Frame File Colour Management (FF_CM) for the ergonomic Display Output of SDR and HDR-*rgb** images on SDR and HDR displays

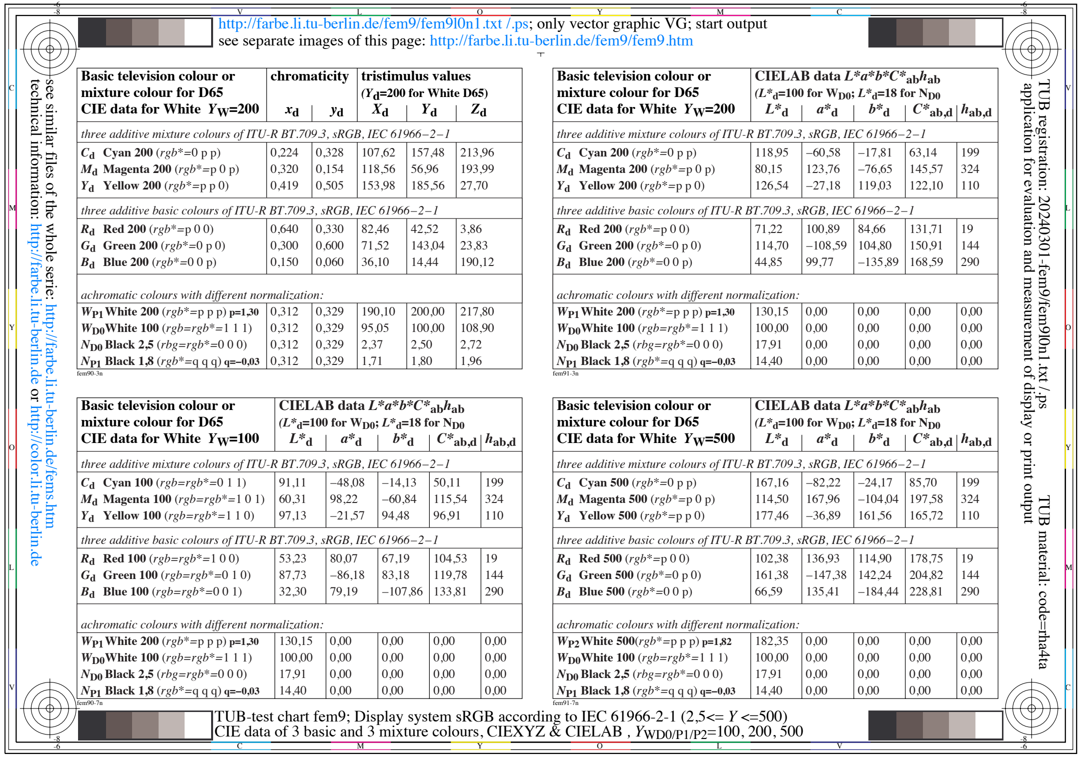
Prof. Dr. Klaus Richter, Berlin University of Technology, section Lighting Technology, 2024-04-01

1. Introduction

New displays of the High Dynamic Range (HDR) lead to new possibilities for the output of images compared to the Standard Dynamic Range (SDR). The ergonomic output according to ISO 9241-306 [1] and ISO/IEC 15775 [2] for SDR images, and the output of images of the High Dynamic Range (HDR) is described and discussed. Two white circles of +1 and +2 stops over exposure are combined to a new image based on two images with colour samples and the flower motif of [1]. In the pdf files the range 0 <= *rgb** <=1 for SDR displays is extended to cover the range of the HDR-display headroom.

The *relative* grey output for the standard luminance range $L_W : L_N$=36 : 1 of [1] and [2] shall be identical on paper and on displays for work places. In a use case the white paper may cover half of the display. At ergonomic work places the luminance of the white display is adjusted to the viewing luminance of the white paper to avoid fatigue of users. For the CIE-tristimulus values the range is 2,5 <= Y <= 90, the luminance range is 3,6 <= L <= 142 cd/m^2, and the CEILAB range is 18 <= L^* <= 95. The Luminance L=142 cd/m^2 is defined by the equation $L = R\ (I / \pi)$ cd/m^2 with the reflection R=0,9 and the illuminance I = 500 lux recommended for offices according to ISO 8895-1 [7].

2. CIEXYZ and CIELAB data for displays with white W_{D0}, W_{P1}, and W_{P2}



http://farbe.li.tu-berlin.de/fem9/fem9l0n1.txt /.ps; only vector graphic VG; start output
see separate images of this page: http://farbe.li.tu-berlin.de/fem9/fem9.htm

see similar files of the whole serie: http://farbe.li.tu-berlin.de/fems.htm
technical information: http://farbe.li.tu-berlin.de or http://color.li.tu-berlin.de

Basic television colour or mixture colour for D65 CIE data for White Y_W=200	chromaticity		tristimulus values (Y_d=200 for White D65)		
	x_d	y_d	X_d	Y_d	Z_d
three additive mixture colours of ITU-R BT.709.3, sRGB, IEC 61966–2–1					
C_d **Cyan 200** (rgb^*=0 p p)	0,224	0,328	107,62	157,48	213,96
M_d **Magenta 200** (rgb^*=p 0 p)	0,320	0,154	118,56	56,96	193,99
Y_d **Yellow 200** (rgb^*=p p 0)	0,419	0,505	153,98	185,56	27,70
three additive basic colours of ITU-R BT.709.3, sRGB, IEC 61966–2–1					
R_d **Red 200** (rgb^*=p 0 0)	0,640	0,330	82,46	42,52	3,86
G_d **Green 200** (rgb^*=0 p 0)	0,300	0,600	71,52	143,04	23,83
B_d **Blue 200** (rgb^*=0 0 p)	0,150	0,060	36,10	14,44	190,12
achromatic colours with different normalization:					
W_{P1} **White 200** (rgb^*=p p p) **p=1,30**	0,312	0,329	190,10	200,00	217,80
W_{D0} **White 100** (rgb=rgb^*=1 1 1)	0,312	0,329	95,05	100,00	108,90
N_{D0} **Black 2,5** (rbg=rgb^*=0 0 0)	0,312	0,329	2,37	2,50	2,72
N_{P1} **Black 1,8** (rgb^*=q q q) **q=–0,03**	0,312	0,329	1,71	1,80	1,96

fem90-3n

Basic television colour or mixture colour for D65 CIE data for White Y_W=200	CIELAB data $L^*a^*b^*C^*_{ab}h_{ab}$ (L^*_d=100 for W_{D0}; L^*_d=18 for N_{D0}				
	L^*_d	a^*_d	b^*_d	$C^*_{ab,d}$	$h_{ab,d}$
three additive mixture colours of ITU-R BT.709.3, sRGB, IEC 61966–2–1					
C_d **Cyan 200** (rgb^*=0 p p)	118,95	–60,58	–17,81	63,14	199
M_d **Magenta 200** (rgb^*=p 0 p)	80,15	123,76	–76,65	145,57	324
Y_d **Yellow 200** (rgb^*=p p 0)	126,54	–27,18	119,03	122,10	110
three additive basic colours of ITU-R BT.709.3, sRGB, IEC 61966–2–1					
R_d **Red 200** (rgb^*=p 0 0)	71,22	100,89	84,66	131,71	19
G_d **Green 200** (rgb^*=0 p 0)	114,70	–108,59	104,80	150,91	144
B_d **Blue 200** (rgb^*=0 0 p)	44,85	99,77	–135,89	168,59	290
achromatic colours with different normalization:					
W_{P1} **White 200** (rgb^*=p p p) **p=1,30**	130,15	0,00	0,00	0,00	0,00
W_{D0} **White 100** (rgb=rgb^*=1 1 1)	100,00	0,00	0,00	0,00	0,00
N_{D0} **Black 2,5** (rbg=rgb^*=0 0 0)	17,91	0,00	0,00	0,00	0,00
N_{P1} **Black 1,8** (rgb^*=q q q) **q=–0,03**	14,40	0,00	0,00	0,00	0,00

fem91-3n

Basic television colour or mixture colour for D65 CIE data for White Y_W=100	CIELAB data $L^*a^*b^*C^*_{ab}h_{ab}$ (L^*_d=100 for W_{D0}; L^*_d=18 for N_{D0}				
	L^*_d	a^*_d	b^*_d	$C^*_{ab,d}$	$h_{ab,d}$
three additive mixture colours of ITU-R BT.709.3, sRGB, IEC 61966–2–1					
C_d **Cyan 100** (rgb=rgb^*=0 1 1)	91,11	–48,08	–14,13	50,11	199
M_d **Magenta 100** (rgb=rgb^*=1 0 1)	60,31	98,22	–60,84	115,54	324
Y_d **Yellow 100** (rgb=rgb^*=1 1 0)	97,13	–21,57	94,48	96,91	110
three additive basic colours of ITU-R BT.709.3, sRGB, IEC 61966–2–1					
R_d **Red 100** (rgb=rgb^*=1 0 0)	53,23	80,07	67,19	104,53	19
G_d **Green 100** (rgb=rgb^*=0 1 0)	87,73	–86,18	83,18	119,78	144
B_d **Blue 100** (rgb=rgb^*=0 0 1)	32,30	79,19	–107,86	133,81	290
achromatic colours with different normalization:					
W_{P1} **White 200** (rgb^*=p p p) **p=1,30**	130,15	0,00	0,00	0,00	0,00
W_{D0} **White 100** (rgb=rgb^*=1 1 1)	100,00	0,00	0,00	0,00	0,00
N_{D0} **Black 2,5** (rbg=rgb^*=0 0 0)	17,91	0,00	0,00	0,00	0,00
N_{P1} **Black 1,8** (rgb^*=q q q) **q=–0,03**	14,40	0,00	0,00	0,00	0,00

fem90-7n

Basic television colour or mixture colour for D65 CIE data for White Y_W=500	CIELAB data $L^*a^*b^*C^*_{ab}h_{ab}$ (L^*_d=100 for W_{D0}; L^*_d=18 for N_{D0}				
	L^*_d	a^*_d	b^*_d	$C^*_{ab,d}$	$h_{ab,d}$
three additive mixture colours of ITU-R BT.709.3, sRGB, IEC 61966–2–1					
C_d **Cyan 500** (rgb^*=0 p p)	167,16	–82,22	–24,17	85,70	199
M_d **Magenta 500** (rgb^*=p 0 p)	114,50	167,96	–104,04	197,58	324
Y_d **Yellow 500** (rgb^*=p p 0)	177,46	–36,89	161,56	165,72	110
three additive basic colours of ITU-R BT.709.3, sRGB, IEC 61966–2–1					
R_d **Red 500** (rgb^*=p 0 0)	102,38	136,93	114,90	178,75	19
G_d **Green 500** (rgb^*=0 p 0)	161,38	–147,38	142,24	204,82	144
B_d **Blue 500** (rgb^*=0 0 p)	66,59	135,41	–184,44	228,81	290
achromatic colours with different normalization:					
W_{P2} **White 500**(rgb^*=p p p) **p=1,82**	182,35	0,00	0,00	0,00	0,00
W_{D0} **White 100** (rgb=rgb^*=1 1 1)	100,00	0,00	0,00	0,00	0,00
N_{D0} **Black 2,5** (rbg=rgb^*=0 0 0)	17,91	0,00	0,00	0,00	0,00
N_{P1} **Black 1,8** (rgb^*=q q q) **q=–0,03**	14,40	0,00	0,00	0,00	0,00

fem91-7n

TUB registration: 20240301-fem9/fem9l0n1.txt /.ps
application for evaluation and measurement of display or print output

TUB material: code=rha4ta

TUB-test chart fem9; Display system sRGB according to IEC 61966-2-1 (2,5<= Y <=500)
CIE data of 3 basic and 3 mixture colours, CIEXYZ & CIELAB , $Y_{WD0/P1/P2}$=100, 200, 500

Fig. 1: CIE-tristimulus values *Y* and CIELAB values for SDR and HDR displays.

ISO 22028-5 [3] defines for the luminance of white W three values which are called here Diffuse (W_{D0}), Peak (W_{P1}), and (W_{P2}). In Fig. 1 the tristimulus values Y are given together with a value for diffuse black (N_{d0}) according to [1] and [2], and a Peak black (N_{d1}). In Fig. 1 the luminance ratio $L_{P2} : L_{P1} : L_{D0}$ of [3] is identical to $Y_{P2} : Y_{P1} : Y_{D0} = 5 : 2 : 1$.

For other tables based on [1] and [2], and for the Y ratio 360 : 180 : 90 = 4 : 2 : 1, see http://farbe.li.tu-berlin.de/fem8/fem8l0np.pdf and Fig. 20 of this paper.

