

TEPAC ENGINEERING BULLETIN

TEB26

1976 CIE-UCS Chromaticity Diagram With Color Boundaries

TEB26

JULY 1988

ELECTRONIC INDUSTRIES ASSOCIATION
ENGINEERING DEPARTMENT



NOTICE

EIA Engineering Standards and Publications are designed to serve the public interest through eliminating misunderstandings between manufacturers and purchasers, facilitating interchangeability and improvement of products, and assisting the purchaser in selecting and obtaining with minimum delay the proper product for his particular need. Existence of such Standards and Publications shall not in any respect preclude any member or non-member of EIA from manufacturing or selling products not conforming to such Standards and Publications, nor shall the existence of such Standards and Publications preclude their voluntary use by those other than EIA members, whether the standard is to be used either domestically or internationally.

Recommended Standards and Publications are adopted by EIA without regard to whether or not their adoption may involve patents on articles, materials, or processes. By such action, EIA does not assume any liability to any patent owner, nor does it assume any obligation whatever to parties adopting the Recommended Standard or Publication.

This TEPAC Engineering Bulletin was developed by the JT-20 Committee on Cathode-Ray Display Devices.

Published by
ELECTRONIC INDUSTRIES ASSOCIATION
Engineering Department
2001 Eye Street, N.W.
Washington, D.C. 20006

PRICE: \$10.00

Printed in U.S.A.

1976 CIE-UCS CHROMATICITY DIAGRAM WITH COLOR BOUNDARIES

Peter Keller
Tektronix, Inc.

The 1931 CIE* chromaticity diagram (Fig 1) has long been used to graphically depict color characteristics of hue and saturation for cathode-ray tube phosphors. In 1943, K. L. Kelly of NBS published a paper¹ that greatly enhanced its usefulness by dividing the diagram into areas with identifying color names (Fig. 2), thus aiding comprehension of the significance of the "cold" numerical x and y coordinates. This is commonly referred to as the "Kelly chart" and is more easily understood by persons untrained in color theory. In 1955, Kelly further revised this to eliminate some of the color blocks that made it more detailed than necessary.² At the same time, a number of the color boundaries were relocated to improve the correlation with empirical data (Fig. 3). This 1955 version is published in such publications as the EIA publication, "Optical Characteristics of Cathode Ray Tubes". Features of the 1931 diagram and Kelly chart include:

- All colors, perceptible to the average human eye fall within the bounded area.
- A straight line drawn through two colors and passing through the equal energy point ($x=0.333$, $y=0.333$) indicates complimentary colors.
- Saturated colors, which are located on the periphery of the curve are monochromatic except purples. Colors become progressively less saturated toward the white region in the center.
- Boundaries between colors are not distinct, rather one color blends gradually into the next.
- The ratio of distances between two colors to a third color located on a line drawn between them is proportional to the ratio of intensities of a mixture of those two colors required to produce the third one.
- Numbers along the periphery indicate wavelength in nanometers of monochromatic sources.
- The curved inner line on the 1931 CIE diagram is known as the blackbody locus. The numbers along it represent the color temperatures in degrees Kelvin of blackbody light sources.

The principal drawback to the 1931 CIE diagram is that equal perceived color differences are not represented by equal distances on the diagram. For instance, a small change in color coordinates in the blue region would be as noticeable as a much larger change in the green area. Figure 4 demonstrates this with what are known as MacAdam ellipses.³ These represent color differences of ten times a just discernable color change. A perfect color

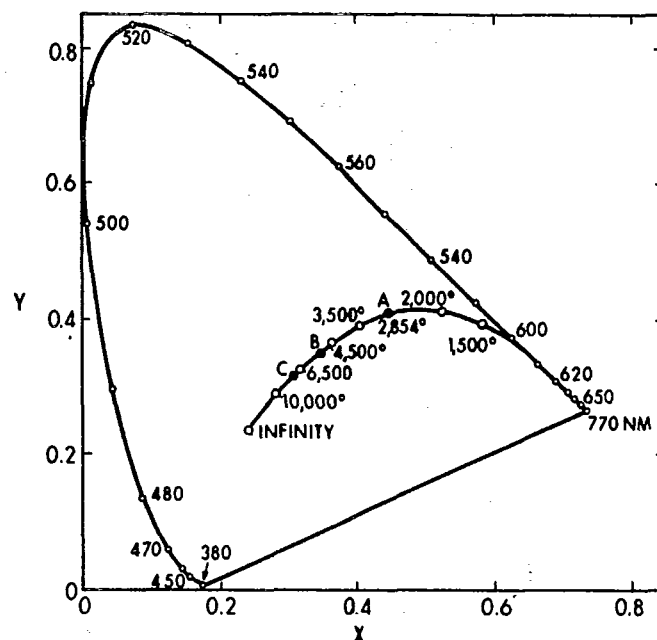


FIG. 1. CIE Chromaticity Diagram Showing Planckian Locus and Chromaticities of CIE Standard Sources. Source: D. L. MacAdam, "Visual Sensitivities to Color Differences in Daylight," J. Opt. Soc. Am. 32, 247 (1942).

diagram, impossible to achieve on a flat surface, would have circles, all of equal size.

Over the years, many schemes have been devised to portray the chromaticity diagram with improved uniformity of color differences. The first to be provisionally accepted by CIE was the 1960 CIE-UCS** diagram (Fig. 5) having coordinates expressed in u and v and mathematically translated from the original 1931 x and y coordinate system. This was recently replaced by the 1976 CIE-UCS system⁴ with the coordinate expressed in u' and v' to differentiate from the 1960 system. The 1976 system differs only in the v values, $v' = 1.5v$ and $u' = u$.

A hindrance to the widespread use of the 1976 CIE-UCS diagram has been the lack of color boundaries to aid comprehension of data plotted on the diagram. In order to promote the use of the 1976 CIE-UCS system, the color boundaries have been translated from the most recent "Kelly" chart using the formulae:

$$u' = \frac{4X}{-2X + 12Y + 3} \quad \text{and} \quad v' = \frac{9Y}{-2X + 12Y + 3}$$

The result is shown in Fig. 6. The features of the original 1931 CIE and "Kelly" diagrams are retained except for the following: