IEC TR 62679-5-1

Edition 1.0 2017-07

TECHNICAL REPORT

colour inside

Electronic paper displays –
Part 5-1: Legibility of EPD in spatial frequency

IEC TR 62679-5-1:2017-07(en)

IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
Fax: +41 22 919 03 00
info@iec.ch
www.iec.ch

About the IEC
The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications
The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigenda or an amendment might have been published.

IEC Catalogue - webstore.iec.ch/catalogue
The stand-alone application for consulting the entire bibliographical information on IEC International Standards, Technical Specifications, Technical Reports and other documents. Available for PC, Mac OS, Android Tablets and iPad.

IEC publications search - www.iec.ch/searchpub
The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee,…). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished
Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and also once a month by email.

Electropedia - www.electropedia.org
The world's leading online dictionary of electronic and electrical terms containing 20 000 terms and definitions in English and French, with equivalent terms in 16 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

IEC Glossary - std.iec.ch/glossary
65 000 electrotechnical terminology entries in English and French extracted from the Terms and Definitions clause of IEC publications issued since 2002. Some entries have been collected from earlier publications of IEC TC 37, 77, 86 and CISPR.

IEC Customer Service Centre - webstore.iec.ch/csc
If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: csc@iec.ch.

IEC TR 62679-5-1

Edition 1.0 2017-07

TECHNICAL REPORT

Electronic paper displays –
Part 5-1: Legibility of EPD in spatial frequency

colour inside

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 31.120; 31.260

ISBN 9978-2-8322-4527-9

Warning! Make sure that you obtained this publication from an authorized distributor.

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

____

ELECTRONIC PAPER DISPLAYS –

Part 5-1: Legibility of EPD in spatial frequency

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
6) All users should ensure that they have the latest edition of this publication.
7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

The main task of IEC technical committees is to prepare International Standards. However, a technical committee may propose the publication of a technical report when it has collected data of a different kind from that which is normally published as an International Standard, for example "state of the art".

IEC TR 62679-5-1, 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
110/836/DTR	110/864A/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 62679 series, published under the general title *Electronic paper displays*, 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
- amended.

A bilingual version of this publication may be issued at a later date.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

A small device for an electronic paper display (EPD)[1] [1] was invented in 1997, and its first product as an electronic book was brought to the market in 2004. This product was the first electronic display which made human beings serious about reading letters and figures as well as those printed on a paper with ink. A definition of "electronic paper" was first given by N. K. Sheridon et al of PARC in 1998, as follows: Plane paper scatters light diffusely and efficiently, allowing for high contrast, high resolution images that can be viewed from broad angles without glare caused by specular reflection, in contrast, electronic display media can provide the extra benefits of reusability and easy integration into digital electronic systems. Electronic display media used in such a fashion can be called "electronic paper" [2]. For these reasons, the benchmark for estimation of EPD has always been printed paper.

The human action of reading is basically analysed through two subjective attributes, that is, legibility and readability. The legibility, as defined at 3.1.2, can be rated and analyzed by means of measuring optophysical or radiometric property of a certain pattern. This pattern is recognised by the retina as an aggregation of spatial frequencies. Legibility can be understood by analysing those kinds of spatial frequency. In 1967, the contrast sensitivity of the human eye for sinusoidal illuminance changes was measured as a function of spatial frequency [3]. As for readability, defined in 3.1.3, lot of human ergonomics tests and sophisticated statistical works are recommended with around a hundred human participants, to compare with printed paper, EPDs, and emissive displays; which will also require economical costs and expenditure of time. The readability of EPDs will be reported elsewhere.

IEC 62679 (all parts) specifies optical measuring methods for electronic paper displays (EPDs), but does not mention legibility and readability for EPDs, because there are no guidelines for measuring and estimating these elements in a practical fashion, especially under variation of optical environments.

This document offers permanent formulae to decide on the legibility level of EPD compared with paper, which will lead to specification of EPD with regard to the human action of reading. Legibility is one of the human actions of reading, which falls in the category of subjective assessments; on the other hand, the properties of EPDs fall in that of physical specifications, that is, objective assessments. The legibility in this document described by using a five-level rating system is revealed to show as a function of physical parameters.

In this document, legibility is suggested as having two essential parameters, that is, the spatial frequency, which can represent the complexity or size of a letter, font, or symbol, and the contrast, which shows brightness between a character and its background.

1 Numbers in square brackets refer to the Bibliography.

ELECTRONIC PAPER DISPLAYS –

Part 5-1: Legibility of EPD in spatial frequency

1 Scope

This part of IEC 62679, which is a technical report, specifies the legibility in terms of contrast, spatial frequency, and reflection of the screen as a function of the physical parameters of an EPD. This legibility evaluation model is introduced through both subjective and objective assessments. The scope of this document is restricted to EPDs using segment, passive, and active matrixes with monochromatic type displays.