3. Definition and output of test charts with HDR-*rgb** values in three use cases

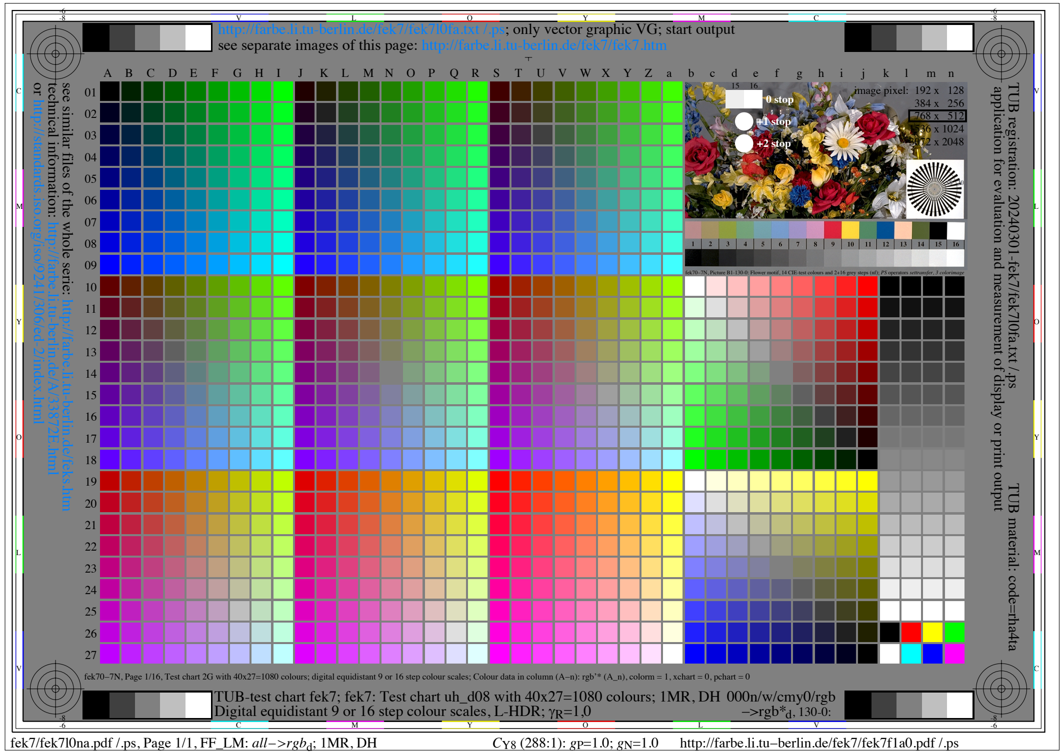
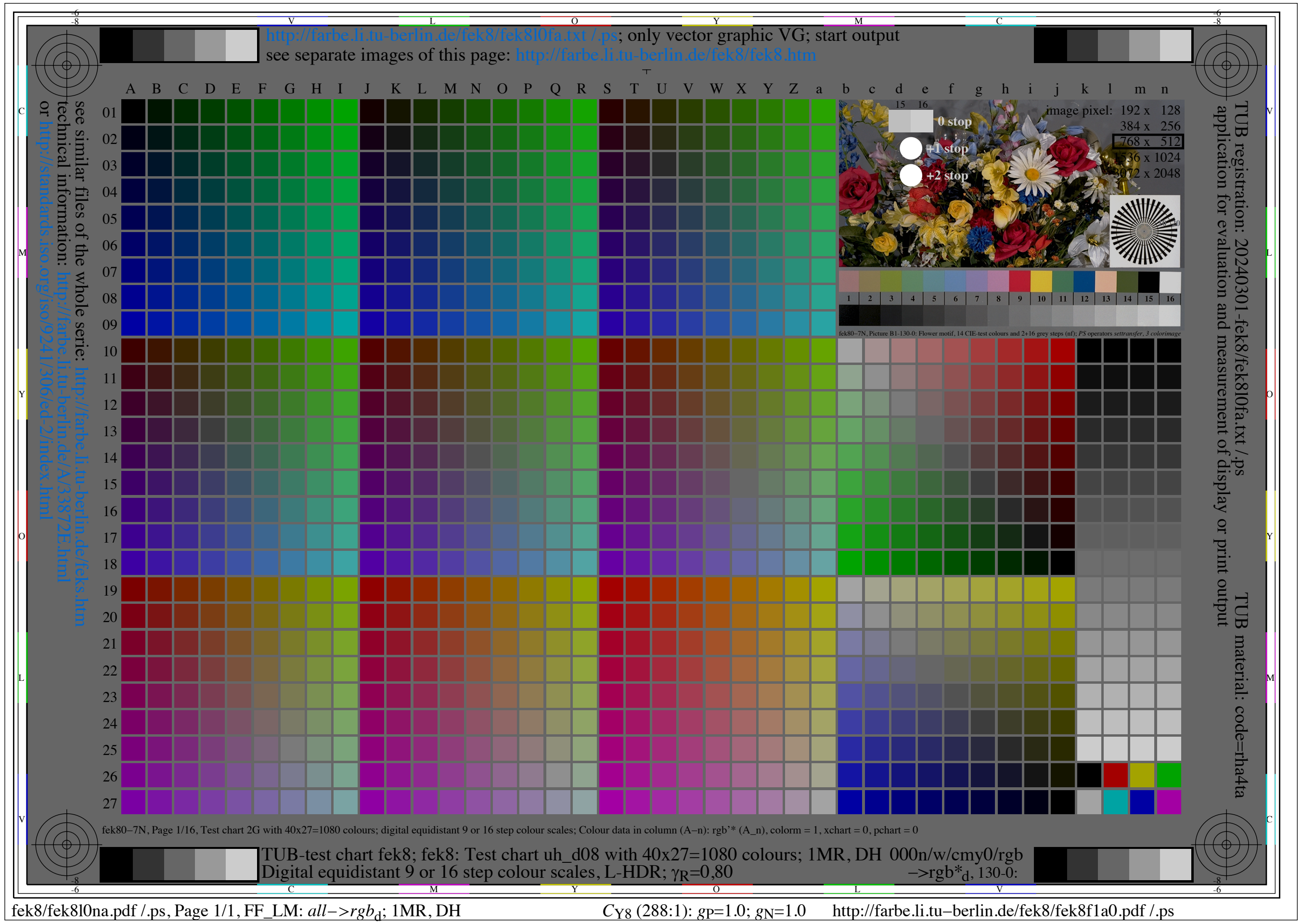


Fig. 2: Output of test chart with flower image of [1] on SDR display with white Y_{D0}.
In Fig. 2 the output of the three whites +2, +1, 0 (Y_{P2}, Y_{P1}, Y_{D0}) is equal. For W_{P1} und W_{P2} the values rgb^*_{P1}=1,25 and rgb^*_{P2}=1,56 are used according to L^*_{P1} = 125 and L^*_{P2} = 156. Both *rgb** values are larger 1 in the *eps* and *pdf* file. However, all values *rgb** >=1 are reduced to 1 be default according to the *eps* and *pdf*-programming languages. No HDR content appears in the output. The white circles are equal to the sample white no. 16 in the flower image with *rgb**=1. Therefore the usual SDR output is presented and viewed.



http://farbe.li.tu-berlin.de/fek8/fek8l0fa.txt /.ps; only vector graphic VG; start output
see separate images of this page: http://farbe.li.tu-berlin.de/fek8/fek8.htm

see similar files of the whole serie: http://farbe.li.tu-berlin.de/feks.htm
technical information: http://farbe.li.tu-berlin.de/A3872E.html
or http://standards.iso.org/iso/9241/306/ed-2/index.html

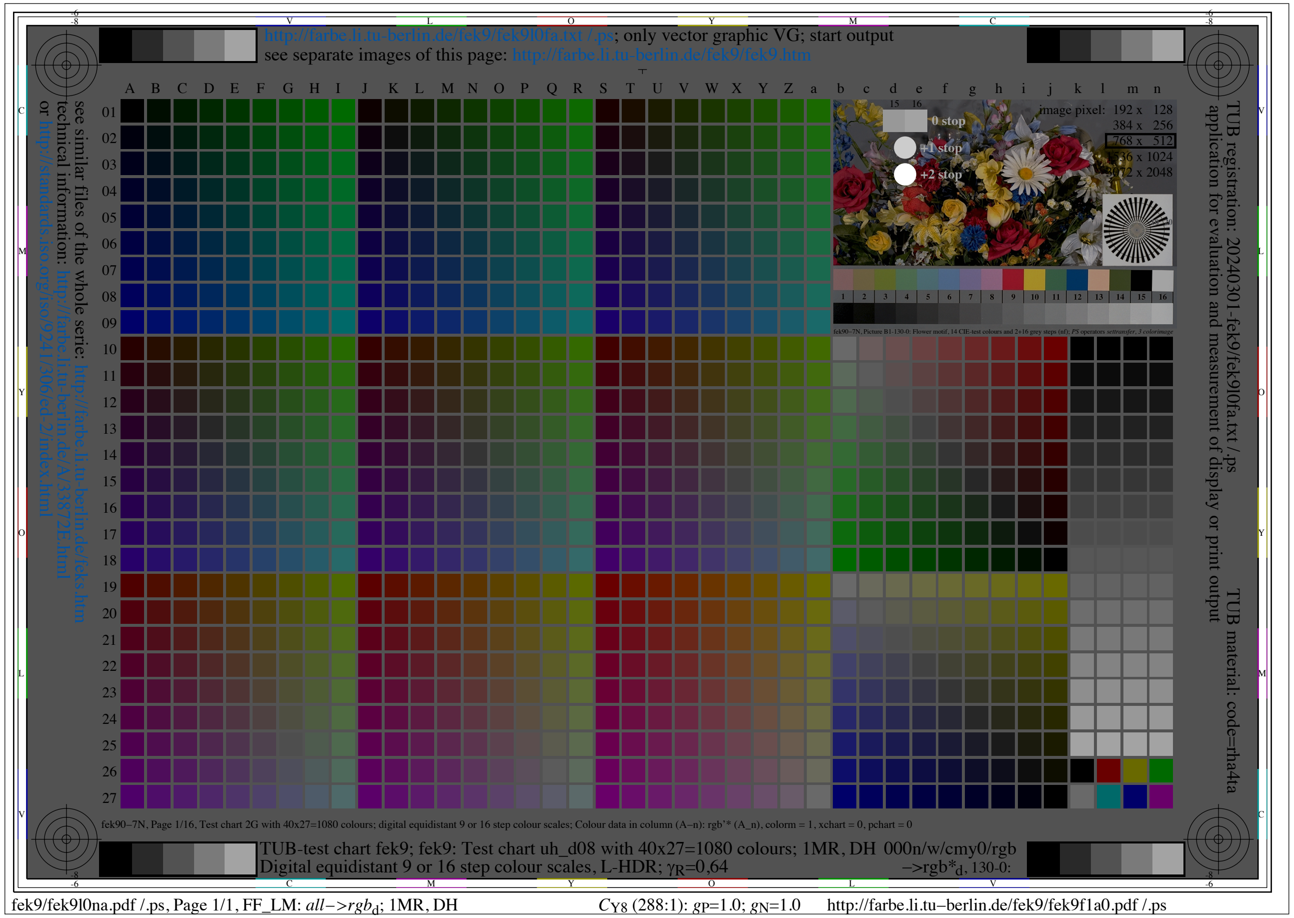
TUB registration: 20240301-fek8/fek8l0fa.txt /.ps
application for evaluation and measurement of display or print output
TUB material: code=rha4ta

fek80–7N, Page 1/16, Test chart 2G with 40x27=1080 colours; digital equidistant 9 or 16 step colour scales; Colour data in column (A–n): rgb'* (A_n), colorm = 1, xchart = 0, pchart = 0

TUB-test chart fek8; fek8: Test chart uh_d08 with 40x27=1080 colours; 1MR, DH 000n/w/cmy0/rgb
Digital equidistant 9 or 16 step colour scales, L-HDR; γ_R=0,80 –>rgb*$_d$, 130-0:

fek8/fek8l0na.pdf /.ps, Page 1/1, FF_LM: *all–>rgb*$_d$; 1MR, DH C_{Y8} (288:1): g_P=1.0; g_N=1.0 http://farbe.li.tu–berlin.de/fek8/fek8f1a0.pdf /.ps

Fig. 3: Output of test chart and flower image of [1] on SDR display with white Y_{D0}. The output of the two whites +2 (Y_{P2}), +1 (Y_{P1}) are equal and both are lighter compared to +0 (Y_{D0}). Compared to Fig. 1 the grey scale in the flower image, and the sample chart is darker. Fig. 2 is based on a reduction of all *rgb** values by a factor GammR= 0,80.



http://farbe.li.tu-berlin.de/fek9/fek9l0fa.txt /.ps; only vector graphic VG; start output
see separate images of this page: http://farbe.li.tu-berlin.de/fek9/fek9.htm

see similar files of the whole serie: http://farbe.li.tu-berlin.de/feks.htm
technical information: http://farbe.li.tu-berlin.de/A/3872E.html
or http://standards.iso.org/iso/9241/306/ed-2/index.html

TUB registration: 20240301-fek9/fek9l0fa.txt /.ps
application for evaluation and measurement of display or print output

TUB material: code=rha4ta

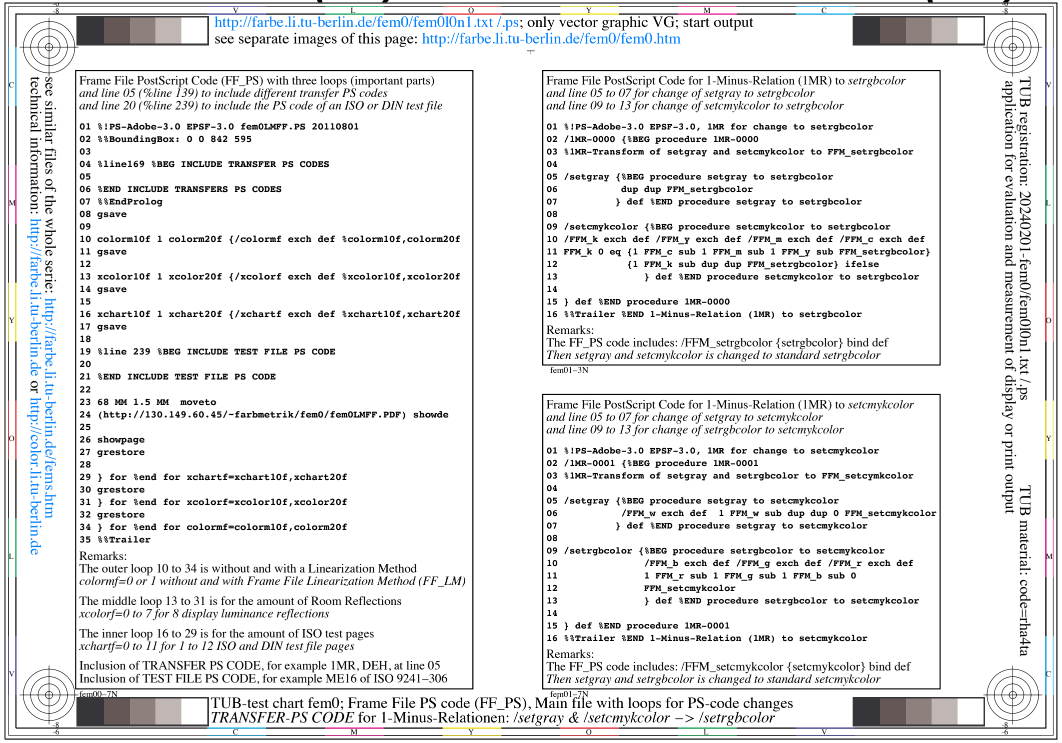
fek90–7N, Page 1/16, Test chart 2G with 40x27=1080 colours; digital equidistant 9 or 16 step colour scales; Colour data in column (A–n): rgb'* (A_n), colorm = 1, xchart = 0, pchart = 0

TUB-test chart fek9; fek9: Test chart uh_d08 with 40x27=1080 colours; 1MR, DH 000n/w/cmy0/rgb
Digital equidistant 9 or 16 step colour scales, L-HDR; γ_R=0,64 ->rgb*$_d$, 130-0:

fek9/fek9l0na.pdf /.ps, Page 1/1, FF_LM: *all->rgb*$_d$; 1MR, DH C_{Y8} (288:1): g_P=1.0; g_N=1.0 http://farbe.li.tu–berlin.de/fek9/fek9f1a0.pdf /.ps

Fig. 4: Output of test chart and flower image of [1] on SDR display with white Y_{D0}. The lightness of the three whites +2 (Y_{P2}), +1 (Y_{P1}) and +0 (Y_{D0}) decrease. Compared to Fig. 1 the grey scale in the flower image, and the sample chart is darker. Fig. 2 is based on a reduction of all *rgb** values by a factor GammR= 0,64. On HDR displays with white Y_{P2} the content 0 <= *rgb** >=1,56 is viewed. Data *rgb** <=1 look then similar to Fig. 2.

