# Global and Local Colour Management for the ergonomic Display Output of SDR and HDR images

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## Introduction

New displays of the High Dynamic Range (HDR) may lead to new possibilities for the ergonomic display output compared to the Standard Dynamic Range (SDR). The ergonomic output according to ISO 9241-306 [1] on displays with the HDR range compared to the SDR range is discussed. ISO 9241-306 defines the standard luminance range $L_W$:$L_N$=36:1 for output on paper and on displays.

For the black *N*, the Grey *U*, and the White *W* the following standard values are given:

black N: $L_N$=3,3 cd/m$^2$, $Y_N$=2,5 = $Y_U$/7,2
grey U: $L_U$=24 cd/m$^2$, $Y_U$=18
white W: $L_W$=142 cd/m$^2$, $Y_W$=90 = 5 $Y_U$.

The luminance contrast ratio is therefore

In applications especially the values for black differ, the values may be

$Y_N$=1,8 = $Y_U$/10 for high glossy photographic paper,
$Y_N$=2,5 = $Y_U$/7,2 for semi glossy offset paper,
$Y_N$=3,6 = $Y_U$/5 for matte office paper.

Advantages and disadvantages of the higher contrast *C* of HDR displays are discussed.

## Global and local Colour Management

The *global colour management* (GCM) is usually a professional colour management, especially in the area of displays used in television, in printing and in photography. This global colour management is often based on metadata which describe the colour gamut of the device, and or the image. In applications, the software use these data different and often produce clipping of colour areas. This clipping is avoided in the *rgb**-colour management according to [1].

The *local colour management* (LCM) is for example the colour management of ISO 9241-306 [1] which produces an ergonomic output at display work places in offices. The well-being of the users and the reduce of fatigue are the intentions of [1]. However, increasing reflections between about 4% and 100% of the ambient light reduce the contrast range. The intended equal spacing of 9 step colour scales is much reduced in the dark range. Appropriate correction methods will be described in Fig. 2 and 5. Already the first edition of [1] in 2008 has described the *LCM* using a *colour slider* on the computer operating system *Mac OS X* as example, see Fig. 2.

The visual effect of 15 the ambient reflections on the spacing of achromatic and chromatic colours is simulated in the test chart of Fig. 1. Increasing reflections lead to many dark grey steps which may not be distinguishable. Colourimetry calculates a gamma value compared to the standard value gamma = 2,4 according to IEC 61966-2-1 [6]. A gamma slider with an inverse gamma makes the steps again equal and visible. For the many variable use cases of [1] only the *local user* can solve the intentions of [1].

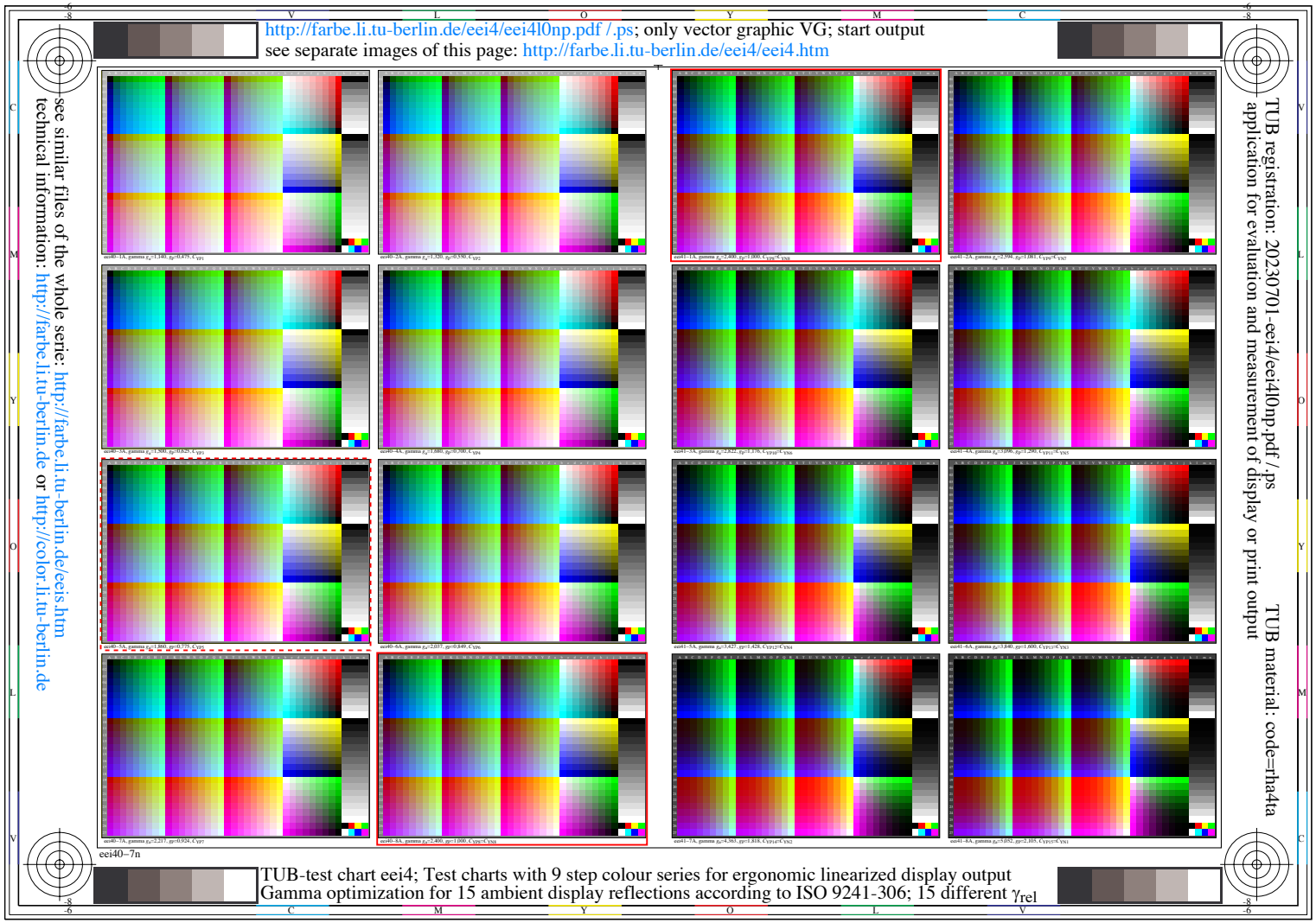
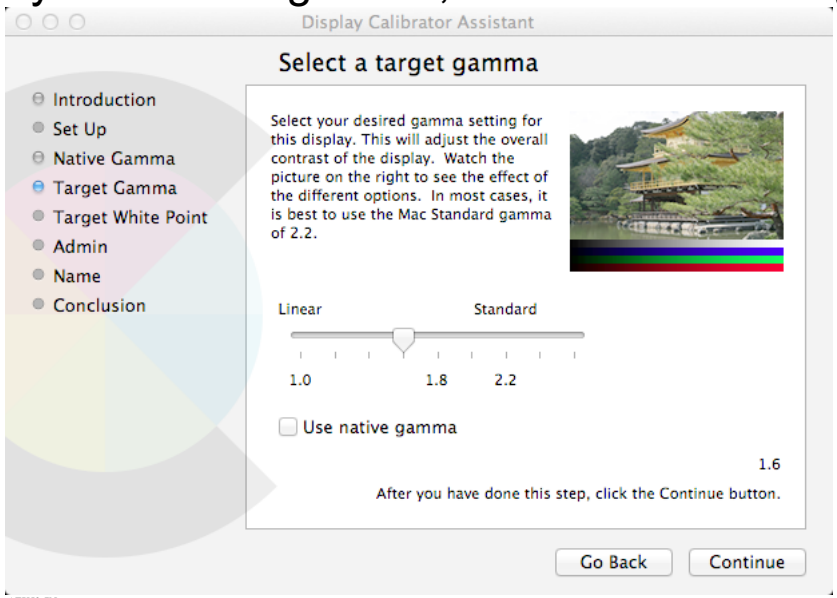



**Fig. 1 Fifteen relative gamma values of a test chart AE49 similar to [1]**

For the study of many effects of the ambient light *(switch it on or off)* the download of the test chart of Fig. 1 is recommend, see http://farbe.li.tu-berlin.de/eei4/eei4l0np.pdf

Fig. 1 simulates the visual display output with increasing reflections of the ambient light on the display. With increasing reflections an increasing amount of dark grey steps is not distinguishable. In the many use cases with displays the gamma slider produces equal steps by an inverse gamma, even if the default gamma deviates.




AEX50-7N

**Fig. 2. Gamma slider for visual change of the display output for many use cases.** The *rgb** data in the file of Fig. 1 can be changed by an inverse value of the measured or calculated gamma. Different Gamma values are used in Fig. 1.

**sensation scaling functions**
**lightness $L^*$ and tristimulus value $Y$**

**adaptation on surround white $W$**

$$L^*_W = 100\,(Y / 100)^{1/2,0}$$

**adaptation on surround grey $U$**

$$L^*_U = 100\,(Y / 100)^{1/2,4}$$

**description with CIELAB 1976**

$$L^*_{CIELAB} = 116\,(Y / 100)^{1/3,0} - 16$$

**adaptation on surround black $N$**

$$L^*_N = 100\,(Y / 100)^{1/3,0}$$

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**Fig. 3 Scaling function with Gamma values 2, 2,4, and 3 for the surrounds W, U, N.**
The inverse exponent in the scaling functions is called the Gamma value. Different values are used in colourimetry. IEC 61966-2-1 (sRGB colour space) [6] defines the standard Gamma value 2,4. The IEC scaling function is an approximation of the lightness function $L^*_{CIELAB}$ of the CIELAB colour space according to ISO/CIE 11664-4. In any case the $L^*$ function is normalized to 100 for the tristimulus value $Y$=100. In image technology a normalization to $Y_U$=18 which corresponds to the mean lightness value $L^*_{U,CIELAB}$=50 is more appropriate and used in Fig. 5 to 7.

The general trend to a lower Gamma for a lighter surround, for example white W, and a higher Gamma for a darker surround, for example black N, is well known in colourimetry. If HDR displays are used in a dark surround, then a Gamma value larger 2,4 is expected.

## CIE $Y$ and lightness $L^*$ for surface colours and for emissive display colours

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | extrapolated surface-colour range | | | | | | | | | | lighter samples | |
| *step* | 0 | 1 | 2 | 3 | 4 | .. | 9 | 10 | | | | | 15 | 20 |
| $L^*_w=100\,(Y/100)^{1/2}$ | | | extrapolated surface-colour range | | | | | | | | | | lighter samples | |
| $L^*_w$ | 0 | 10 | 20 | 30 | 40 | .. | 90 | 100 | | | | | 150 | 190 |
| | | | extrapolated surface-colour range | | | | | | | | | | lighter samples | |
| $Y$ | 0 | 1 | 4 | 9 | 16 | .. | 81 | 100 | | | | | 225 | 360 |
| | | | black | real matte surface-colours | | | | white | | | | | lighter samples | |
| $Y_2$ | | | 3,6 | 18 | | | | 90 | | | | | 180 | 360 |
| | | black | intended emissive display colours without reflection | | | | | | | | | white | lighter samples | |
| $Y_3$ | | 1,8 | | 18 | | | | | | | | | 180 | 360 |
| | | | black emissive display colours with 3,6% reflection | | | | | | | | | white | lighter samples | |
| $Y_4=18\,(Y_3+3{,}6)/21{,}6$ | | | 4,5 | 18 | | | | | | | 153 | | 190 | 303 |
| $L^*_{CIE}=116\,(Y/100)^{1/3}-16$ | | | extrapolated surface-colour range | | | | | | | | | | lighter samples | |
| $L^*_{CIE}$ | 0 | 8 | 14 22 23 | 35 | 46 49 | 57 | 92 | 95 | 100 | 125 | | | 125 | 161 |
| $L^*_{TUB}=40\,\log(Y/18)/\log 5$ | | | extrapolated surface-colour range | | | | | | | | | | lighter samples | |
| $L^*_{TUB}$ | | −71 | −57 −40 −37 | −17 | −2 0 | 8 | 37 | 40 | 42 | 57 | | | 57 | 74 |
| | | | extrapolated surface-colour range | | | | | | | | | | lighter samples | |
| $50+L^*_{TUB}$ | | −21 | −7 10 12 | 32 | 47 50 | 58 | 87 | 90 | 92 | 107 | | | 107 | 124 |

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**Fig. 4 CIE tristimulus value $Y$ and lightness $L^*$ for surface and display colours**

Fig 4 shows the lightness values and the corresponding tristimulus values for the Gamma value 2,0 in the first three lines. In Fig 5 the matte surface-colour range between $Y_N$=3,6 and $Y_W$=90 for SDR displays (green colour) may be extended for the HDR displays (red colour).

The luminance contrast range for $Y_N$=3,6 and $Y_W$=90 is $C$=25:1. If this range is extended by a factor 2 at both ends, then the contrast range is $C$=100:1 with $Y_N$=1,8 and $Y_W$=180. ISO/TC 22028-5 uses the range $C$=625:1 which uses a factor 5 at both ends.

In offices a white paper with the reflection $R$=0,9 under the standard illuminance $E$=500 lux shall have the same luminance as the white display. This case is recommended to increase the well-being and to reduce the fatigue of users according to the ergonomic standard ISO/CEN/DIN 9241-306 [1] for display work. This leads for white W to the luminance $L=E\,R\,/\,\pi$ = 142 cd/m$^2$.

Most displays have a surface reflection near $R$=0,036 or the tristimulus value $Y$=3,6 in standard offices. For example by a special coating of the display surface the HDR display *Apple iPod 2022* has a reflection $R$=0,018, which is used in Fig. 5 as example.

If for example the emissive tristimulus value is $Y_3$=1,8 and the reflective value is $Y_{ref}$=3,6, then the physical mixture of both leads to the tristimulus value $Y$=4,5. This value is calculated with the formula $Y_4 = 18\,(Y_3 + Y_{ref})/21{,}6$ for the normalization $Y_U$=18.

**Ergonomic equally spaced colour output with free application software for still images and video**

**Application program**

**Modify the relative Gamma $\gamma_{rel}$ for the equally spaced display or print output**


at least relative Gamma values 0,5 <= $\gamma_{rel}$ <= 2,0 with $\Delta\gamma_{rel}$ = 0,1
shall be available compared to the absolute Gamma value
$\gamma_a$ = 2,4 according to IEC 61966-2-1 (sRGB colour space)

Application programs for *macOS 10.15* or later, see a free test version: https://www.lemkesoft.com
For whole display output, see: https://www.lemkesoft.info/files/gammaadjuster/gammaadjuster.dmg
For still images in many files formates, see: https://www.lemkesoft.info/files/graphicconverter/gc12.dmg
For application programs on *Windows* see the paper: http://color.li.tu-berlin.de/RUSCHIN22.PDF

**Produce an ergonomic equally spaced output with the software $\gamma_{rel}$. Use for example 1080 colours with 9 step colour series according to ISO CEN DIN 9241–306/ed–2:2018**

Standard ISO page of ISO 9241-306 with links to the languages English, French, and German
https://standards.iso.org/iso/9241/306/ed-2/index.html

Recommendation, use:
*Adobe Reader* for the links.
Some web browsers change capital to small letters and output is then not possible.

1 or 3 ISO pages, gP = 1,000 without or with output questions
https://standards.iso.org/iso/9241/306/ed-2/AE49/AE49L1NP.PDF
https://standards.iso.org/iso/9241/306/ed-2/AE49/AE49L0NP.PDF

8 or 24 ISO pages, 0,475 <= gP <= 1,000 without or with output questions
https://standards.iso.org/iso/9241/306/ed-2/AE49/AE49F0P0.PDF
https://standards.iso.org/iso/9241/306/ed-2/AE49/AE49F0PX.PDF

8 or 24 ISO pages, 1,000 <= gp <= 2,105 without or with output questions
https://standards.iso.org/iso/9241/306/ed-2/AE49/AE49F0N0.PDF
https://standards.iso.org/iso/9241/306/ed-2/AE49/AE49F0NX.PDF

**For similar ISO-test charts of ISO/IEC 15775/ed-2:2022 with 5, 9, and 16 step colour series, see**
https://standards.iso.org/iso-iec/15775/ed-2/en/

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**Fig. 5 Gamma-change software for the output on the whole display or still-image files.**

ISO 9241-306 includes test charts for 16 relative gamma values between about 0,5 and 2,0 on 16 different pages. The output of the 16 pages with the 16 gamma values are all included in Fig. 1. Usually only one of the 16 outputs produces the ergonomic equally spaced output. The software *gammaadjuster* allows to change between 16 or only one gamma value.

If the equal spacing of the output of Fig. 1 is approximately fulfilled for one of 16 gammas on an SDR or HDR device, then the Gamma software of Fig. 5 can fulfill the intention of [1] for an approximately equally spaced output on both the SDR or the HDR device. This intended output according to [1] is possible for both the whole display output, for example with the *gammaadjuster*, and for the image file output, for example with the *graphicconverter.* Similar software tools are available for the operating system *Windows*.

Application tests may show, if the methods of ISO 9241-306 with the example software tools in Fig. 5 are usefull for both the *Global Colour Management* (many HDR to SDR transfers) and the *Local Colour Management* (many local SDR to work-place transfers).

Application tests may show, if the combined conversion of HDR material for viewing at SDR workstation, and with different ambient reflections is possible by only one gamma change. Fig. 6 to Fig. 8 shows the contrast-range transfer $C$=25:1 to $C$=13:1, $C$=25:1 to $C$=2:1, and $C$=225:1 to $C$=2:1 on SDR devices.

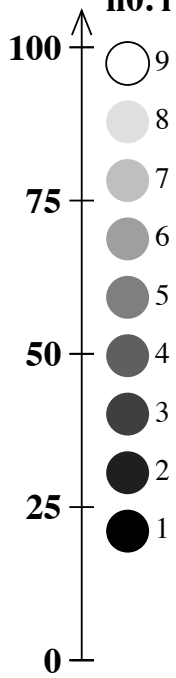
**Equal 9 step grey scaling between $L^*_{0aN}$=22.3 and $L^*_{0aW}$=95.9, $Y_{0ref}$=3.6, normalisation grey $U$**

$L^*_{0aN}$=22.3, $L^*_{0aU}$=59.1, $L^*_{0aW}$=96.0, $Y_{0aN}$=3.6, $Y_{0aU}$=27.2, $Y_{0aW}$=90.0, $C_{0aY}$=$Y_{0aW}$:$Y_{0aN}$=25.0

$L^*_{taN}$=30.3, $L^*_{taU}$=59.1, $L^*_{taW}$=92.9, $Y_{taN}$=6.3, $Y_{taU}$=27.2, $Y_{taW}$=82.6, $C_{taY}$=$Y_{taW}$:$Y_{taN}$=13.0

**Regularity index according to ISO/IEC 15775:2022, annex G for 5 and 9 steps**

**$g^*$ = 100 [$\Delta L^*_{min}$] / [$\Delta L^*_{max}$], $L^*_{CIELAB}$ = 116 [$Y/Y_n$]$^{1/3}$ – 16 with $Y$ >= 0,882, $Y_n$=100**




| | $g^*_5$= 99, $g^*_9$= 99 intended output | | | | $g^*_5$= 77, $g^*_9$= 71 real output | | | | | $g^*_5$= 98, $g^*_9$= 97 linearized output | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| n0. i | L*0a | L*0r | Y0a | Y0r | L*ta | ΔL*ta | L*tr | Yta | (L*tr)$^{1/1.12}$ | L*la | ΔL*la |
| 9 | 96.0 | 1.0 | 90.0 | 1.0 | 92.9 | | 1.0 | 82.6 | 1.0 | 92.9 | |
| | | | | | | 8.6 | | | | | 7.7 |
| 8 | 86.8 | 0.875 | 69.6 | 0.763 | 84.3 | | 0.863 | 64.6 | 0.876 | 85.1 | |
| | | | | | | 8.5 | | | | | 7.8 |
| 7 | 77.6 | 0.75 | 52.5 | 0.566 | 75.8 | | 0.727 | 49.5 | 0.751 | 77.3 | |
| | | | | | | 8.4 | | | | | 7.8 |
| 6 | 68.4 | 0.625 | 38.5 | 0.403 | 67.4 | | 0.593 | 37.1 | 0.626 | 69.5 | |
| | | | | | | 8.2 | | | | | 7.9 |
| 5 | 59.1 | 0.5 | 27.2 | 0.273 | 59.1 | | 0.461 | 27.2 | 0.5 | 61.6 | |
| | | | | | | 8.0 | | | | | 7.9 |
| 4 | 49.9 | 0.375 | 18.4 | 0.171 | 51.1 | | 0.333 | 19.4 | 0.374 | 53.7 | |
| | | | | | | 7.6 | | | | | 7.8 |
| 3 | 40.7 | 0.25 | 11.7 | 0.094 | 43.5 | | 0.211 | 13.5 | 0.248 | 45.8 | |
| | | | | | | 7.0 | | | | | 7.7 |
| 2 | 31.5 | 0.125 | 6.9 | 0.038 | 36.5 | | 0.098 | 9.2 | 0.125 | 38.1 | |
| | | | | | | 6.1 | | | | | 7.8 |
| 1 | 22.3 | 0.0 | 3.6 | 0.0 | 30.3 | | 0.0 | 6.3 | 0.0 | 30.3 | |

**$\Delta L^*_{0a}$=9.2** **(i=1,2,...,8)**

**normalisation: $Y_{taiU}=Y_{0aU}\frac{Y_{0ai}+Y_{0ref}}{Y_{0aU}+Y_{0ref}}$**

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**Fig. 6 *Change* of display colours from the contrast range $C_Y$= $Y_{0aW}$:$Y_{0aN}$=25:1 to the range $C_Y$=13:1**

**Equal 9 step grey scaling between $L^*_{0aN}$=22.3 and $L^*_{0aW}$=95.9, $Y_{0ref}$=90.0, normalisation grey $U$**

$L^*_{0aN}$=22.3, $L^*_{0aU}$=59.1, $L^*_{0aW}$=96.0, $Y_{0aN}$=3.6, $Y_{0aU}$=27.2, $Y_{0aW}$=90.0, $C_{0aY}$=$Y_{0aW}$:$Y_{0aN}$=25.0

$L^*_{taN}$=53.7, $L^*_{taU}$=59.1, $L^*_{taW}$=70.7, $Y_{taN}$=21.7, $Y_{taU}$=27.2, $Y_{taW}$=41.8, $C_{taY}$=$Y_{taW}$:$Y_{taN}$=1.9

**Regularity index according to ISO/IEC 15775:2022, annex G for 5 and 9 steps**

**$g^*$ = 100 [$\Delta L^*_{min}$] / [$\Delta L^*_{max}$], $L^*_{CIELAB}$ = 116 [$Y/Y_n$]$^{1/3}$ – 16 with $Y$ >= 0,882, $Y_n$=100**

| $L^*_{CIELAB}$ | | $g^*_5$= 99, $g^*_9$= 99 intended output | | | | $g^*_5$= 30, $g^*_9$= 23 real output | | | | | $g^*_5$= 88, $g^*_9$= 74 linearized output | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | n0. i | L*0a | L*0r | Y0a | Y0r | L*ta | ΔL*ta | L*tr | Yta | (L*tr)$^{1/1.6}$ | L*la | ΔL*la |
| 100 | 9 | 96.0 | 1.0 | 90.0 | 1.0 | 70.7 | | 1.0 | 41.8 | 1.0 | 70.7 | |
| | | | | | | | 3.4 | | | | | 2.2 |
| | 8 | 86.8 | 0.875 | 69.6 | 0.763 | 67.3 | | 0.799 | 37.0 | 0.869 | 68.5 | |
| | | | | | | | 3.1 | | | | | 2.2 |
| 75 | 7 | 77.6 | 0.75 | 52.5 | 0.566 | 64.2 | | 0.617 | 33.1 | 0.74 | 66.3 | |
| | | | | | | | 2.7 | | | | | 2.1 |
| | 6 | 68.4 | 0.625 | 38.5 | 0.403 | 61.5 | | 0.457 | 29.8 | 0.613 | 64.1 | |
| | | | | | | | 2.3 | | | | | 2.1 |
| | 5 | 59.1 | 0.5 | 27.2 | 0.273 | 59.1 | | 0.319 | 27.2 | 0.491 | 62.1 | |
| | | | | | | | 1.9 | | | | | 2.0 |
| 50 | 4 | 49.9 | 0.375 | 18.4 | 0.171 | 57.2 | | 0.205 | 25.1 | 0.372 | 60.0 | |
| | | | | | | | 1.5 | | | | | 1.9 |
| | 3 | 40.7 | 0.25 | 11.7 | 0.094 | 55.7 | | 0.115 | 23.6 | 0.259 | 58.1 | |
| | | | | | | | 1.1 | | | | | 1.9 |
| | 2 | 31.5 | 0.125 | 6.9 | 0.038 | 54.5 | | 0.047 | 22.5 | 0.149 | 56.3 | |
| 25 | | | | | | | 0.8 | | | | | 2.5 |
| | 1 | 22.3 | 0.0 | 3.6 | 0.0 | 53.7 | | 0.0 | 21.7 | 0.0 | 53.7 | |
| 0 | | | | | | | | | | | | |

**$\Delta L^*_{0a}$=9.2** **(i=1,2,...,8)**

**normalisation: $Y_{taiU}=Y_{0aU}\frac{Y_{0ai}+Y_{0ref}}{Y_{0aU}+Y_{0ref}}$**

eek11–7n

**Fig. 7 *Change* of display colours from the contrast range $C_Y$= $Y_{0aW}$:$Y_{0aN}$=25:1 to the range $C_Y$=2:1**

**Equal 9 step grey scaling between $L^*_{0aN}$=3.6 and $L^*_{0aW}$=95.9, $Y_{0ref}$=90.0, normalisation grey $U$**

$L^*_{0aN}$=3.6, $L^*_{0aU}$=49.8, $L^*_{0aW}$=96.0, $Y_{0aN}$=0.4, $Y_{0aU}$=18.2, $Y_{0aW}$=90.0, $C_{0aY}$=$Y_{0aW}$:$Y_{0aN}$=225.0

$L^*_{taN}$=46.0, $L^*_{taU}$=49.8, $L^*_{taW}$=62.0, $Y_{taN}$=15.2, $Y_{taU}$=18.2, $Y_{taW}$=30.3, $C_{taY}$=$Y_{taW}$:$Y_{taN}$=2.0

**Regularity index according to ISO/IEC 15775:2022, annex G for 5 and 9 steps**

**$g^*$ = 100 [$\Delta L^*_{min}$] / [$\Delta L^*_{max}$], $L^*_{CIELAB}$ = 116 [$Y/Y_n$]$^{1/3}$ – 16 with $Y$ >= 0,882, $Y_n$=100**

| $L^*_{CIELAB}$ | | $g^*_5$= 99, $g^*_9$= 99 intended output | | | | $g^*_5$= 14, $g^*_9$= 9 real output | | | | | $g^*_5$= 92, $g^*_9$= 71 linearized output | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | n0. i | L*0a | L*0r | Y0a | Y0r | L*ta | ΔL*ta | L*tr | Yta | (L*tr)$^{1/2.0}$ | L*la | ΔL*la |
| 100 | 9 | 96.0 | 1.0 | 90.0 | 1.0 | 62.0 | | 1.0 | 30.3 | 1.0 | 62.0 | |
| | | | | | | | 3.8 | | | | | 2.0 |
| | 8 | 84.4 | 0.875 | 64.9 | 0.72 | 58.2 | | 0.762 | 26.1 | 0.873 | 59.9 | |
| | | | | | | | 3.3 | | | | | 2.0 |
| 75 | 7 | 72.9 | 0.75 | 45.0 | 0.498 | 54.8 | | 0.554 | 22.8 | 0.745 | 57.9 | |
| | | | | | | | 2.8 | | | | | 2.0 |
| | 6 | 61.3 | 0.625 | 29.6 | 0.326 | 52.0 | | 0.379 | 20.2 | 0.616 | 55.8 | |
| | | | | | | | 2.2 | | | | | 2.0 |
| 50 | 5 | 49.8 | 0.5 | 18.2 | 0.199 | 49.8 | | 0.24 | 18.2 | 0.49 | 53.8 | |
| | | | | | | | 1.7 | | | | | 1.9 |
| | 4 | 38.2 | 0.375 | 10.2 | 0.11 | 48.1 | | 0.136 | 16.9 | 0.369 | 51.9 | |
| | | | | | | | 1.1 | | | | | 1.8 |
| 25 | 3 | 26.7 | 0.25 | 5.0 | 0.051 | 47.0 | | 0.064 | 16.0 | 0.254 | 50.0 | |
| | | | | | | | 0.7 | | | | | 1.7 |
| | 2 | 15.2 | 0.125 | 1.9 | 0.017 | 46.3 | | 0.022 | 15.5 | 0.148 | 48.3 | |
| | | | | | | | 0.3 | | | | | 2.4 |
| 0 | 1 | 3.6 | 0.0 | 0.4 | 0.0 | 46.0 | | 0.0 | 15.2 | 0.0 | 46.0 | |

**$\Delta L^*_{0a}$=11.5 (i=1,2,...,8)**

**normalisation: $Y_{taiU}$=$Y_{0aU}$ $\frac{Y_{0ai}+Y_{0ref}}{Y_{0aU}+Y_{0ref}}$**

eeq31–7n

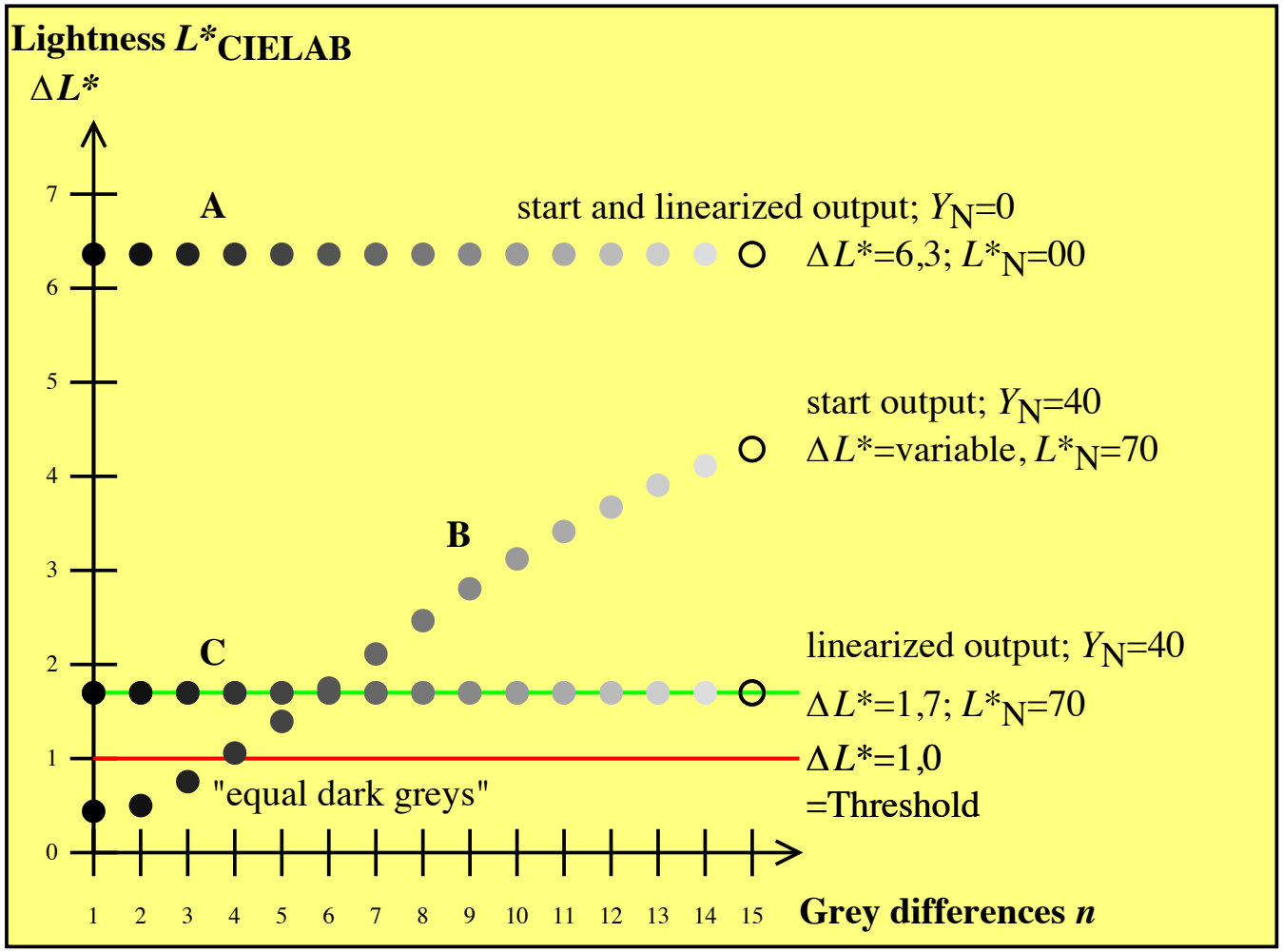
**Fig. 8 *Change* of display colours from contrast range $C_Y$=$Y_{0aW}$:$Y_{0aN}$=225:1 to the range 2:1**

The Fig. 6 to 8 show grey scales, their changes with the reflection of the ambient light on the display, and the appropriate changes by a gamma correction.
For example Fig. 8 shows the equally spaced lightness between $L^*_{0aN}$=3,6 and $L^*_{0aW}$=96 with constant $\Delta L^*_{0a}$=11,5 The tristimulus values vary between $Y_{0aN}$=0,4 and $Y_{0aW}$ =90. The reflection $Y_{ref}$=90 is assumed. For a 9step grey scale which is equally spaced in $L^*_{CIELAB}$ the original values $L^*_{0a}$ are changed to the test values $L^*_{ta}$. Instead of equal original differences $\Delta L^*_{0a}$ now unequal test differences $\Delta L^*_{ta}$ are calculated. The dark steps have a small difference $\Delta L^*_{ta}$=0,3 compared to the light steps with $\Delta L^*_{ta}$=3,8. However, by a gamma change of the relative lightness values $L^*_{tr}$ with the formula $(L^*_{tr})^{1/1,2}$ the approximately equal lightness differences near $\Delta L^*_{la}$=2,0 are produced.

ISO/IEC 15775, Annex G, defines a regularity index $g^*$ which specifies the quality of equal spacing of a 5step or 9 step grey scale. With the four lightness differences it is calculated

$$g^* = 100\ (\Delta L^*_{min} / \Delta L^*_{max})$$

If one difference is cero, then the index is $g^*$=0. If all differences are equal ($\Delta L^*_{min}=\Delta L^*_{max}$), then the index is $g^*$ =100. The output quality in the range 90 <= $g^*$ <=100 may be called *very good* and in the range 80 <= $g^*$ <90 *good*. The red lightness values have non visible differences smaller compared to the threshold $\Delta L^*_{ta}$=1. A similar example is shown in the next figure for a 16step grey scale.




DEQ71-3N

**Fig. 9 Change of the display colours from contrast range $C_Y=Y_{0aW}:Y_{0aN}$ >225:1 to the range $C_Y$=2:1**

In Fig 9 the luminance of a projector on the screen, and the luminance of the daylight on the screen are equal. Then the contrast is $L_W : L_N = 2 :1$. In this worse case three grey steps are not distinguishable, see B. Output linearization produces the equal steps, see C.

**Application for output on HDR and SDR displays**

IEC 61966-2-1 (sRGB colour space) defines the standard Gamma value $\gamma = 2{,}4$. For local colour management with reflections of the ambient light, a gamma value $\gamma < 2{,}4$ is necessary, see Fig. 5 und 6 for two different ambient reflections. For colour management of HDR displays a Gamma value larger $\gamma = 2{,}4$ seems appropriate.

ISO/TS 22028-5:2023 [3] with the title *Photography and graphic technology - Extended colour encodings for digital image storage, manipulation and interchange - Part 5: High dynamic range and wide colour gamut encoding for still images (HDR/WCG)* includes more information about HDR displays and their luminance range.

One problem for many applications is the following statement in an informative Annex E of [3]: *E.4.1 Display-viewing colorimetry - Display viewing colorimetry images are intended to produce pleasing images on an HDR display*, I could not find a definition for the intention *to produce pleasing images on an HDR display.* Until clarification it is difficult to evaluate the application of HDR devices and software for the display applications in offices according to [1]. In the following Fig. 8 the clear intention of [1] to produce equal spacing on any display (SDR or HDR if used in offices) for the ISO-test charts according [1] is the basis. The question of the *pleasing* output will be discussed further with Fig. 12.

| Properties of the visual system and use cases for the copier and display output | | | | |
|---|---|---|---|---|
| According to ISO 9241-306:2018 the luminance of the white (W) display and the white office paper shall be equal to avoid fatique and incease well-being of users. The illuminance 500 lux of ISO 8995-1 is equal to the luminance $L_W$=142 cd/m$^2$. **Table: Ergonomy, energy consumption and sustainability of output** | | | | |
| **Standard document and device output** | **ISO/IEC 15775 /ed-2:2022 copier** | **ISO 9241-306 /ed-2:2018 display** | **ISO 22028-5 HDR range display** | **ISOWD 21496 HDR<–>SDR display** |
| **tone mapping visual (vis.) & colourimetric** | ergonomic equal spacing vis. & metric | ergonomic equal spacing vis. & metric | pleasing output?, definition? | pleasing output?, definition? |
| **ergonomic output quality 0 <= g* <=100** | high quality vis. spacing & regularity g* | high quality vis. spacing & regularity g* | low quality, no reflection considered | low quality?, no reflection considered? |
| **optimized energy consumption** | yes, 500 lux ISO 8995-1 or 142 cd/m^2 | yes, 500 lux ISO 8995-1 or 142 cd/m^2 | no, up to 3300 lux or 1000 cd/m^2 | no, up to 3300 lux or 1000 cd/m^2? |
| **optimized sustainable software SSW** | yes, SSW is for >3 use cases (papers) | yes, SSW is for >15 cases of reflections | no, SW is only for us case HDR output | no, SW inten-ded for HDR or SDR output |
| *Display reflection is NOT considered, this is called "stone age image technology".* | | | | |

eej01–6n

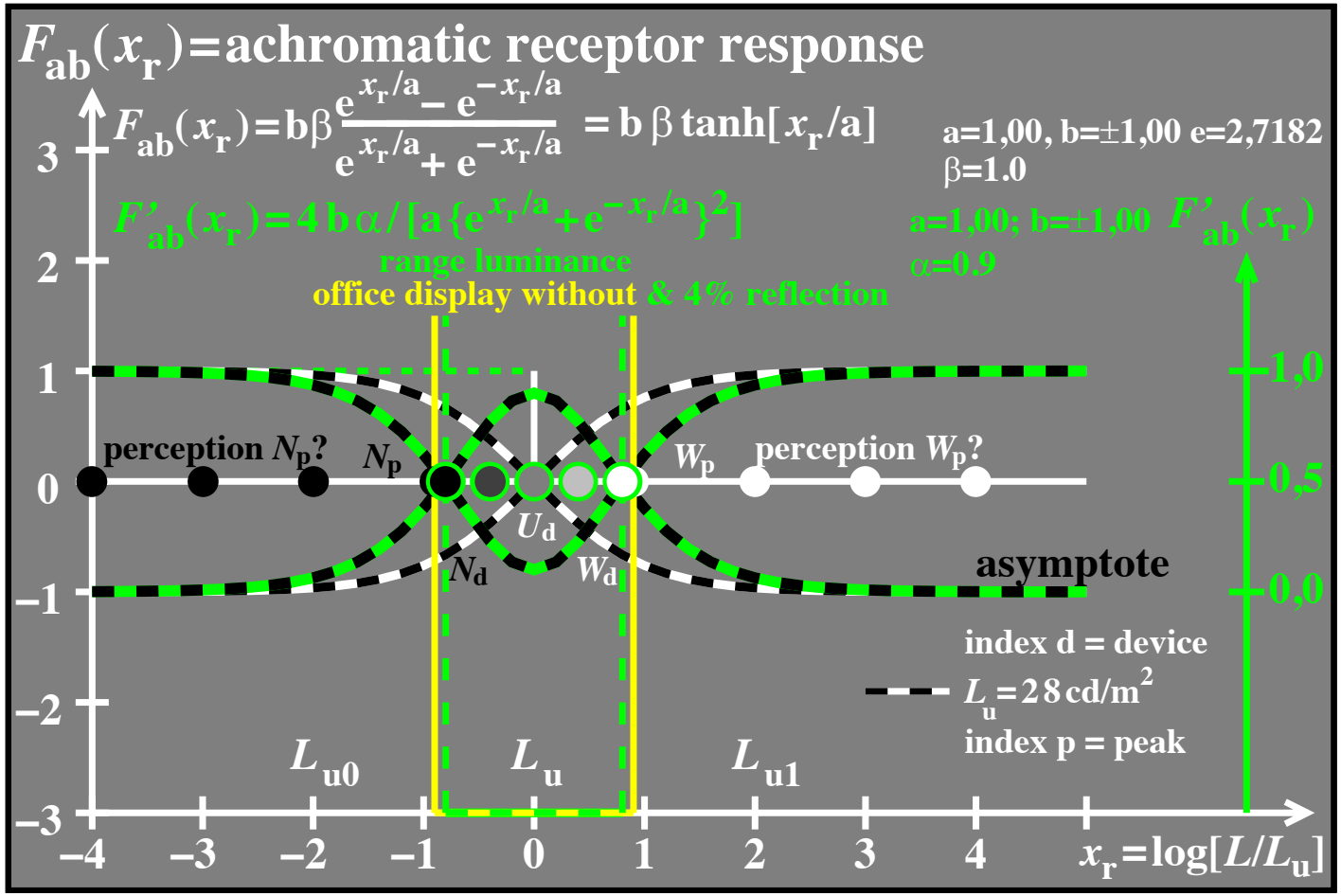
**Fig. 10: Standards for copier, and SDR & HDR display output, and display viewing requirements**

ISO/TS 22028-5 [3] defines a nominal diffuse white luminance $L_{WD}$ = 203 cd/m$^2$ and a peak white luminance $L_{WP}$ = 1000 cd/m$^2$ = 5 $L_{WD.}$ The luminance of the surround shall be $L_{NS}$ = 5 cd/m$^2$ and the luminance of the periphery $L_{NP}$ <= 5 cd/m$^2$. The **reference viewing environment** according to ISO/TS 22028-5 is therefore a **cinema condition** with a black surrounding. The luminance ratio between white W and black N is $L_W$ : $L_N$ = 203 : 5 = 40 : 1. This luminance ratio is larger compared to standard surface colours according to [1] or [2]. All are near the visual window, see Fig. 12.

The **reference viewing environment** according to ISO 9241-306 is an **ergonomic office condition** (see the green part in Fig. 10). According to ISO 8995-1 *Indoor illuminant,* the recommended office illuminance of 500 lux produces a luminance of $L_{WP}$ = 142 cd/m$^2$ on the white standard paper (P). The white display (D) shall have the same luminance $L_{WD}$ = 142 cd/m$^2$. Grey U has the luminance $L_{UD}$ = 28 cd/m$^2$, and the Black N has the luminance $L_{ND}$ = 5,7 cd/m$^2$.

ISO/TS 22028-5:2023 intended a **pleasing** display output in the informative Annex E 4.1. There is no definition and a list of adjustments in this ISO. Therefore it seems not possible to evaluate the output quality. The term “low quality” may be appropriate in the red part of Fig. 10 because both the visual and colorimetric output quality of the test charts according to ISO/IEC 15775 and ISO 9241-306 may be low.

In the main part a default peak white $L_{WP}$ = 1000 cd/m$^2$ = 5 $L_{WD}$ is defined. For the default black point the minimum luminance of the default reference display shall be 0,0005 cd/m$^2$. This is by a factor 10000 smaller compared to the diffuse Black $L_{ND}$=5 cd/m$^2$. The tech specification of the HDR device *iPod 203 (2023)* includes the display surface reflection 1,8%. In the ergonomic condition then the luminance ratio is $L_{WP}$ : $L_{NP}$ = 90 : 1,8 = 50 : 1 with $L_N$=3,6 cd/m$^2$. Therefore there are many reasons, why the HDR display output seems not usefull for ergonomic office work stations.




eeg01–4n

**Fig. 11 Vision window of the visual luminance ratio $L_W$ : $L_N$ = 36:1 and a device luminance ratio $L_W$ : $L_N$ = 50:1.**

*Valeton and van Norren (1973)* have measured the achromatic receptor response in the retina of monkeys. The responses as function of the test luminance $L$ and the surround luminance $L_U$. are shwn in Fig. 11. The increasing black and white curve is a reponse which is approximated by the function tanh. This function is S-shaped and the derivation is *Gauß*-shaped. Within the visual system there are often two antagonistic responses which are shown in Fig. 11.

Fig. 11 shows five colours between black and white *(in circles)*, which are defined by the derivations of two antagonistic response curves. Both define a visual window *(in yellow)* for the luminance ratio $\boldsymbol{L_W : L_N = 50 : 1}$**.** If 3,6% of the luminance of white (90%) is reflected on the display, then the device luminance ratio is reduced to $L_W : L_N = 25 : 1$. This is the matte surface color range (dashed green lines).

According to the TUB model both the black and the white perception is reached at the two borders of the visual window. For the grey adaptation luminance $L_U = 28$ cd/m$^2$ the limits of this window are dependent on the presentation time and are calculated here for a presentation time near 0,4s for the test luminance $L$. If for example the adaptation luminance is reduced by a factor 100 to 0,28 cd/m$^2$ then also the visual window shifts by a factor 100**.** The luminance ratio $L_W : L_N = 50 : 1$ is constant for these two adaptations. This is similar for a shift by a factor 100 towards 2800 cd/m$^2$.

In Germany we have discussed an actual visual case. An birch tree has a white and black surface. If during sunshine there is s shadow of another three on the viewed birch tree, then the luminance may reduce by a factor 100 in the shadow area. Then the surface of the birch tree appears completely black N in the shadow area. In the case of the birch tree still luminance differences appear in the software *Adobe Photoshop*. Changes of the image data allow to make the not visible differences in the shadow area visible. Changes of this kind may be a basis for a *pleasant output* which is used but not defined in [3].

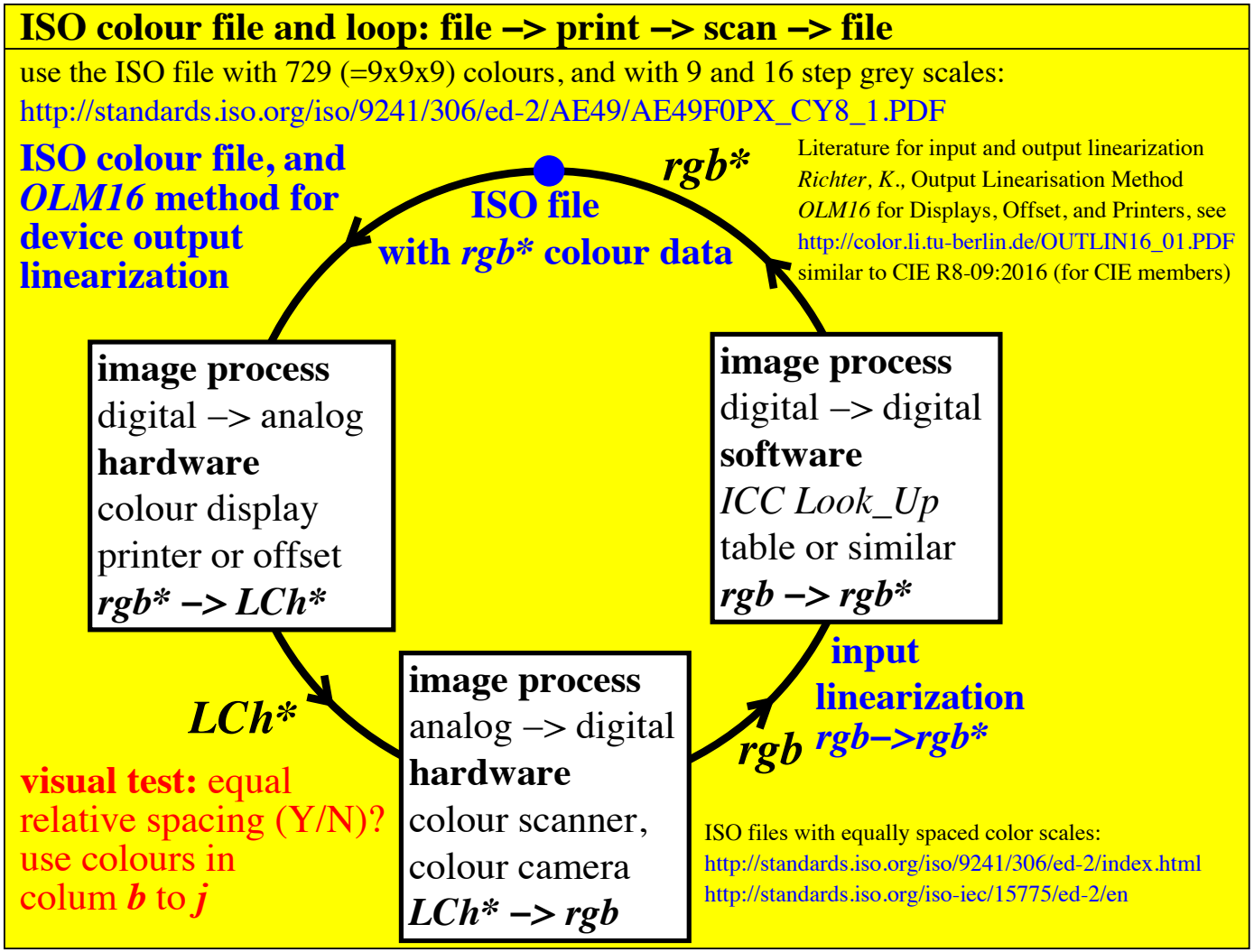



**Fig. 12 Colour circle with image capture by a camera and SDR or HDR display output**

There are digital and analog test charts according to ISO 9241-306 [1] and ISO/IEC 15775 [2]. The analog test charts are equally spaced in CIELAB for the equally spaced *rgb** values in the ISO-files. For example the output linearization of Fig. 12 has produced 16 CIELAB lightness values between $L^*_N$=20 and $L^*_W$=95 with $\Delta L^*$=5 for the equally spaced *rgb** values between $rgb^*_N$=0 and $rgb^*_W$=1 with $\Delta rgb^*$=1/15=0,067. There are tables with the *rgb** and CIELAB-*Lab** values for any of the 1080 test-chart samples.

For the 1080 colour samples of the test chart according to [1] any camera produces different *rgb* values. For example the *software Adobe Photoshop* made all *rgb* values visible. Then input linearization transfers the 1080 *rgb* values to the 1080 *rgb** values which are approximately equal to the 1080 *rgb** values of the test-chart according to [1].

The *rgb* values are different for any film or digital camera. For film or digital cameras within the exposure range between 2 stops under exposure and 4 stops over exposure there is after input linearization no visual difference of the final image. Therefore in Fig. 12 the output and input linearization produce approximately equal *rgb** data in the final image file. For visual examples see http://farbe.li.tu-berlin.de/AECS.HTM, and for a paper, see *Richter* (2018) [8].

The TUB model [9] limits the luminance ratio of the visual system to a visual window of less than two log luminance units (luminance ratio $L_W : L_N = 100 : 1$). This is valid for samples of the *luminance L*, *a constant adaptation luminance* $L_U$ in the range 0,28 cd/m$^2$ < $L_U$ < 2800 cd/m$^2$, and a *viewing time* 0,4s. With any input device (camera or scanner) any recording of the test chart according to [1] produces the *rgb* values within this visual window, and allows to produce the *rgb**-image data.

**Conclusions:**
The ISO-test chart AE49 according to ISO 9241-306 [1] includes 1080 colours with 16 gamma values on 16 pages. The TUB-test chart of Fig. 1 includes the 16 gamma values of [1] on one page. The output quality is evaluated visually by Yes/No questions and specified by colourimetry with the regularity index *g** according to ISO/IEC 15775 [2].

If the output of the TUB-test chart reaches the ergonomic intention of [1] for one of the 16 gamma values, then

1. the available software of Fig. 5 can change the whole display output on the display work places, and/or the display output of a still-image file.

2. on HDR displays the two output steps *Global Colour Management* (GCM) and *Local Colour Management* (LCM) may reduce to one step for many user applications.

3. in the cases 1 and 2 the display output is ergonomic, optimized for energy consumption, and sustainable according to the reasons given in Fig. 9.

*The antagonistic TUB-relativity model of colour vision for chromatic and luminance adaptation* [9] may be considered to optimize the capture and reproduction of luminance and colour on visual displays. This may lead to improvements of ISO/TS 22028-5:2023 [3]. On www.iso.org two similar ISO projects ISO/AWI 22028-5 [4] and ISO/WD 21496-1 [5] are listed.

***Literature***

[1] ISO 9241-306:2019*,* Ergonomics of human-system interaction - Part 306: Field assessment methods for electronic visual displays, see for download of the test charts with user question for an ergonomic output on displays, see for download of test charts AE49: https://standards.iso.org/iso/9241/306/ed-2/index.html

[2] ISO/IEC 15775/ed-2:2022, Information Technology – Office Equipment –Method of Specifying image reproduction on colour copying machines and multifunctional devices with copying modes by printed test charts, see for download of test charts with user questions *for sustainable copiers.* The test charts of [1] and [2] are similar, see https://standards.iso.org/iso-iec/15775/ed-2/en

[3] ISO/TS 22028-5:2023 Photography and graphic technology - Extended colour encodings for digital image storage, manipulation and interchange - Part 5: High dynamic range and wide colour gamut encoding for still images (HDR/WCG)

[4] ISO/AWI 22028-5:2023 Photography and graphic technology - Extended colour encodings for digital image storage, manipulation and interchange - Part 5: High dynamic range and wide colour gamut encoding for still images (HDR/WCG), (Under development according to www.iso.org).

[5] ISO/WD 21496-1:2023 Digital Photography — Gain map metadata for image conversion - Part 1: Dynamic Range Conversion (Under development according to www.iso.org).

[6] IEC 61966-2-1, Multimedia systems and equipment - Colour measurement and management - Part 2-1: Colour management – Default RGB colour space - sRGB.

[7] ISO 8995-1:2002 Lighting at work place – Part 1: Indoor, (Under development according to www.iso.org).

[8] *Richter, Klaus (2019),* Colorimetric scan, display, and print for archiving based on the ergonomic International Standard ISO 9241-306:2018 at work places **,** *Proc. IS&T Archiving 2019*, pp 111-112, see for free pdf download
https://doi.org/10.2352/issn.2168-3204.2019.1.0.25

[9] *Richter, Klaus (2023)*, Deductive and inductive antagonistic TUB colourimetry to improve the CIE colourimetry for wide ranges of luminance and chromatic adaptation, see
http://farbe.li.tu-berlin.de/dfwg23e.pdf
*Remark:* Since 2019 the antagonistic TUB-relativity model of colour vision is under development. For more information see for example
http://farbe.li.tu-berlin.de/eea_s.htm,
or see different papers since 2020 at the link
http://farbe.li.tu-berlin.de/XY91FEN.html