Output Linearization of visual displays based on a human visual *RGB** colour space

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Abstract

This paper is a so called “white paper” for discussion in standard committees, especially for colour applications in ISO/TC159/SG4/WG2: “Visual Display Requirements”. The author has worked as editor for ISO 9241-306:2008, Ergonomics of human system interaction – Part 306: Field Assessment methods. The application includes an ISO-test chart in black and white and visual test method for output and visibility at office work places.

New test charts and test methods for colour are proposed here. For the colour area also user friendly and ergonomic colour coordinates are essential. The application of a human visual *RGB** colour system which is device independent in hue is proposed here. This visual *RGB** system is based on recent proposals of the CIELAB h_{ab} hue angles of the elementary colours. The Report CIE R1-47 of CIE Division 1: Vision and Colour defines the four elementary hue angles 26, 92, 162, and 272 degree in CIELAB for the four elementary colours Red *R*, Yellow *J*, Green *G,* and Blue *B*. These definitions are used in the standard series DIN 33872-1 to -6 (in print): Information technology - Office machines - Method of specifying relative colour reproduction with YES/NO criteria.

A colour output linearization method for visual displays and for eight reflections of the ambient light on the display surface is described here, similar as the one for black and white in ISO 9241-306. The output linearization method can fulfill the criteria of DIN 33872 to produce visually equally spaced 5- and 16-step colour series and an elementary hue angle agreement in the output. The advantages for colour management of visual displays are discussed.

Introduction

Table 1 – International standards and technical reports for Colour input and output

Input	Output	Input and output media and applications Input media	 Output media	 Application	Technical Report (TR) or Standard
–	–	–	–	**Basis**	**ISO/IEC TR 24705**
analog	**analog**	ISO/IEC-test chart (hardcopy)	Hardcopy	**Copier**	**ISO/IEC 15775**
analog	**digital**	ISO/IEC-test chart (hardcopy)	File	**Scanner**	**ISO/IEC TR 24705**
digital	**analog**	ISO/IEC-test chart (file)	Hardcopy Softcopy	**Printer** **Monitor**	**ISO/IEC TR 24705** **ISO/IEC TR 24705**

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Table 1 shows a Standard and a Technical Report in which the equally spaced visual and colorimetric output is defined for equally spaced digital input data. The standard documents of table 1 correspond to the standard series DIN 33866-1 to 5. All standard documents include ISO/IEC- and DIN-test charts for input and output.

Output Linearization of visual displays based on a human visual RGB* colour space

The new standard series DIN 33872-1 to -6 and english translation on an ISO-template (Document N1280 in ISO/IEC JTC1/SC28 and Document N1068 in ISO/TC159/SC4/WG2) are the first standard documents which consider the elementary hue angles of the report CIE R1-47. The output linearization method in device space of the standard document ISO/IEC TR 19797 is now developed further to include output linearization in the elementary hue space. This allows the linearized output in both the elementary hue and the device hue space. For applications the output in the device independent hue space is preferred.

During last years in the standard committees ISO/TC159/SC4/WG2 "Visual Display Requirements", ISO/IEC JTC1/SC28 "Office equipment", ISO SCIT "Steering Committee of Image Technology" and CIE Division 1 "Vision and Colour" there were a lot of discussions about a more user friendly visual *RGB* colour space for Image Technology.

Based on a request of ISO/TC159/SC4/WG2 to the CIE in 2007 the CIE Division 1 has produced in 2009 the report CIE R1-47 with the title "Hue Angles of Elementary Colours". For the elementary hue angles this CIE report proposes the hue angles 26, 92, 162, and 272 degree in CIELAB. The CIE-test colours no. 9 to 12 of CIE Publication 13.3 have the same hue angles. The four CIE samples represent the hues of Red *R*, Yellow *J*, Green *G*, and Blue *B*.

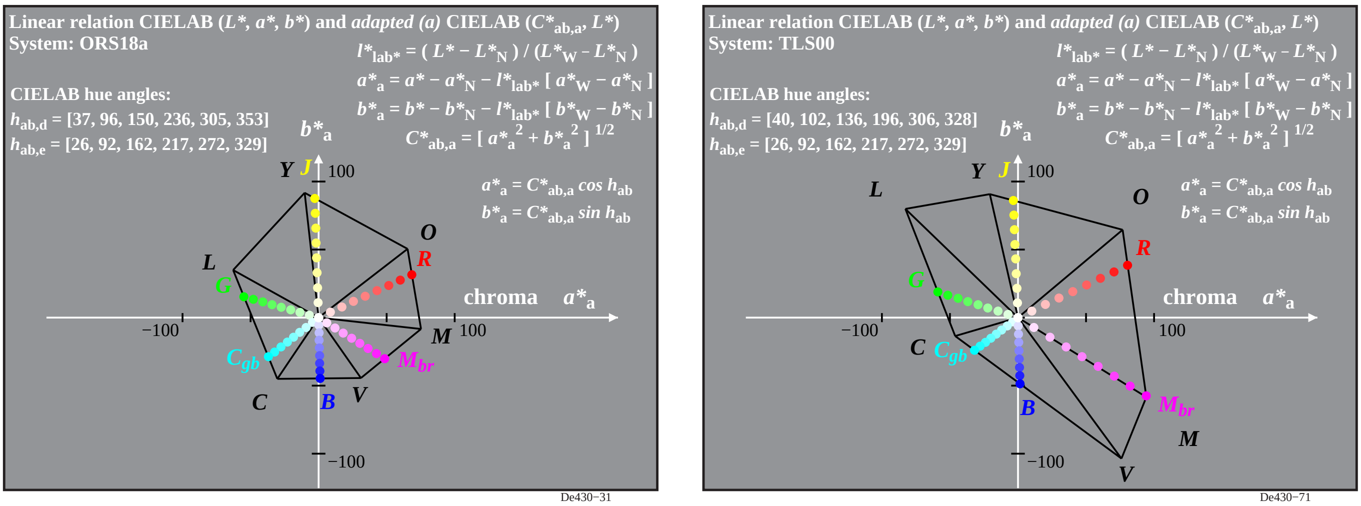

Figure 1 – Device colours *OYLCVM* of systems ORS18a and TLS00 and elementary hue output of *RJGB.*

Fig. 1 shows the device colours OYLCVM of the standard offset system ORS18 *(left)* and the standard television system TLS00 *(right)* according to ISO/IEC 15775. The four elementary colours Red *R*, Yellow *J*, Green *G*, Blue *B* are mixed from the six device colours. According to CIE R1-47 the elementary colours are defined by the hue angles 26, 92, 162, and 272 degree in the CIELAB *(a*, b*)* chroma diagram. This paper describes a method to produce the device independent hue output of the elementary colours *RJGB* on any colour device. The output linearization method produces for example equally spaced colour series White W – Blue B in CIELAB for the hue angle 272 degree as shown in Fig. 1.

In applications it is a user wish that the four colour coordinates *rgb* = 100, 110, 010, and 001 produce the four elementary hue angles of the elementary colours *RJGB* on any colour output device, for example a colour display or a colour printer. Any user can decide by a visual criteria and with his visual system if this goal is reached. For example the hue angle of elementary Yellow *J* is reached, if the hue appears "neither greenish nor reddish" out of a hue circle part Red – Yellow – Green. The user decision is worldwide very similar and is possible without any reference colour sample. The elementary reference hues are stored in the human visual system, see for example the *Swedish Natural Colour System NCS*. If a colour circle of high chroma is used in visual experiments then the standard deviation is 2 degree for Red, Yellow and Green and 4 degree for Blue. Therefore the visual precision is about 1% (less than 4 degree of 360) according to CIE R1-47.

The DIN-test charts according to DIN 33872-4 include a 16-step highly chromatic hue circle produced by the four colour coordinates *rgb* = 100, 110, 010, and 001. The agreement of the hue output with the four elementary hue angles of the elementary colours *RJGB* is visually tested on any colour output device. The DIN-test charts are freely available by the URL

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

The *Relative Elementary Colour System RECS* includes about 2000 colour samples of the standard offset process with standard offset colours on standard offset paper, see ISO/IEC 15775. A highly chromatic hue circle based on the four elementary hues, and 5- and 16-step colour scales in the 16 hue planes of this colour circle serve as reference colours for display and printer output. In contrast to many other statements in the literature the hue perception of the colours of equal CIELAB hue angle appears very equal, for example for the elementary hue plane Blue *B*.

Scope

In image technology the many *rgb* colour spaces are nearly all based on device colours of monitors or printers. New technologies propose or create more and more of these device dependent *rgb* colour spaces. Therefore a device independent colour space based on visual criteria is necessary to fulfill both user wishes and standardization needs.

Different ISO committees and CIE Division 1 “Vision and Colour” have worked together to define and apply a device independent visual *RGB* colour space. In applications the correct hue output is much more critical compared to the output of lightness and chroma. This paper describes a method for equal hue angle output on all colour devices. To reach this goal both the output linearization method of ISO/IEC TR 19797 is further developed and the elementary hue angles of CIE R1-47 are used. For any visual display output eight viewing conditions similar compared to ISO 9241-306 are considered. The equal elementary hue output is possible for any visual display for eight reflection conditions of the ambient light, for example for data projectors in office rooms which are illuminated by the CIE indoor daylight iD65 according to CIE Publ. 184.

1. Normative reference

CIE 13.3, Method of measuring and specifying colour rendering of light sources

CIE 15, Colorimetry

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

CIE 184, Indoor Daylight Illuminants

DIN V 18599-4, Energy efficiency of buildings – Calculation of the net, final and primary energy demand for heating, cooling, ventilation, domestic hot water and lighting – Part 4: Net and final energy demand for lighting

ISO 8995; CIE S 008:2002-05, Lighting of indoor work places

ISO 15076-1, Image Technology – ICC 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 analog test charts – Realization and application

ISO/IEC 15775/Amd.1, Information technology – Office machines – Machines for colour image reproduction – Method of specifying image reproduction of colour copying machines by analog test charts – Realization and application – Amendment 1

ISO/IEC TR 19797:2004, Information technology – Office machines – Machines for colour image reproduction – Device output for 16-step colour scales, output linearization method (LM) and specification of the reproduction properties

ISO/IEC TR 24705:2005, Information technology – Office machines – Machines for colour image reproduction – Method of specifying image reproduction of colour devices by digital and analog test charts

2.Terms and definitions

The terms and definitions of the translation of DIN 33872-1 apply, see Document N1280 of ISO/IEC JTC1/SC28 or Document N1068 of ISO/TC159/SC4/WG2.

3. User friendly colour image technology

Increasingly the colour image technology must consider the visual properties of colour vision. User friendliness is for example reached if the CIELAB hue angles of the elementary colours according to CIE R1-47 are considered.

A high user friendliness is further reached by a simple and efficient colour coding with linear relationships between the relative colorimetric coordinates ***rgb**** or ***ncu**** (see Fig. 2 and 3) and the colour coordinates ***L*, a*, b**** or ***L*, C****$_{ab}$***,*** ***h***$_{ab}$***,*** of CIELAB.

We will study first the application of colour in daily life and in colour image technology. It is obvious that simple relations are necessary according to user wishes.

Then the relative colorimetric coordinates ***rgb**** according to CIE R1-47 and the linear relation to the still more user friendly colour coordinates relative blackness ***n****, relative chroma ***c**** and elementary hue text ***u**** (***ncu****) are given and discussed.

There is approximately no connection between the device dependent coordinates *rgb* and *cmy* of colour image technology and the colour coordinates of the colour systems *RAL, Munsell* and *NCS*. In the area of image technology there are many device dependent *rgb* definitions which are based on device systems and not on colorimetric colour order systems.

Application of colour in daily life or in Colour Information Technology (IT)	
Design, architecture, art, industrial products **Measured for CIE standard illuminant D65**	**Colour Information Technology** **Measured for CIE illuminants D65 and D50**
colour order system; name and coordinates: ***RAL Design System (CIELAB)*** $L^*C^*_{ab}h_{ab}$, lightness, chroma, hue angle ***Munsell Colour System*** ***VCH***, lightness (Value), Chroma, Hue text ***Natural Colour System (NCS)*** ***ncu****: relative blackness, relative chroma relative elementary hue text	**Device system name and coordinates:** **Printer system (illuminants D50 or D65):** ***cmy***, content of "cyan", "magenta", "yellow" **Display system (standard illuminant D65):** ***rgb/sRGB***, content of "red", "green", "blue" ***No user friendly colour coordinates*** ***Nearly no connection to colour order systems***

Aim: define user friendly connection

New: Interpretation of the *rgb* colour data in the range 0 to 1 as elementary colour data rgb^*_3

Linear relations between ***relative*** and ***absolute*** coordinates ***lab* − LAB****

$rgb^*_3 - L^*a^*b^*C^*_{ab}h_{ab}$ (CIELAB)

rgb* − *cmy, $rgb^*_3 - cmy^*_3$ ("1-minus"-relation)

$rgb^*_3 - nce^*$, $rgb^*_3 - ncu^*$

relative coordinates ***lab****: elementary redness r^*_3, greenness g^*_3, blueness b^*_3, blackness ***n****
chroma ***c****, elementary hue ***e****, elementary hue text ***u****

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Figure 2 – Colour order systems and colour image technology

Fig. 2 shows the application of colour in daily life *(left)* and in colour image technology *(right)*. The *rgb* data of the colour spaces *sRGB* and *AdobeRGB* are especially based on special device properties of television monitors (see Table 2) and only to a small part on the visual and colorimetric colour systems. In Fig. 3 the interpretation of the ***rgb*** colour data of information technology as elementary colour data ***rgb**** defines a *linear* and therefore especially simple and efficient connection.

The colorimetric *relative* coordinates ***ncu**** (*relative* blackness ***n*****,** *relative* chroma ***c**** and the elementary hue text ***u****) are for every hue text defined as ***linear*** functions (F_{lin} or f_{lin}) of the *adapted* CIELAB coordinates LCH^*_a (= L^*, $C^*_{ab,a}$, $h_{ab,a}$ = lightness, *adapted* chroma and hue angle) and the *relative* CIELAB coordinates ***lch**** (= ***l*****, *c*****, *h****; *relative* lightness, *relative* chroma and *relative* hue angle ***h**** = $h_{ab,a}$ / 360)

$$ncu^* = F_{lin}(L^*, C^*_{ab}, h_{ab,a}) \qquad (1)$$

$$ncu^* = f_{lin}(l^*, c^*, h^*) \qquad (2)$$

If the application program allows to input the appropriate and user friendly colour coordinates ***ncu**** then the colour image technology is connected in a new way to the colour coordinates used in design, art and architecture, for example in the *NCS* system. For every elementary hue text ***u**** the coordinates ***rgb*** of colour image technology are interpreted as elementary colour coordinates ***rgb**** which are connected by the simple and linear relations

$$n^* = 1 - max(r^*, g^*, b^*) \qquad (3)$$

$$c^* = max(r^*, g^*, b^*) - min(r^*, g^*, b^*) \qquad (4)$$

to the new user friendly coordinates ***ncu****. Similar coordinates are used in the *Natural Colour System NCS* of the Swedish Standards SS 01 91 00 to 03. In agreement with *NCS* the relative blackness ***n**** and the relative chroma ***c**** have a colorimetric definition. In the colour system *NCS* these colour attributes are defined *device independent* by visual experiments.

In the following the coordinates *rgb* of colour image technology are either interpreted as device colour data *olv** or as elementary colour data *rgb**. In the following the two above equations are explained further. The missing elementary hue text ***u**** is defined as function of the hue angle h_{ab} of CIELAB and therefore completely *device independent*. Therefore we produce by output linearization a device independent hue output. The *relative* blackness ***n**** and the *relative* chroma ***c**** is defined relative to the maximum colour Ma of a device for any given hue and therefore device dependent.

Table 2 – Colorimetric coordinates of the Television Luminous Systems TLS00(a) and TLS18(a)

Basic television colour or mixture colour for D65 TLS00(a) for Yw=88,6	**chromaticity**		**tristimulus values** *(Y=88,6 for white D65)*			***adapted = standard* CIELAB data *LAB**** *(L*=95,4 for white; L*=0,00 for black)*					***relative* CIELAB data *lab**** *(L*=95,4 for white; L*=0,00 for black)*								
	x	*y*	*X*	*Y*	*Z*	$L^*_a=L^*$	$a^*_a=a^*$	$b^*_a=b^*$	$C^*_{ab,a}$	$h_{ab,a}$	o^*_3 (r)	l^*_3 (g)	v^*_3 (b)	*n**	*c**	*h**	*e**	*u**	*t**
N d* name N	*three additive mixture colours: television colours according to ISO/IEC 15775:1999*																		
C c00m cyan-blue	0,225	0,329	47,67	69,76	94,78	86,88	−46,17	−13,56	48,12	196	0,00	1,00	1,00	0,00	1,00	0,545	0,578	g31b	0,50
M m00o magenta-red	0,321	0,154	52,53	25,24	85,93	57,30	94,35	−58,42	110,97	328	1,00	0,00	1,00	0,00	1,00	0,912	0,875	b50r	0,50
Y y00l yellow	0,419	0,505	68,22	82,20	12,27	92,66	−20,70	90,75	93,08	103	1,00	1,00	0,00	0,00	1,00	0,286	0,289	j15g	0,50
N d* name N	*three aditive basic colours: television colours according to ISO/IEC 15775:1999*																		
O o00y orange red	0,640	0,330	36,54	18,84	1,71	50,50	76,92	64,54	100,42	40	1,00	0,00	0,00	0,00	1,00	0,111	0,056	r22j	0,50
L l00c leaf green	0,300	0,600	31,68	63,36	10,56	83,63	−82,77	79,90	115,04	136	0,00	1,00	0,00	0,00	1,00	0,378	0,406	j62g	0,50
V v00m violet blue	0,150	0,060	15,99	6,40	84,22	30,39	76,06	−103,58	128,52	306	0,00	0,00	1,00	0,00	1,00	0,851	0,825	b29r	0,50
achromatic colours:																			
W (ideal white, 100,00%)	0,313	0,329	95,05	100,00	108,90	100,00	0,00	0,00	0,00	0	1,05	1,05	1,05	0,00	0,00	0,00	0,00	−	1,05
W1 (white monitor, 88,6%)	0,313	0,329	84,21	88,60	96,49	95,41	0,00	0,00	0,00	0	1,00	1,00	1,00	0,00	0,00	0,00	0,00	r00j	1,00
N (black monitor, 0,00%)	−	−	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0	0,00	0,00	0,00	1,00	0,00	0,00	0,00	r00j	0,00
N0 −	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−

