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Utgåva 1

Ergonomiska krav på kontorsarbete med platta bildskärmar –
Del 2: Ergonomiska krav på platta bildskärmar
(ISO 13406-2:2001)

Ergonomic requirements for work with visual displays based on flat panels –
Part 2: Ergonomic requirements for flat panel displays
(ISO 13406-2:2001)

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EUROPEAN STANDARD

NORME EUROPÉENNE

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EN ISO 13406-2

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Ergonomic requirements for work with visual displays based on flat panels - Part 2: Ergonomic requirements for flat panel displays (ISO 13406-2:2001)

Exigences ergonomiques pour travail sur écrans de visualisation à panneau plat - Partie 2: Exigences ergonomiques des écrans à panneau plat (ISO 13406-2:2001)

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Ref. No. EN ISO 13406-2:2001 E

Contents

Foreword

The text of the International Standard ISO 13406-2:2001 has been prepared by Technical Committee ISO/TC 159 "Ergonomics" in collaboration with Technical Committee CEN/TC 122 "Ergonomics", the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by June 2002, and conflicting national standards shall be withdrawn at the latest by June 2002.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

Endorsement notice

The text of the International Standard ISO 13406-2:2001 was approved by CEN as a European Standard without any modification.

NOTE: Normative references to International Standards are listed in annex ZA (normative).

Introduction

ISO 13406 extends its companion standard ISO 9241 to account for the significant differences in ergonomic trade offs present when flat panels are used.

The rationale for this part of ISO 13406 is presented in ISO 13406-1.

This part of ISO 13406 presents the requirements for visual display units (VDUs) based on flat panels as defined in ISO 13406-1. It is intended for evaluators and users of this technology. Some document users will find part of the material complex. Notes, figures and examples are provided to lessen the problem. The legibility of flat panels is a principal concern. The requirements are primarily based on the visual ergonomic research used in ISO 9241-3 and on new research referenced in this part of ISO 13406. Here, as in ISO 9241-3, some requirements are based on visual comfort, muscular comfort and user acceptability. This part of ISO 13406 includes requirements and recommendations that are based on legibility, comfort and acceptability that arise when multicolour displays are used, based on the visual ergonomic research described in ISO 9241-8, but modified and extended to consider the unique trade offs of flat panels. Legibility in the presence of ambient room light and the acceptability of unwanted reflected images are addressed covering the flat panel aspects covered in ISO 9241-7 for cathode ray tube (CRT) technology.

Clause 3 Definitions presents or recalls those terms needed to specify requirements and measurements. Where possible, definitions taken from other publications are quoted verbatim. If some change has been made, the definition is followed by a note stating “Adopted from ISO xxxx:date,x.x”. Since this part of ISO 13406 often relies on mathematical models and physical measurements to ensure the fitness of purpose of flat panel VDUs, a clause 8 (Symbols) is presented as a convenient reference.

Guiding principles and performance requirements’ clauses modelled on ISO 9241-3 are presented to remind document users of the foundations of the work.

Design requirements and recommendations present the physical attributes that are to be strictly followed to conform (indicated by the word: shall) or preferred but not necessarily required (indicated by the word: should). The topics of design viewing distance, design viewing direction and design screen illumination depart somewhat from the precedents of ISO 9241-3. Two reasons exist:

a) an important type of flat panel has viewing characteristics that require more careful control and consideration of viewing direction than considered in ISO 9241-3;

b) there is no basis to assume that a flat panel VDU is tabletop mounted. These topics are presented as ergonomically constrained, supplier-specifications. This is not unprecedented, viewing distance was handled this way in ISO 9241-3. Once specified, these requirements become the conditions under which all other attributes are to be measured or decided.

A departure from ISO 9241-3 is the use of area-luminance. For CRT technology, the addressed locations are generally close together so that a *high-low-high-low-high-low*-pixel pattern will exhibit less contrast than a sparse pattern. Since the flat-panel pixel area is less than 100 % optically modulated (the fill factor is less than 1), the difference between sparse and dense pattern contrast is minor. The luminance determination has to be complicated by the need for viewing direction precision. The use of area-luminance simplification offsets that somewhat.

