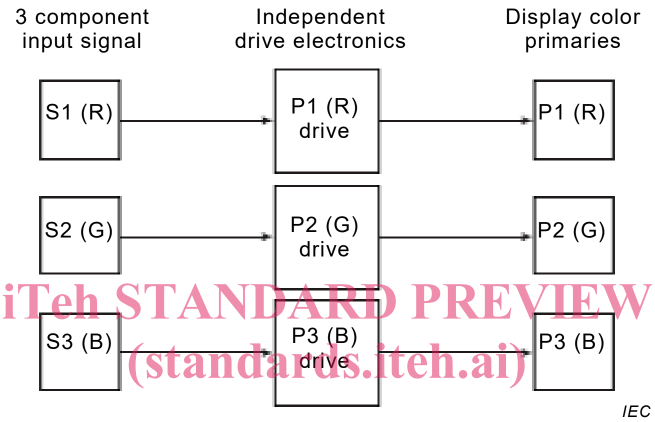

Figure 1 – Legacy model

4.2 Modern displays

As colour display technology has advanced over the years, so has the colour management of display devices. Display designers have introduced multi-primary pixel formats, and can apply real-time image processing based on specific pixel values contained in the frame to dynamically change how the image is rendered. Modern display electronics often include look-up tables (LUTs) as a programmable conversion interface between the input signal and pixel output (see top schematic in Figure 2). The use of LUTs allows the physical primary colours to be abstracted to conceptual primary colorants, where these colorants could be tailored to achieve the desired colour gamut. But the colorimetry of these systems may not necessarily follow colorimetric additive mixing. In addition, as the processing power of the electronics has increased, the image processing can also analyse the upcoming image frame and dynamically change the LUT for the desired appearance.

The use of LUTs has enabled an input signal from only one RGB component to activate more than one primary emitter (see for example the bottom schematic in Figure 2). For multi-primary displays, there may be several combinations of primary emitters that can produce the desired colour. The calibration of the LUT defines how the input signal will be rendered, which will not necessarily result in the expected colorimetric additive mixing based on the input signals. This lack of additivity can have an impact on how accurately the intended image content is rendered. In addition, the lack of additivity also means that the colour gamut area may not be accurately represented by just measuring the response of the R, G, and B inputs in turn. The colour gamut area may no longer be bounded by the triangle connecting the RGB chromaticity coordinates in the CIE 1931 or 1976 chromaticity diagram (see CIE 15).

Given this ambiguity, it is important to test how well the display renders luminance and colour relative to the intent of the input content. If the content is intended for viewing on sRGB displays, then the colour management should be tested to verify that the colours are rendered correctly. In addition, if the display also employs dynamic colour management, then the performance of the display can depend on the type of test pattern used. A set of colour test patterns have been developed to address these issues, and serve as the recommended patterns that should be used to evaluate displays. These patterns are a best effort attempt to create a technology-neutral input signal that uniformly samples the colour gamut and queries the colour-managed response of the display in a fair manner. The value of these colour test patterns is illustrated by comparing them to traditional single-colour box patterns.

