ISO-CIE trend for Color Output of equally spaced Color Series and Elementary Hues *RJGB* on Displays for Eight Ambient Reflections of ISO 9241-306:2008

Version 1.0, (32 pages, 350 KB), /CIE_ISCCG_10.PDF

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For recent publications of the TUB group see: http://130.149.60.45/~farbmetrik/XY91FEN.html

Introduction

The report CIE R1-47:2009 “Hue Angles of Elementary Colours” is used to define an *efficient* colour output for displays in offices. The output considers the eight luminance reflections compared to the white display luminance according to ISO 9241-306:2008

This paper defines an *efficient* description of the display gamut by *visual human rgb** coordinates. For example elementary Red *R* is defined by a visual criteria Red *R* as neither yellowish nor blueish.

Achromatic colours	**Elementary colours** **"*Neither-nor*"*-colours***	**Device colours** ***Television (TV), Print (PR) Photography (PH)***
five achromatic colours:	*four elementary colours:*	*six device 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

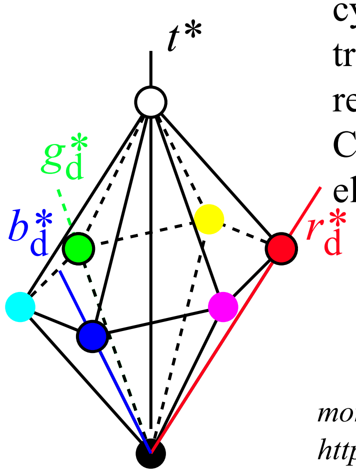
YE980–3

8 Device Colours in device (d) system

OYLCVM and NW

triangle system $\boldsymbol{rgb}^*_\mathrm{d}$

cylindric system *tch**
triangle lightness t^*
relative chroma c^*
CIELAB hue angle h_{ab}
elementary hue text u^*_d



more coordinates and relations:
http://www.ps.bam.de/33872E

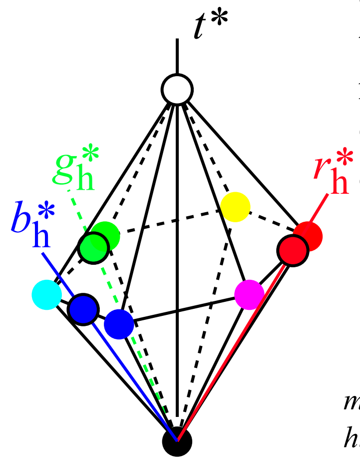
IE151-2N

8 Device Colours in elementary hue (h) system

OYLCVM and NW

triangle system $\boldsymbol{rgb}^*_\mathrm{h}$

cylindric system *tch**
triangle lightness t^*
relative chroma c^*
CIELAB hue angle h_{ab}
elementary hue text u^*_h



more coordinates and relations:
http://www.ps.bam.de/33872E

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Figure 1: Definition of device and elementary colours and systems

There are 6 chromatic device colours: ***OYLCVM*** (e. g. *L*=Leaf green)

There are 4 chromatic elementary colours: ***RJGB*** (e. g. *J*=Yellow)

In addition for the most chromatic colours of a device, one of the three coordinates *rgb** have the **value 1** and one other have the **value 0**.

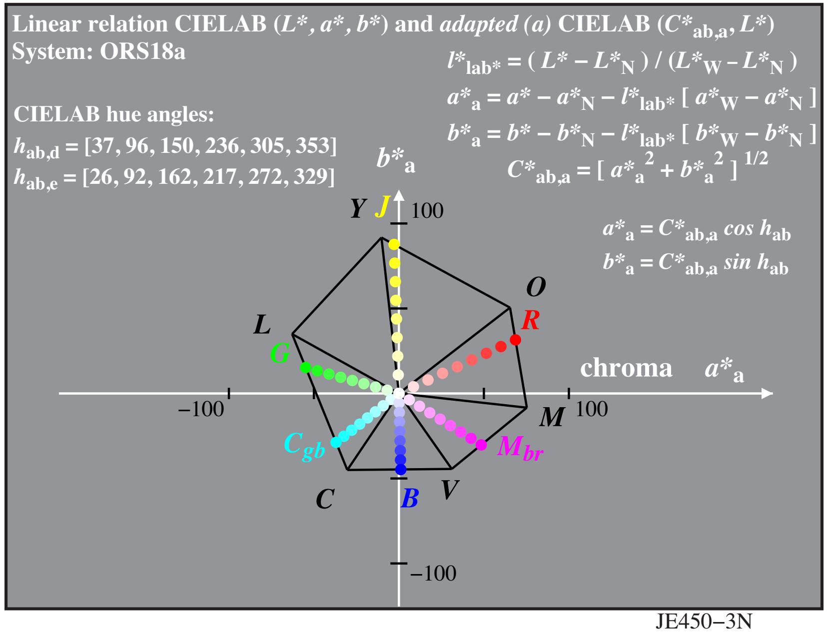
For example the yellow red colours have the values ***rgb*= 1 x 0*** with *x*=0 for elementary Red *R* and *x*=1 for elementary Yellow *J*.

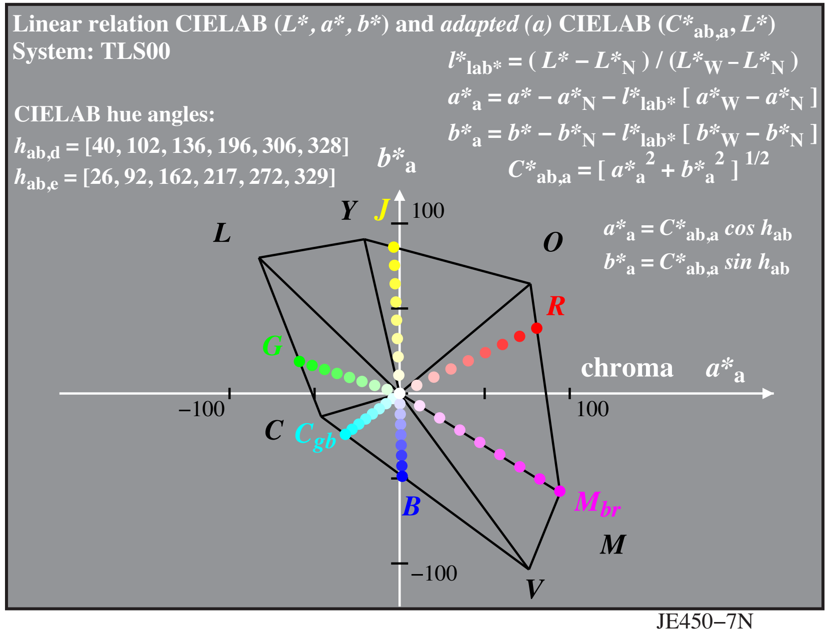
Therefore for all yellow red colours *x*-value is in the range 0<=*x*<=1.

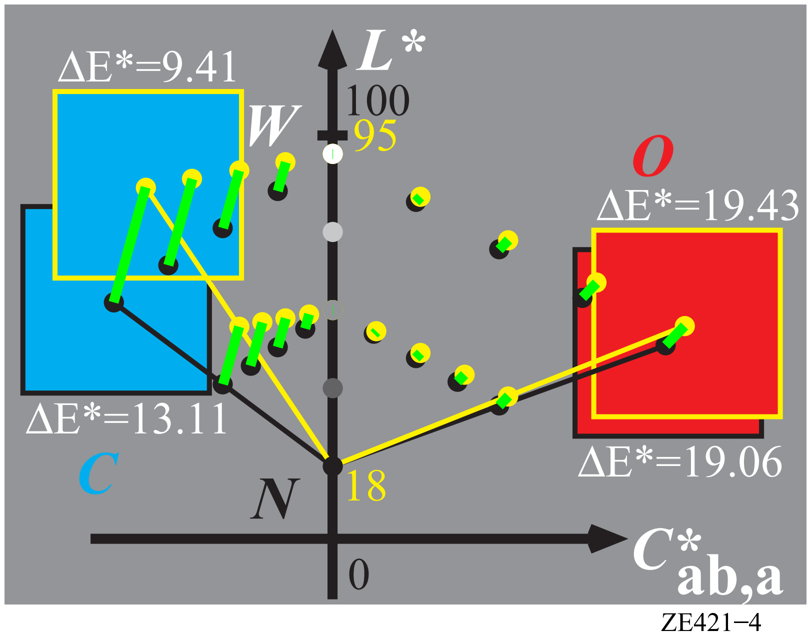
In the CIEXYZ colour space and in any hue plane any colour of a *display* is located exactly within a colour **triangle**.

The colours of this triangle are defined by the three colours Black *N*, most chromatic X, and White W.

In CIELAB colour space the three colours *N* - *X* - *W* are still approximately on a triangle for any CIELAB hue h_{ab} in any hue plane L^*, C^*_{ab}.







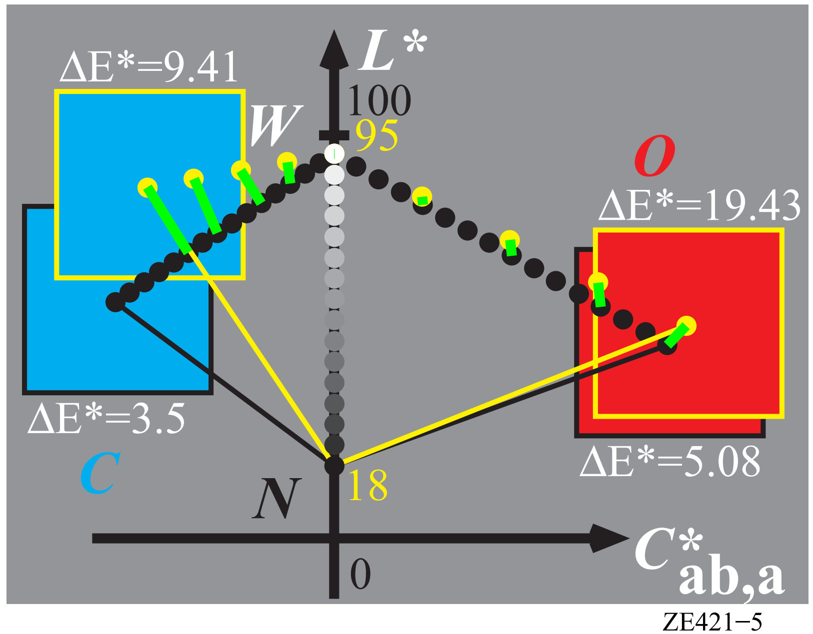


Figure 2: Hues; softcopy - hardcopy; matching and “affine” transfer

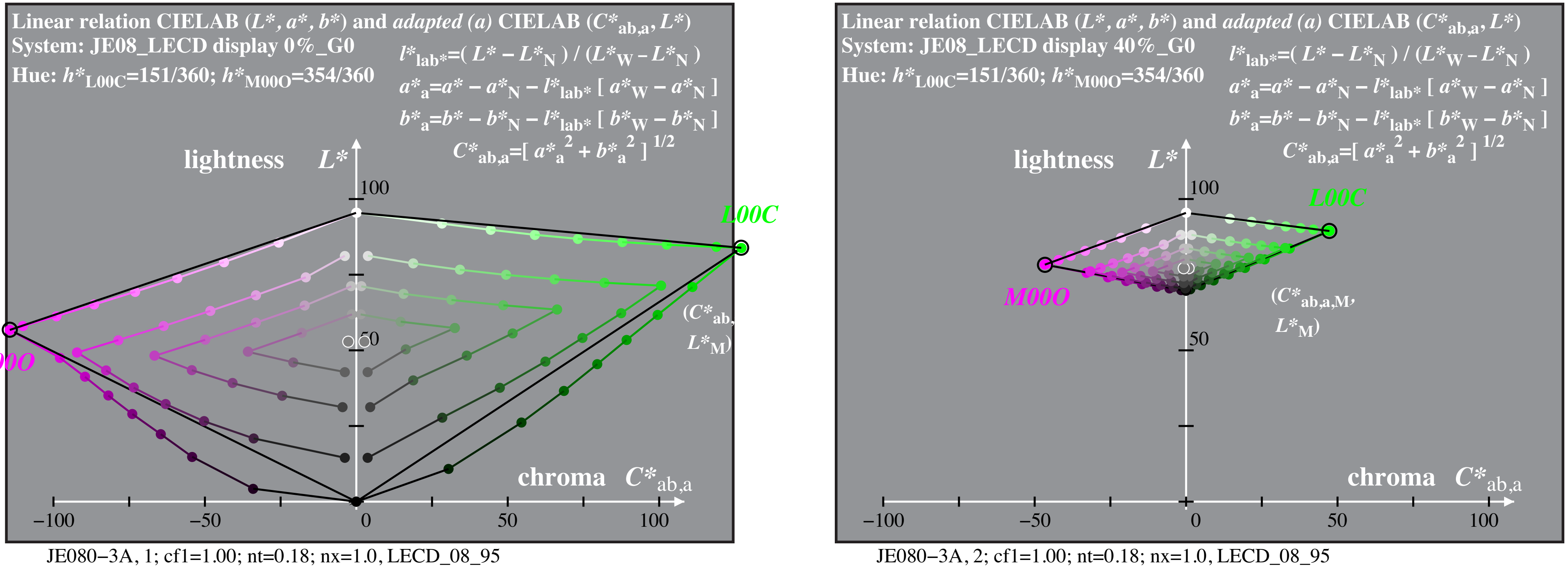
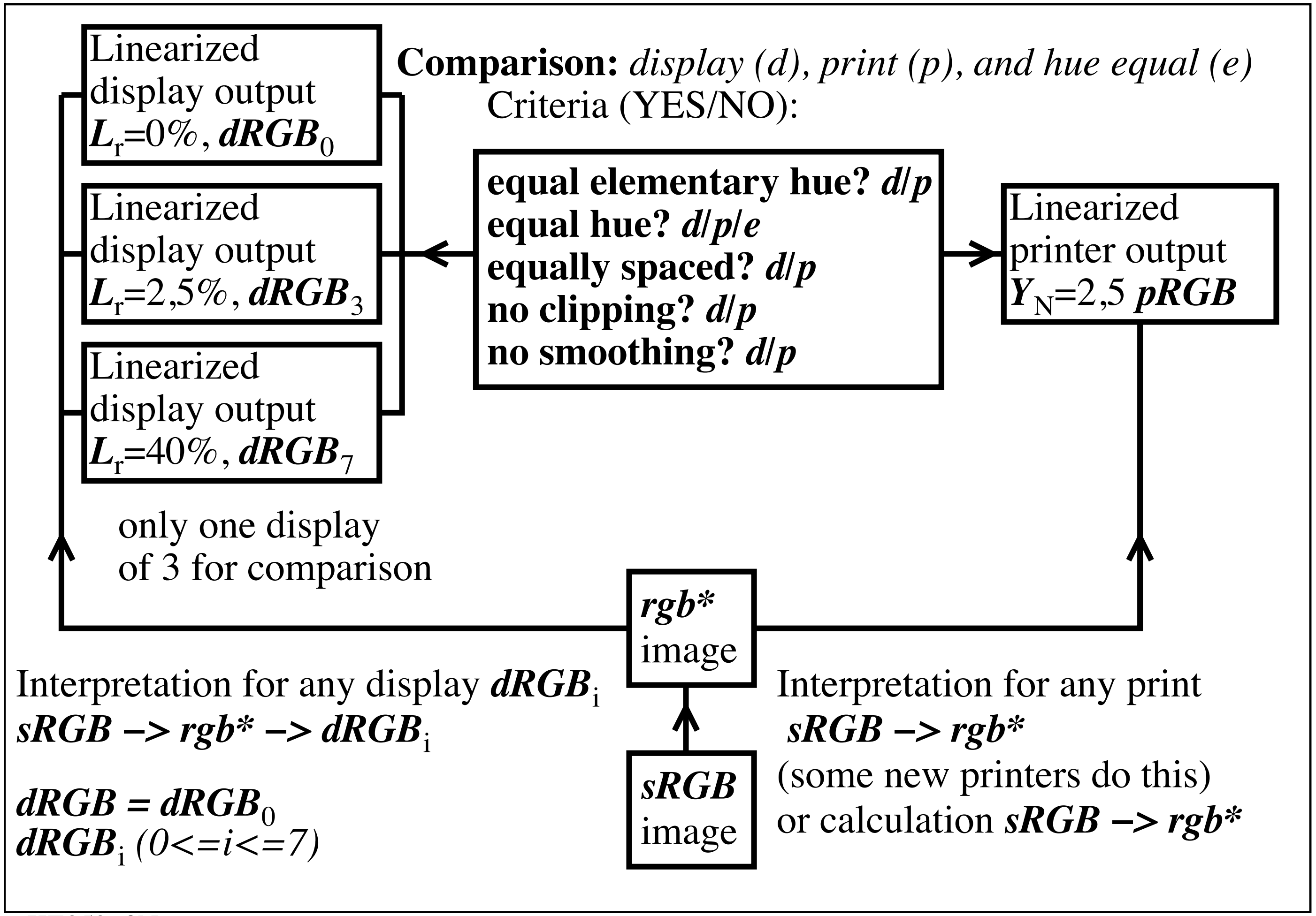


Figure 3: Output colours in (C^*_{ab}, L^*) for LECD with L_r=0 and 40%

Figure 3 shows the output colours in a (C^*_{ab}, L^*) hue plane for an LCD display with LED backlight and luminance reflections L_r=0% and L_r=40%.

There is a decrease of the grey and chromatic range to 30%. Therefore the 3D size (volume) of the output gamut reduces from 100% for L_r=0% to about 3% for L_r=40%. The last case may occur for a data projector and one may not see differences for up to 3 dark grey steps of 9 grey steps.



KE250–3N

Figure 4: *rgb* interpretation as elementary colours *rgb, device linearization, and comparison display and printer output**

The *rgb** data are used for linearization and this will produce on all devices the elementary and equal hues, equal spacing, and *no* clipping.

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

Code	L^*_a	a^*_a	b^*_a	$C^*_{ab,a}$	h_{ab}	*rgb –> rgb**
Red R of the elementary hues RJGB: $h_{ab,a}$ = 25.4 , 92.3 , 162.2 , 271.7						
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**
5 step equidistant grey scale: L^* = 0.0 , 23.8 , 47.7 , 71.5 , 95.4						
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**

KE310–4N, LAB*la0, adapted=not adapted

Figure 5: _rgb*_ and CIE data of elementary colour Red _R_ and mixtures with _W_ and _N_ for the standard _sRGB_$_0$ display with L_r=0%.

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

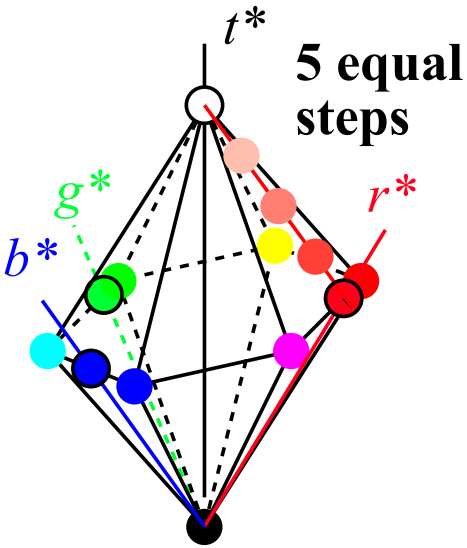
Code	L^*_a	a^*_a	b^*_a	$C^*_{ab,a}$	h_{ab}	*rgb* –> *rgb**
16 step elementary hue circle with hues: $h_{ab,a}$ = 25.4 , 92.3 , 162.2 , 271.7						
r00j=R	50.9	78.1	37.1	86.4	**25.4**	**1.00 0.00 0.00**
r25j	52.2	71.9	65.2	97.1	**42.1**	**1.00 0.25 0.00**
r50j	63.1	42.7	70.7	82.6	**58.8**	**1.00 0.50 0.00**
r75j	72.7	19.7	76.7	79.2	**75.5**	**1.00 0.75 0.00**
5 step equidistant grey scale: L^* = 0.0 , 23.8 , 47.7 , 71.5 , 95.4						
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**

KE310–3N, LAB*la0, adapted=not adapted

Figure 6: *rgb and CIE data of the elementary colour Red *R* and three mixtures with *J* for the standard *sRGB*$_3$ display with L_r=0%.**

For the colour output the CIELAB hue angles h_{ab} are equal for the three colour outputs. However, CIELAB L^* and C^*_{ab} data are different.

6 Elementary (e) colours ***rgb^*_e=rgb* in CIELAB: RJGB*** **and** ***NW***



Hexagon-triangle system based on elementary (e) colours: ***rgb^*_e=rgb****
with **linear relations** between ***rgb_e −> rgb* − LCH****
(compare linear relations between rgb_{sRGB} and L)*

Equations *rgb* − LCH** in both directions have been published, see:
Richter, CIE-Proceedings, Beijing, 2008, Volume 3 und DIN 33872-1

Three equations (tables) are needed for office applications:

rgb_e − LCH*' for a 9x9x9 grid of equally spaced *rgb_e*-input data
rgb* − LCH* a 9x9x9 grid of equally spaced data *rgb** and *LCH**
rgb'*− LCH* ***Device output linearisation by rgb_e −> rgb'****

KE291-5N

Figure 7: Elementary colour data *rgb and three sets of relations for device linearization**

A first table connects the *rgb_e* input data with the measurement data *LCH*'* of the start output, for the notation compare ISO/IEC 15775.

The second relation *rgb** - *LCH** is an equation in both directions, see for example Figure 5 and 6, and DIN 33872-1.

The third relation shows the calculated *rgb'** input data for the output of the intended *LCH** data.

Finally, if the table rgb_e - *rgb'** is applied then the intended equally spaced colour series will appear on the output device. These tables are available for offset print, different *rgb* displays and printers and different *cmyn* separations of *PostScript (PS)* printers.

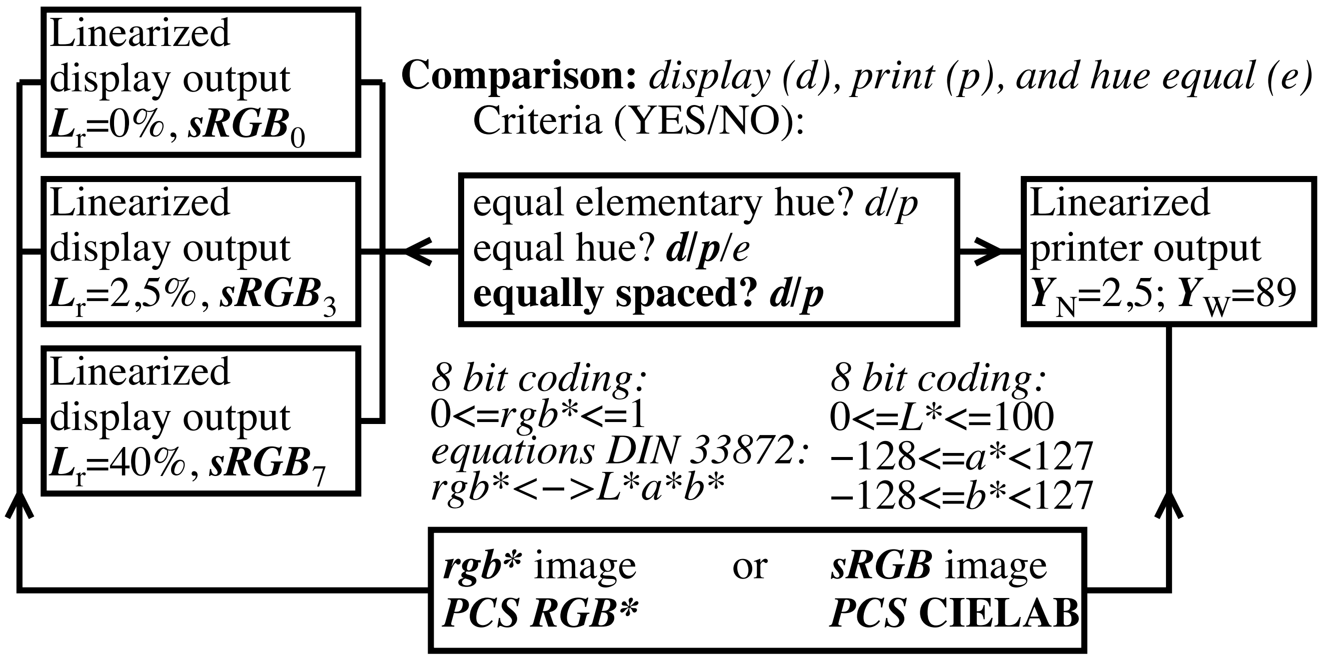
There are a few limitations:

- The start output *LCH*'* should produce continuous output series.
- It there are some colours located outside the chosen hue triangle then these are not reproduced *(small reduction of output colour space).*

For examples of calculated *rgb'** data for different printers and different *cmyn* separations see

http://130.149.60.45/~farbmetrik/GE.HTM

http://130.149.60.45/~farbmetrik/HE.HTM



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,

Figure 8: Output and efficiency with Profile Connection space *(PCS) RGB and *PCS* CIELAB.**

If the *Profile Connection Space (PCS) RGB** is used, then the coding efficiency has the value 1,00 for the three luminance reflections.

If the *PCS* CIELAB is used, then the coding efficiency reduces from the value 0,2 to 0,004.

Therefore the *PCS RGB** of this paper produces a much higher coding efficiency.

This coding efficiency has a constant value 1 for all display luminance reflections.

Therefore especially for displays with the standard luminance reflection according to ISO 9241-306 at office work places, and for data projectors which much ambient light, the colour management according to ISO 15076-1 (ICC colour management) has a low efficiency.

Therefore the application of ICC colour management, for example for the softcopy - hardcopy comparison, may not be useful for L_r=2,5%.

At office work places there are problems with the luminance reflection. The user wishes not only to linearize any file output, for example of

http://www.ps.bam.de/ME16/10L/L16E00NP.PDF

The *whole display* output *shall change* according to the ambient light!

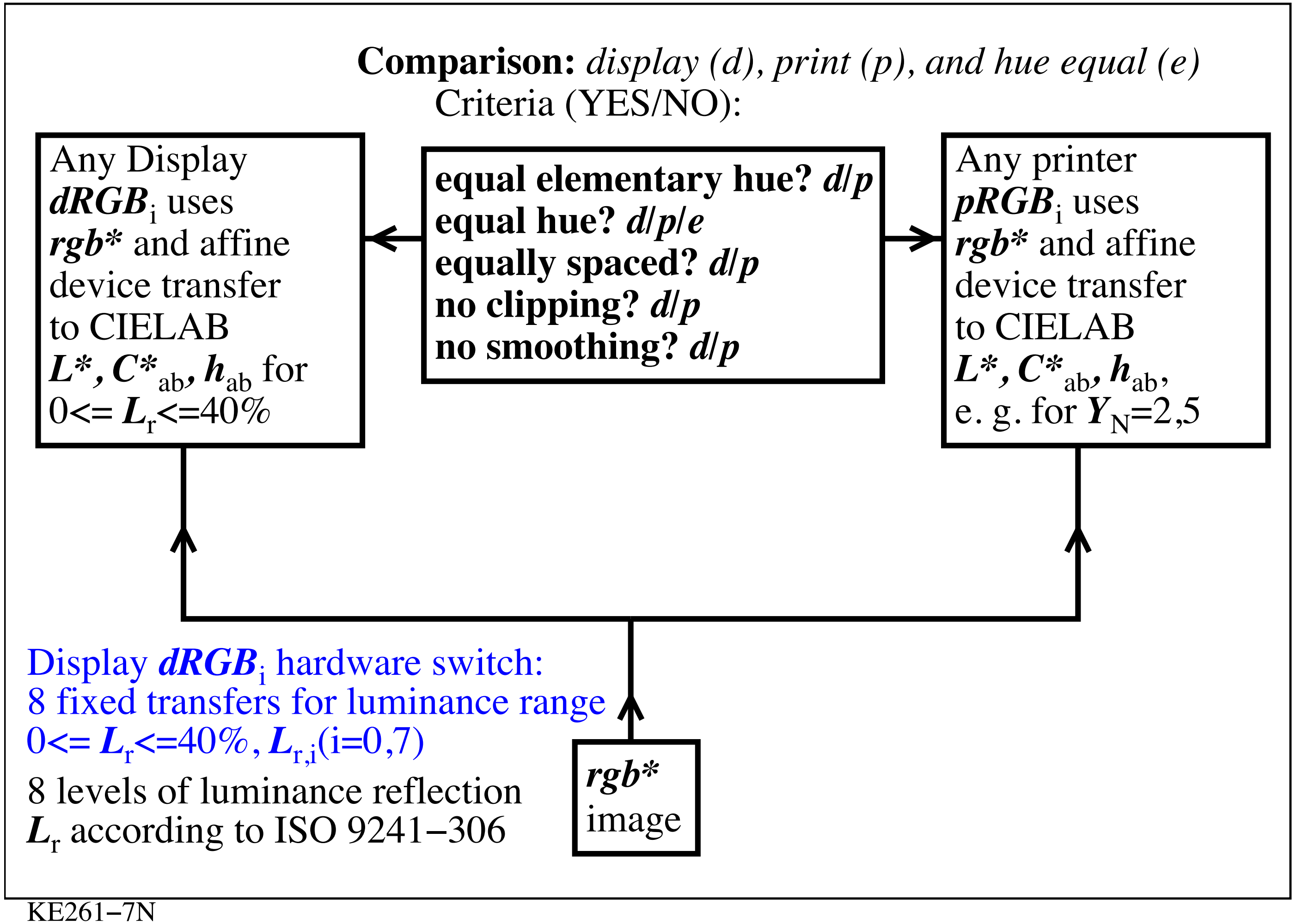


Figure 9: Workflow *rgb* interpretation as elementary colours *rgb** and *rgb** linearization

The *rgb*$_e$ -> *rgb'** data tables of Fig. 9 may be used for linearization within the devices which will produce on both devices the elementary hues, the equal intermediate hues, the equal spacing and no clipping.

If 8 data tables are within the display a hardware switch allows to choose visually the equal output spacing for example with the ISO-test chart according to ISO 9241-306, see the ISO-test charts (200 KB, 1 page) for a hardware switch

http://www.ps.bam.de/ME16/10L/L16E00NP.PDF

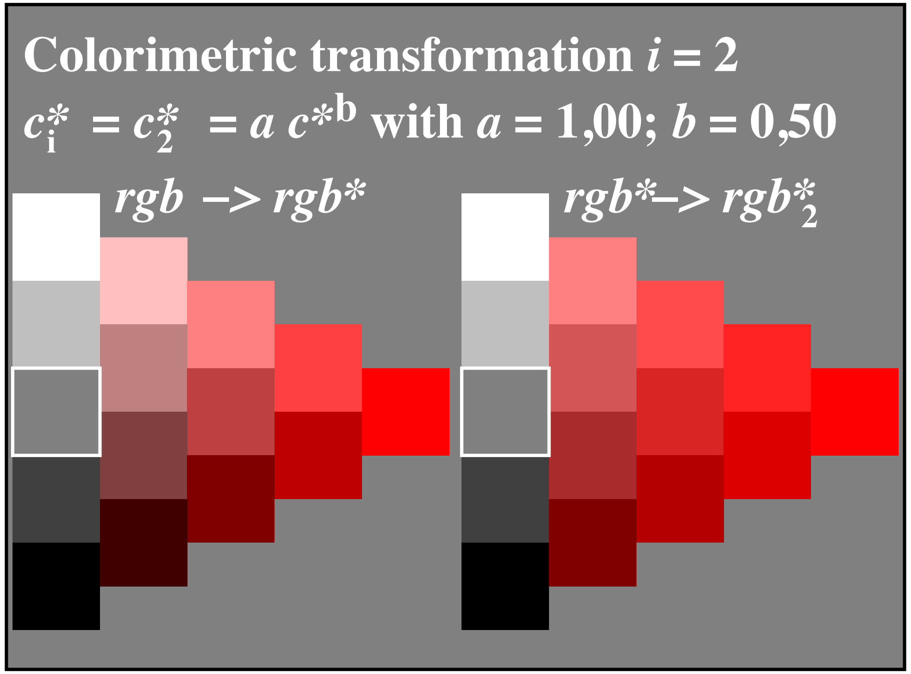
and (1800 KB, 16 pages) for a software solution

http://www.ps.bam.de/ME15/10L/L15E00FP.PDF

Annex D of ISO 9241-306 includes a solution for the computer operation system *MAC OS 10.4 or later.*

The equal output spacing is the requirement for a “trusted” output. The trusted output does not allow any colour enhancement, any clipping or smoothing.

However, in other cases there may be a user wish to make the output more chromatic compared to the original



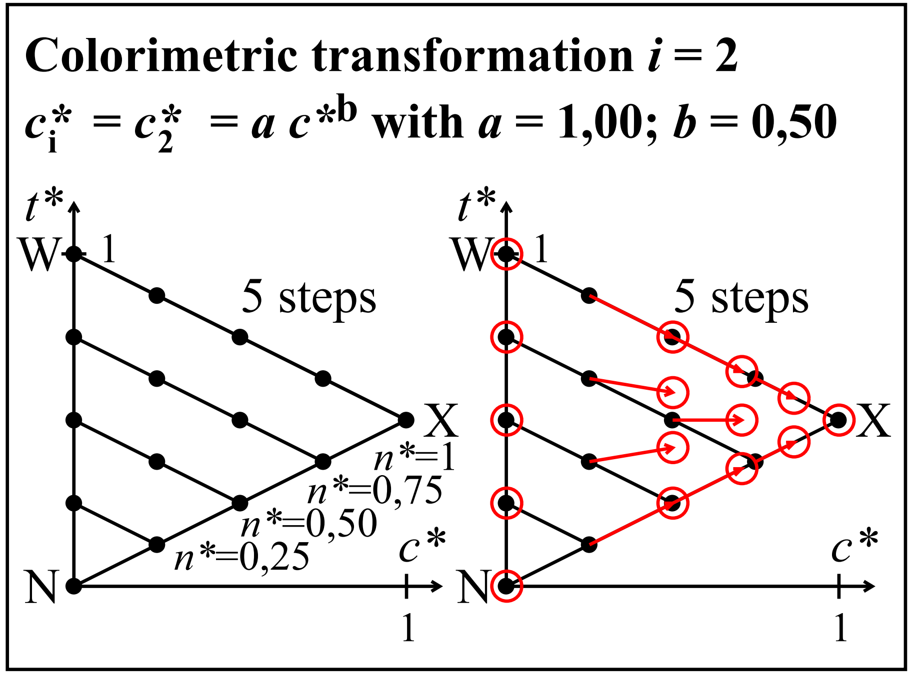


Figure 10: Chroma enhancement by $c^{*\prime}=c^{*0,5}$ and visualization in hue triangle *N - X - W*

Figure 10 shows the chroma enhancement by a formula $c^{*\prime}= c^{*0,5}$.

The changed colours are still located within the colour triangle and can therefore be reproduced. The achromatic colours and the most chromatic colour are not changed. This transfer may be used for chroma enhancement of photos.

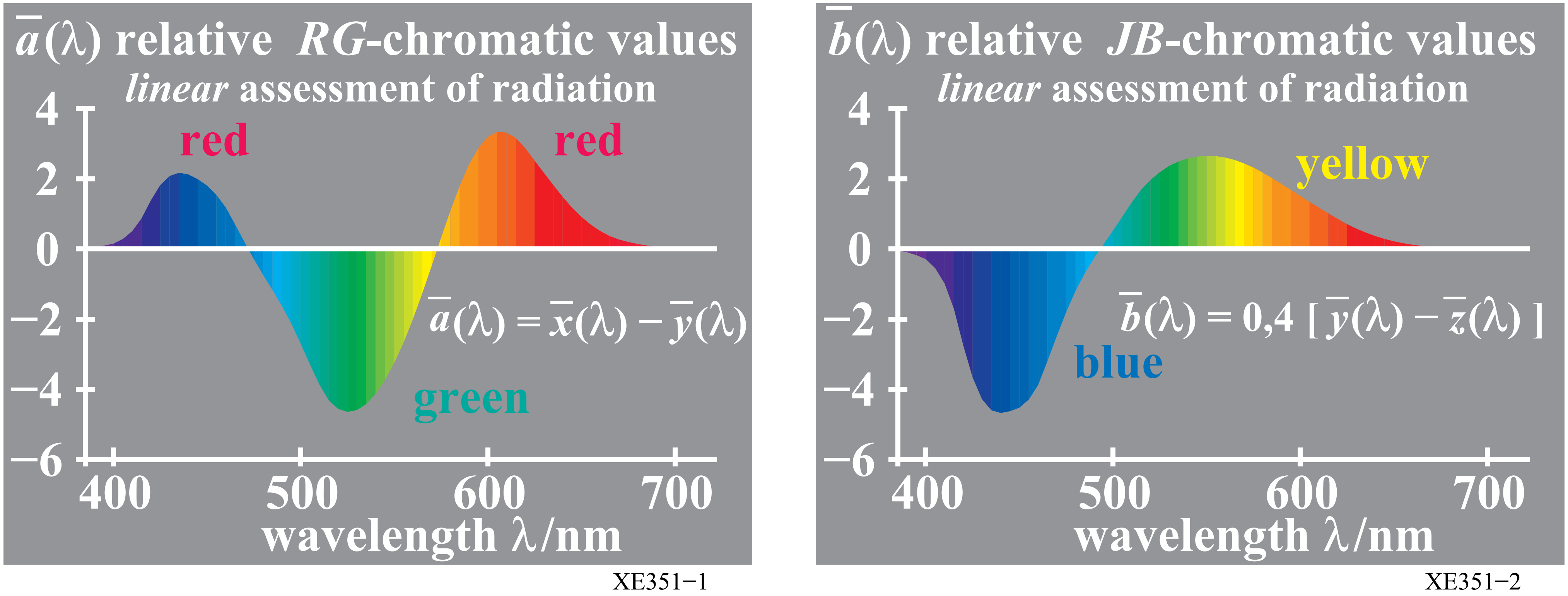
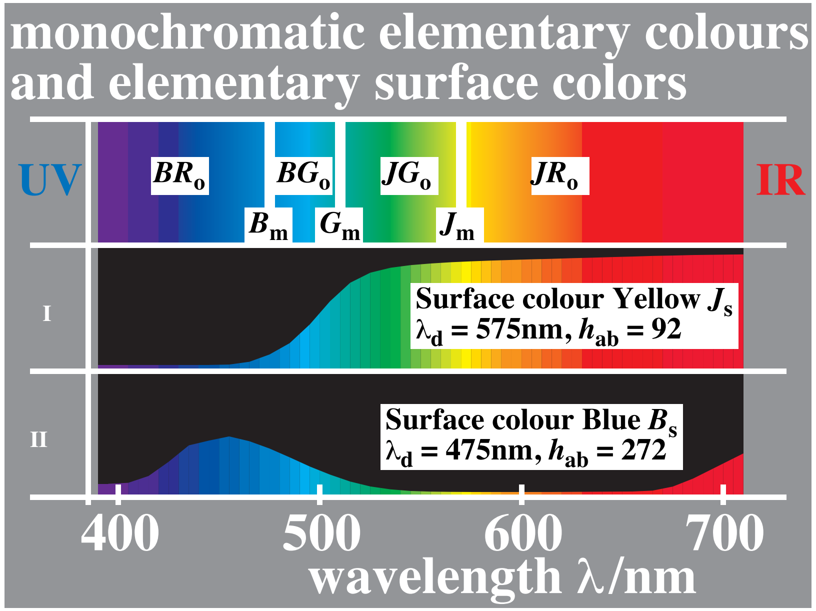
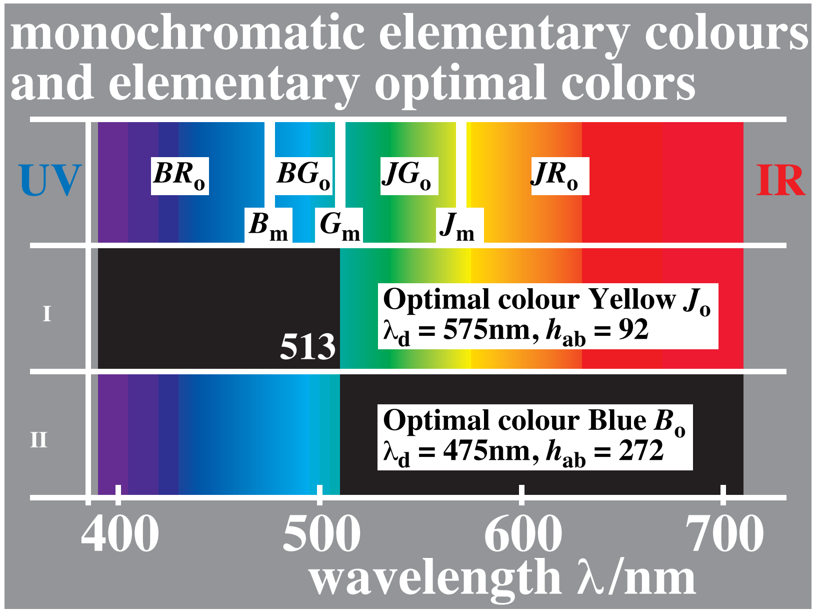


Figure 11: Chromatic values of *RG*- and *JB*-visual processes

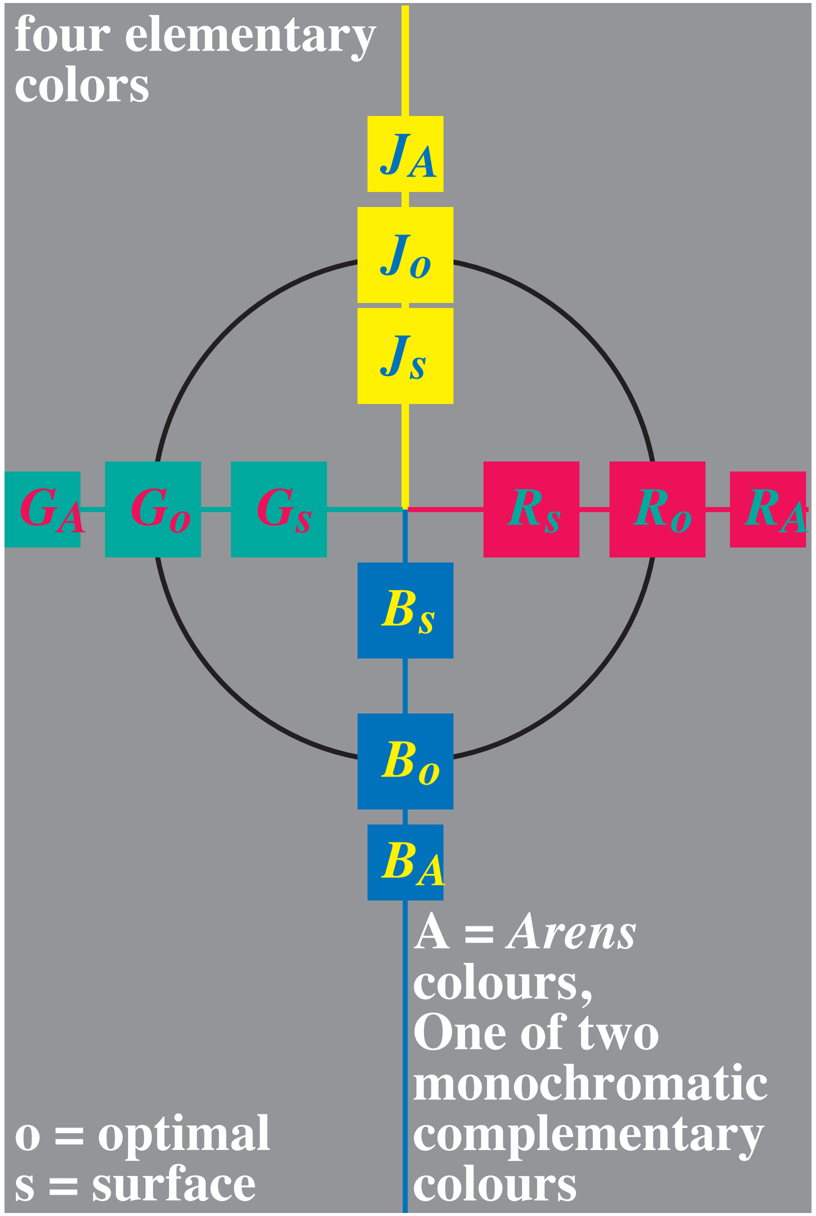
Figure 11 includes the equations for the calculation of the chromatic values from the CIE tristimulus values. The zero points are near 475nm *(B)*, 575nm (J) and 500nm *(G)*. The last value deviates slightly from the experimental value 513nm used in the next figure.



KE300−2N



KE300−1N



KE300−6N

Figure 12: Elementary surface (s), optimal (o), *Arens*-colours (A)

Figure 12 shows in the spectrum with the elementary monochromatic *(m)* colours JGB_m, the elementary surface *(s)* colours J_s and B_s and the elementary optimal *(o)* colours J_o and B_o.

In addition to the elementary surface and optimal colours Fig. 12 shows the *Arens*-colours, for example J_A and B_A.

For example the two monochromatic colours $\lambda_d = 475$nm and $\lambda_d = 575$nm mix to White *W* if appropriate amounts are chosen. Each of these two mixture colours has a well defined chroma C^*_{ab} and lightness L^*.

For the *Arens*-colours the chroma is larger or equal compared to the optimal colours. For the optimal colours the chroma is larger or equal compared to the surface colours.

Display manufacturers have started to use more then three LED's for the displays. With only Yellow and Blue a production of Red *R* and Green *G* is impossible. The first solution is to divide the Yellow *J* in Yellow-Green *(JG)* and Yellow-Red *(JR)*. In addition the Blue *B* may be divided in Blue-Green *(BG)* and Blue-Red *(BR)*, compare Fig. 12 *(left)*. There may be ergonomic problems (e. g. visual fatigue) if *Arens* colours are used.

Summary and possible applications

The report CIE R1-47:2009 “Hue Angles of Elementary Colours” is used to define an *efficient rgb** output for displays and for *eight luminance reflections* according to Annex D of ISO 9241-306.

In addition an efficient description of the device gamut by the *visual human rgb** coordinates is described.

The *efficiency* of the *rgb** output is constant and *has the equal value 1* for any luminance reflection of the display.

However, if colour management according to ISO 15076-1 is applied and if 8 bit coding in *ICC-LAB* is used, then the efficiency reduces between 0,2, 0,1, and 0,004 for the luminance reflections between 0%, 2,5%, and 40% respectively.

Therefore a large improvement is reached if the proposed *Profile Connection Space PCS RGB** is used.

For many application in offices colour management is possible without a PCS and still the high efficiency is reached, for example if the device manufacturers have included the transfer rgb_e - rgb'^* in their device.

Display manufacturers may include the transfer for 8 luminance reflections within their devices. Then a *device independent hue output* is reached for eight luminance reflections of the whole display.

An additional hardware switch may allow to produce 8 chroma transfers between more chromatic and achromatic for any of the above 8 viewing conditions.

Instead of the hardware solutions there are already software solutions, see for example Annex D of ISO 9241-306.

Some of these solutions linearize only the file output and leave the rest of the computer operating screen of the display unchanged.

However, most users wish a change of the whole computer operating screen according to the ambient conditions. In addition users wish an independent change of the computer display and the data projector display which both have different luminance reflections.

An example software solution is given in Annex D of ISO 9241-306.

Summary and differences compared to present output solutions

The preferred output of this paper on displays and printers produces:

- a **device independent** elementary hue output
- a **device independent** intermediate hue output
- an **equally space output** for equally spaced *rgb* input
- **no clipping** and no smoothing

All these properties lead to a “trusted” output. There is only one solution for any device by an 8 bit rgb_e -> *rgb'** table, compare Fig. 7. All the properties may be tested by DIN-test files according to DIN 33872, see

http://www.ps.bam.de/33872E

In future **8 modes for the display output** may be appropriate, for example by a hardware switch. According to user wishes the whole display output is changed, for example at the office work place.

This is usually not the case by the present colour management method according to ISO 15076-1 where usually only one file output is managed. The **higher efficiency** of the *rgb** output will support new applications.

References

Arens, Hans, Farbmetrik, Akademie-Verlag, Berlin, 1951, 79 pages

CIE R1-47:2009, Hue angles of elementary colours (35 pages, 2,1 MB), see the CIE web site under “Meetings”
http://div1.cie.co.at

CIE 168:2005: Criteria for the Evaluation of Extended-Gamut Colour Encodings

DIN 33872-1 to -6 (in print), Information technology - Office machines - Method of specifying relative colour reproduction with YES/NO criteria
- Part 1: Classification, terms and principles
- Part 2: Test charts for output properties - Testing of discriminability of 5 and 16 step colour series
- Part 3: Test charts for output properties - Testing of equality for four equivalent grey definitions and discriminability of the 16 grey steps
- Part 4: Test charts for output properties - Testing of equality for two equivalent colour definitions with 5 and 16 step colour series
- Part 5: Test charts for output properties - Testing of elementary hue agreement and hue discriminability
- Part 6: Test charts for output properties - Testing of the equivalent spacing and of the regular chromatic spacing

For additional information see the PDF file (41 pages, 1,4 MByte) with the title
Colorimetric supplement to DIN 33872-1 to -6
http://www.ps.bam.de/D33872-AE.PDF
For the test charts according to DIN 33872-1 to -6 see

http://www.ps.bam.de/33872E

ISO 9241-306:2008, Ergonomics of human-system interaction - Part 306: Field assessment methods for electronic visual displays
For the test charts according to ISO 9241-306 see
http://www.ps.bam.de/9241E

ISO 11664-4:2008(E)/CIE S 014-4/E:2007: Joint ISO/CIE Standard: CIE Colorimetry — Part 4: 1976 L*a*b* Colour Space (CIELAB)

ISO 15076-1:2005, Image technology colour management -- Architecture, profile format and data structure -- Part 1: Based on ICC.1:2004-10

ISO/IEC 15775:1999, Information technology – Office machines – Method of specifying image reproduction of colour copying machines by digital and analog test charts – Realization and application

ISO/IEC TR 19797:2004, Device output of 16-step colour scales, output linearization method (LM) and specification of the reproduction properties
For the test charts according to ISO/IEC TR 19797 see
http://www.ps.bam.de/19797TE

ISO/IEC TR 24705:2005, Method of specifying image reproduction of colour devices by digital and analog test charts
For the test charts according to ISO /IEC TR 24705 see
http://www.ps.bam.de/24705TE

Annex A: Abbreviations used for the workflow of this paper

The abbreviations display (d), print (p) and standard (s) lead to image coding in the spaces:

dRGB, pRGB, and ***sRGB.***

ISO 9241-306 defines 8 luminance reflections: $L_{r,i}$ = 0, 0,6, 1,2, 2,5, 5, 10, 20, 40% *(i=0 to 7).*

This leads to 8 image data sets $dRGB_i$ and/or $sRGB_i$ and 8 luminance reflections $L_{r,i}$ *(i=0 to 7)*.

Fig. 4 includes ***YES/NO questions*** for the ***comparison softcopy - hardcopy***. The three displays and the printer fulfills all the ***YES criteria*** according to the workflow.

Fig. 8 shows for the ***sRGB*** image the workflow with *rgb* interpretation as elementary colours ***rgb**** (*rgb->rgb*),* and ***rgb**** linearization for 8 modes of luminance reflections L_r.

The *rgb** data are used for linearization which will produce on both devices the elementary hues, the equal hues, the equal spacing and no clipping.

The DIN-test chart according to DIN 33872-6 allow to test if *no* smoothing occurs. In addition DIN-test chart according to DIN 33872-5 may be used for the equal elementary hue test.

Fig. 6 includes the technical property, that the *rgb** data are equal for the display device and the printer device. In addition they are equal for all display devices $\boldsymbol{dRGB}_i$ and the standard display devices $\boldsymbol{sRGB}_i$ (i=0 to 7).