Some requirements are presented in categories. For example, some flat panels exhibit long image-formation times. For static images, such panels are ergonomically acceptable without reservation. Not all modern applications rely solely on such static images. Requirement categories are therefore established. If the supplied equipment has such a limitation, the supplier/evaluator is required to identify it. The system integrator, purchaser or user then can consider whether the category is consistent with intended applications.

Clause 8 covering measurements is intended for evaluators of flat panel VDUs. The panel surface is sampled for evaluation. Three evaluation sites are chosen and measured, and compliance decisions can be made from these measurements. Panels with large requirement margins do not require precision-evaluation equipment but panels with small margins can.

Clause 9 covering compliance is closely modelled on ISO 9241-3. The alternative test (Visual performance and comfort test) prepared as a normative annex in an amendment to ISO 9241-3, is cited as an alternative compliance route.

Annex A provides additional information on colour difference. Annex B extends the analytic flicker determination method of ISO 9241-3 to luminance-time modulation that is not CRT-like. Annex C informs the users of this International Standard of new work on an alternate modelling method for screens with reflection properties that cannot be adequately modelled with a simple combination of luminance coefficient (diffuse reflection) and luminance factor (specular or regular reflection) and standardized assumptions about the environment. This method develops the bidirectional reflection distribution function. When this work progresses further, it can possibly become a normative method and replace the method in clause 8. The bibliography cites references.

Ergonomic requirements for work with visual displays based on flat panels —

Part 2:
Ergonomic requirements for flat panel displays

1 Scope

This part of ISO 13406

— establishes ergonomic image-quality requirements for the design and evaluation of flat panel displays,

— defines terms needed to address image quality on flat panel displays,

— specifies methods of determining image quality on flat panel displays, and

— establishes ergonomic principles for guiding these requirements.

This part of ISO 13406 is applicable to

— flat panel display screens when used to perform office tasks,

— flat panel display screens that consist of a regular array of picture elements arranged in evenly spaced rows without built-in gaps,

— the presentation of fonts based on Latin-, Cyrillic- and Greek-origin alphabetic characters and Arabic numerals on flat panel display screens,

— the presentation of Asian characters, and

— flat panel display screens that are large enough to display at least 40 Latin-origin characters.

This part of ISO 13406 is not applicable to

— flat panel technology applied to a display that uses optics to form an image that is not the same size as the electro-optical transducer (projection applications of flat panel displays), or

— flat panel technology applied to a display limited to fixed-messages or segmented alphanumerics. [See 2.13 IEC SC 47C (Central Office) 3:1992].

NOTE Some of the measurement methods (e.g. contrast and luminance) in this part of ISO 13406 are not applicable for reflective flat panels. When technology has developed, appropriate measurement methods will be added to this part of ISO 13406.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of ISO 13406. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of ISO 13406 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

CIE Publication No. 15.2:1986, *Colorimetry*. (Central Bureau of the Commission International d'Éclairage CIE), Vienna, Austria.

ISO 9241-3:1992, *Ergonomic requirements for office work with visual display terminals (VDTs) — Part 3: Visual display requirements*.

ISO 9241-6, *Ergonomic requirements for office work with visual display terminals (VDTs) — Part 6: Guidance on the work environment.*

ISO 9241-7, *Ergonomic requirements for office work with visual display terminals (VDTs) — Part 7: Requirements for display with reflections*.

ISO 9241-8:1997, *Ergonomic requirements for office work with visual display terminals (VDTs) — Part 8: Requirements for displayed colours.*

3 Definitions

For the purposes of this part of ISO 13406, the following definitions apply.

NOTE The symbols used in certain definitions are explained in clause 4.

3.1 Photometry

3.1.1
area-luminance
luminance of an area of the screen that has a diameter of at least 10 pixels, such that the state of an individual pixel has less than 2 % effect

NOTE Area-luminance is expressed in candelas per square metre (cd/m^2).

3.1.2
background luminance
luminance of an area of the screen with no graphic images present

NOTE Background luminance is expressed in candelas per square metre (cd/m^2).

3.1.3
contrast
⟨in a perceptual sense⟩ assessment of the difference in appearance of two or more parts of a field seen simultaneously or successively (hence: brightness contrast, lightness contrast, colour contrast, etc.)

NOTE Adapted from IEC 60050 (845-02-47):1987.

3.1.4
EUT
Equipment Under Test

3.1.5
Lambert's (cosine) law
for a surface element whose radiance or luminance is the same in all directions of the hemisphere above the surface:

$$I(\theta) = I_n \cos(\theta) \quad (1)$$

Where $I(\theta)$ and I_n are the radiant or luminous intensities of the surface element in a direction at an angle θ from the normal to the surface and in the direction of that normal, respectively

[IEC 60050 (845-04-56):1987]

3.1.6
Lambertian surface
ideal surface for which the radiation coming from that surface is distributed angularly according to Lambert's cosine law

[IEC 60050 (845-04-57):1987]

For an ideal diffuse reflectance standard:

$$\rho_{\mathrm{STD}} = \pi \cdot q_{\mathrm{STD}} \quad (2)$$

3.1.7
luminance contrast
ratio between the higher, L_{H} and lower, L_{L}, luminances that define the feature to be detected, measured by contrast modulation (C_{m}) defined as:

$$C_{\mathrm{m}} = \frac{L_{\mathrm{H}} - L_{\mathrm{L}}}{L_{\mathrm{H}} + L_{\mathrm{L}}} \quad (3)$$

or contrast ratio (CR), defined as:

$$\mathrm{CR} = \frac{L_{\mathrm{H}}}{L_{\mathrm{L}}} \quad (4)$$

NOTE 1 For flat panels, area-luminance targets can be used to approximate the luminances that define the feature to be detected because pixels are discrete.

NOTE 2 Adapted from ISO 9241-3:1992, 2.22.

3.1.8
luminance coefficient (at a surface element, in a given direction, under specified conditions of illumination)
q_{v}, q
quotient of the luminance of the surface element in the given direction by the illuminance of the medium

NOTE 1 The luminance coefficient is expressed in reciprocal steradians.

NOTE 2 Adapted from IEC 60050 (845-04-71):1987.

$$q = \frac{L}{E} \quad (5)$$

3.1.9
luminance factor (at a surface element of a non-self-radiating medium, in a given direction, under specified conditions of illumination)
β_v, β
ratio of the luminance of the surface element in the given direction to that of a perfect reflecting or transmitting diffuser identically illuminated

$$\beta = \frac{L_{\text{sample}}}{L_{\text{perfect diffuser}}} \tag{6}$$

NOTE 1 The luminance factor is expressed as unit: 1

NOTE 2 Adapted from IEC 60050 (845-04-69):1987.

3.1.10
optically anisotropic surface
optical surface for which the radiation deviates from that of a Lambertian surface by more than 10 % at any inclination angle, $\theta < 45°$

3.2 Colorimetry

3.2.1
CIE 1976 $L^*u^*v^*$ colour space
CIELUV colour space
three-dimensional, approximately uniform colour space produced by plotting in rectangular coordinates L^*, u^*, v^* quantities defined by the three equations:

$$\left.\begin{aligned} L^* &= 116\,(Y/Y_n)^{\frac{1}{3}} - 16, \text{ when } Y/Y_n > 0{,}008\,856 \\ L^* &= 903{,}3\,(Y/Y_n), \text{ when } Y/Y_n \leqslant 0{,}008\,856 \\ u^* &= 13L^*(u' - u'_n) \\ v^* &= 13L^*(v' - v'_n) \end{aligned}\right\} \tag{7}$$

Y, u', v' describe the colour stimulus considered and Y_n, u'_n, v'_n describe a specified white achromatic stimulus.

NOTE Approximate correlates of lightness, saturation, chroma and hue may be calculated as follows:

$$\text{CIE 1976 } u, v \textit{ saturation } s_{uv} = 13\left[(u' - u'_n)^2 + (v' - v'_n)^2\right]^2 \tag{8}$$

$$\text{CIE 1976 } u, v \textit{ chroma } C^*_{uv} = \left[u^{*2} + v^{*2}\right]^{\frac{1}{2}} = L^* s_{uv} \tag{9}$$

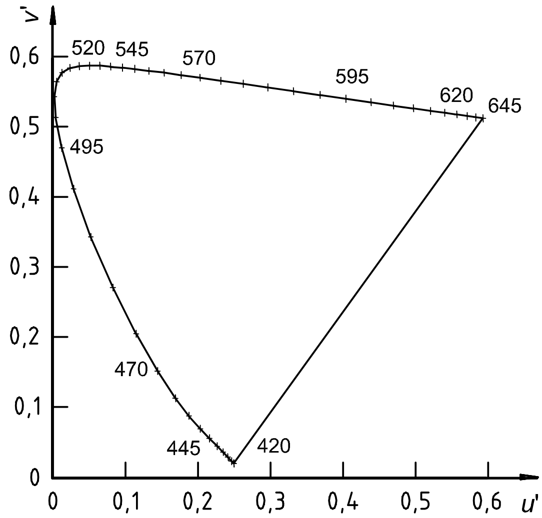
$$\text{CIE 1976 } u, v \textit{ hue-angle} \quad \begin{aligned} h_{uv} &= \arctan\left(\frac{v' - v'_n}{u' - u'_n}\right) = \arctan\left(\frac{v^*}{u^*}\right), \text{ such that} \\ 0° &\leqslant h_{uv} < 90°, \; \textit{if} \; v^* \geqslant 0 \text{ and } u^* \geqslant 0 \\ 90° &\leqslant h_{uv} < 180°, \; \textit{if} \; v^* \geqslant 0 \text{ and } u^* < 0 \\ 180° &\leqslant h_{uv} < 270°, \; \textit{if} \; v^* < 0 \text{ and } u^* < 0 \\ 270° &\leqslant h_{uv} < 360°, \; \textit{if} \; v^* < 0 \text{ and } u^* \geqslant 0 \end{aligned} \tag{10}$$

[IEC 60050 (845-03-54)]

3.2.2
CIE 1976 uniform-chromaticity scale diagram
CIE 1976 UCS diagram
uniform-chromaticity-scale diagram produced by plotting in rectangular coordinates v' against u', quantities defined by the equations (11):

$$u' = \frac{4X}{X + 15Y + 3Z} = \frac{4x}{-2x + 12y + 3}$$
$$v' = \frac{9Y}{X + 15Y + 3Z} = \frac{9y}{-2x + 12y + 3} \quad (11)$$

See Figure 1 and IEC 60050 (845-03-53).



NOTE The curve annotations are wavelengths in nanometers.

Figure 1 — CIE 1976 UCS Diagram

3.2.3
CIE 1976 $L^*u^*v^*$ colour difference
CIELUV colour difference
difference between two colour stimuli, defined as the Euclidean distance between the points representing them in the $L^*u^*v^*$ space and calculated as equation:

$$\Delta E^*_{uv} = \left[\left(\Delta L^*\right)^2 + \left(\Delta u^*\right)^2 + \left(\Delta v^*\right)^2 \right]^{\frac{1}{2}} \quad (12)$$

The set X_n Y_n Z_n and corresponding u'_n v'_n define the colour of the nominally white object-colour stimulus.

(See CIE Publication No. 15.2.)

[IEC 60050 (845-03-55)]

3.2.4
chromaticity uniformity difference
distance on the CIE 1976 UCS diagram

$$\Delta u'v' = \sqrt{(u'_1 - u'_2)^2 + (v'_1 - v'_2)^2} \tag{13}$$

where

u'_1, v'_1 and u'_2, v'_2 are the coordinates of the same colour displayed at sites 1 and 2.

NOTE This is the appropriate measure of colour uniformity if luminance is not uniform or if the objects are not adjacent. (See 3.2.2.)

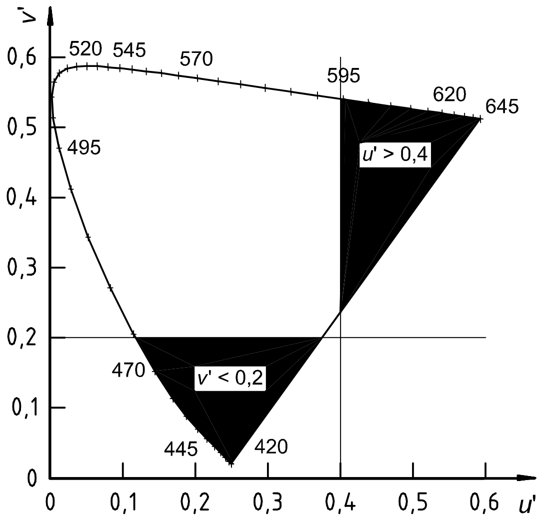
3.2.5
dominant wavelength of a colour stimulus, λ_d
wavelength of the monochromatic stimulus that, when additively mixed in suitable proportions with the specified achromatic stimulus, matches the colour stimulus considered

NOTE In the case of purple stimuli, the dominant wavelength is replaced by the complementary wavelength. See IEC 60050 (845-03-44).

3.2.6
same dominant wavelength
two colours have the same dominant wavelength if the difference between the hue angles of each colour is small

3.2.7
spectrally extreme colours
spectrally extreme colours are extreme blue and extreme red

NOTE Extreme blue is any colour with $v' < 0{,}2$. Extreme red is any colour with $u' > 0{,}4$. The extreme regions are illustrated in Figure 2.



NOTE The curve annotations are wavelengths in nanometers.

Figure 2 — Extreme red and extreme blue

3.2.8
uniform colour space
colour space in which equal distances are intended to represent a threshold or suprathreshold perceived colour differences of equal size

[IEC 60050 (845-03-51):1987]

3.2.9
uniform-chromaticity-scale diagram
UCS diagram
two-dimensional diagram in which the coordinates are defined with the intention of making equal distances represent as nearly as possible equal steps of colour discrimination for colour stimuli of the same luminance throughout the diagram

[IEC 60050 (845-03-52):1987]

3.3 Geometry

3.3.1
active area
part of a display screen area delimited by picture elements [*2.1*, IEC SC 47C(Central Office) 3]

3.3.2
angular subtence
size of a visual target at a specified viewing distance, e.g. at the design viewing distance

$$\text{Angular subtence in degrees} = 2 \arctan\left(\frac{\text{target height}}{2 \times \text{viewing distance}}\right) \tag{14}$$

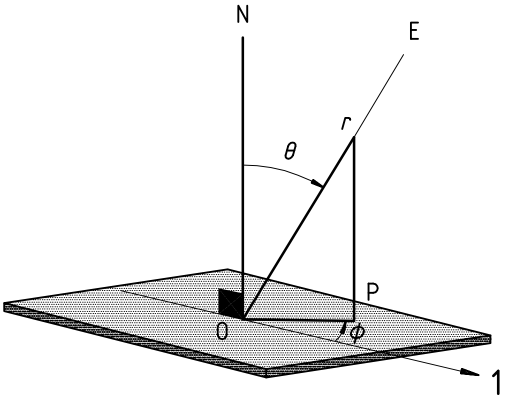
$$\text{Angular subtence in minutes of arc} = 60 \times 2 \arctan\left(\frac{\text{target height}}{2 \times \text{viewing distance}}\right) \approx \frac{3\,438 \times \text{target height}}{\text{viewing distance}} \tag{15}$$

NOTE The dimension for angular subtence is degrees (°), which is further divided into minutes of arc (′) and seconds of arc (″).

3.3.3
anisotropic display
display (usually a liquid crystal display) with emitted luminance and/or luminance coefficient that meets the criterion in 3.1.10

3.3.4
coordinate system
a normal spherical coordinate system (r, θ, ϕ)

See Figure 3.



Key

E Position of the entrance pupil of the luminance meter

OE = r Working distance

1 $\phi = 0°$ (3 o'clock)

NOTE 1 In some literature, the azimuth is specified by clock positions. 3 o'clock is defined as $\phi = 0°$.

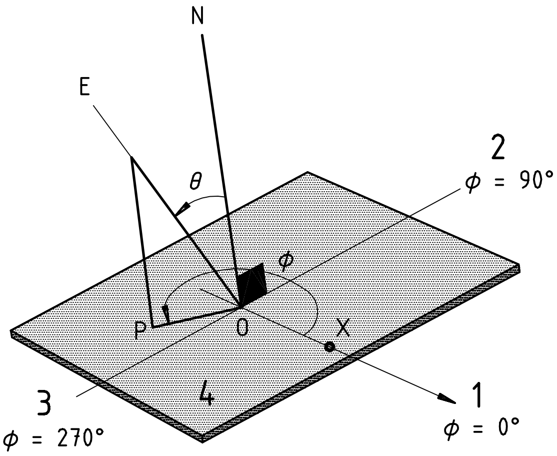
NOTE 2 Normally only positive values for θ are used. ($-\theta$, ϕ) is identical to the direction ($+\theta$, $\phi \pm 180°$).

Figure 3 — Coordinate system

NOTE 1 The following is a detailed definition of the coordinate system. See Figure 4.

Let a point (pixel or centre of a visual target) be labelled O. Construct a line, from O to the entrance pupil of the measuring instrument, OE, and a line, ON normal to the image plane of the display. The angle from ON to OE in the ON - OE plane is the inclination angle, θ. The distance OE is the radius r.

Let P be any point on the line that is formed by the projection of OE on the image plane. Construct a line, OX in that plane to the right of and parallel to the line that bisects the active area horizontally. This is the X axis. The azimuth angle, ϕ, is the counterclockwise angle between OX and OP.



Key

1 3 o'clock; right edge of the screen as seen from the user

2 12 o'clock; top edge of the screen as seen from the user

3 6 o'clock; bottom edge of the screen as seen from the user

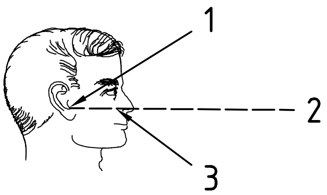
4 Image surface of the screen

Figure 4 — Coordinate system - definition

NOTE 2 For more information on coordinates and viewing angles, see VESA Flat Panel Display Measurements Standards (1998), chapter 300-2.

3.3.5
Frankfort plane
is an imaginary plane through the head established by the lateral extensions of a line between the tragion and the lowest point of the orbit

See Figure 5.



Key

1 Tragion

2 Frankfort plane

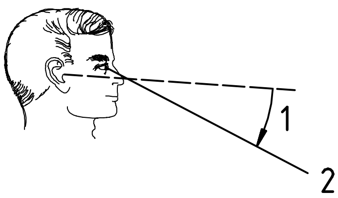
3 Inferior ridge of the orbit

Orbit is the cavity in the skull that contains the eye. Tragion (or tragus) is the projection of cartilage in the pinna of the outer ear that extends back over the opening of the external auditory meatus.

Figure 5 — Frankfort plane

3.3.6
gaze angle
angle from the Frankfort plane to the plane formed by the pupils and the visual target

See Figure 6.



Key

1 Gaze angle

2 Line of sight

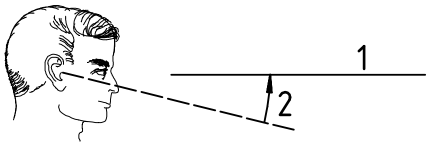
Figure 6 — Gaze angle

NOTE The comfortable range is about 0° to about 45°.

3.3.7
head tilt angle
angle from the Frankfort plane to the horizontal plane and due to tilt of the head

NOTE When the head is erect, the head tilt angle is about 4°

See Figure 7.



Key

1 Horizontal plane

2 Head tilt angle

Figure 7 — Head tilt angle

NOTE The comfortable range is about 0° to about 20°.

3.3.8
viewing angle range
conical space originating at a pixel that includes all viewing directions for which specifications are satisfied

[IEC SC 47C (Central Office) 3]

3.4 Display technology

3.4.1
fill factor
fraction (of the total area geometrically available to a pixel) that can be altered to display information

[ISO 9241-3:1992, 2.15]

3.4.2
emissive display
display that contains its own source(s) of light

NOTE 1 This light can be produced by the transducer itself or provided by one or more internal light source(s) modulated by the transducer.

NOTE 2 Adapted from 2.4, IEC/SC 47C (Central Office) 3.

3.4.3
gray scale
a display is said to have gray scale if it can display images demanding more than two luminance levels

[2.4, IEC/SC 47C (Central Office) 3]

3.4.4
image formation time
time for the relative luminance of a visual object to change from 0,1 to 0,9

NOTE 1 The relative luminance is

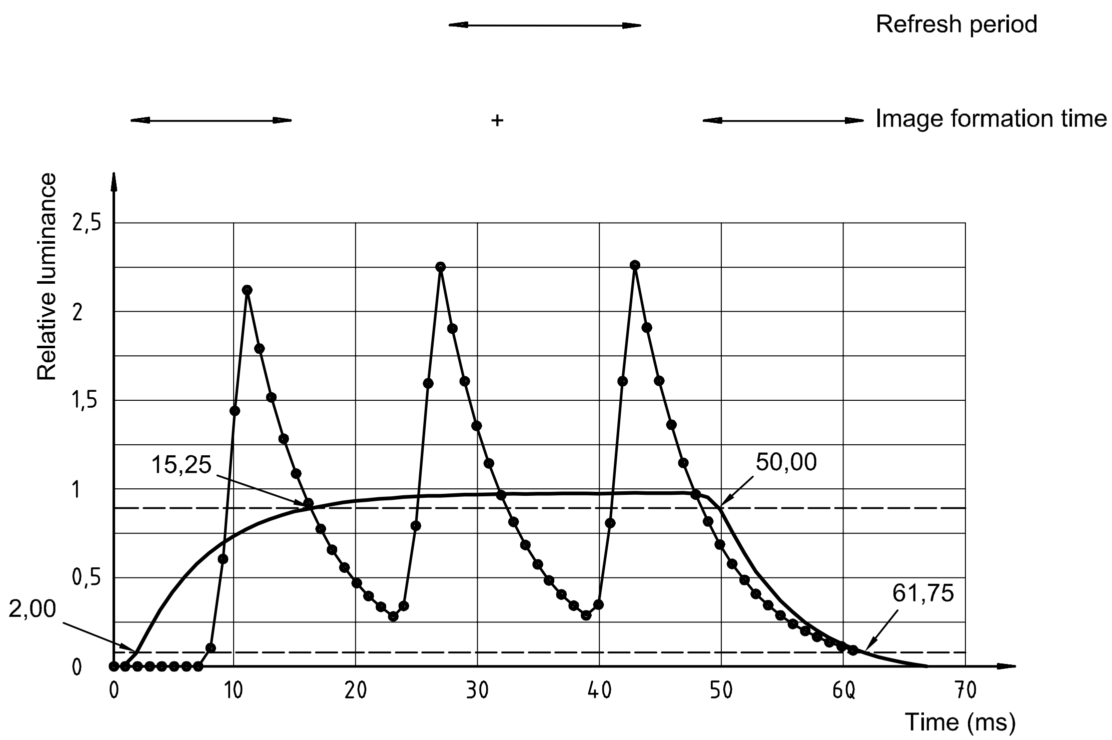
$(L - L_{\mathrm{MAX}})/(L_{\mathrm{MAX}} - L_{\mathrm{MIN}})$;

where

L_{MAX} and L_{MIN} are the time averaged highest and lowest luminance states, respectively;

L is the instantaneous luminance.

NOTE 2 The relative luminance is filtered to eliminate temporal variations that are not visually detectable. Image formation time is resolved to the ranges shown in Table 1 and is expressed in milliseconds.



NOTE 1 This illustrates a typical case.

NOTE 2 A constant-luminance back light is assumed (after prefiltering for 4kS/s sampling).

NOTE 3 Figure 8 illustrates the image formation time. The trace with the marks represents the unfiltered luminance time, normalized to a range of 1,0. The bold trace is the first trace filtered to include those frequencies that are psychophysically significant. The image formation time is judged on this trace. In this example, t_1 = 2,00 ms is the time recorded at 0,1 of the maximum luminance with the luminance increasing; t_2 = 15,25 ms is the time recorded at 0,9 of the maximum luminance with the contrast increasing; t_3 = 50,00 ms, is the time recorded at 0,9 of the maximum luminance with the luminance decreasing; and, t_4 = 61,75 ms is the time recorded at 0,1 of the maximum luminance with the luminance decreasing. Image formation time is $t_2 - t_1 + (t_4 - t_3)$ = 25 ms. The luminance time is sampled at 4 kS/s, so the precision is ± 0,5 ms.

NOTE 4 For flat panel displays with very fast electro-optic physics, the refresh period is the image formation time.

Figure 8 — Image formation time

Table 1 — Image formation time in milliseconds

Time range	Significance
$t \leqslant 10$	Motion artefacts become undetectable at image formation times less than 3 ms.
$10 < t \leqslant 55$	Contrast is stable for most applications. Motion artefacts can be distracting.
$55 < t \leqslant 200$	Applications using scrolling, animation and pointing devices lose detectable contrast. Blink coding from 0,33 Hz to 5 Hz is operable.
$t > 200$	Noticeable loss of contrast observed during key entry, scrolling, animation, and blink coding. Pointing devices with rapid cursor positioning can be used only with special techniques.

3.4.5
absolute luminance coding
information presented where the only dimension that is used for visual differentiation is difference in image luminances