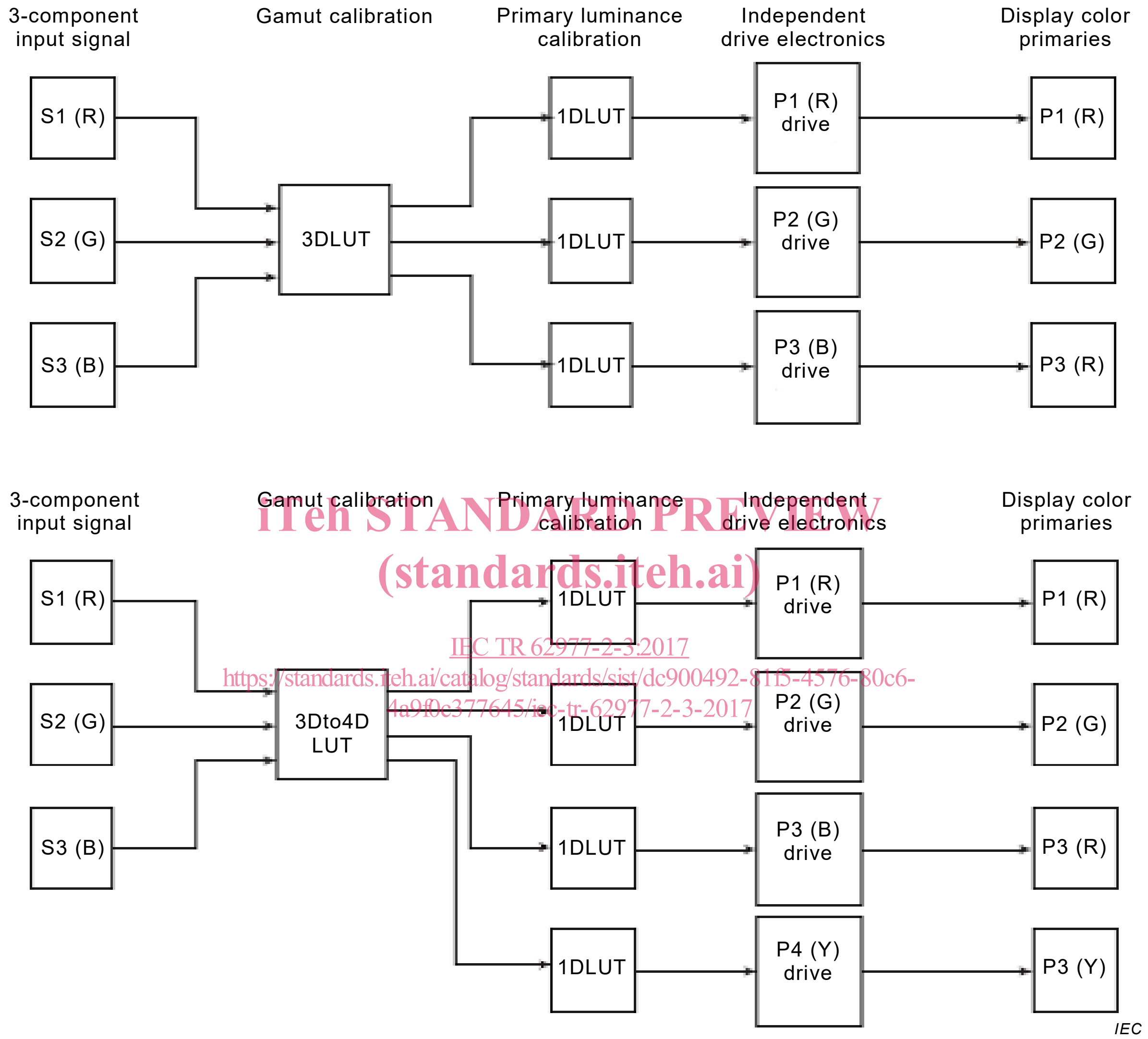

Figure 2 – Example of modern drive models

5 Results

Prior research on multi-primary projectors demonstrated that some colour-managed systems adapted to the rendered test pattern. The colour management system in some displays would preferentially boost the white luminance/illuminance output on white images. However, this white luminance could not be achieved in more natural colour images. This was demonstrated for a projector by Kelley *et al* using the set of three RGB test patterns shown in Figure 3. [1][1] Each coloured box was scaled to 1/3 the dimension of the screen. The red, green, and blue boxes were rendered by applying a maximum input signal to the respective RGB channel. As each pattern was rendered in turn, the red, green, and blue illuminance was measured for

1 Figures in square brackets refer to the bibliography.

each colour at all of the nine equally-spaced locations at the image plane. An average illuminance for each colour was then determined from the nine locations. By using these patterns on several WRGB projectors, Kelley showed that the average additive colour white illuminance ($E_{R+G+B} = E_R + E_G + E_B$), or colour-signal white illuminance, was up to 2,3 times smaller than the average full screen white illuminance.[1] Therefore, the illuminance of the white pattern did not equal the sum of the illuminance values for the R, G, and B primary colours. This lack of colour additivity indicates that the display cannot render a standard colour space, and may suggest a potential problem in the colour management. The benefit of the colour-signal white pattern (Figure 3) has been recognized by the display industry, and included as an important measurement in an industry standard.[2] For these patterns, the R, G, and B primary colours are rendered as nine equal sized boxes in the screen area. Measurements are taken at the centres of each box.

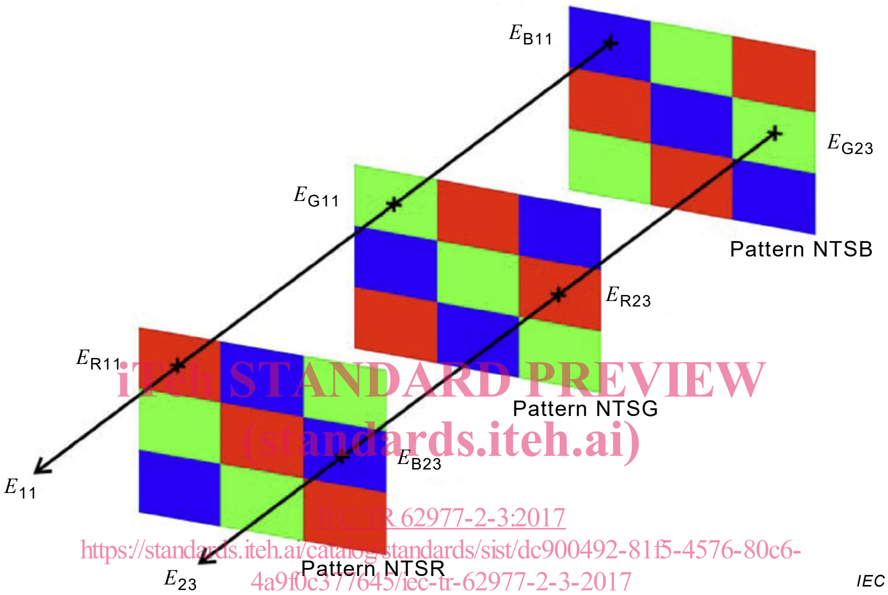

Figure 3 – Example of RGB checkerboard patterns

In a separate experiment, the introduction of even a small amount of colour in an otherwise full white screen also showed a dramatic impact. Figure 4 illustrates the example where each coloured box was 0,3 % of the active area. In this example, the average white illuminance of a laser phosphor hybrid projector measured at the nine locations was found to drop by 60 % when the small amounts of colour were added between the measurement locations (see Figure 4).