16 Step Elementary Color Circle: *olv**, *rgb**, and CIE Data for a *sRGB* Display in Offices

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Abstract

CIE R1-47:2009 "Hue Angles of Elementary Colours" defines four elementary colours *RJGB* (Red, Yellow, Green and Blue). The four CIELAB hue angles of *RJGB* are h_{ab} = 26, 92, 162 and 272. These hue angles are identical to the hue angles of the CIE-test colours no. 9 to 12 according to CIE 13.3 "Color Rendering of Light Sources".

For example these four hue angles of *RJGB* have been used in DIN 33872 to define a 16 step elementary colour circle for the standard *sRGB* monitor in a dark room (without luminance reflection of the ambient lighting) for CIE standard illuminant D65 and the CIE 2 degree observer.

In this paper a method is given how to calculate many CIE data including CIELAB for a 16 step elementary hue circle.

At the same time the linear relations between *rgb** data and CIELAB data define a device independent *RGB** system which is based on the human visual *elementary hue angles in CIELAB* and which may be used for many applications in image technology.

Introduction

The elementary hues are defined by visual criteria, for example *Yellow J* as neither greenish nor reddish. The four elementary hues are included as reference in the human visual system.

The question was raised why these elementary hues which seem to be important from an ergonomic point of view have not been used earlier in image technology. The answer is simple: Before 2008 the CIE Division 1 “Vision and colour” has not looked at the problem. The following conclusion 31/2007 of ISO/IEC /SC4/WG2 “Visual Display Requirements” was the starting point to produce the report CIE R1-47 which is now for free on the CIE Division 1 web site.

Conclusion 31/2007 of ISO TC159/SG4/WG2 "Visual Display Requirements"

ISO TC159/SG4/WG2 "Visual Display Requirements" realizes that the colour spaces CIELAB and CIELUV of CIE Division 1 will soon become ISO/CIE standards.

In applications we use these CIE colour spaces and *device-dependent* relative *RGB* colour spaces.

For users of visual display systems a *device-independent RGB* colour space is useful.

This produces via software the elementary hues Red, Green and Blue for the *RGB* data 100, 010 and 001 and equally spaced output in CIE colour spaces for equally spaced *RGB* input.

We recommend that CIE Division 1 study the colorimetric definition of such a space, which can be used in visual display applications.

Remark: We have realized that an example colour space of this type is published in CIE X030:2006, p. 139-144

Achromatic colours	**Elementary colours** *"Neither-nor"-colours*	**Reproduction colours** *Television (TV), Print (PR) Photography (PH)*
five achromatic colours:	*four elementary colours:*	*six reproduction colours:*
N black (french noir)	*R* red *neither yellowish nor blueish*	*C* cyanblue
D dark grey	*G* green *neither yellowish nor blueish*	*M* magentared
Z central grey	*B* blue *neither greenish nor reddish*	*Y* yellow
H light grey	*J* yellow (french jaune) *neither greenish nor reddish*	*O* orangered
W white		*L* leafgreen
		V violetblue

YE980-3

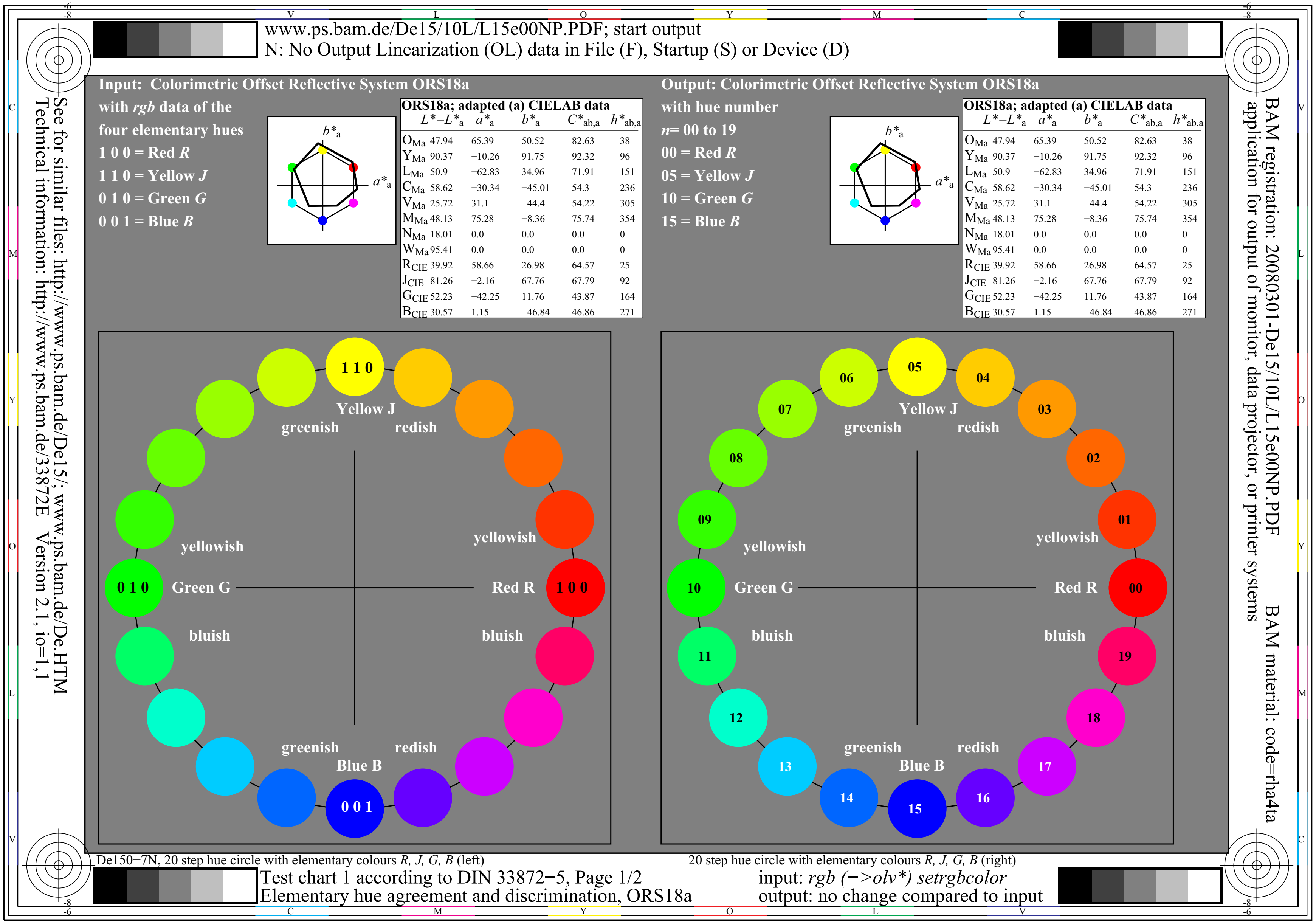
Fig. 1: Elementary colours *RJGB* and device colours *OYLCVM*.

Fig. 1 shows elementary colours *RJGB* and device colours *OYLCVM* according to ISO/IEC 15775.

A physiological and/or colorimetric model for the description of the four elementary colours is still missing.

Any display or print device can produce any hue and therefore an elementary hue circle can be produced by any colour device.

16 Step Elementary Color Circle: *olv**, *rgb**, CIE Data for a *sRGB* Display in Offices



ORS18a; adapted (a) CIELAB data

	$L^*=L^*_a$	a^*_a	b^*_a	$C^*_{ab,a}$	$h^*_{ab,a}$
O_{Ma}	47.94	65.39	50.52	82.63	38
Y_{Ma}	90.37	−10.26	91.75	92.32	96
L_{Ma}	50.9	−62.83	34.96	71.91	151
C_{Ma}	58.62	−30.34	−45.01	54.3	236
V_{Ma}	25.72	31.1	−44.4	54.22	305
M_{Ma}	48.13	75.28	−8.36	75.74	354
N_{Ma}	18.01	0.0	0.0	0.0	0
W_{Ma}	95.41	0.0	0.0	0.0	0
R_{CIE}	39.92	58.66	26.98	64.57	25
J_{CIE}	81.26	−2.16	67.76	67.79	92
G_{CIE}	52.23	−42.25	11.76	43.87	164
B_{CIE}	30.57	1.15	−46.84	46.86	271

ORS18a; adapted (a) CIELAB data

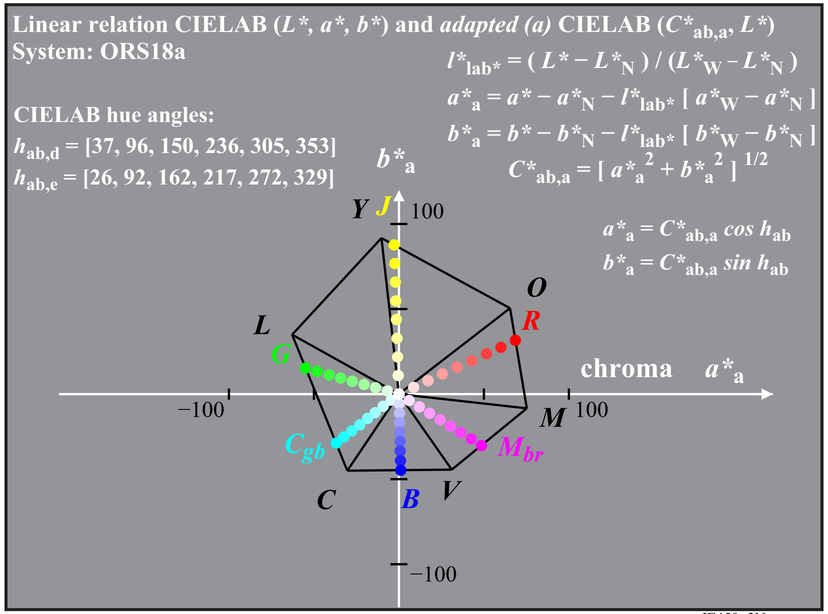
	$L^*=L^*_a$	a^*_a	b^*_a	$C^*_{ab,a}$	$h^*_{ab,a}$
O_{Ma}	47.94	65.39	50.52	82.63	38
Y_{Ma}	90.37	−10.26	91.75	92.32	96
L_{Ma}	50.9	−62.83	34.96	71.91	151
C_{Ma}	58.62	−30.34	−45.01	54.3	236
V_{Ma}	25.72	31.1	−44.4	54.22	305
M_{Ma}	48.13	75.28	−8.36	75.74	354
N_{Ma}	18.01	0.0	0.0	0.0	0
W_{Ma}	95.41	0.0	0.0	0.0	0
R_{CIE}	39.92	58.66	26.98	64.57	25
J_{CIE}	81.26	−2.16	67.76	67.79	92
G_{CIE}	52.23	−42.25	11.76	43.87	164
B_{CIE}	30.57	1.15	−46.84	46.86	271

Fig. 2: DIN-test chart with 16 step hue circle according DIN 33872-5

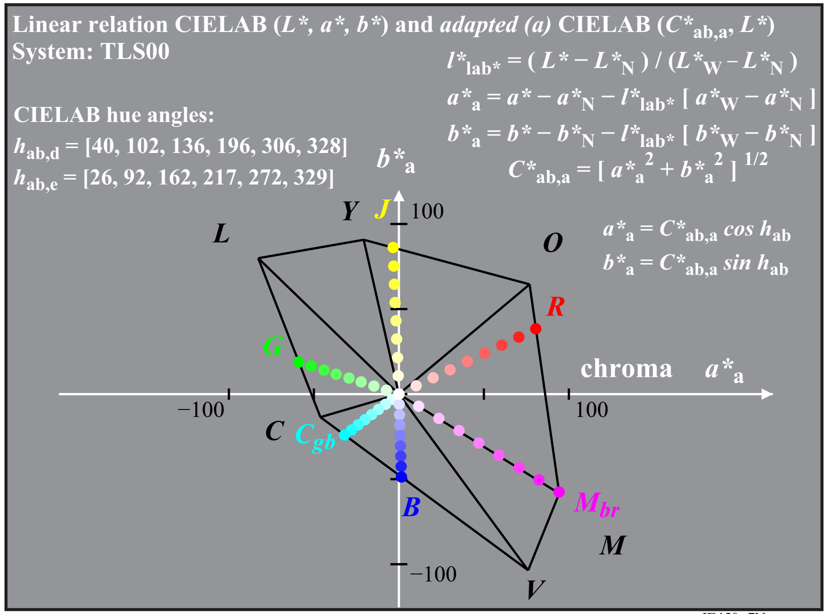
Visual *rgb** data and the CIELAB data of the 16 step hue circle

Fig. 2 shows a DIN-test chart with a 16 step hue circle according DIN 33872-5. Visual *rgb** data (e. g. 1 0 0 for Red R) and the CIELAB data of the 6 chromatic offset device colours *OYLCVM* and the two achromatic colours are given in the test chart. Page 2 of the test chart includes questions with Yes/No criteria. Most devices produce elementary Red, Yellow and Green at the intended positions no. 0, 5, and 10 respectively and fulfill the DIN-Yes/No criteria. There are some new printers on the market which produce elementary Blue *B* at the intended position number 15 (*rgb* input 0 0 1). However, often the output of printers and displays produce elementary Blue at no. 14 and some at no. 13. Then the DIN-Yes/No criteria according to DIN 33872-5 fails.