2 References

There are no normative references in this document.

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the following terms and definitions apply [16].

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

- IEC Electropedia: available at http://www.electropedia.org/ [4]
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1.1
contrast sensitivity test chart [5,6]
CSC
chart for measuring and quantifying visual sensitivity in terms of contrast sensitivity and spatial frequency response, which contains a multiplicity of grating patches whose contrast, in term of luminance, varies sinusoidally for differing spatial frequencies

Note 1 to entry CSC is sometimes used for diagnosis in ophthalmology clinics.

3.1.2
legibility
ability for unambiguous identification of single characters or symbols that may be presented in a non-contextual format

[SOURCE: ISO 9241-302:2008, 3.3.35] [7]

3.1.3
readability
characteristics of a text presentation on a display that affect performance when groups of characters are to be easily discriminated, recognized and interpreted

[SOURCE: ISO 9241-302:2008, 3.3.38] [7]

3.1.4
multiple regression analysis [8]
analysis technique for composing a prediction formula which is easily and precisely calculated by making multiple selections for variables

3.1.5
spatial frequency
component of an image transferred by Fourier transform

[SOURCE: ISO 9241-302: 2008, 3.5.48, modified – the note has been removed.] [7]

3.2 Abbreviated terms

CCD	charge-coupled device
CSC	contrast sensitivity test chart
CSF	contrast sensitivity function
EPD	electronic paper display
IR	infrared
SEP	standard error of prediction

4 Contrast sensitivity test chart (CSC)

CSC is mostly used in ophthalmologic diagnoses, to evaluate the progression of cataract or glaucoma [9 to 11]. There was a US patent to define generalized visual sensitivity, but this idea has been already in the public domain [5, 6].

CSC consists of a multiplicity of grating patches whose contrast, in terms of luminance, varies sinusoidally for differing spatial frequencies. These patches, in this document, were printed by offset printing with a black ink on several kinds of papers. The CSC consists of thirty types of sinusoidal grating, based on six levels of spatial frequency (1, 2, 4, 8, 16, 32) cycles per degree and five levels of contrast (3,8, 7,5, 15, 30, 60) % defined in Formula (1). These contrasts are Michelson contrast. The spatial frequency is defined as the number of cycles per unit viewing angle. The measure of contrast in this document follows Formula (1).

These combinations of patches are shown schematically in Figure 1. The dimensions of the patches are a square 76 mm on a side. These kinds of patches are printed simultaneously in the order given in Table 1, on a paper with dimensions of 610 mm x 920 mm.

The properties of the papers for printing are shown in Table 1 [12, 13]. These kinds of paper are widely used for books, paperbacks, magazines, and calendars (or posters) which will satisfy adequately any case of the human action of reading. This means there has been no standardized paper before for both legibility and readability testing. In Table 1, the specular gloss is given by ISO 8254-1 [19], and the ISO brightness is described in ISO 2470-1 [20] for paper.

Contrast m (also known as the Michelson contrast, which relates to visual stimuli) is defined in Formula (1) and shown in Figure 2:

$$\mathrm{m}(\%) = \frac{Lmax - Lmin}{Lmax + Lmin} \times 100 \quad m(\%) = \frac{L_{\max} - L_{\min}}{L_{\max} + L_{\min}} \times 100 \qquad (1)$$

where $L_{\max}$ and $L_{\min}$ are the maximum luminance and minimum luminance of a sinusoidal pattern on a patch, respectively.

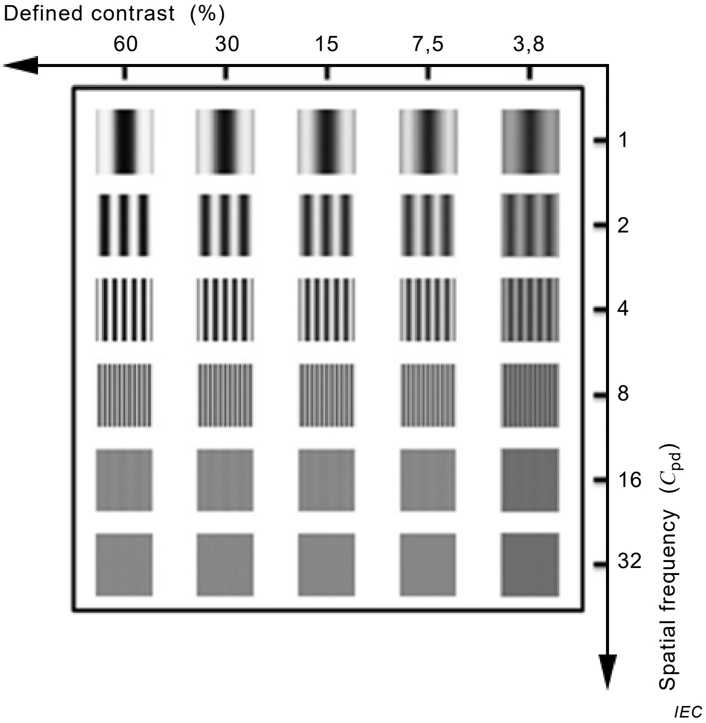

Figure 1 – Layout of patches

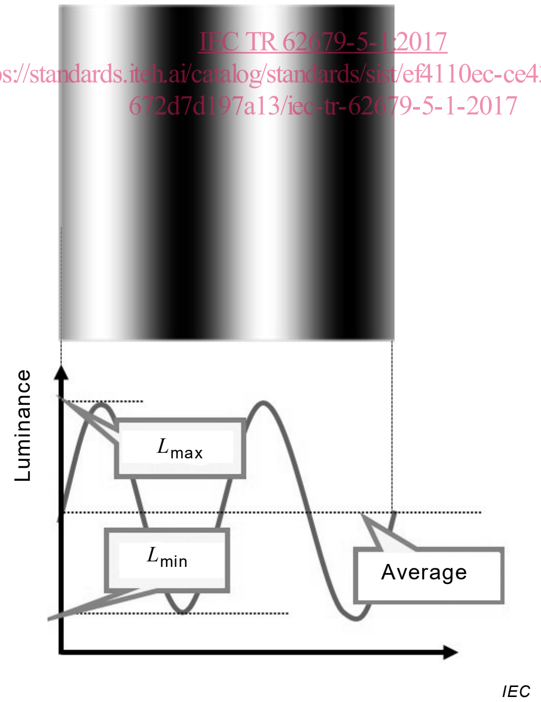

Figure 2 – Example of patch of CSC

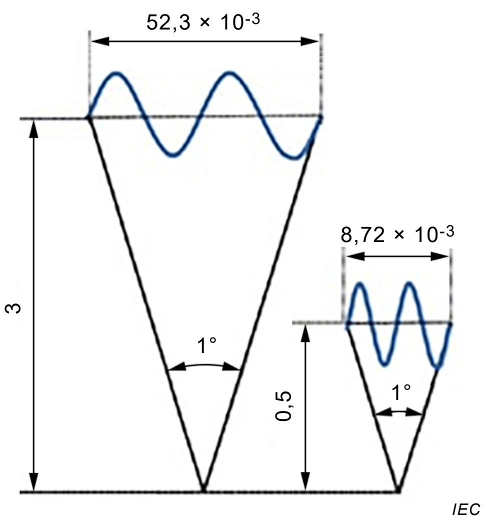

Figure 3 – Spatial frequency per unit viewing angle

Spatial frequency is defined as the number of cycles per unit viewing angle. Even though the spatial frequency is the same, the wavelength varies with the viewing distance (as shown in Figure 3). The expression of the relation is represented by Formula (8).

Table 1 – Properties of five kinds of paper

samples	Sample A	Sample B	Sample C	Sample D	Sample E
Typical application	Book	Book	Book	Magazine	Calendar
Specular gloss (%)	7	19	19	59	70
ISO brightness (%)	67,3	77,3	83,5	83,2	83,8

5 Objective assessment

5.1 General

A photometric measurement system is described below. Microscopic goniophotometry assumes an important role for quantifying a visual sense [14 to 17] by scanning the printed sinusoidal gratings. The goniophometric system was constructed to measure the distribution of the reflective intensity as shown in Figure 4.

This experimental apparatus consists of three movable parts:

a) The size of a sample holder is 76 mm × 76 mm. Each sample was fixated using two magnetic plates that were fixed to the sample holder.

b) The light source was connected to a diffused light source where the light was guided by optical fibres to the flat panel, scattered in the flat panel, and emitted diversely from the surface. The incident angle was defined as the angle formed by the light source's optical axis and the direction perpendicular to the sample holder.

c) The photometric unit consists of a focus lens and a charge-coupled device (CCD) camera that is equipped with a sensor array and a personal computer. The CCD camera (monochrome, with and image size of 35 mm × 20 mm) was calibrated using the grey-scale chart. An optical filter which can cut IR is necessary. Images were acquired using a personal computer that had a built-in image capture board, and they were quantized to an 8-bit grey scale (256 grey levels). The photometric angle was defined as the angle formed