Annex B: Intended output by "absolute" ICC-colour management according to ISO 15076-1

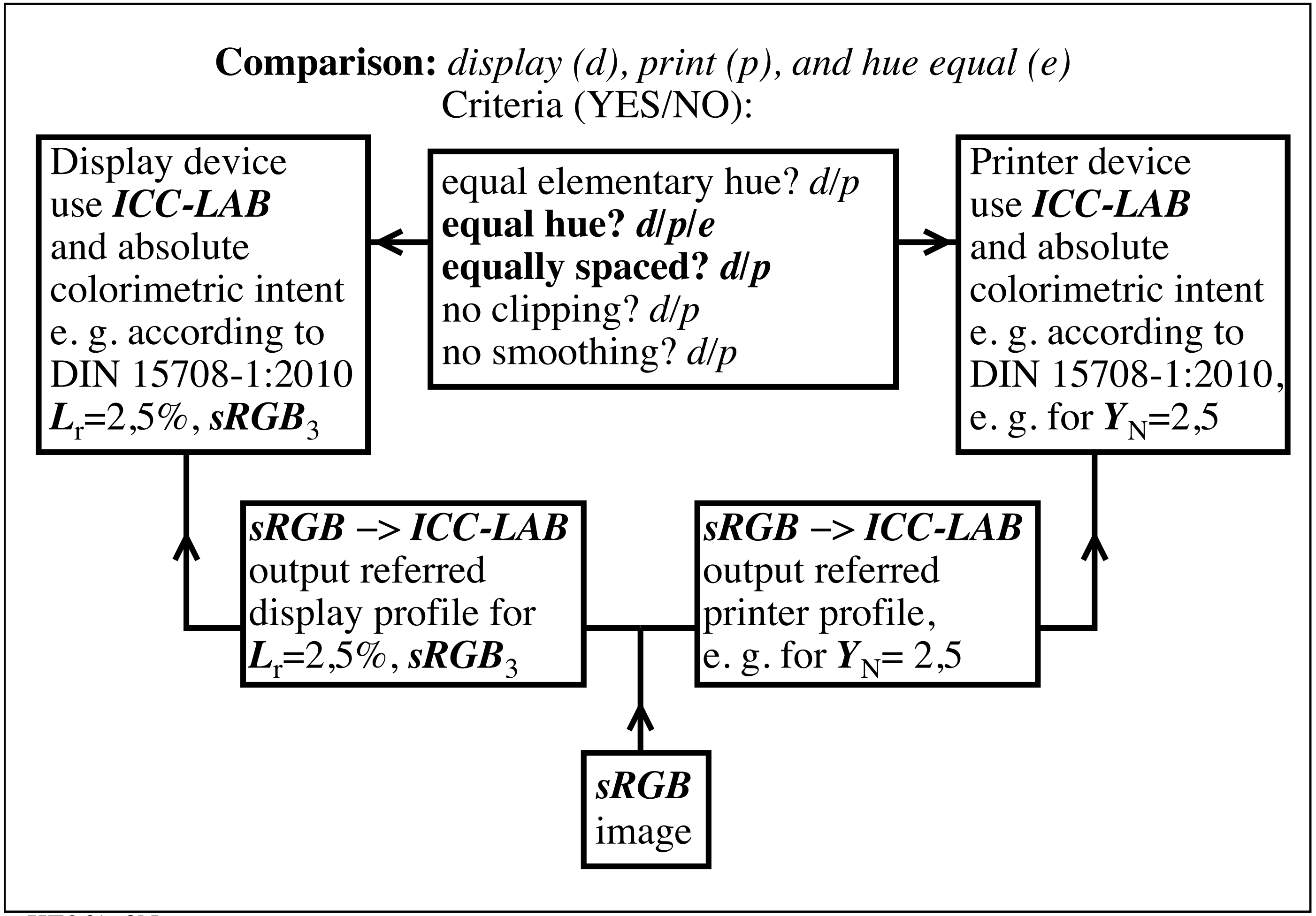


Figure 13: Workflow *sRGB* interpretation as output referred device colours *ICC-LAB*

For the *sRGB* image Figure 13 shows the workflow *rgb* interpretation as output referred device colours *ICC-LAB*. For 8 display reflections 8 *ICC-LAB* profiles are necessary. According to ISO 9241-306 the gamma value changes from 2,4 for L_r=0% to about 1,1 for L_r=40%.

The main part of this paper describes the output gamut boundary of any display or printer by an equation in both directions similar to the following equations for any hue plane:

rgb^* <-> L^*, C^*_{ab}, h_{ab}.

In addition in both directions there is an equation

sRGB <-> L^* C^*_{ab}, h_{ab}

and an equation

sRGB <-> *ICC-LAB*

Remark: ICC-LAB is not identical to CIELAB. For example there are differences in normalization (media white in ICC instead of perfect white diffuser in CIELAB equations).

All relations together allow to make *ICC*-profiles for colour management according to ISO 15076-1. If the *ICC-LAB* data are calculated for the 9 step colour series in an elementary hue plane and sent to the display or printer device with the task to reproduce the *ICC-LAB* data by ”absolute” colour management, then the equally spaced colour series in CIELAB will appear on the display or the printer.

Examples of this kind of ”absolute” colour management are given in the new standard DIN 15708-1:2010 with the title: Electronic still picture - Quality check of digital *RGB* input data - Part 1: Output on printing devices.

For the DIN-test charts according to DIN 15708-1 see

http://130.149.60.45/~farbmetrik/_Referenzkeil_DIN_15708-1/

The last figures show an example change of digital data by “smoothing”.

An alternate and *more efficient* solution may be to use the 8-bit tables rgb_e <-> *rgb'** as “device link” *rgb*-profiles in *ICC*-colour management.

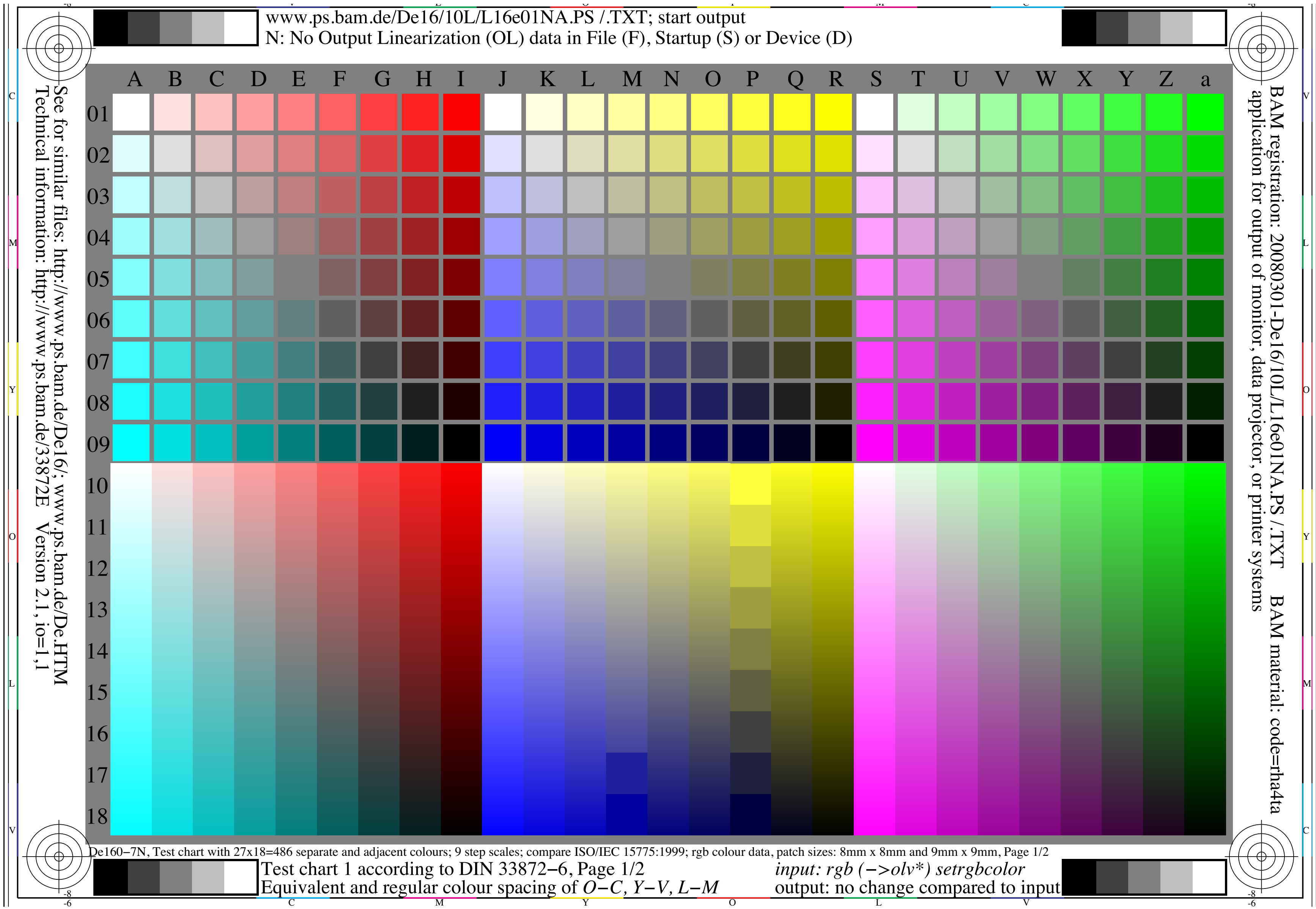


Figure 14: *Smoothing* of the 9 steps of DIN-test chart according to DIN 33872-6 if the *PS*-file is displayed on *Mac OS 10.4* or later.

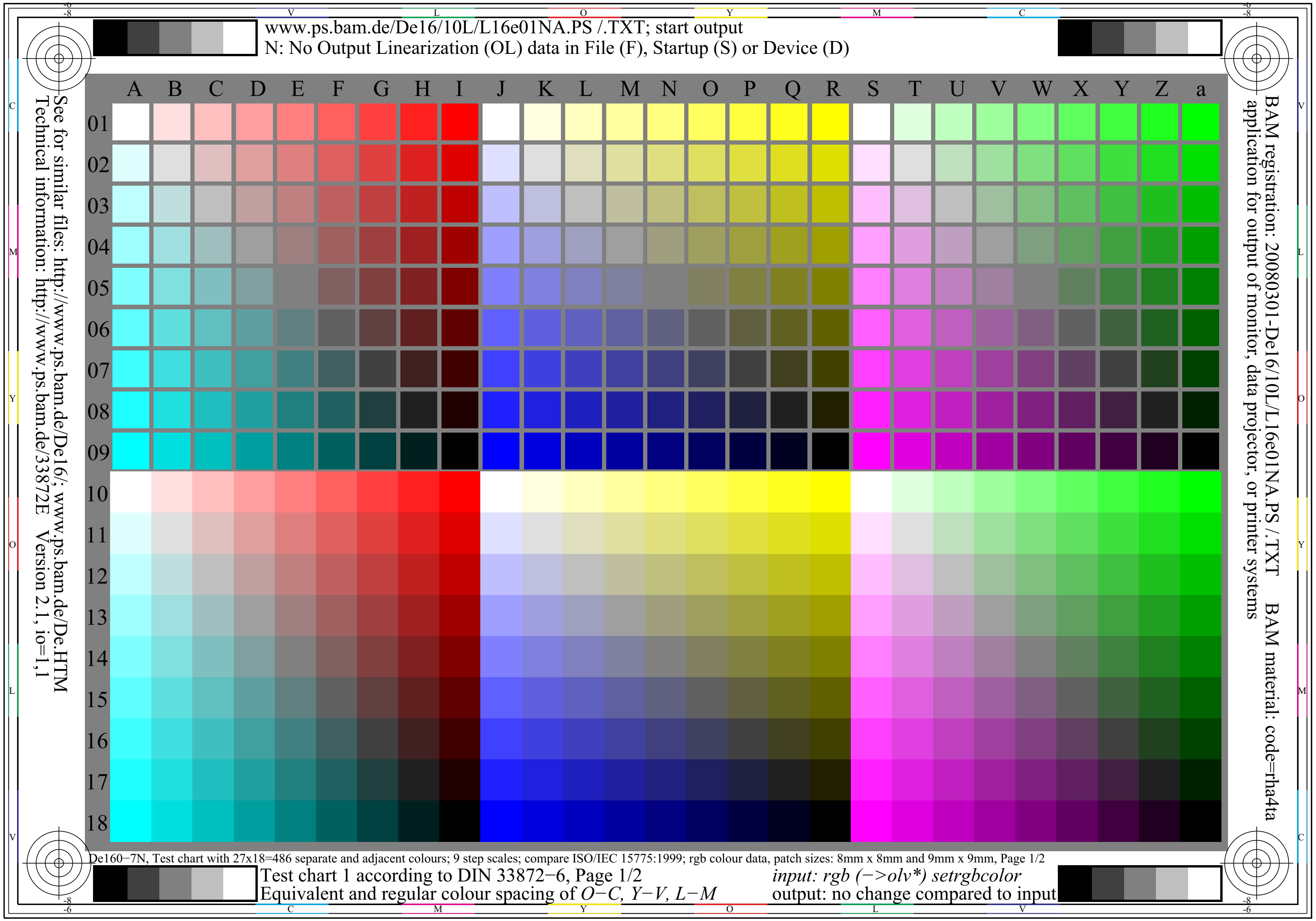


Figure 15: ***No smoothing*** **of 9 steps of DIN-test chart according to DIN 33872-6 if a** ***PS*****-test file via** ***Acrobat*** **is displayed on** ***Mac OS 10.4***

Annex C: Relations *rgb** - CIELAB for different output devices

***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 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

***rgb* −> *rgb** and CIE data of a elementary hue circle according to CIE R1-47:2009 for photo printer**

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	34.1	61.4	29.2	68.0	**25.4**	**1.00 0.00 0.00**
0,5(R+N)	21.4	30.7	14.6	34.0	**25.4**	**0.50 0.00 0.00**
0,5(R+W)	63.4	30.7	14.6	34.0	**25.4**	**1.00 0.50 0.50**
j00g=J	83.9	−4.3	106.1	106.2	**92.3**	**1.00 1.00 0.00**
0,5(J+N)	46.2	−2.1	53.0	53.1	**92.3**	**0.50 0.50 0.00**
0,5(J+W)	88.3	−2.1	53.0	53.1	**92.3**	**1.00 1.00 0.50**
g00b=G	46.8	−58.9	18.9	61.8	**162.1**	**0.00 1.00 0.00**
0,5(G+N)	27.7	−29.4	9.4	30.9	**162.1**	**0.00 0.50 0.00**
0,5(G+W)	69.7	−29.4	9.4	30.9	**162.1**	**0.50 1.00 0.50**
b00r=B	38.1	1.3	−43.4	43.5	**271.7**	**0.00 0.00 1.00**
0,5(B+N)	23.4	0.6	−21.7	21.7	**271.7**	**0.00 0.00 0.50**
0,5(B+W)	65.4	0.6	−21.7	21.7	**271.7**	**0.50 0.50 1.00**

5 step equidistant grey scale: L^* = 8.6 , 29.6 , 50.6 , 71.6 , 92.6

Code	L^*_a	a^*_a	b^*_a	$C^*_{ab,a}$	h_{ab}	*rgb −> rgb**
n000w=N	**8.7**	0.0	0.0	0.0	1.2	**0.00 0.00 0.00**
n025w	**29.6**	−0.3	−7.1	7.1	266.8	**0.25 0.25 0.25**
n050w	**50.7**	−2.8	−5.4	6.1	242.2	**0.50 0.50 0.50**
n075w	**71.7**	−1.8	−5.0	5.3	250.0	**0.75 0.75 0.75**
n100w=W	**92.6**	0.0	0.0	0.0	220.9	**1.00 1.00 1.00**

KE110−4N, photo printer, printer separation olv*

Figure 16: *rgb and CIE data of elementary colours *RJGB* and mixtures with *W* and *N* for the standard *sRGB*$_3$ display with L_r=2,5%, and *sRGB*$_3$ with L_r=0% (dark room), and a photo printer *pRGB*.**

The CIELAB hue angles h_{ab} are equal and L^* and C^*_{ab} data are different.

32/32 ISO-CIE trend for Color Output of equally spaced Series and Elementary Hues *RJGB*

***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=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 photo printer**

16 step elementary hue circle: 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	34.1	61.4	29.2	68.0	**25.4**	**1.00 0.00 0.00**
r25j	39.9	54.2	49.2	73.2	**42.2**	**1.00 0.25 0.00**
r50j	52.8	38.2	63.2	73.9	**58.8**	**1.00 0.50 0.00**
r75j	65.4	20.5	79.9	82.5	**75.5**	**1.00 0.75 0.00**
j00g=J	83.9	−4.3	106.1	106.2	**92.3**	**1.00 1.00 0.00**
j25g	70.7	−31.0	86.2	91.6	**109.8**	**0.75 1.00 0.00**
j50g	57.4	−50.3	66.1	83.1	**127.2**	**0.50 1.00 0.00**
j75g	43.6	−62.7	44.2	76.7	**144.7**	**0.25 1.00 0.00**
g00b=G	46.8	−58.9	18.9	61.8	**162.1**	**0.00 1.00 0.00**
g25b	49.7	−45.9	−7.7	46.6	**189.5**	**0.00 1.00 0.50**
g50b	51.7	−33.5	−25.2	41.9	**217.0**	**0.00 1.00 1.00**
g75b	46.8	−17.2	−35.9	39.9	**244.3**	**0.00 0.50 1.00**
b00r=B	38.1	1.3	−43.4	43.5	**271.7**	**0.00 0.00 1.00**
b25r	24.2	31.0	−53.4	61.7	**300.1**	**0.50 0.00 1.00**
b50r	30.3	68.8	−42.0	80.6	**328.6**	**1.00 0.00 1.00**
b75r	35.8	67.2	−3.4	67.3	**357.0**	**1.00 0.00 0.50**

5 step equidistant grey scale: L^* = 8.6 , 29.6 , 50.6 , 71.6 , 92.6

Code	L^*_a	a^*_a	b^*_a	$C^*_{ab,a}$	h_{ab}	*rgb –> rgb**
n000w=N	**8.7**	0.0	0.0	0.0	1.2	**0.00 0.00 0.00**
n025w	**29.6**	−0.3	−7.1	7.1	266.8	**0.25 0.25 0.25**
n050w	**50.7**	−2.8	−5.4	6.1	242.2	**0.50 0.50 0.50**
n075w	**71.7**	−1.8	−5.0	5.3	250.0	**0.75 0.75 0.75**
n100w=W	**92.6**	0.0	0.0	0.0	220.9	**1.00 1.00 1.00**

KE110−3N, photo printer, printer separation olv*

Figure 17: *rgb and CIE data of elementary colours *RJGB* and intermediate colours for the standard *sRGB*$_3$ display with L_r=2,5%, and *sRGB*$_0$ with L_r=0% (dark room), and a photo printer *pRGB*.**

The CIELAB hue angles h_{ab} are equal and L^* and C^*_{ab} data are different.