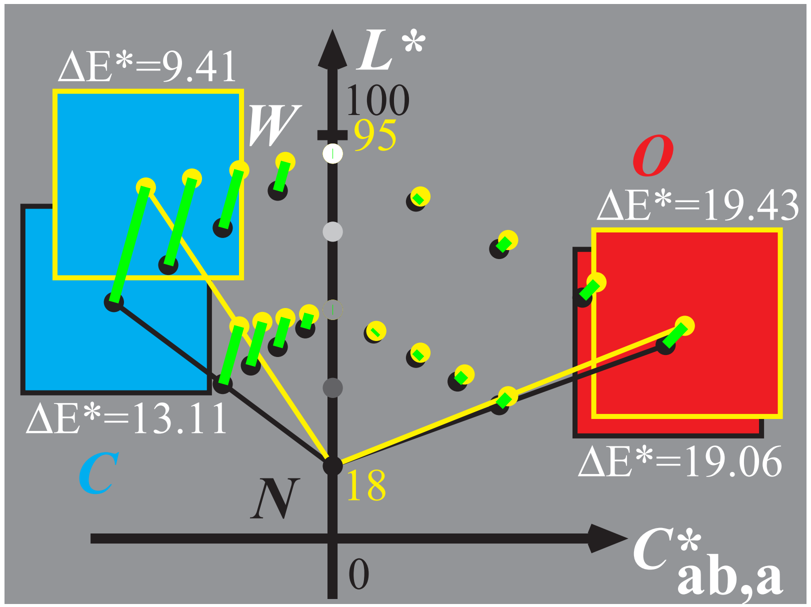
In Fig. 3 for the *rgb* input data 0 0 1 often the Violet blue *V* is produced. This colour has a CIELAB hue angle h_{ab}=305 degree instead of h_{ab}=272 degree for elementary Blue *B* for both the display and print output. The visual standard deviation of *B* is 4 degree according to CIE R1-47 and therefore the output no. 15 is reddish blue and no. 13 may be Blue *B*.



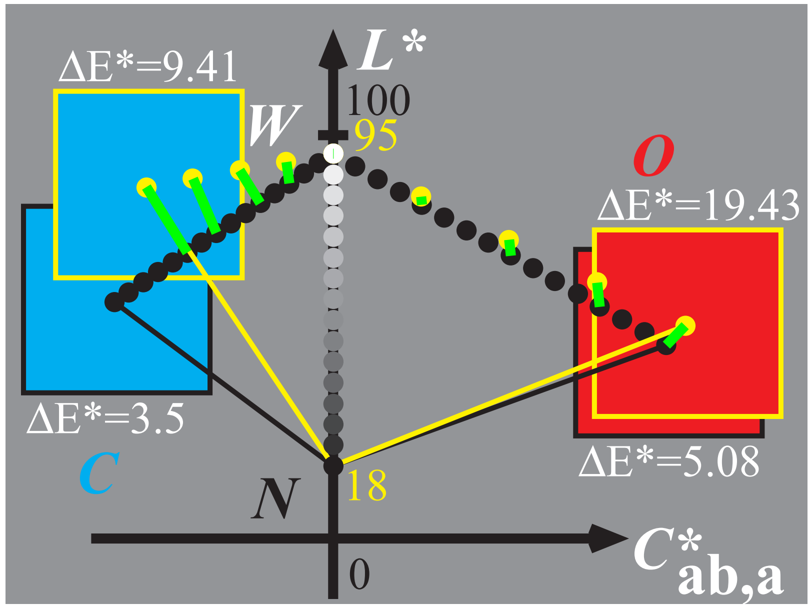
JE450−3N



JE450−7N



ZE421−4



ZE421−5

Fig. 3: Hues; softcopy - hardcopy “matching” and “affine” transfer

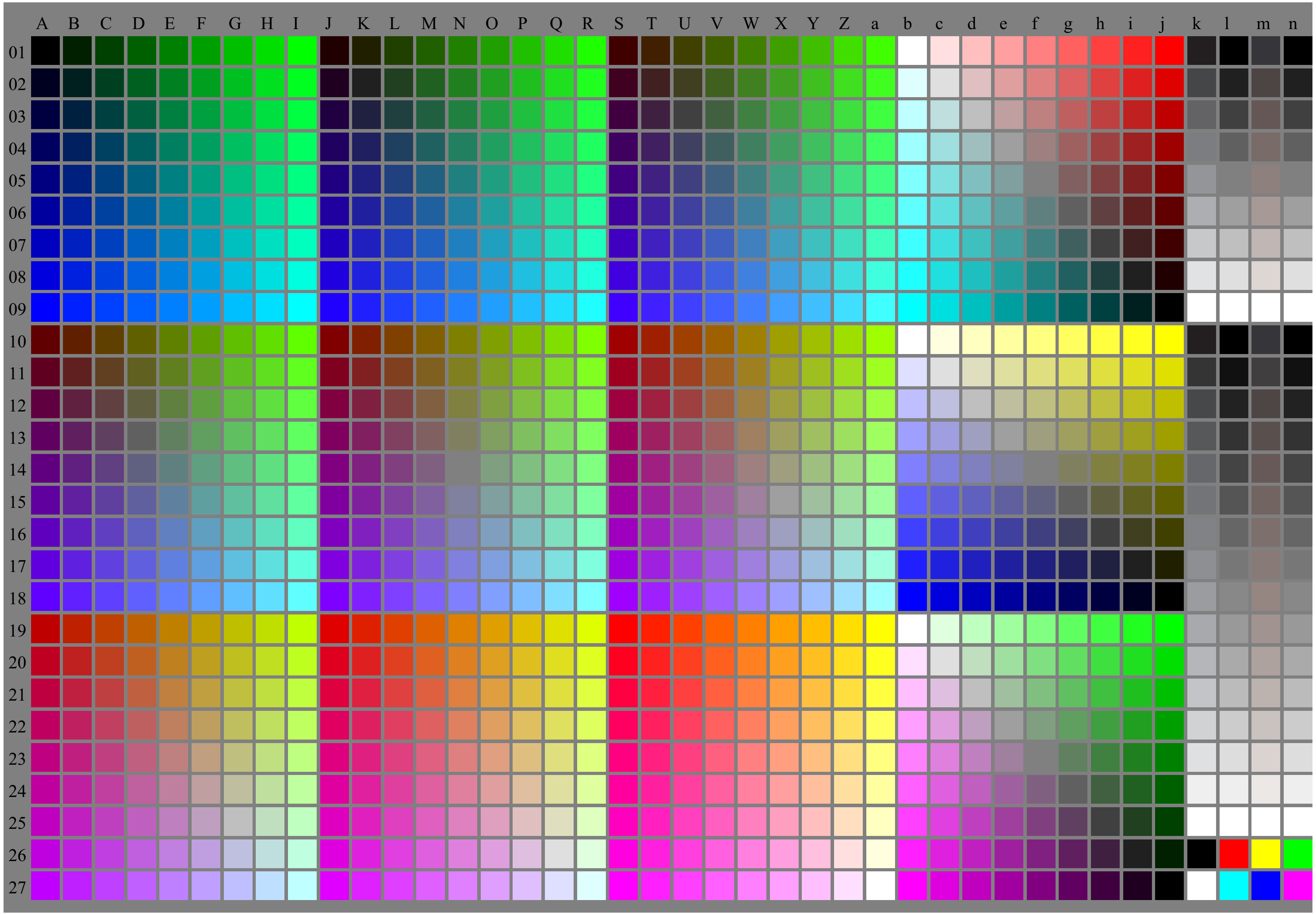
Fig. 3 shows the device hues *OYLCVM* and the elementary hues *RJGB* in the adapted CIELAB (a^*_a, b^*_a) diagram. The softcopy - hardcopy comparison can use the “matching” criteria “equal colour” or the “affine” criteria “equally spaced output series” and in addition “use the full device gamut” in the hue triangle “most chromatic colour - White - Black”

For all displays and in any hue plane there is a real triangle in the linear CIEXYZ colour space and also approximately in the nonlinear CIELAB colour space, at least for the series “Black - most chromatic Colour”. This is similar for (raster) laser printers. So we can describe the series *N-O* by a coordinate o^* and the series *N-R* by the coordinate r^* ($0 <= o^*, r^* <= 1$).

There is a trend in modern colour management according to ISO 15076-1 that the hue remains equal. The “affine” output is possible and often preferred which has for example the following advantages:

1. use of the full gamut of the output device
2. equal spacing of the output colour series
3. no clipping and loose of information which leads to a “trusted” output.

However, the CIELAB L^* and C^*_{ab} data are different on different devices.



IE000−7N, Test chart G with 40x27=1080 colours; digital equidistant 9 or 16 step colour scales; Colour data in column (A−n): **rgb (A−j, n), 000n (k), w (l), nnn0 (m)**, 5,4mm x 5,4mm, Page 1/1

Fig. 4: 1080 *rgb* input colours with 9x9x9 step series used for a standard *sRGB* display output with no luminance reflections.

Interpretation *rgb* –> *olv and CIELAB data of a 48 step device hue circle**
for a sRGB display with the luminance reflection L_r=0% compared to the white reference (100%)
48 step device hue circle with six device hues *OYLCVM*: $h_{ab,a}$ = 40.0 , 102.8 , 136.0 , 196.3 , 306.2 , 328.2
Comparison with four elementary hues *RJGB*: $h_{ab,a}$ = 25.4 , 92.3 , 162.2 , 271.7

Code	L*	a*a	b*a	C*ab	hab,a	rgb –> olv*		Code	L*	a*a	b*a	C*ab	hab,a	rgb –> olv*	
o00y=O	50.4	76.9	64.5	100.4	**40.0**	**1.00 0.00 0.00**		*c00v=C*	86.8	−46.1	−13.5	48.1	**196.3**	**0.00 1.00 1.00**	
o12y	51.5	73.9	64.9	98.3	**41.3**	**1.00 0.12 0.00**		*c12v*	77.9	−32.3	−27.0	42.1	**219.8**	**0.00 0.87 1.00**	
o25y	54.0	66.7	65.9	93.8	**44.6**	**1.00 0.25 0.00**		*c25v*	69.1	−17.0	−40.7	44.1	**247.2**	**0.00 0.75 1.00**	
o37y	58.2	55.4	67.9	87.7	**50.7**	**1.00 0.37 0.00**		*c37v*	60.3	−0.1	−54.6	54.6	**269.8**	**0.00 0.62 1.00**	B
o50y	63.6	41.3	71.0	82.2	**59.7**	**1.00 0.50 0.00**		*c50v*	51.7	18.3	−68.3	70.7	**285.0**	**0.00 0.50 1.00**	
o62y	70.1	25.7	75.0	79.3	**71.0**	**1.00 0.62 0.00**		*c62v*	43.8	37.6	−81.2	89.5	**294.8**	**0.00 0.37 1.00**	
o75y	77.2	9.8	79.7	80.4	**82.9**	**1.00 0.75 0.00**	J	*c75v*	37.1	55.9	−92.3	107.9	**301.1**	**0.00 0.25 1.00**	
o87y	84.8	−5.7	85.0	85.2	**93.8**	**1.00 0.87 0.00**		*c87v*	32.4	69.5	−100.0	121.8	**304.8**	**0.00 0.12 1.00**	
y00l=Y	92.6	−20.7	90.7	93.0	**102.8**	**1.00 1.00 0.00**		*v00m=V*	30.3	76.0	−103.5	128.5	**306.2**	**0.00 0.00 1.00**	
y12l	90.4	−33.1	88.1	94.1	**110.5**	**0.87 1.00 0.00**		*v12m*	31.0	76.2	−102.4	127.7	**306.6**	**0.12 0.00 1.00**	
y25l	88.5	−44.9	85.8	96.8	**117.6**	**0.75 1.00 0.00**		*v25m*	32.6	76.8	−99.8	125.9	**307.5**	**0.25 0.00 1.00**	
y37l	86.9	−55.8	83.9	100.7	**123.6**	**0.62 1.00 0.00**		*v37m*	35.1	77.9	−95.5	123.3	**309.2**	**0.37 0.00 1.00**	
y50l	85.7	−65.2	82.4	105.1	**128.3**	**0.50 1.00 0.00**		*v50m*	38.5	79.8	−89.7	120.0	**311.6**	**0.50 0.00 1.00**	
y62l	84.7	−72.8	81.2	109.1	**131.8**	**0.37 1.00 0.00**		*v62m*	42.7	82.5	−82.7	116.8	**314.8**	**0.62 0.00 1.00**	
y75l	84.1	−78.2	80.5	112.2	**134.1**	**0.25 1.00 0.00**		*v75m*	47.2	85.8	−75.1	114.0	**318.8**	**0.75 0.00 1.00**	
y87l	83.7	−81.4	80.0	114.2	**135.5**	**0.12 1.00 0.00**		*v87m*	52.1	89.8	−66.9	112.0	**323.3**	**0.87 0.00 1.00**	
l00c=L	83.6	−82.7	79.8	115.0	**136.0**	**0.00 1.00 0.00**		*m00o=M*	57.2	94.3	−58.4	110.9	**328.2**	**1.00 0.00 1.00**	
l12c	83.6	−82.1	76.6	112.3	**137.0**	**0.00 1.00 0.12**		*m12o*	55.6	90.3	−43.9	100.4	**334.0**	**1.00 0.00 0.87**	
l25c	83.8	−80.5	69.1	106.1	**139.3**	**0.00 1.00 0.25**		*m25o*	54.2	86.7	−28.6	91.3	**341.6**	**1.00 0.00 0.75**	
l37c	84.0	−77.8	58.1	97.1	**143.2**	**0.00 1.00 0.37**		*m37o*	53.0	83.6	−12.6	84.6	**351.4**	**1.00 0.00 0.62**	
l50c	84.3	−73.7	44.9	86.4	**148.6**	**0.00 1.00 0.50**		*m50o*	52.0	81.1	4.1	81.2	**2.9**	**1.00 0.00 0.50**	
l62c	84.7	−68.5	30.6	75.0	**155.8**	**0.00 1.00 0.62**	G	*m62o*	51.3	79.2	21.6	82.1	**15.2**	**1.00 0.00 0.37**	R
l75c	85.3	−62.0	15.9	64.0	**165.6**	**0.00 1.00 0.75**		*m75o*	50.8	77.9	39.2	87.2	**26.7**	**1.00 0.00 0.25**	
l87c	86.0	−54.5	1.0	54.5	**178.8**	**0.00 1.00 0.87**		*m87o*	50.6	77.2	54.9	94.8	**35.4**	**1.00 0.00 0.12**	

KE200−3N, , Page 4 /11, LAB*la0, adapted=not adapted

Fig. 5: Interpretation *rgb* as *olv data and adapted CIELAB data of a 48 step device hue circle for the standard *sRGB* display (L_r=0%)**

Fig. 4 shows 1080 *rgb* input colours with 9x9x9 step colour series used for a standard *sRGB* display output with no luminance reflection (L_r=0%) of the display. This chart is usually used for visual assessment. For measurement in the dark room the following digital *PDF*-file produces 1080 pages, and the same colours as in Fig. 4 and one by one, see

http://130.149.60.45/~farbmetrik/IE31/IE31L0NP.PDF

Fig. 5 shows the interpretation of the *rgb* input data as *olv** input data (notation *rgb -> olv**) and the adapted CIELAB data of a 48 step device hue circle for the standard *sRGB* display (L_r=0%).

For example the first 9 colours between the colours *O* and *Y* have the *rgb* values between 1 0 0 and 1 1 0 in 9 steps. In Fig. 4 this is the 9 step series located between the positions 19S and 19a.

In Fig. 5 the location of the elementary colours *RJGB* is shown by 4 chromatic lines. For example the elementary Blue *B* is located away from the device hue Violet blue *V* of the *sRGB* device.

In the following the *rgb* input data are interpreted as elementary *rgb** data. Then the output colours have the intended hues of CIE R1-47.

16 Step Elementary Color Circle: *olv**, *rgb**, CIE Data for a *sRGB* Display in Offices

rgb −> rgb* and CIE data of a elementary hue circle according to CIE R1-47:2009 for sRGB display L_r=0%

16 step elementary hue circle with hues: $h_{ab,a}$ = 25.4 , 92.3 , 162.2 , 271.7

Code	L^*_a	a^*_a	b^*_a	$C^*_{ab,a}$	h_{ab}	rgb −> rgb*
r00j=R	50.9	78.1	37.1	86.4	**25.4**	**1.00 0.00 0.00**
r25j	52.2	71.9	65.2	97.1	**42.1**	**1.00 0.25 0.00**
r50j	63.1	42.7	70.7	82.6	**58.8**	**1.00 0.50 0.00**
r75j	72.7	19.7	76.7	79.2	**75.5**	**1.00 0.75 0.00**
j00g=J	83.6	−3.4	84.2	84.3	**92.3**	**1.00 1.00 0.00**
j25g	90.8	−31.8	88.5	94.0	**109.7**	**0.75 1.00 0.00**
j50g	85.9	−63.0	82.7	104.0	**127.2**	**0.50 1.00 0.00**
j75g	84.1	−76.6	54.1	93.8	**144.7**	**0.25 1.00 0.00**
g00b=G	85.1	−64.2	20.5	67.4	**162.2**	**0.00 1.00 0.00**
g25b	87.1	−49.5	−8.4	50.2	**189.6**	**0.00 1.00 0.50**
g50b	79.1	−33.9	−25.6	42.5	**217.0**	**0.00 1.00 1.00**
g75b	70.1	−18.8	−39.1	43.4	**244.2**	**0.00 0.50 1.00**
b00r=B	59.3	1.7	−56.0	56.1	**271.7**	**0.00 0.00 1.00**
b25r	38.3	52.5	−90.3	104.4	**300.1**	**0.50 0.00 1.00**
b50r	57.3	94.2	−57.4	110.4	**328.6**	**1.00 0.00 1.00**
b75r	52.5	82.3	−4.2	82.4	**357.0**	**1.00 0.00 0.50**

5 step equidistant grey scale: L^* = 0.0 , 23.8 , 47.7 , 71.5 , 95.4

Code	L^*_a	a^*_a	b^*_a	$C^*_{ab,a}$	h_{ab}	rgb −> rgb*
n000w=N	**0.0**	0.0	0.0	0.0	0.0	**0.00 0.00 0.00**
n025w	**23.8**	0.0	0.0	0.0	325.3	**0.25 0.25 0.25**
n050w	**47.7**	0.0	0.0	0.0	325.1	**0.50 0.50 0.50**
n075w	**71.4**	0.0	0.0	0.0	325.1	**0.75 0.75 0.75**
n100w=W	**95.4**	0.0	0.0	0.0	0.0	**1.00 1.00 1.00**

KE170−3N, LAB*la0, adapted=not adapted

rgb −> rgb* and CIE data of a elementary hue circle according to CIE R1-47:2009 for sRGB display L_r=0%

3 colours of the elementary hues RJGB: $h_{ab,a}$ = 25.4 , 92.3 , 162.2 , 271.7

Code	L^*_a	a^*_a	b^*_a	$C^*_{ab,a}$	h_{ab}	rgb −> rgb*
r00j=R	50.9	78.1	37.1	86.4	**25.4**	**1.00 0.00 0.00**
0,5(R+N)	25.4	39.0	18.5	43.2	**25.4**	**0.50 0.00 0.00**
0,5(R+W)	73.1	39.0	18.5	43.2	**25.4**	**1.00 0.50 0.50**
j00g=J	83.6	−3.4	84.2	84.3	**92.3**	**1.00 1.00 0.00**
0,5(J+N)	41.8	−1.7	42.1	42.1	**92.3**	**0.50 0.50 0.00**
0,5(J+W)	89.5	−1.7	42.1	42.1	**92.3**	**1.00 1.00 0.50**
g00b=G	85.1	−64.2	20.5	67.4	**162.2**	**0.00 1.00 0.00**
0,5(G+N)	42.5	−32.1	10.2	33.7	**162.2**	**0.00 0.50 0.00**
0,5(G+W)	90.2	−32.1	10.2	33.7	**162.2**	**0.50 1.00 0.50**
b00r=B	59.3	1.7	−56.0	56.1	**271.7**	**0.00 0.00 1.00**
0,5(B+N)	29.6	0.8	−28.0	28.0	**271.7**	**0.00 0.00 0.50**
0,5(B+W)	77.4	0.8	−28.0	28.0	**271.7**	**0.50 0.50 1.00**

5 step equidistant grey scale: L^* = 0.0 , 23.8 , 47.7 , 71.5 , 95.4

Code	L^*_a	a^*_a	b^*_a	$C^*_{ab,a}$	h_{ab}	rgb −> rgb*
n000w=N	**0.0**	0.0	0.0	0.0	0.0	**0.00 0.00 0.00**
n025w	**23.8**	0.0	0.0	0.0	325.3	**0.25 0.25 0.25**
n050w	**47.7**	0.0	0.0	0.0	325.1	**0.50 0.50 0.50**
n075w	**71.4**	0.0	0.0	0.0	325.1	**0.75 0.75 0.75**
n100w=W	**95.4**	0.0	0.0	0.0	0.0	**1.00 1.00 1.00**

KE170−4N, LAB*la0, adapted=not adapted

Fig. 6: *rgb data and *adapted* CIELAB data of a 16 step hue circle and a 5 step grey scale for a standard *sRGB* display (L_r=0%)**

***rgb* –> *rgb** and CIE data of a elementary hue circle according to CIE R1-47:2009 for sRGB display L_r=2,5%**

16 step elementary hue circle with hues: $h_{ab,a}$ = 25.4 , 92.3 , 162.2 , 271.7

Code	L^*_a	a^*_a	b^*_a	$C^*_{ab,a}$	h_{ab}	*rgb –> rgb**
r00j=R	53.0	72.6	34.5	80.4	**25.4**	**1.00 0.00 0.00**
r25j	57.1	59.5	53.9	80.3	**42.1**	**1.00 0.25 0.00**
r50j	65.7	37.3	61.7	72.1	**58.8**	**1.00 0.50 0.00**
r75j	74.0	17.7	69.0	71.2	**75.6**	**1.00 0.75 0.00**
j00g=J	83.8	−3.0	77.4	77.5	**92.2**	**1.00 1.00 0.00**
j25g	91.2	−29.9	83.0	88.2	**109.8**	**0.75 1.00 0.00**
j50g	86.5	−58.7	77.1	96.9	**127.2**	**0.50 1.00 0.00**
j75g	84.4	−73.5	51.9	90.0	**144.7**	**0.25 1.00 0.00**
g00b=G	85.4	−61.5	19.7	64.6	**162.1**	**0.00 1.00 0.00**
g25b	87.4	−47.7	−8.0	48.4	**189.5**	**0.00 1.00 0.50**
g50b	79.7	−32.6	−24.6	40.8	**217.0**	**0.00 1.00 1.00**
g75b	71.1	−18.0	−37.5	41.6	**244.3**	**0.00 0.50 1.00**
b00r=B	60.9	1.6	−53.5	53.6	**271.7**	**0.00 0.00 1.00**
b25r	40.5	50.3	−86.6	100.2	**300.1**	**0.50 0.00 1.00**
b50r	59.0	89.1	−54.4	104.4	**328.6**	**1.00 0.00 1.00**
b75r	54.5	77.1	−4.0	77.2	**357.0**	**1.00 0.00 0.50**

5 step equidistant grey scale: L^* = 18.0 , 37.3 , 56.7 , 76.0 , 95.4

Code	L^*_a	a^*_a	b^*_a	$C^*_{ab,a}$	h_{ab}	*rgb –> rgb**
n000w=N	**18.0**	0.0	0.0	0.0	0.0	**0.00 0.00 0.00**
n025w	**37.3**	0.0	0.0	0.0	325.3	**0.25 0.25 0.25**
n050w	**56.7**	0.0	0.0	0.0	324.8	**0.50 0.50 0.50**
n075w	**76.1**	0.0	0.0	0.0	323.7	**0.75 0.75 0.75**
n100w=W	**95.4**	0.0	0.0	0.0	0.0	**1.00 1.00 1.00**

KE171−7N, LAB*la3, adapted=not adapted

***rgb* –> *rgb** and CIE data of a elementary hue circle according to CIE R1-47:2009 for sRGB display L_r=2,5%**

3 colours of the elementary hues RJGB: $h_{ab,a}$ = 25.4 , 92.3 , 162.2 , 271.7

Code	L^*_a	a^*_a	b^*_a	$C^*_{ab,a}$	h_{ab}	*rgb –> rgb**
r00j=R	53.0	72.6	34.5	80.4	**25.4**	**1.00 0.00 0.00**
0,5(R+N)	35.5	36.3	17.2	40.2	**25.4**	**0.50 0.00 0.00**
0,5(R+W)	74.2	36.3	17.2	40.2	**25.4**	**1.00 0.50 0.50**
j00g=J	83.8	−3.0	77.4	77.5	**92.2**	**1.00 1.00 0.00**
0,5(J+N)	50.9	−1.5	38.7	38.7	**92.2**	**0.50 0.50 0.00**
0,5(J+W)	89.6	−1.5	38.7	38.7	**92.2**	**1.00 1.00 0.50**
g00b=G	85.4	−61.5	19.7	64.6	**162.1**	**0.00 1.00 0.00**
0,5(G+N)	51.7	−30.7	9.8	32.3	**162.1**	**0.00 0.50 0.00**
0,5(G+W)	90.4	−30.7	9.8	32.3	**162.1**	**0.50 1.00 0.50**
b00r=B	60.9	1.6	−53.5	53.6	**271.7**	**0.00 0.00 1.00**
0,5(B+N)	39.4	0.8	−26.7	26.8	**271.7**	**0.00 0.00 0.50**
0,5(B+W)	78.1	0.8	−26.7	26.8	**271.7**	**0.50 0.50 1.00**

5 step equidistant grey scale: L^* = 18.0 , 37.3 , 56.7 , 76.0 , 95.4

Code	L^*_a	a^*_a	b^*_a	$C^*_{ab,a}$	h_{ab}	*rgb –> rgb**
n000w=N	**18.0**	0.0	0.0	0.0	0.0	**0.00 0.00 0.00**
n025w	**37.3**	0.0	0.0	0.0	325.3	**0.25 0.25 0.25**
n050w	**56.7**	0.0	0.0	0.0	324.8	**0.50 0.50 0.50**
n075w	**76.1**	0.0	0.0	0.0	323.7	**0.75 0.75 0.75**
n100w=W	**95.4**	0.0	0.0	0.0	0.0	**1.00 1.00 1.00**

KE171−8N, LAB*la3, adapted=not adapted

Fig. 7: *rgb** data and adapted CIELAB data of a 16 step hue circle and a 5 step grey scale for a standard *sRGB* display (L_r=2,5%)

rgb –> rgb* and CIE data of a elementary hue circle according to CIE R1-47:2009 for sRGB display L_r=2,5%