4. *Frame File (FF), Linearization Method (LM), and Colour Management (CM)*



http://farbe.li.tu-berlin.de/fem0/fem0l0n1.txt /.ps; only vector graphic VG; start output
see separate images of this page: http://farbe.li.tu-berlin.de/fem0/fem0.htm

see similar files of the whole serie: http://farbe.li.tu-berlin.de/fems.htm
technical information: http://farbe.li.tu-berlin.de or http://color.li.tu-berlin.de

Frame File PostScript Code (FF_PS) with three loops (important parts)
and line 05 (%line 139) to include different transfer PS codes
and line 20 (%line 239) to include the PS code of an ISO or DIN test file

```
01 %!PS-Adobe-3.0 EPSF-3.0 fem0LMFF.PS 20110801
02 %%BoundingBox: 0 0 842 595
03
04 %line169 %BEG INCLUDE TRANSFER PS CODES
05
06 %END INCLUDE TRANSFERS PS CODES
07 %%EndProlog
08 gsave
09
10 colorm10f 1 colorm20f {/colormf exch def %colorm10f,colorm20f
11 gsave
12
13 xcolor10f 1 xcolor20f {/xcolorf exch def %xcolor10f,xcolor20f
14 gsave
15
16 xchart10f 1 xchart20f {/xchartf exch def %xchart10f,xchart20f
17 gsave
18
19 %line 239 %BEG INCLUDE TEST FILE PS CODE
20
21 %END INCLUDE TEST FILE PS CODE
22
23 68 MM 1.5 MM  moveto
24 (http://130.149.60.45/~farbmetrik/fem0/fem0LMFF.PDF) showde
25
26 showpage
27 grestore
28
29 } for %end for xchartf=xchart10f,xchart20f
30 grestore
31 } for %end for xcolorf=xcolor10f,xcolor20f
32 grestore
34 } for %end for colormf=colorm10f,colorm20f
35 %%Trailer
```

Remarks:
The outer loop 10 to 34 is without and with a Linearization Method
colormf=0 or 1 without and with Frame File Linearization Method (FF_LM)

The middle loop 13 to 31 is for the amount of Room Reflections
xcolorf=0 to 7 for 8 display luminance reflections

The inner loop 16 to 29 is for the amount of ISO test pages
xchartf=0 to 11 for 1 to 12 ISO and DIN test file pages

Inclusion of TRANSFER PS CODE, for example 1MR, DEH, at line 05
Inclusion of TEST FILE PS CODE, for example ME16 of ISO 9241–306

fem00–7N

Frame File PostScript Code for 1-Minus-Relation (1MR) to *setrgbcolor*
and line 05 to 07 for change of setgray to setrgbcolor
and line 09 to 13 for change of setcmykcolor to setrgbcolor

```
01 %!PS-Adobe-3.0 EPSF-3.0, 1MR for change to setrgbcolor
02 /1MR-0000 {%BEG procedure 1MR-0000
03 %1MR-Transform of setgray and setcmykcolor to FFM_setrgbcolor
04
05 /setgray {%BEG procedure setgray to setrgbcolor
06           dup dup FFM_setrgbcolor
07          } def %END procedure setgray to setrgbcolor
08
09 /setcmykcolor {%BEG procedure setcmykcolor to setrgbcolor
10 /FFM_k exch def /FFM_y exch def /FFM_m exch def /FFM_c exch def
11 FFM_k 0 eq {1 FFM_c sub 1 FFM_m sub 1 FFM_y sub FFM_setrgbcolor}
12            {1 FFM_k sub dup dup FFM_setrgbcolor} ifelse
13               } def %END procedure setcmykcolor to setrgbcolor
14
15 } def %END procedure 1MR-0000
16 %%Trailer %END 1-Minus-Relation (1MR) to setrgbcolor
```

Remarks:
The FF_PS code includes: /FFM_setrgbcolor {setrgbcolor} bind def
Then setgray and setcmykcolor is changed to standard setrgbcolor

fem01–3N

Frame File PostScript Code for 1-Minus-Relation (1MR) to *setcmykcolor*
and line 05 to 07 for change of setgray to setcmykcolor
and line 09 to 13 for change of setrgbcolor to setcmykcolor

```
01 %!PS-Adobe-3.0 EPSF-3.0, 1MR for change to setcmykcolor
02 /1MR-0001 {%BEG procedure 1MR-0001
03 %1MR-Transform of setgray and setrgbcolor to FFM_setcymkcolor
04
05 /setgray {%BEG procedure setgray to setcmykcolor
06           /FFM_w exch def  1 FFM_w sub dup dup 0 FFM_setcmykcolor
07          } def %END procedure setgray to setcmykcolor
08
09 /setrgbcolor {%BEG procedure setrgbcolor to setcmykcolor
10               /FFM_b exch def /FFM_g exch def /FFM_r exch def
11               1 FFM_r sub 1 FFM_g sub 1 FFM_b sub 0
12               FFM_setcmykcolor
13               } def %END procedure setrgbcolor to setcmykcolor
14
15 } def %END procedure 1MR-0001
16 %%Trailer %END 1-Minus-Relation (1MR) to setcmykcolor
```

Remarks:
The FF_PS code includes: /FFM_setcmykcolor {setcmykcolor} bind def
Then setgray and setrgbcolor is changed to standard setcmykcolor

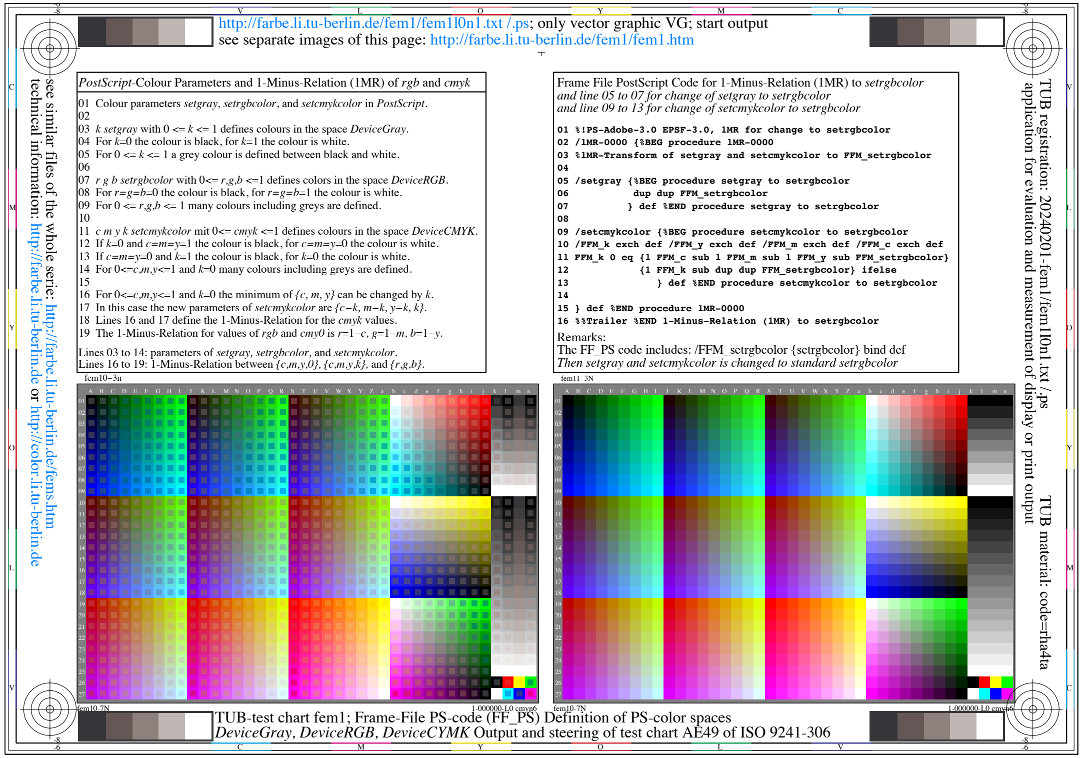
fem01–7N

TUB registration: 20240201-fem0/fem0l0n1.txt /.ps
application for evaluation and measurement of display or print output
TUB material: code=rha4ta

TUB-test chart fem0; Frame File PS code (FF_PS), Main file with loops for PS-code changes
TRANSFER-PS CODE for 1-Minus-Relationen: */setgray & /setcmykcolor –> /setrgbcolor*

Fig. 5: *PostScript (PS) Code* of a *Frame File* (left) and examples for output steering
The output of any EPS file can be steered by some EPS code in a Frame File (FF), see left part. The steering method is called a Linearization Method (LM) or a Colour Management Method (CM). A description of this method for the consumer and professional area is based on *PostScript.* This FF_CM is available in CIE R09 (2014, for CIE members only) or in a paper with a similar technical content of *Richter* (2013) [4].

The right part includes the PS code which is used to steer the PS values *setgray* and *setcmykcolor* towards *setrgbcolor.* An application example is shown in Fig. 6.



http://farbe.li.tu-berlin.de/fem1/fem1l0n1.txt /.ps; only vector graphic VG; start output
see separate images of this page: http://farbe.li.tu-berlin.de/fem1/fem1.htm

PostScript-Colour Parameters and 1-Minus-Relation (1MR) of *rgb* and *cmyk*

01 Colour parameters *setgray*, *setrgbcolor*, and *setcmykcolor* in *PostScript*.
02
03 *k setgray* with 0 <= *k* <= 1 defines colours in the space *DeviceGray*.
04 For *k*=0 the colour is black, for *k*=1 the colour is white.
05 For 0 <= *k* <= 1 a grey colour is defined between black and white.
06
07 *r g b setrgbcolor* with 0<= *r,g,b* <=1 defines colors in the space *DeviceRGB*.
08 For *r*=*g*=*b*=0 the colour is black, for *r*=*g*=*b*=1 the colour is white.
09 For 0 <= *r,g,b* <= 1 many colours including greys are defined.
10
11 *c m y k setcmykcolor* mit 0<= *cmyk* <=1 defines colours in the space *DeviceCMYK*.
12 If *k*=0 and *c*=*m*=*y*=1 the colour is black, for *c*=*m*=*y*=0 the colour is white.
13 If *c*=*m*=*y*=0 and *k*=1 the colour is black, for *k*=0 the colour is white.
14 For 0<=*c,m,y*<=1 and *k*=0 many colours including greys are defined.
15
16 For 0<=*c,m,y*<=1 and *k*=0 the minimum of *{c, m, y}* can be changed by *k*.
17 In this case the new parameters of *setcmykcolor* are *{c−k, m−k, y−k, k}*.
18 Lines 16 and 17 define the 1-Minus-Relation for the *cmyk* values.
19 The 1-Minus-Relation for values of *rgb* and *cmy0* is *r*=1−*c*, *g*=1−*m*, *b*=1−*y*.

Lines 03 to 14: parameters of *setgray*, *setrgbcolor*, and *setcmykcolor*.
Lines 16 to 19: 1-Minus-Relation between *{c,m,y,0}*, *{c,m,y,k}*, and *{r,g,b}*.

Frame File PostScript Code for 1-Minus-Relation (1MR) to *setrgbcolor*
and line 05 to 07 for change of setgray to setrgbcolor
and line 09 to 13 for change of setcmykcolor to setrgbcolor

```
01 %!PS-Adobe-3.0 EPSF-3.0, 1MR for change to setrgbcolor
02 /1MR-0000 {%BEG procedure 1MR-0000
03 %1MR-Transform of setgray and setcmykcolor to FFM_setrgbcolor
04
05 /setgray {%BEG procedure setgray to setrgbcolor
06          dup dup FFM_setrgbcolor
07         } def %END procedure setgray to setrgbcolor
08
09 /setcmykcolor {%BEG procedure setcmykcolor to setrgbcolor
10 /FFM_k exch def /FFM_y exch def /FFM_m exch def /FFM_c exch def
11 FFM_k 0 eq {1 FFM_c sub 1 FFM_m sub 1 FFM_y sub FFM_setrgbcolor}
12           {1 FFM_k sub dup dup FFM_setrgbcolor} ifelse
13              } def %END procedure setcmykcolor to setrgbcolor
14
15 } def %END procedure 1MR-0000
16 %%Trailer %END 1-Minus-Relation (1MR) to setrgbcolor
```

Remarks:
The FF_PS code includes: /FFM_setrgbcolor {setrgbcolor} bind def
Then setgray and setcmykcolor is changed to standard setrgbcolor

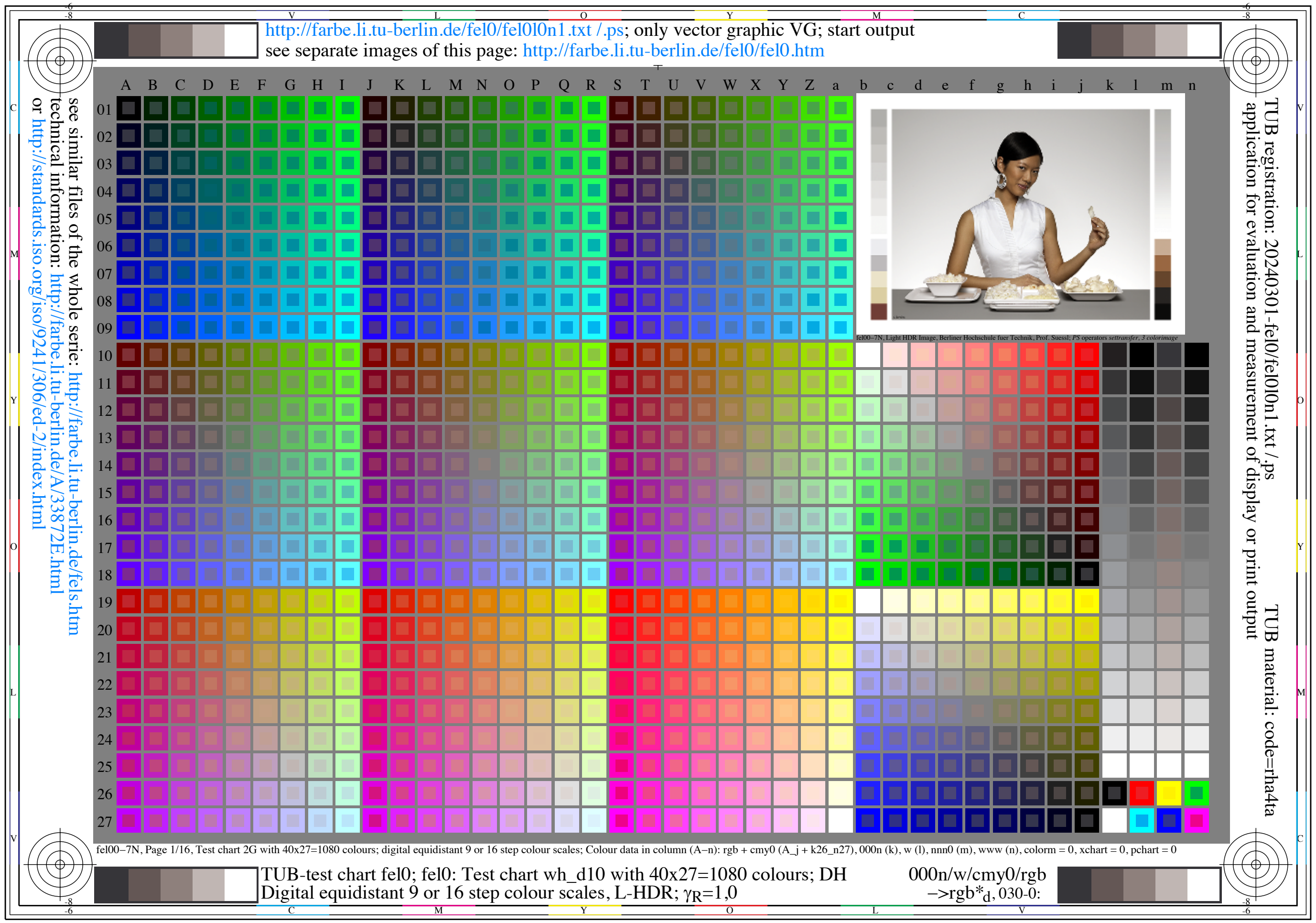
TUB-test chart fem1; Frame-File PS-code (FF_PS) Definition of PS-color spaces
DeviceGray, *DeviceRGB*, *DeviceCYMK* Output and steering of test chart AE49 of ISO 9241-306

see similar files of the whole serie: http://farbe.li.tu-berlin.de/fems.htm
technical information: http://farbe.li.tu-berlin.de or http://color.li.tu-berlin.de

TUB registration: 20240201-fem1/fem1l0n1.txt /.ps
application for evaluation and measurement of display or print output
TUB material: code=rha4ta

Fig. 6: Original *PS* code *w and *cmyk** which is steered towards the *rgb** code.** Different PS-operators *setrgbcolor, setgray* and *setcmykcolor* are used to describe the same colour. For example there are four possibilities to describe the same grey colour. The four PS operators (left) are all changed by a Frame-File to the *rgb** values. DIN 33872-1 to 6 [10] tests the output properties, see http://farbe.li.tu-berlin.de/A/33872E.html

4. Output of images of most formats with a possible HDR content (*rgb** >=1)



http://farbe.li.tu-berlin.de/fel0/fel0l0n1.txt /.ps; only vector graphic VG; start output
see separate images of this page: http://farbe.li.tu-berlin.de/fel0/fel0.htm

see similar files of the whole serie: http://farbe.li.tu-berlin.de/fels.htm
technical information: http://farbe.li.tu-berlin.de/A/3372E.html
or http://standards.iso.org/iso/9241/306/ed-2/index.html

TUB registration: 20240301-fel0/fel0l0n1.txt /.ps
application for evaluation and measurement of display or print output
TUB material: code=rha4ta

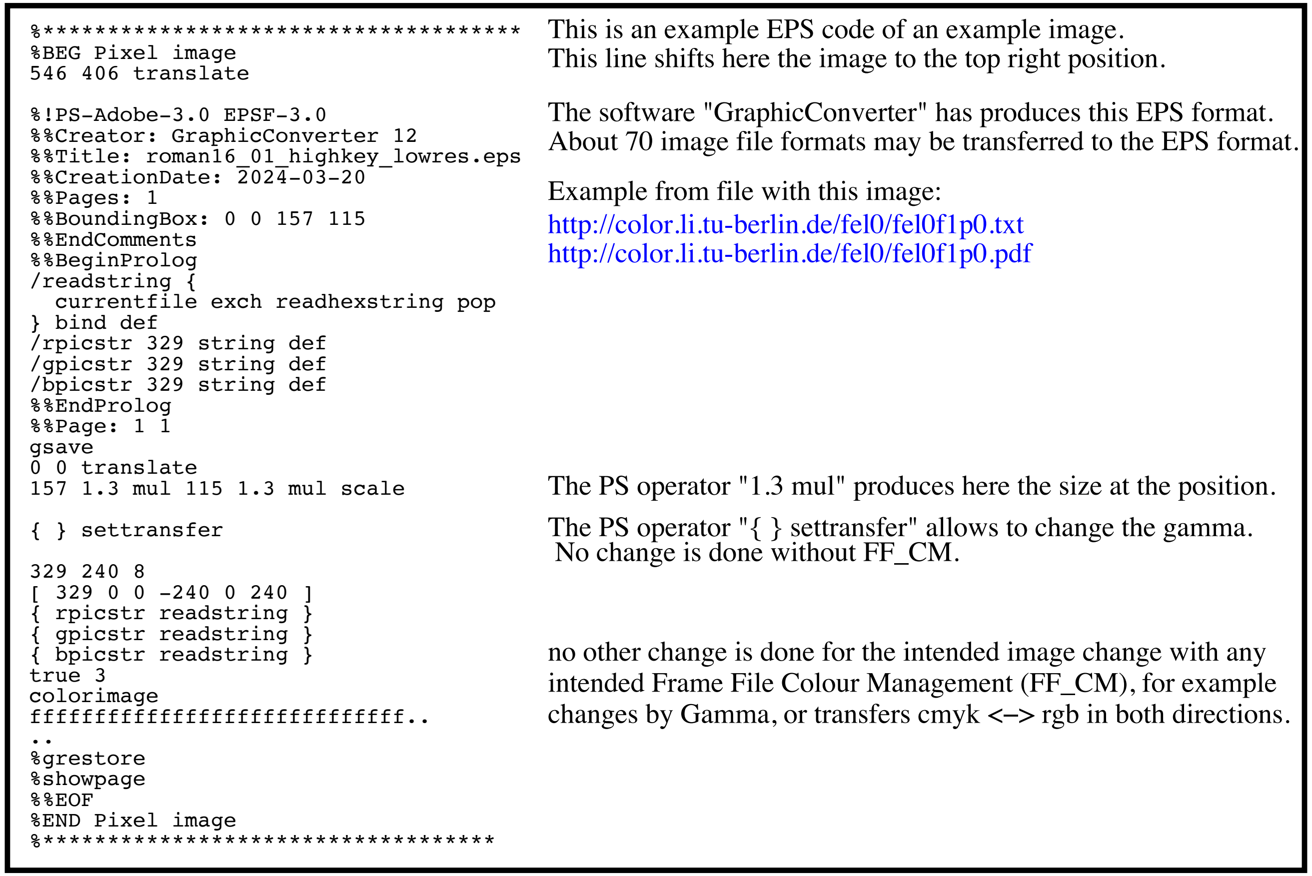
fel00–7N, Light HDR Image, Berliner Hochschule fuer Technik, Prof. Suessl; *PS* operators *settransfer, 3 colorimage*

fel00–7N, Page 1/16, Test chart 2G with 40x27=1080 colours; digital equidistant 9 or 16 step colour scales; Colour data in column (A–n): rgb + cmy0 (A_j + k26_n27), 000n (k), w (l), nnn0 (m), www (n), colorm = 0, xchart = 0, pchart = 0

TUB-test chart fel0; fel0: Test chart wh_d10 with 40x27=1080 colours; DH
Digital equidistant 9 or 16 step colour scales, L-HDR; γ_R=1,0

000n/w/cmy0/rgb
–>rgb*$_d$, 030-0:

Fig. 7: Output of an image with HDR content on a SDR display with white Y_{D0}.
Images come in many file formats. If the file format is changed to the eps format, then the Frame-File method can be used to steer the output. This is shown in the following.



```
%*************************************
%BEG Pixel image
546 406 translate

%!PS-Adobe-3.0 EPSF-3.0
%%Creator: GraphicConverter 12
%%Title: roman16_01_highkey_lowres.eps
%%CreationDate: 2024-03-20
%%Pages: 1
%%BoundingBox: 0 0 157 115
%%EndComments
%%BeginProlog
/readstring {
  currentfile exch readhexstring pop
} bind def
/rpicstr 329 string def
/gpicstr 329 string def
/bpicstr 329 string def
%%EndProlog
%%Page: 1 1
gsave
0 0 translate
157 1.3 mul 115 1.3 mul scale

{ } settransfer

329 240 8
[ 329 0 0 -240 0 240 ]
{ rpicstr readstring }
{ gpicstr readstring }
{ bpicstr readstring }
true 3
colorimage
ffffffffffffffffffffffffffff..
..
%grestore
%showpage
%%EOF
%END Pixel image
%***********************************
```

This is an example EPS code of an example image.
This line shifts here the image to the top right position.

The software "GraphicConverter" has produces this EPS format.
About 70 image file formats may be transferred to the EPS format.

Example from file with this image:
http://color.li.tu-berlin.de/fel0/fel0f1p0.txt
http://color.li.tu-berlin.de/fel0/fel0f1p0.pdf

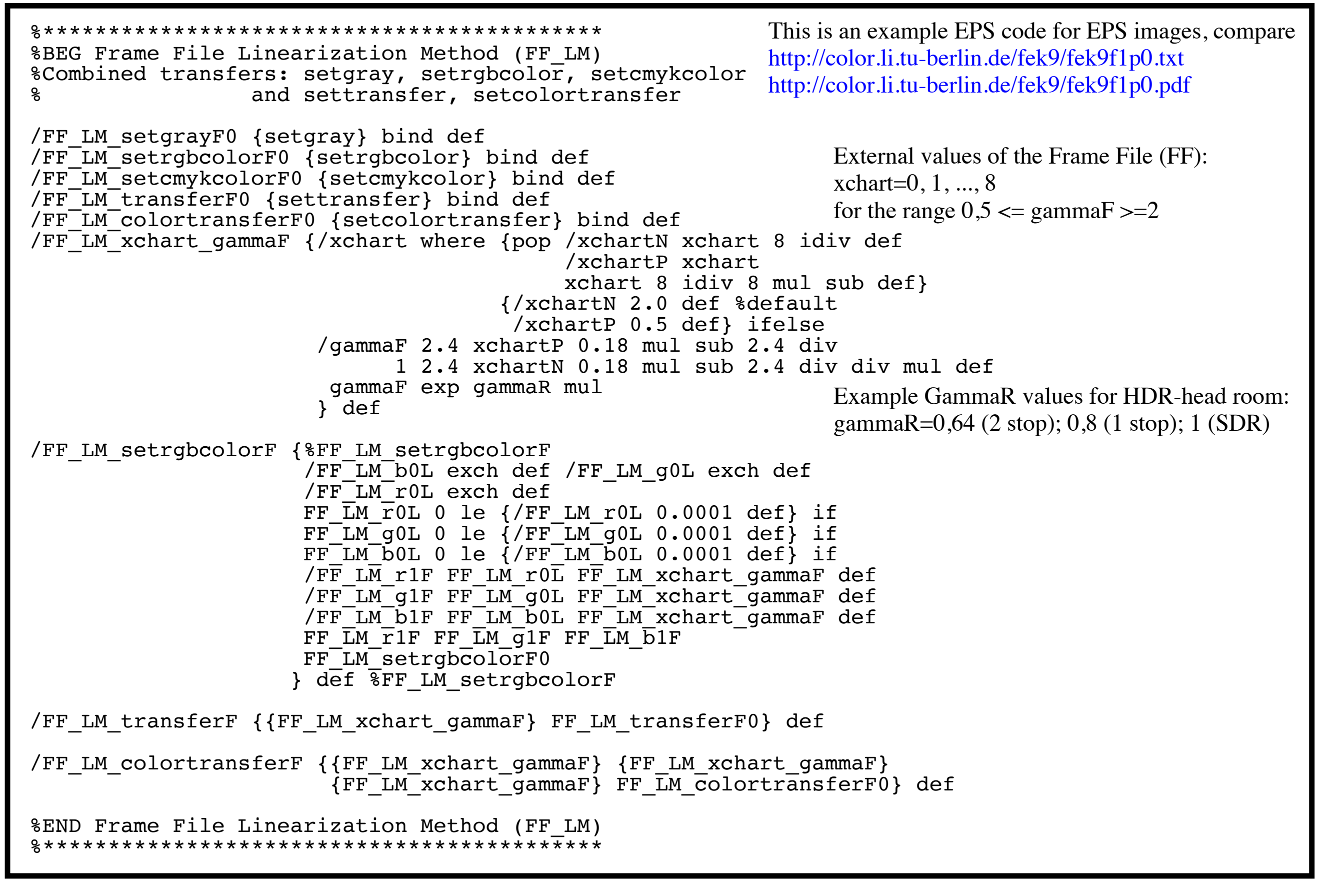
The PS operator "1.3 mul" produces here the size at the position.

The PS operator "{ } settransfer" allows to change the gamma.
No change is done without FF_CM.

no other change is done for the intended image change with any intended Frame File Colour Management (FF_CM), for example changes by Gamma, or transfers cmyk <–> rgb in both directions.

fek10–1n

Fig. 8: EPS format of the image in Fig. 7 on a SDR display with white Y_{D0}.
The file format of the image in Fig. 7 is changed to the EPS format by the example software *GraphicConverter*. This lady image is included instead of the flower image in Fig. 2. Important for the following is the inclusion of the PS operator *{ } settransfer*.



```
%*******************************************
%BEG Frame File Linearization Method (FF_LM)
%Combined transfers: setgray, setrgbcolor, setcmykcolor
%                and settransfer, setcolortransfer

/FF_LM_setgrayF0 {setgray} bind def
/FF_LM_setrgbcolorF0 {setrgbcolor} bind def
/FF_LM_setcmykcolorF0 {setcmykcolor} bind def
/FF_LM_transferF0 {settransfer} bind def
/FF_LM_colortransferF0 {setcolortransfer} bind def
/FF_LM_xchart_gammaF {/xchart where {pop /xchartN xchart 8 idiv def
                                         /xchartP xchart
                                         xchart 8 idiv 8 mul sub def}
                                    {/xchartN 2.0 def %default
                                     /xchartP 0.5 def} ifelse
                      /gammaF 2.4 xchartP 0.18 mul sub 2.4 div
                            1 2.4 xchartN 0.18 mul sub 2.4 div div mul def
                       gammaF exp gammaR mul
                      } def

/FF_LM_setrgbcolorF {%FF_LM_setrgbcolorF
                     /FF_LM_b0L exch def /FF_LM_g0L exch def
                     /FF_LM_r0L exch def
                     FF_LM_r0L 0 le {/FF_LM_r0L 0.0001 def} if
                     FF_LM_g0L 0 le {/FF_LM_g0L 0.0001 def} if
                     FF_LM_b0L 0 le {/FF_LM_b0L 0.0001 def} if
                     /FF_LM_r1F FF_LM_r0L FF_LM_xchart_gammaF def
                     /FF_LM_g1F FF_LM_g0L FF_LM_xchart_gammaF def
                     /FF_LM_b1F FF_LM_b0L FF_LM_xchart_gammaF def
                     FF_LM_r1F FF_LM_g1F FF_LM_b1F
                     FF_LM_setrgbcolorF0
                    } def %FF_LM_setrgbcolorF

/FF_LM_transferF {{FF_LM_xchart_gammaF} FF_LM_transferF0} def

/FF_LM_colortransferF {{FF_LM_xchart_gammaF} {FF_LM_xchart_gammaF}
                       {FF_LM_xchart_gammaF} FF_LM_colortransferF0} def

%END Frame File Linearization Method (FF_LM)
%*******************************************
```

This is an example EPS code for EPS images, compare
http://color.li.tu-berlin.de/fek9/fek9f1p0.txt
http://color.li.tu-berlin.de/fek9/fek9f1p0.pdf

External values of the Frame File (FF):
xchart=0, 1, ..., 8
for the range 0,5 <= gammaF >=2

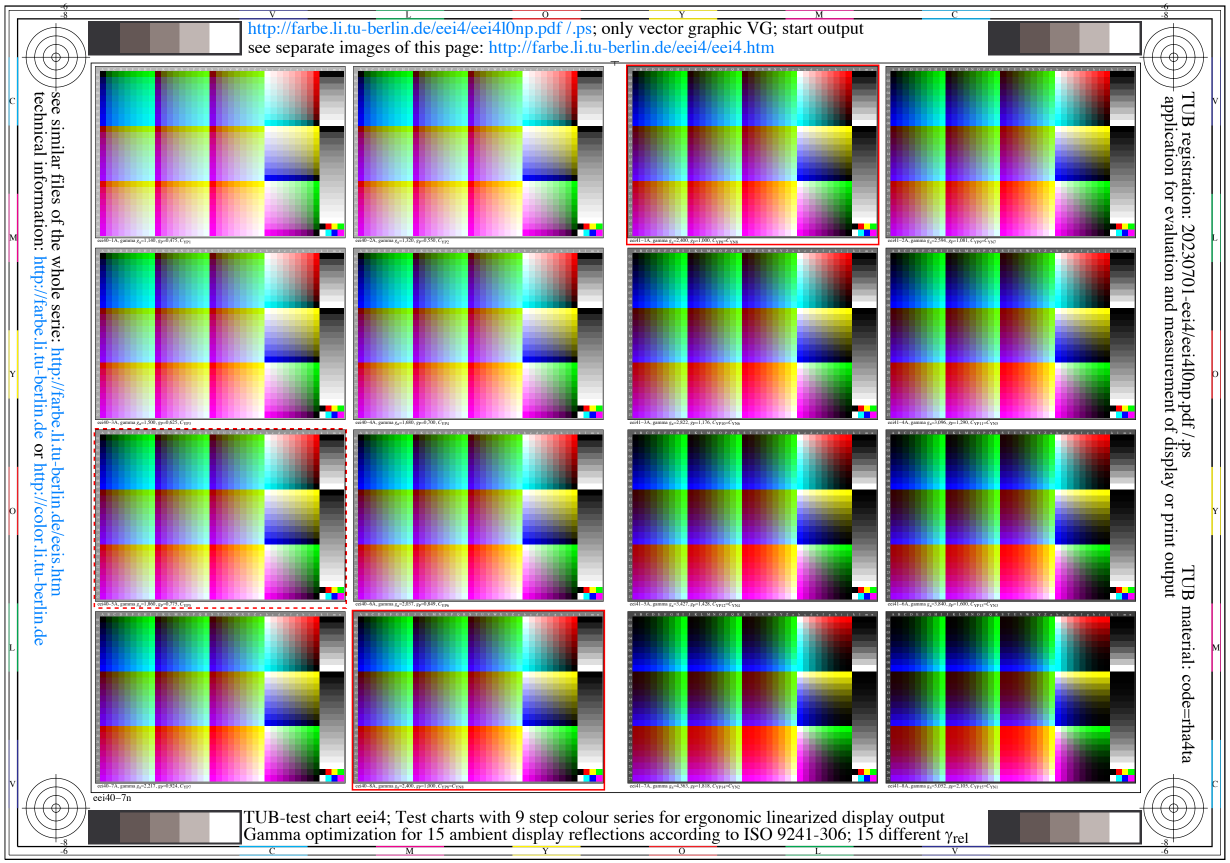
Example GammaR values for HDR-head room:
gammaR=0,64 (2 stop); 0,8 (1 stop); 1 (SDR)

fek10–7n

Fig. 9: Frame-File EPS-Code for a display output with different gamma values

The ergonomic display output at work stations requires a gamma change on any display, see [1]. The EPS code of Fig. 9 produces 16 gamma values for 0 <= xchart <= 15. A parameter GammaR, used in Fig. 2 to 4, can make the HDR content visible or not on any display. On SDR displays the content 0 <= *rgb** <=1 looks darker compared to HDR.

5. Output of a test chart for 16 different gamma values



http://farbe.li.tu-berlin.de/eei4/eei4l0np.pdf /.ps; only vector graphic VG; start output
see separate images of this page: http://farbe.li.tu-berlin.de/eei4/eei4.htm

see similar files of the whole serie: http://farbe.li.tu-berlin.de/eeis.htm
technical information: http://farbe.li.tu-berlin.de or http://color.li.tu-berlin.de

TUB registration: 20230701-eei4/eei4l0np.pdf /.ps
application for evaluation and measurement of display or print output
TUB material: code=rha4ta

eei40−7n

TUB-test chart eei4; Test charts with 9 step colour series for ergonomic linearized display output
Gamma optimization for 15 ambient display reflections according to ISO 9241-306; 15 different γ_{rel}

Fig. 10 Fifteen relative gamma values of a test chart AE49 similar to [1]

Usually only one of the 16 outputs is approximately equally spaced at the display-work place. In actual use cases users realize, that equal spacing is detroyed, if the ambient reflection changes (for example switch light on or off), or the age of the observer changes.

Therefore equal spacing in a cinema-viewing condition of [3] with approximately no ambient reflection is destroyed by any real ambient display reflection. The same effect happens for any user to a high degree by his stray light of his optical eye media. This stray light increases with the observer age. Usually a software company does not know the application-use case. Therefore only a local user can made appropriate image adjustments, for example by the ISO-test charts of [1].

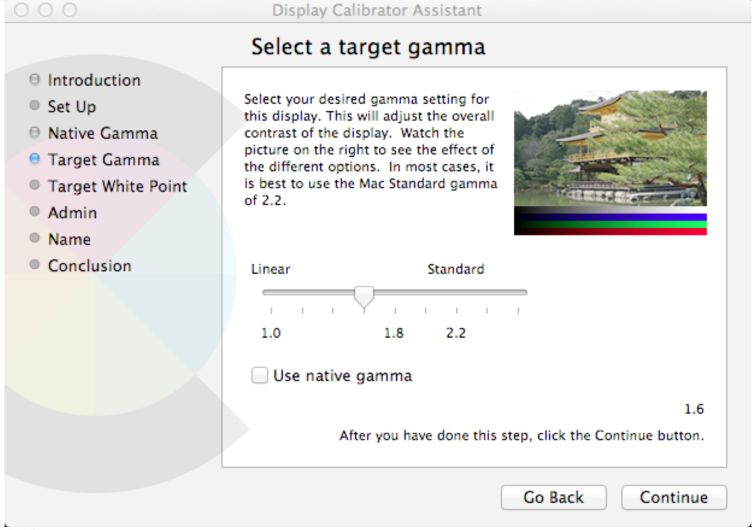
For the study of many effects of the ambient light *(switch it on or off)* the download of the test chart of Fig. 10 is recommend, see http://farbe.li.tu-berlin.de/eei4/eei4l0np.pdf

Fig. 10 simulates the visual display output with increasing reflections of the ambient light on the display from the down right to the top left.

The output of the 8 example images on the left side with relative gamma values 0,5 <= gammaP <= 1 are similar compared to the eight pages of the file output according to [1]. Links to the ISO-test chart with 1080 samples will be given in Fig. 12. The links to the test chart with the sample and flower image for eight reflections on 8 pages are:

http://farbe.li.tu-berlin.de/fek7/fek7f1p0.pdf
or within 24 pages which include the changes of the *rgb** values and gamma grahics
http://farbe.li.tu-berlin.de/fek7/fek7f1px.pdf

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.



Select your desired gamma setting for this display. This will adjust the overall contrast of the display. Watch the picture on the right to see the effect of the different options. In most cases, it is best to use the Mac Standard gamma of 2.2.

After you have done this step, click the Continue button.

Fig. 11 Gamma slider for visual change of the display output for many use cases. The *rgb** data in the file of Fig. 10 can be changed by an inverse value of the measured or calculated gamma. Different Gamma values on different pages are used in Fig. 2, 3, and 4. The Gamma slider is described in two editions of [1] and has been deleted in 2022. Similar the option to view eps and ps file by a double klick disappeared. A reinstallation is recommended to remain the application of [1] in the area of ergonomics. This may support the ISO goal to produce standards for the well-being of users.

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

Application program

Modify the relative Gamma γ_{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 γ_{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

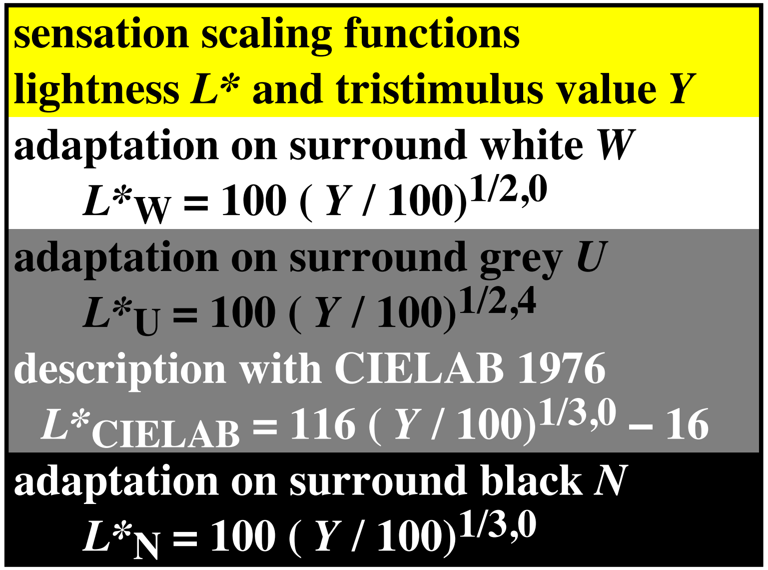
8 or 24 ISO pages, 1,000 <= gp <= 2,105 without or with output questions
https://standards.iso.org/iso/9241/306/ed-2/AE49/AE49F0N0.PDF
https://standards.iso.org/iso/9241/306/ed-2/AE49/AE49F0NX.PDF

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/

eem20–7n

Fig. 12 Gamma-change software for output on the whole display or still-images.
On the *Apple operating system* the colour slider of Fig. 11 and in addition the function to output the file formats *eps* and *ps* by a double click has been deleted in 2022. However, for example the software of a company in Fig. 12 allows alternate solutions on a *Mac*. The *GammaAdjuster* and *GraphicConverter* can change the gamma for many file formats.

6. Colourimetric basis for the need of different Gamma values in applications.


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

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

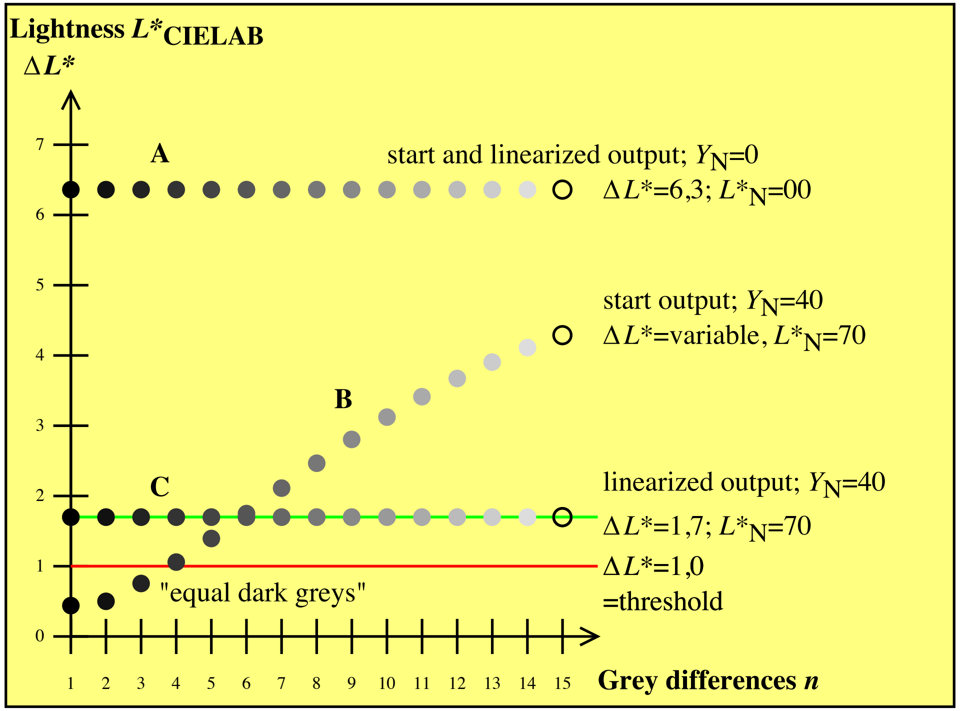
adaptation on surround black N

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

eej00–4n, eea00–4n

Fig. 13 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 [5].

In Fig. 13 all L^* function are normalized to 100 for the tristimulus value Y=100. However, the diffuse white W_{D0} on displays in [1] and on paper in [2] has the tristimulus value near Y_{D0} = 90. Then for one and two stop over exposure the Peak whites have the tristimulus values Y_{P1} = 180 and Y_{P2} = 360. These values will appear in Fig. 20.

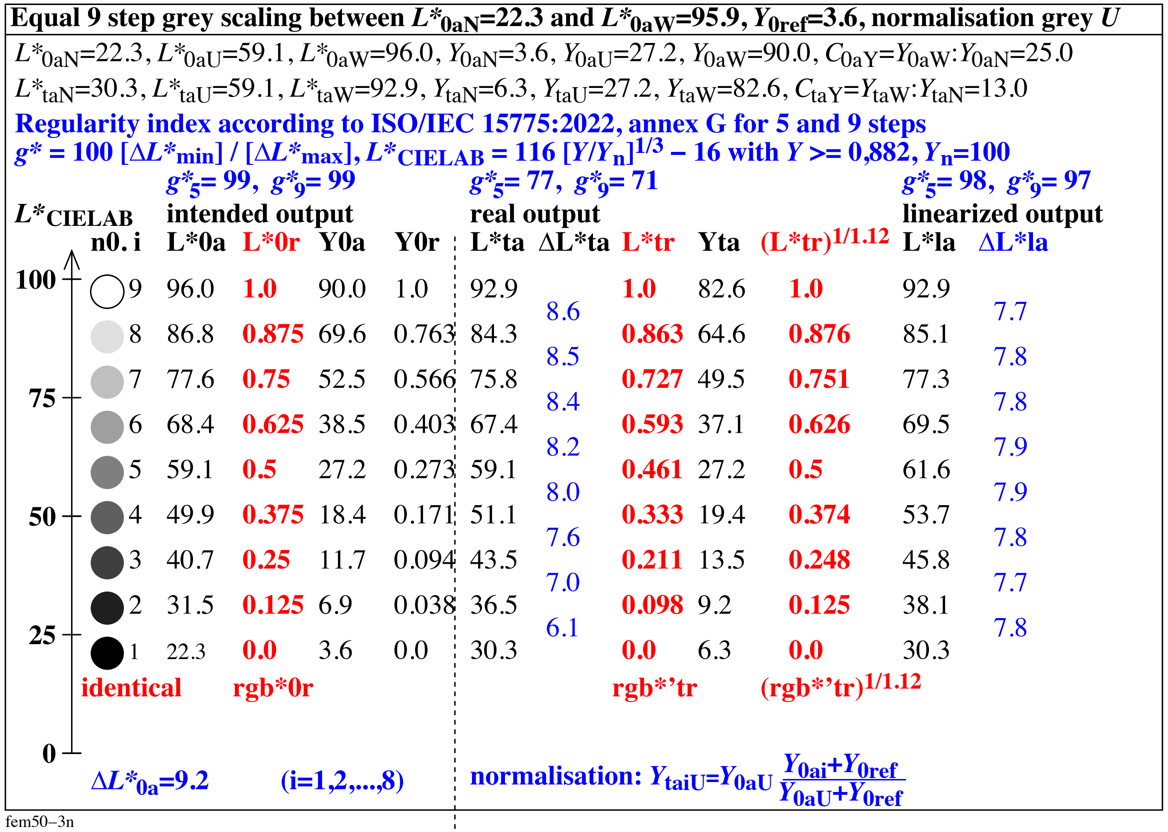


eeb11-3n. AE981-3N

Fig. 14 Change of the display colours from high contrast $C_Y=Y_W:Y_N$ >225:1 to C_Y=2:1

In Fig 14 the luminance of a data projector on the screen may produce equal steps in lightness L^*_{CIELAB} in a dark room, see A.

In a daylighted room the luminance of the data projector and the daylight may be equal on the screen. Then the contrast is $L_W : L_N$ = 2 :1. In this worse case three grey steps of 16 steps are not distinguishable, see B. Output linearization produces the equal steps, see C. The lightness difference between the samples is reduced from ΔL^*=6,3 to ΔL^*=1,7.



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 $Y >= 0{,}882$, $Y_n=100$

L^*_{CIELAB}	n0. i	L*0a	L*0r	Y0a	Y0r	L*ta	ΔL*ta	L*tr	Yta	$(L^*tr)^{1/1.12}$	L*la	ΔL*la
		g^*_5= 99, g^*_9= 99				g^*_5= 77, g^*_9= 71					g^*_5= 98, g^*_9= 97	
		intended output				real output					linearized output	
	○ 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	
	identical		rgb*0r					rgb*'tr		$(rgb^{*'}tr)^{1/1.12}$		

ΔL^*_{0a}=9.2 (i=1,2,...,8)

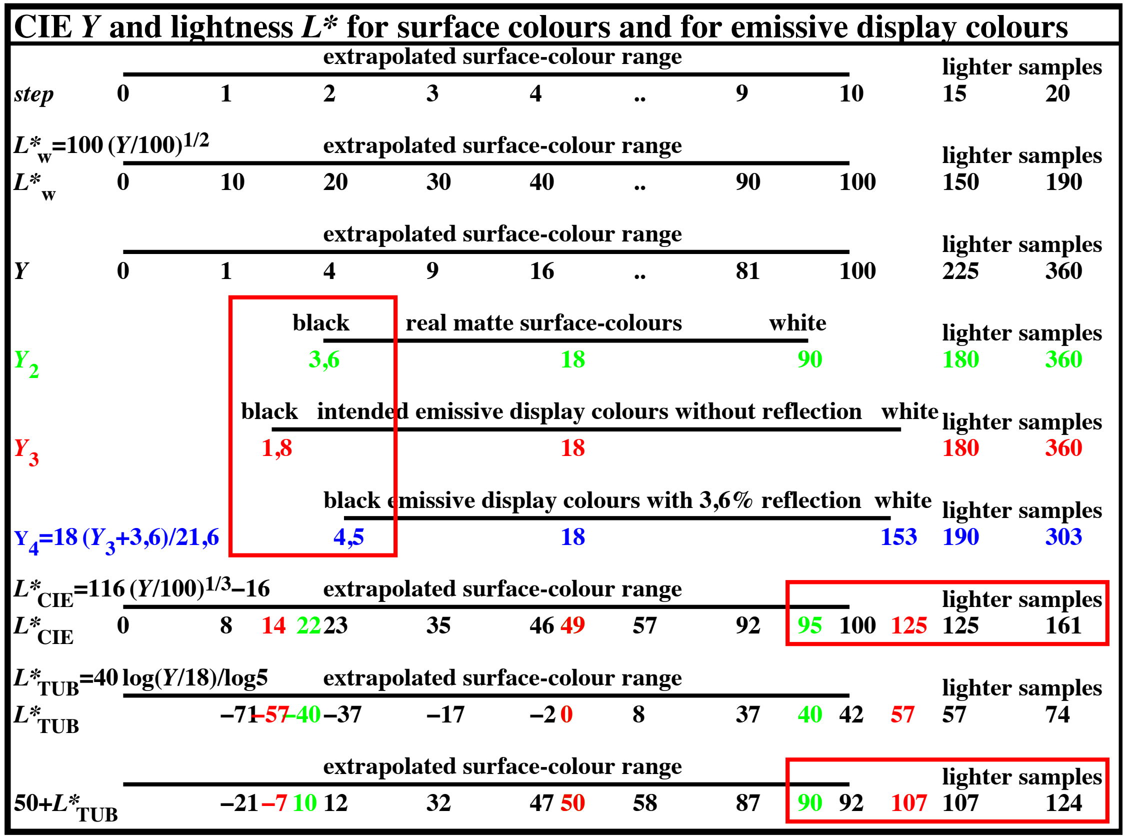
normalisation: $Y_{taiU}=Y_{0aU}\,\frac{Y_{0ai}+Y_{0ref}}{Y_{0aU}+Y_{0ref}}$

Fig 15 Definition of colour image quality by the Regularity index *g according to [2]**

A gray scale on paper on the display may be equally spaced, see L^*_{0a} and L^*_{0r}. The display reflection $Y_{0,ref}$ = 3,6 destroys the equal spacing, see L^*_{ta} and L^*_{tr}. A gamma value 1/1,2 makes the output again equally spaced, see L^*_{la} and ΔL^*_{la}.

For a high image quality output the value *g** is near 100 and cero if two steps are equal A Gamma change with the exponent (1/1,12) produced the intended high quality.

7. Diffuse black N_{d0} and white W_{D0}, Peak black N_{p1} and Peak whites W_{P1} and W_{P2}



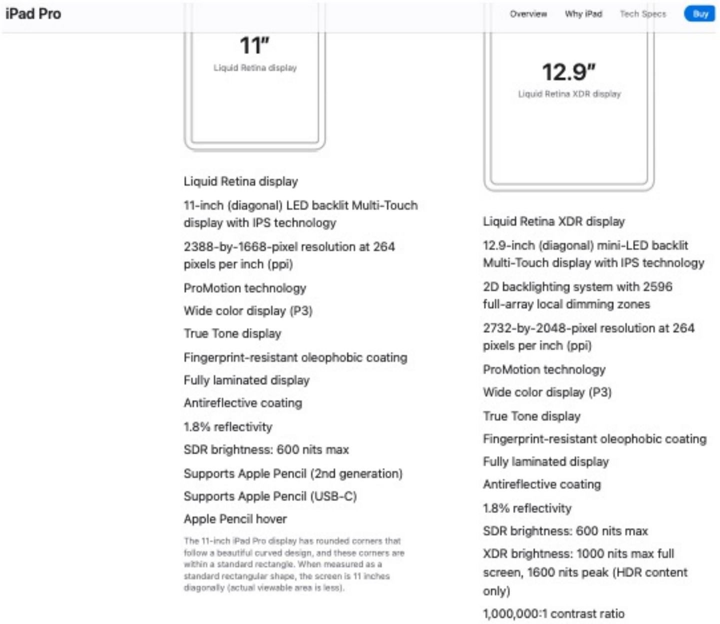
CIE *Y* and lightness *L** for surface colours and for emissive display colours

			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
$L^*_{TUB}=40\log(Y/18)/\log5$			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

eej21−7n

Fig. 16 CIE tristimulus value *Y* and lightness *L for surface and display colours**

Different colour metrics can describe the lightness including the values between 90 and 500 in Fig. 12, 20, and 1. The values differ between L^*_{TUBLAB} = 124 and L^*_{CIELAB} = 161 in Fig. 12 for *Y*=360. Appropriate values to code the *rgb** data in the HDR-head room seem to be unknown. Scaling data between Peak white P2 and Diffuse black d0 are important.



Liquid Retina display
11-inch (diagonal) LED backlit Multi-Touch display with IPS technology
2388-by-1668-pixel resolution at 264 pixels per inch (ppi)
ProMotion technology
Wide color display (P3)
True Tone display
Fingerprint-resistant oleophobic coating
Fully laminated display
Antireflective coating
1.8% reflectivity
SDR brightness: 600 nits max
Supports Apple Pencil (2nd generation)
Supports Apple Pencil (USB-C)
Apple Pencil hover

The 11-inch iPad Pro display has rounded corners that follow a beautiful curved design, and these corners are within a standard rectangle. When measured as a standard rectangular shape, the screen is 11 inches diagonally (actual viewable area is less).

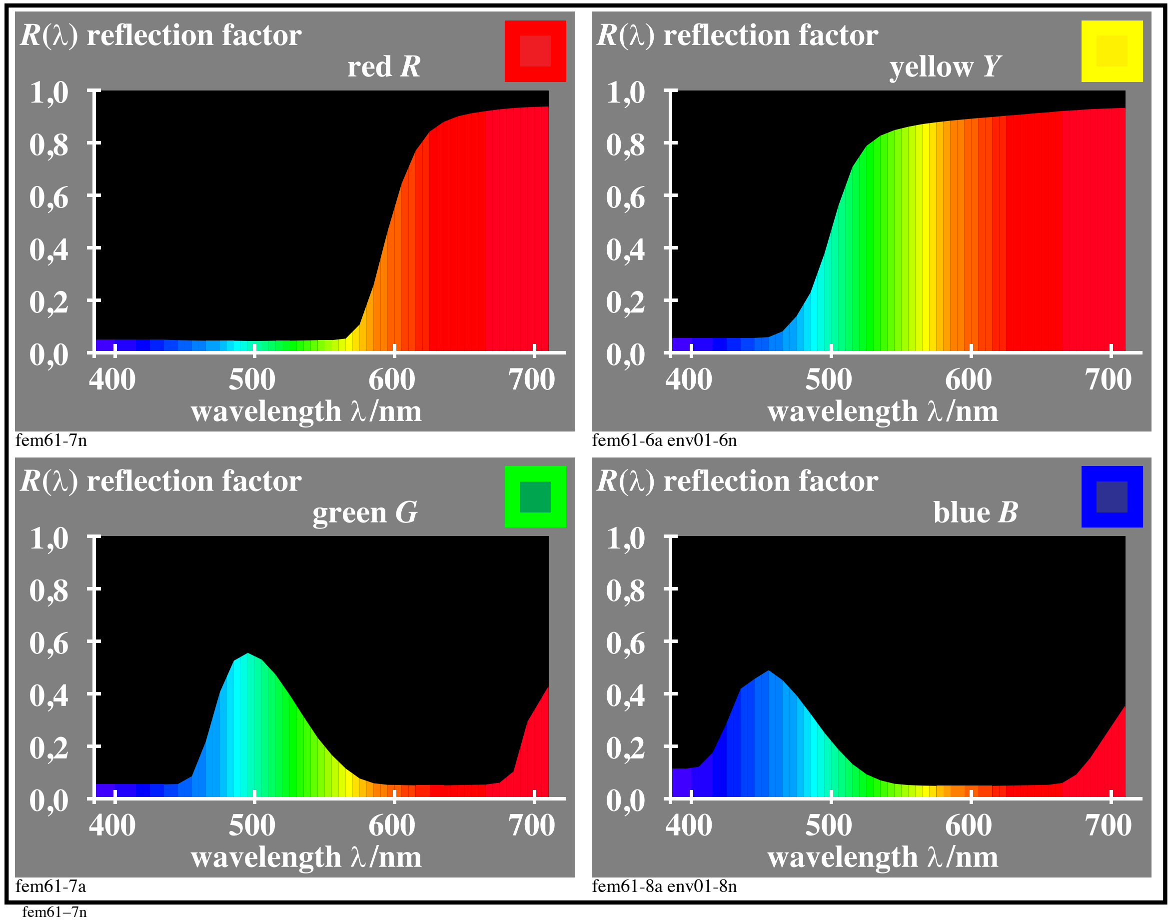
Liquid Retina XDR display
12.9-inch (diagonal) mini-LED backlit Multi-Touch display with IPS technology
2D backlighting system with 2596 full-array local dimming zones
2732-by-2048-pixel resolution at 264 pixels per inch (ppi)
ProMotion technology
Wide color display (P3)
True Tone display
Fingerprint-resistant oleophobic coating
Fully laminated display
Antireflective coating
1.8% reflectivity
SDR brightness: 600 nits max
XDR brightness: 1000 nits max full screen, 1600 nits peak (HDR content only)
1,000,000:1 contrast ratio

Fig. 17 Reflectivity 1,8% for actual displays with antireflective coating

An example technical specification of the actual 2024-display *iPad_Pro* includes a line **1,8% reflectivity**. For an ergonomic work space the luminance of the white paper and the display in the viewing condition shall be equal.

The tristimulus value of the diffuse black is Y_{d0} = 2,5 for the test charts of [1] and [2]. This corresponds to the reflectivity 2,5% in the above technical specification. Therefore in Fig. 1 the value Y_{p1} = 1,8 is used for the Peak black.

About the display contrast ratio 1.000.000 : 1, see Fig. 15 and the explanation.



fem61−7n

Fig. 18 Spectral reflection of matte surface colours for all wavelength

The reflection for any matte surface colour is near 3,6%. The reflection is reduced to 2,5% for semi-glossy offset paper according to [1]. Usually the reflection seems between 1,8% and 3,6 %. For displays with antireflective coating and glossy papers 1,8% may be appropriate. For SDR displays and matte papers 3,6% may represent most use cases.

The optical media of any observer produce stray light. Compared to the diffuse white this stray light may have a similar value because similar physical effects are the basis. If the case R=1,8% is assumed, then the effective visual contrast ratio is near $Y_{D0} : Y_{p1} = 90 : 1,8 = 50:1$. However, in actual use cases the contrast ratio may be near $Y_{D0} : Y_{d0} = 90 : 2,5 = 36 : 1$, or for matte colours, see Fig. 18, near $Y_{D0} : Y_{p1} = 90 : 3,6 = 25 : 1$.

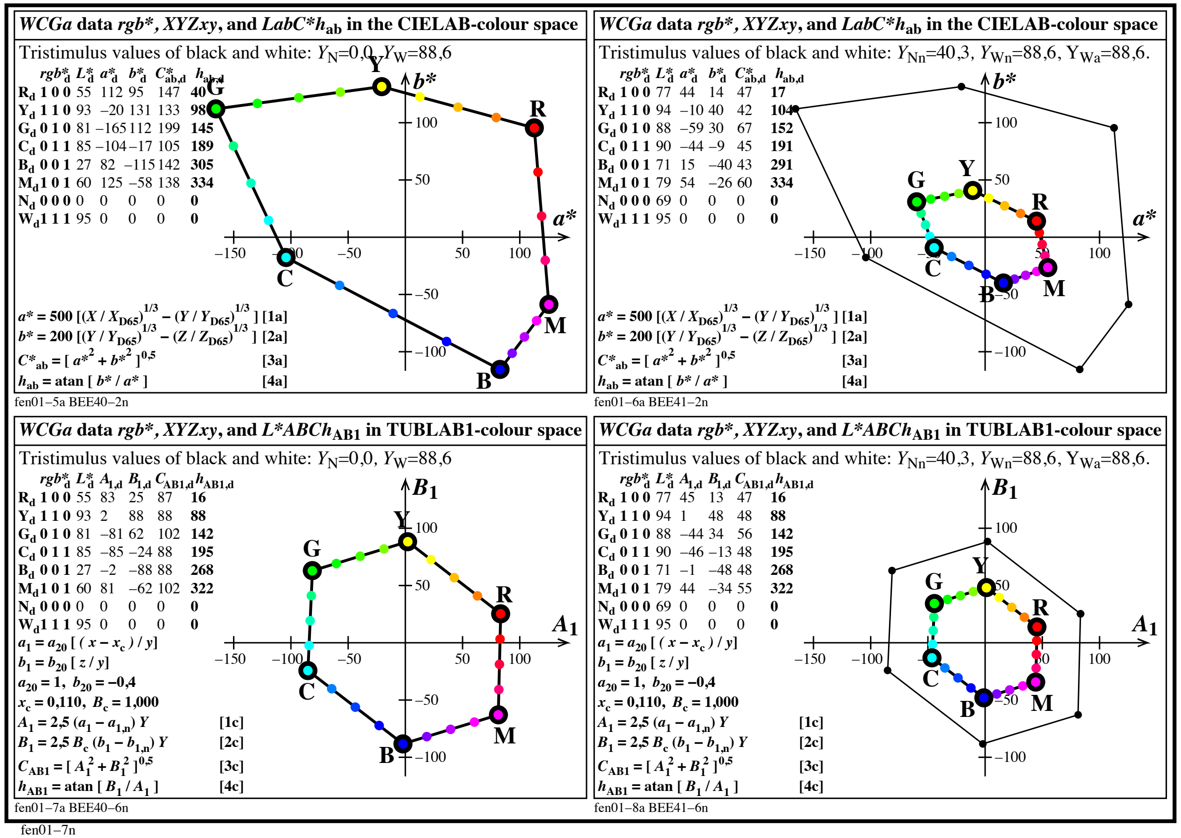
In addition in actual display-use cases the contrast ratio is reduced with increasing reflections of the ambient light on the display surface. In addition with increasing observer age the increasing stray of the optical eye media reduces the contrast ratio.

The technical display specification of Fig. 17 includes at the end line *1.000.000 : 1 contrast ratio*. The measurement data may be correct.

However, the largest *visual* ratio of the visual system may be near $Y_{D0} : Y_{p1} = 90 : 1,8 = 50 : 1$ for the white display and the white paper with a grey scale between white W_{D0} and black $N_{p1.}$

This ratio will change by about 10% towards 55:1, if the adapting luminance increases by a factor 4 (+2 stop over exposure) in Fig.2. However, the luminance of the black N_{d0} also increases by a factor 4. In the case of small areas with a 4 times higher luminance in the HDR images the luminance increase of the black N_{d0} is lower compared to 4 times. It has to be considered that the luminance L >= 142 cd/m^2 ais recommended at work places. Higher luminance may increase user fatigue and increase energy consumption.

8. CIEXYZ and CIELAB data for achromatic and chromatic colours



***WCGa* data *rgb*, XYZxy*, and *LabC*h*$_{ab}$ in the CIELAB-colour space**

Tristimulus values of black and white: Y_N=0,0, Y_W=88,6

	rgb^*_d	L^*_d	a^*_d	b^*_d	$C^*_{ab,d}$	$h_{ab,d}$
R_d	**1 0 0**	55	112	95	147	**40**
Y_d	**1 1 0**	93	–20	131	133	**98**
G_d	**0 1 0**	81	–165	112	199	**145**
C_d	**0 1 1**	85	–104	–17	105	**189**
B_d	**0 0 1**	27	82	–115	142	**305**
M_d	**1 0 1**	60	125	–58	138	**334**
N_d	**0 0 0**	0	0	0	0	**0**
W_d	**1 1 1**	95	0	0	0	**0**

$a^* = 500\ [(X / X_{D65})^{1/3} - (Y / Y_{D65})^{1/3}]$ [1a]
$b^* = 200\ [(Y / Y_{D65})^{1/3} - (Z / Z_{D65})^{1/3}]$ [2a]
$C^*_{ab} = [\ a^{*2} + b^{*2}\ ]^{0,5}$ [3a]
$h_{ab} = \text{atan}\ [\ b^* / a^*\ ]$ [4a]

fen01–5a BEE40–2n

***WCGa* data *rgb*, XYZxy*, and *LabC*h*$_{ab}$ in the CIELAB-colour space**

Tristimulus values of black and white: Y_{Nn}=40,3, Y_{Wn}=88,6, Y_{Wa}=88,6.

	rgb^*_d	L^*_d	a^*_d	b^*_d	$C^*_{ab,d}$	$h_{ab,d}$
R_d	**1 0 0**	77	44	14	47	**17**
Y_d	**1 1 0**	94	–10	40	42	**104**
G_d	**0 1 0**	88	–59	30	67	**152**
C_d	**0 1 1**	90	–44	–9	45	**191**
B_d	**0 0 1**	71	15	–40	43	**291**
M_d	**1 0 1**	79	54	–26	60	**334**
N_d	**0 0 0**	69	0	0	0	**0**
W_d	**1 1 1**	95	0	0	0	**0**

$a^* = 500\ [(X / X_{D65})^{1/3} - (Y / Y_{D65})^{1/3}]$ [1a]
$b^* = 200\ [(Y / Y_{D65})^{1/3} - (Z / Z_{D65})^{1/3}]$ [2a]
$C^*_{ab} = [\ a^{*2} + b^{*2}\ ]^{0,5}$ [3a]
$h_{ab} = \text{atan}\ [\ b^* / a^*\ ]$ [4a]

fen01–6a BEE41–2n

***WCGa* data *rgb*, XYZxy*, and *L*ABCh*$_{AB1}$ in TUBLAB1-colour space**

Tristimulus values of black and white: Y_N=0,0, Y_W=88,6

	rgb^*_d	L^*_d	$A_{1,d}$	$B_{1,d}$	$C_{AB1,d}$	$h_{AB1,d}$
R_d	**1 0 0**	55	83	25	87	**16**
Y_d	**1 1 0**	93	2	88	88	**88**
G_d	**0 1 0**	81	–81	62	102	**142**
C_d	**0 1 1**	85	–85	–24	88	**195**
B_d	**0 0 1**	27	–2	–88	88	**268**
M_d	**1 0 1**	60	81	–62	102	**322**
N_d	**0 0 0**	0	0	0	0	**0**
W_d	**1 1 1**	95	0	0	0	**0**

$a_1 = a_{20}\ [\ (\ x - x_c\ ) / y]$
$b_1 = b_{20}\ [\ z / y]$
$a_{20} = 1,\ b_{20} = -0{,}4$
$x_c = 0{,}110,\ B_c = 1{,}000$
$A_1 = 2{,}5\ (a_1 - a_{1,n})\ Y$ [1c]
$B_1 = 2{,}5\ B_c\ (b_1 - b_{1,n})\ Y$ [2c]
$C_{AB1} = [\ A_1^2 + B_1^2\ ]^{0,5}$ [3c]
$h_{AB1} = \text{atan}\ [\ B_1 / A_1\ ]$ [4c]

fen01–7a BEE40–6n

***WCGa* data *rgb*, XYZxy*, and *L*ABCh*$_{AB1}$ in TUBLAB1-colour space**

Tristimulus values of black and white: Y_{Nn}=40,3, Y_{Wn}=88,6, Y_{Wa}=88,6.

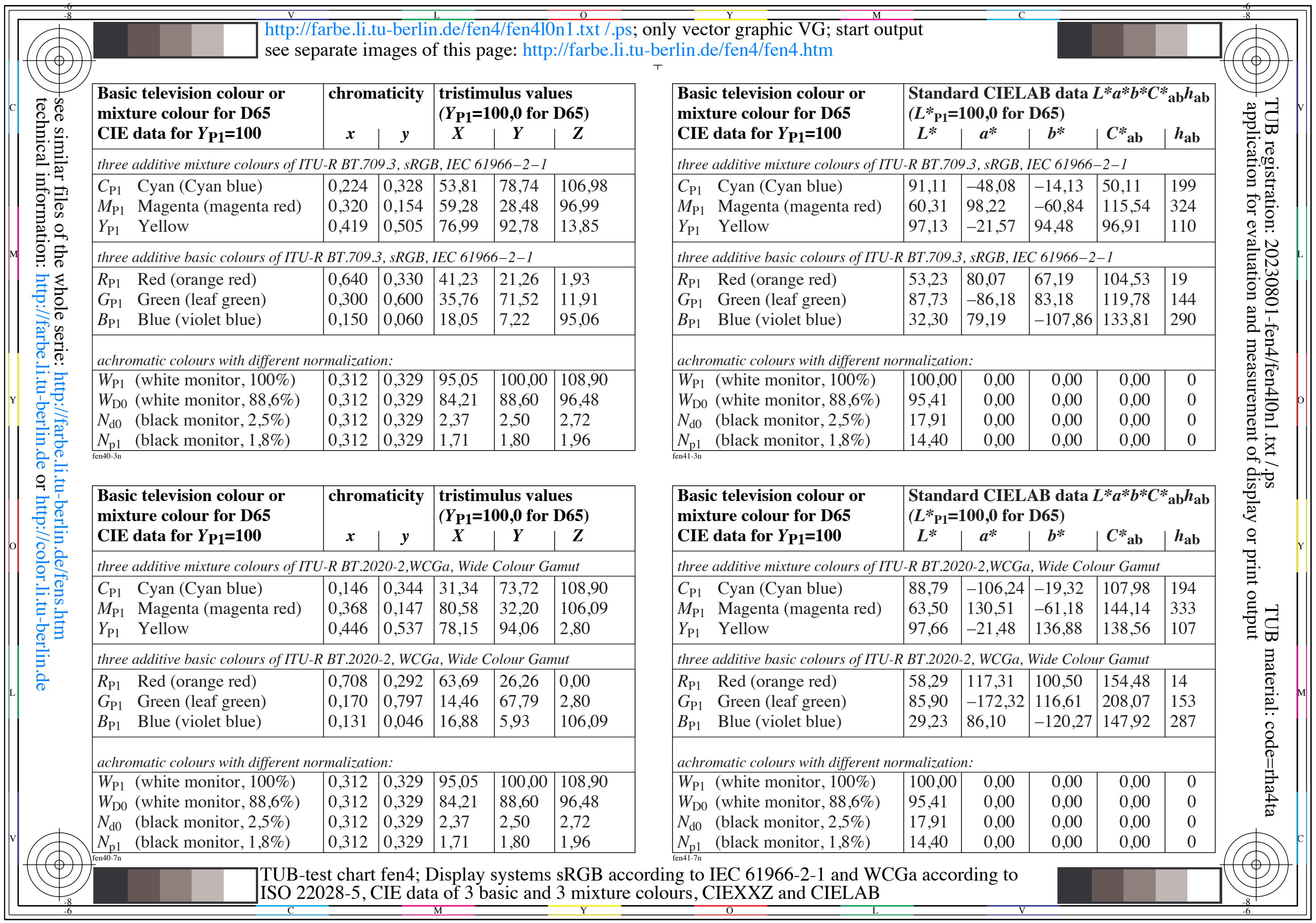
	rgb^*_d	L^*_d	$A_{1,d}$	$B_{1,d}$	$C_{AB1,d}$	$h_{AB1,d}$
R_d	**1 0 0**	77	45	13	47	**16**
Y_d	**1 1 0**	94	1	48	48	**88**
G_d	**0 1 0**	88	–44	34	56	**142**
C_d	**0 1 1**	90	–46	–13	48	**195**
B_d	**0 0 1**	71	–1	–48	48	**268**
M_d	**1 0 1**	79	44	–34	55	**322**
N_d	**0 0 0**	69	0	0	0	**0**
W_d	**1 1 1**	95	0	0	0	**0**

$a_1 = a_{20}\ [\ (\ x - x_c\ ) / y]$
$b_1 = b_{20}\ [\ z / y]$
$a_{20} = 1,\ b_{20} = -0{,}4$
$x_c = 0{,}110,\ B_c = 1{,}000$
$A_1 = 2{,}5\ (a_1 - a_{1,n})\ Y$ [1c]
$B_1 = 2{,}5\ B_c\ (b_1 - b_{1,n})\ Y$ [2c]
$C_{AB1} = [\ A_1^2 + B_1^2\ ]^{0,5}$ [3c]
$h_{AB1} = \text{atan}\ [\ B_1 / A_1\ ]$ [4c]

fen01–8a BEE41–6n

fen01–7n

Fig. 19 Change of chromatic colour coordinates with ambient reflection
The chromatic colour coordinates decrease with increasing reflection. The chromatic coordinates in the two colour spaces CIELAB and TUBLAB are calculated with equations of Fig. 19. The colour space TUBLAB produces equal opponent coordinates for the complementary colour pairs C – M, Y – B, and G – M. They all mix to the display white.



http://farbe.li.tu-berlin.de/fen4/fen4l0n1.txt /.ps; only vector graphic VG; start output
see separate images of this page: http://farbe.li.tu-berlin.de/fen4/fen4.htm

see similar files of the whole serie: http://farbe.li.tu-berlin.de/fens.htm
technical information: http://farbe.li.tu-berlin.de or http://color.li.tu-berlin.de

TUB registration: 20230801-fen4/fen4l0n1.txt /.ps
application for evaluation and measurement of display or print output
TUB material: code=rha4ta

Basic television colour or mixture colour for D65 CIE data for Y_{P1}=100		**chromaticity** x	y	**tristimulus values (Y_{P1}=100,0 for D65)** X	Y	Z
three additive mixture colours of ITU-R BT.709.3, sRGB, IEC 61966–2–1						
C_{P1}	Cyan (Cyan blue)	0,224	0,328	53,81	78,74	106,98
M_{P1}	Magenta (magenta red)	0,320	0,154	59,28	28,48	96,99
Y_{P1}	Yellow	0,419	0,505	76,99	92,78	13,85
three additive basic colours of ITU-R BT.709.3, sRGB, IEC 61966–2–1						
R_{P1}	Red (orange red)	0,640	0,330	41,23	21,26	1,93
G_{P1}	Green (leaf green)	0,300	0,600	35,76	71,52	11,91
B_{P1}	Blue (violet blue)	0,150	0,060	18,05	7,22	95,06
achromatic colours with different normalization:						
W_{P1}	(white monitor, 100%)	0,312	0,329	95,05	100,00	108,90
W_{D0}	(white monitor, 88,6%)	0,312	0,329	84,21	88,60	96,48
N_{d0}	(black monitor, 2,5%)	0,312	0,329	2,37	2,50	2,72
N_{p1}	(black monitor, 1,8%)	0,312	0,329	1,71	1,80	1,96

fen40-3n

Basic television colour or mixture colour for D65 CIE data for Y_{P1}=100		**Standard CIELAB data $L^*a^*b^*C^*_{ab}h_{ab}$ (L^*_{P1}=100,0 for D65)** L^*	a^*	b^*	C^*_{ab}	h_{ab}
three additive mixture colours of ITU-R BT.709.3, sRGB, IEC 61966–2–1						
C_{P1}	Cyan (Cyan blue)	91,11	–48,08	–14,13	50,11	199
M_{P1}	Magenta (magenta red)	60,31	98,22	–60,84	115,54	324
Y_{P1}	Yellow	97,13	–21,57	94,48	96,91	110
three additive basic colours of ITU-R BT.709.3, sRGB, IEC 61966–2–1						
R_{P1}	Red (orange red)	53,23	80,07	67,19	104,53	19
G_{P1}	Green (leaf green)	87,73	–86,18	83,18	119,78	144
B_{P1}	Blue (violet blue)	32,30	79,19	–107,86	133,81	290
achromatic colours with different normalization:						
W_{P1}	(white monitor, 100%)	100,00	0,00	0,00	0,00	0
W_{D0}	(white monitor, 88,6%)	95,41	0,00	0,00	0,00	0
N_{d0}	(black monitor, 2,5%)	17,91	0,00	0,00	0,00	0
N_{p1}	(black monitor, 1,8%)	14,40	0,00	0,00	0,00	0

fen41-3n

Basic television colour or mixture colour for D65 CIE data for Y_{P1}=100		**chromaticity** x	y	**tristimulus values (Y_{P1}=100,0 for D65)** X	Y	Z
three additive mixture colours of ITU-R BT.2020-2,WCGa, Wide Colour Gamut						
C_{P1}	Cyan (Cyan blue)	0,146	0,344	31,34	73,72	108,90
M_{P1}	Magenta (magenta red)	0,368	0,147	80,58	32,20	106,09
Y_{P1}	Yellow	0,446	0,537	78,15	94,06	2,80
three additive basic colours of ITU-R BT.2020-2, WCGa, Wide Colour Gamut						
R_{P1}	Red (orange red)	0,708	0,292	63,69	26,26	0,00
G_{P1}	Green (leaf green)	0,170	0,797	14,46	67,79	2,80
B_{P1}	Blue (violet blue)	0,131	0,046	16,88	5,93	106,09
achromatic colours with different normalization:						
W_{P1}	(white monitor, 100%)	0,312	0,329	95,05	100,00	108,90
W_{D0}	(white monitor, 88,6%)	0,312	0,329	84,21	88,60	96,48
N_{d0}	(black monitor, 2,5%)	0,312	0,329	2,37	2,50	2,72
N_{p1}	(black monitor, 1,8%)	0,312	0,329	1,71	1,80	1,96

fen40-7n

Basic television colour or mixture colour for D65 CIE data for Y_{P1}=100		**Standard CIELAB data $L^*a^*b^*C^*_{ab}h_{ab}$ (L^*_{P1}=100,0 for D65)** L^*	a^*	b^*	C^*_{ab}	h_{ab}
three additive mixture colours of ITU-R BT.2020-2,WCGa, Wide Colour Gamut						
C_{P1}	Cyan (Cyan blue)	88,79	–106,24	–19,32	107,98	194
M_{P1}	Magenta (magenta red)	63,50	130,51	–61,18	144,14	333
Y_{P1}	Yellow	97,66	–21,48	136,88	138,56	107
three additive basic colours of ITU-R BT.2020-2, WCGa, Wide Colour Gamut						
R_{P1}	Red (orange red)	58,29	117,31	100,50	154,48	14
G_{P1}	Green (leaf green)	85,90	–172,32	116,61	208,07	153
B_{P1}	Blue (violet blue)	29,23	86,10	–120,27	147,92	287
achromatic colours with different normalization:						
W_{P1}	(white monitor, 100%)	100,00	0,00	0,00	0,00	0
W_{D0}	(white monitor, 88,6%)	95,41	0,00	0,00	0,00	0
N_{d0}	(black monitor, 2,5%)	17,91	0,00	0,00	0,00	0
N_{p1}	(black monitor, 1,8%)	14,40	0,00	0,00	0,00	0

fen41-7n

TUB-test chart fen4; Display systems sRGB according to IEC 61966-2-1 and WCGa according to ISO 22028-5, CIE data of 3 basic and 3 mixture colours, CIEXXZ and CIELAB

Fig. 20 Colourimetric data CIEXYZ and CIELAB for the displays sRGB and WCGa

For many applications colourimetric data of the figure 20 (and Figure 1) are necessary. Many of these data do not appear in ISO 22028-5 and are used for example in Fig. 2 to 4.

Conclusions

A coding of SDR and HDR images with *rgb** data is shown. In the examples the lightness L^*_{CIELAB} is used as a starting point, for example up to +2,3 stops. This corresponds to $L^*_{\mathrm{CIELAB,+2,3\ stop}}$= 182, see Fig. 1. The range 100 <= *L** <= 182 of the HDR display of ISO 22028-5 is approximately equal compared to the range 18 <= *L** <=100. In this case the coding room for SDR is reduced to 50%. The parameters GammR=0,80=100/125 and GammR=0,64=100/156 defines the SDR range in Fig. 3 to 4.

The paper shows in Figure 2 to 4 that users can store and output an HDR image with data up to *rgb** = 1,56 = $L^*_{\mathrm{CIELAB,\ P2}}$/100. The eps and pdf files include no metadata and no ICC-colour management data, see [11].
It is assumed that the HDR image includes data in the range 0 <= *rgb** <= 1,56.
A user with an SDR display has many possibilities for the output.

1. All *rgb** values >=1 (> +0 stop) are skipped to 1.
   This is done in Fig. 2 by default for any pdf file.
2. All *rgb** values <=1,25 (<= +1 stop) are transferred to the range 0 <= rgb* <=1.
   This is done in Figure 3 with the parameter GammR=0,8=1/1,25. All colour samples look darker. The circle +2 stop is lighter compared to the circle +1 stop.
3. All *rgb** values <=1,56 (> +2 stop) are transferred to the range 0 <= rgb* <=1.
   This is done in Figure 4 with the parameter GammR=0,64=1/1,56. The colour samples look more dark and both circles +1 and +2 stops look lighter compared to the white sample.

Advantages:

1. Different outputs may be produced for any values in the range 0,64 <= GammR <=1.
2. The *gain map* profile HDR -> SDR is the mathematical reduction factor GammR.
3. Data *rgb** >=1 are used to store the HDR content. This content is not deleted for the output.
4. The images are coded in 8 bits/channel in the visual *rgb** space. This coding is proportional to the lightness in the range $0 <= L^*_{\mathrm{CIELAB}} <= 156$ or +2 stop exposure.
5. A transfer to about 16 bits/channel for the *rgb* with a linear relation to the luminance *L* instead of *rgb** with a linear relation to lightness *L** is obvious. This is similar compared to the device link profiles in ICC.
6. A *gain map* seems not necessary for the consumer area. Then problems where and how to store the *gain map* data seem to disappear for the consumer area.
7. Usually ICC profiles try to produce the minimum colour difference, for example between the original and a copy. Usually the copier paper has a lower contrast range near black. Then for example the ICC profile produces no colour difference for 7 samples and two to equal black samples. 10% information within the image is lost.

…This image quality is described by the regularity index *g**=0 (worst case) of [2]. The g*-image quality shall be recommended. High values are reached by a gamma change.

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, 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] Richter, Klaus (2013), Output Linearization Methods for Displays, Printers, and Offset Print (63 pages, 1,4 MB, Format A4), see http://farbe.li.tu-berlin.de/OUTLIN13_02.PDF

[5] ISO/CIE 11664-4 (2019), Colorimetry, Part 4: CIE 1976 $L^*a^*b^*$ colour space

[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

[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 (2020),* see different papers especially since 2020 at the link http://farbe.li.tu-berlin.de/XY91FEN.html

[10] DIN 33872-1 to 6:2010, Information technology - Office machines - Method of specifying colour reproduction with YES/NO criteria - Part 1: Classification, terms and principles, only on CD-ROM and following Parts 2 to 6

[11] ISO 20677:2019, Image technology colour management - Extensions to architecture, profile format and data structure

Annex – Copyright

Acknowledgements

For discussions and proposals to optimize the content of this paper I thank especially:
Detlef Ruschin, German Representative in CIE Div. 1 "Vision and Colour", and
Prof. Florian Suessl, German Representative in CIE Div. 8 "Image Technology".