3 colours of the elementary hues RJGB: $h_{ab,a}$ = 25.4 , 92.3 , 162.2 , 271.7

Code	L^*_a	a^*_a	b^*_a	$C^*_{ab,a}$	h_{ab}	rgb –> rgb*
r00j=R	53.0	72.6	34.5	80.4	**25.4**	**1.00 0.00 0.00**
0,5(R+N)	35.5	36.3	17.2	40.2	**25.4**	**0.50 0.00 0.00**
0,5(R+W)	74.2	36.3	17.2	40.2	**25.4**	**1.00 0.50 0.50**
j00g=J	83.8	−3.0	77.4	77.5	**92.2**	**1.00 1.00 0.00**
0,5(J+N)	50.9	−1.5	38.7	38.7	**92.2**	**0.50 0.50 0.00**
0,5(J+W)	89.6	−1.5	38.7	38.7	**92.2**	**1.00 1.00 0.50**
g00b=G	85.4	−61.5	19.7	64.6	**162.1**	**0.00 1.00 0.00**
0,5(G+N)	51.7	−30.7	9.8	32.3	**162.1**	**0.00 0.50 0.00**
0,5(G+W)	90.4	−30.7	9.8	32.3	**162.1**	**0.50 1.00 0.50**
b00r=B	60.9	1.6	−53.5	53.6	**271.7**	**0.00 0.00 1.00**
0,5(B+N)	39.4	0.8	−26.7	26.8	**271.7**	**0.00 0.00 0.50**
0,5(B+W)	78.1	0.8	−26.7	26.8	**271.7**	**0.50 0.50 1.00**

5 step equidistant grey scale: L^* = 18.0 , 37.3 , 56.7 , 76.0 , 95.4

Code	L^*_a	a^*_a	b^*_a	$C^*_{ab,a}$	h_{ab}	rgb –> rgb*
n000w=N	**18.0**	0.0	0.0	0.0	0.0	**0.00 0.00 0.00**
n025w	**37.3**	0.0	0.0	0.0	325.3	**0.25 0.25 0.25**
n050w	**56.7**	0.0	0.0	0.0	324.8	**0.50 0.50 0.50**
n075w	**76.1**	0.0	0.0	0.0	323.7	**0.75 0.75 0.75**
n100w=W	**95.4**	0.0	0.0	0.0	0.0	**1.00 1.00 1.00**

KE171−8N, LAB*la3, adapted=not adapted

rgb –> rgb* and CIE data of a elementary hue circle according to CIE R1-47:2009 for offset print

3 colours of the elementary hues RJGB: h_{ab} = 25.4 , 92.3 , 162.2 , 271.7

Code	L^*_a	a^*_a	b^*_a	$C^*_{ab,a}$	h_{ab}	rgb –> rgb*
r00j=R	48.7	66.7	31.8	73.9	**25.4**	**1.00 0.00 0.00**
0,5(R+N)	35.5	33.3	15.9	36.9	**25.4**	**0.50 0.00 0.00**
0,5(R+W)	72.5	33.3	15.9	36.9	**25.4**	**1.00 0.50 0.50**
j00g=J	86.1	−3.3	83.2	83.3	**92.3**	**1.00 1.00 0.00**
0,5(J+N)	54.2	−1.6	41.6	41.6	**92.3**	**0.50 0.50 0.00**
0,5(J+W)	91.2	−1.6	41.6	41.6	**92.3**	**1.00 1.00 0.50**
g00b=G	56.9	−61.5	19.6	64.5	**162.2**	**0.00 1.00 0.00**
0,5(G+N)	39.6	−30.7	9.8	32.2	**162.2**	**0.00 0.50 0.00**
0,5(G+W)	76.6	−30.7	9.8	32.2	**162.2**	**0.50 1.00 0.50**
b00r=B	41.2	1.3	−45.0	45.0	**271.7**	**0.00 0.00 1.00**
0,5(B+N)	31.7	0.6	−22.5	22.5	**271.7**	**0.00 0.00 0.50**
0,5(B+W)	68.8	0.6	−22.5	22.5	**271.7**	**0.50 0.50 1.00**

5 step equidistant grey scale: L^* = 22.2 , 40.7 , 59.3 , 77.8 , 96.3

Code	L^*_a	a^*_a	b^*_a	$C^*_{ab,a}$	h_{ab}	rgb –> rgb*
n000w=N	**22.5**	0.0	0.0	0.0	37.9	**0.00 0.00 0.00**
n025w	**40.8**	−0.3	−1.4	1.4	256.8	**0.25 0.25 0.25**
n050w	**59.2**	−0.3	−1.8	1.8	258.1	**0.50 0.50 0.50**
n075w	**77.8**	−0.2	−1.4	1.4	259.2	**0.75 0.75 0.75**
n100w=W	**96.4**	0.0	0.0	0.0	100.0	**1.00 1.00 1.00**

KE110−8N, Offset print, model separation cmyn6*

Fig. 8: *rgb data and adapted CIELAB data of 4 elementary hues and a 5 step grey scale for output of a *sRGB* device and of offset print**

Fig. 6 and 7 show *rgb** data and adapted CIELAB data of a 16 step elementary hue circle and a 5 step grey scale, a 4 step elementary hue and mixture colour between *RJGB* and *N*, *W*.

The data are given for a standard *sRGB* display for the luminance reflection L_r=0% in Fig. 6 and for L_r=2,5% in Fig. 7.

There is a reduction of the CIELAB lightness range ΔL^* from L^*=96 to L^*=74. This lightness range reduction to 77% by the luminance reflection L_r=2,5% reduces the *JB*- and *RG*-chroma by about the same amount.

Therefore the **colour gamut is reduced to approximately 50%** ($0,77^3$100%) for L_r=2,5% instead of L_r=0%. This is a real problem for all application in offices. In ISO TC130 “Graphic Technology” this problem is avoided by reducing the ambient illuminance to about 50 lux which reduces the luminance reflection by a factor 10 compared to offices and increases the colour gamut by a factor 2 compared to the office viewing condition. This larger gamut of the display output in dim ambient lighting and the use of wide gamut displays is the possibility for TC130 to match most of the colours of a printer or offset print in advance for output.

Fig. 8 shows the *rgb** data and *adapted* CIELAB data

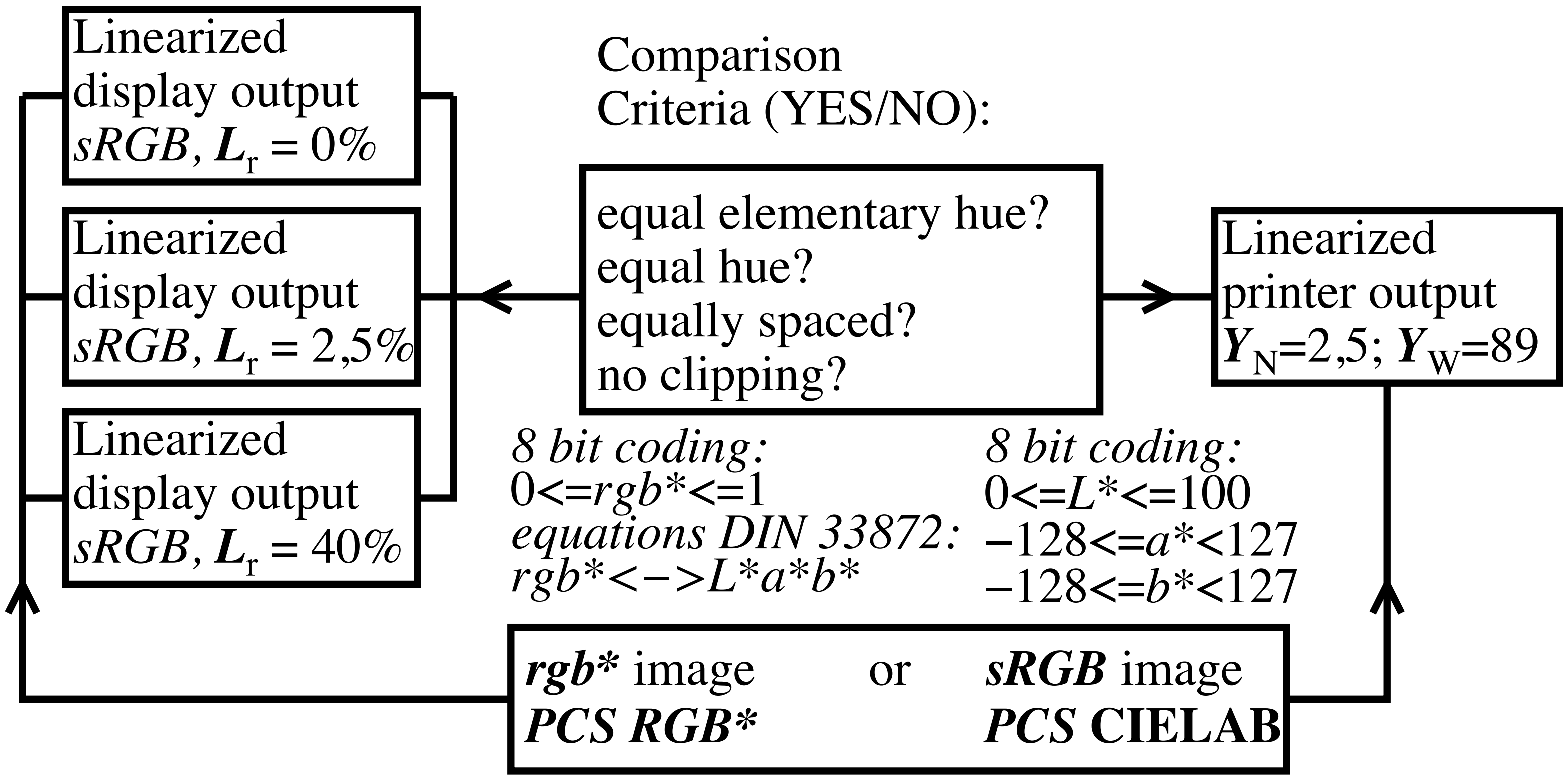
- of 4 elementary colours *RJGB*
- mixture colours of *RJGB* and White *W*, and Black *N*
- 5 step equally spaced grey scale between *N* and *W*

The output is on a *sRGB* device for L_r=2,5% according to IEC 61966-2-1 *(left)*, and in standard offset print on standard offset paper according to ISO/IEC 15775 *(right)*.

As intended the CIELAB hue angles are the same for both the *sRGB* device and the offset print.

The largest differences appear in CIELAB lightness *L** for Green *G* and Blue *B*.

For the colours *G* and *B* the lightness *L** is larger on the standard *sRGB* display compared to standard offset print.



Luminance reflection L_r	***RGB**coding efficiency** e_{3D}	**CIELAB Lightness** L^*_N	L^*_W	**relative Lightness** $l_r = (L^*_W - L^*_N)/95$	**3D-Colour Gamut size** $g_{3D} = [\, l_r]^3$	**CIE coding efficiency** e_{3D}(CIE 168)
0%	1,00	0	95	1,00	1,00	0,20 (*sRGB*)
2,5%	1,00	18	95	0,81	0,53	0,10
40%	1,00	70	95	0,26	0,02	0,004

KE231–3N

Fig. 9: *RGB coding efficiency with a *PCS RGB** instead of *CIELAB***

Fig 9 shows the *RGB** coding efficiency with a *Profile Connection Space (PCS) RGB** instead of a *PCS CIELAB*. There are some technical data which change according to the luminance reflection L_r of the *sRGB* display.
For example the lightness range and the 3D-Colour Gamut size changes between the luminance reflection $L_r = 0\%$ in the dark room, $L_r = 2{,}5\%$ in the standard office room, and $L_r = 40\%$ for a data projector in a room with much daylight. All numbers are from ISO 9241-306.

Usually there is an 8bit-coding for all colours within a fixed CIELAB space, see the data range of the *PCS* CIELAB in Fig. 4 for all colour devices. All surface and display colours are within this CIELAB range.

The reduction of g_{3D} from 100% to 53% for office applications indicates that only 53% of the *PCS* CIELAB is filled. In addition CIE Publ.168 calculates in Table 2.1 that the *sRGB* data fill only 20% of the *PCS* CIELAB. Therefore the coding efficiency is only 10% for *sRGB* office applications.

A coding in relative *rgb** with a *PCS RGB** shows the maximum and equal efficiency for all luminance reflections. A *PCS RGB** is in the framework of *ICC* Colour management (ISO 15076-1) but not realized. Up to now there seem to be no plans for realization according to leading members of *ICC.*

A work around is output linearization of colour devices for *rgb** input. This technology trend is supported by new display devices. For example, the new ***RYGB*** colour display devices (2010) with **four** primaries according to the human visual system may support the following trend:

- ***rgb**** **data instead of** ***xRGB*** **data are send and used by the display.**
- **the manufacturer includes the transfer between** ***rgb**** **and his device primaries (3 to 6 up to now) within his display.**
- **the manufacturer includes the transfer for 8 luminance reflections** **L_r=0 to 40% according to ISO 9241-306 within his display.**
- **there is a hardware switch to choose one of 8 viewing conditions according to ISO 9142-306** (compare software solution in Annex D).

Summary

A method is given how to calculate many CIE data including CIELAB for a 16 step elementary hue circle on the standard *sRGB* display according to IEC 61966-2-1 with different luminance reflections L_r.

For this goal a 48 step device colour scale is used as start output which has 9 step colour series, for example between device Orange red *O* and device Yellow *Y*.

Linear relations between *rgb** data and CIELAB data define a device independent *RGB** system in hue.

The device independent *RGB** system is based on the human visual *elementary hue angles* in CIELAB defined in CIE R1-47:2009

This elementary *RGB** system may be used for many applications in image technology.

The *Relative Elementary Colour System RECS* shows about 2000 colour samples in standard offset print on standard offset paper according to ISO/IEC 5775. This System is based on a *16 step elementary hue circle*.