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Basic television colour or mixture colour for D65 TLS18(a); Yw=86,1 + 2,5	**chromaticity**		**tristimulus values** *(Y=88,6 for white D65)*			***adapted = standard* CIELAB data *LAB**** *(L*=95,4 for white; L*=18,01 for black)*					***relative* CIELAB data *lab**** *(L*=95,4 for white; L*=18,01 for black)*								
	x	*y*	*X*	*Y*	*Z*	*L**	*a**	*b**	C^*_{ab}	h_{ab}	o^*_3 (r)	l^*_3 (g)	v^*_3 (b)	*n**	*c**	*h**	*e**	*u**	*t**
N d* name N	*three additive mixture colours: television colours acc. to ISO/IEC 15775:1999*																		
C c00m cyan-blue	0,228	0,329	48,71	70,30	94,79	87,14	−44,44	−13,14	46,32	196	0,00	1,00	1,00	0,00	1,00	0,546	0,578	g31b	0,50
M m00o magenta-red	0,321	0,162	53,43	27,04	86,23	59,01	89,33	−55,69	105,26	328	1,00	0,00	1,00	0,00	1,00	0,911	0,875	b50r	0,50
Y y00l yellow	0,414	0,497	68,67	82,33	14,67	92,74	−20,06	84,97	87,30	103	1,00	1,00	0,00	0,00	1,00	0,287	0,289	j15g	0,50
N d* name N	*three aditive basic colours: television colours acc. to ISO/IEC 15775:1999*																		
O o00y orange red	0,600	0,330	37,89	20,82	4,41	52,76	71,63	49,87	87,29	35	1,00	0,00	0,00	0,00	1,00	0,097	0,036	r14j	0,50
L l00c leaf green	0,301	0,581	33,18	64,08	13,00	84,01	−79,02	73,94	108,20	137	0,00	1,00	0,00	0,00	1,00	0,380	0,411	j64g	0,50
V v00m violet blue	0,161	0,079	17,93	8,73	84,57	35,47	64,92	−95,08	115,12	304	0,00	0,00	1,00	0,00	1,00	0,845	0,822	b28r	0,50
achromatic colours:																			
W (ideal white, 100,00%)	0,313	0,329	95,05	100,00	108,90	100,00	0,00	0,00	0,00	0	1,05	1,05	1,05	0,00	0,00	0,00	0,00	r00j	1,05
W1 (white monitor, 88,6%)	0,313	0,329	84,21	88,60	96,49	95,41	0,00	0,00	0,00	0	1,00	1,00	1,00	0,00	0,00	0,00	0,00	r00j	1,00
N (black monitor, 2,52%)	0,313	0,329	2,40	2,52	2,74	18,01	0,00	0,00	0,00	0	0,00	0,00	0,00	1,00	0,00	0,00	0,00	r00j	0,00
N0 (ideal black, 0,00%)	−	−	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0	−0,19	−0,19	−0,19	1,19	0,00	0,00	0,00	−	−0,19

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Output Linearization of visual displays based on a human visual RGB* colour space

Table 2 shows the colorimetric data of the Television Luminous Systems TSL00(a) and TLS18(a) according to ISO/IEC 15775. In both cases the white point is normalized to L^*_W=95,4 which is the white point of the standard offset paper. The CIELAB data of the standard and adapted Systems TLS00 and TLS00a, and TLS18 and TLS18a are identical because it is valid in the standard case for the CIELAB data of Black *N* and White *W*:

$$(a^*_N, b^*_N) = (a^*_W, b^*_W) = (a^*_{N,a}, b^*_{N,a}) = (a^*_{W,a}, b^*_{W,a}) = (0, 0)$$

The Systems TLS00 and TLS18 differ in lightness with L^*_N = 00 and L^*_N = 18 for Black *N*. In application the luminance reflectance of the black colour differs between Y_N = 2,5 for silk matt Black *N* and Y_N = 4,0 for matt Black *N*. The luminance reflectance Y_N = 2,5 corresponds to the lightness L^*_N=18 and these two values are the standard values of standard offset printing, compare ISO/IEC 15775.

There are many advantages in applications, if the value L^*_N =18 is chosen for black in offices. Often in offices the reflection varies between 2,5% and 10% compared to the white CRT display. Then the black lightness L^*_N varies between L^*_N = 18 and L^*_N = 33. ISO 8995 requests an illuminance of 500 lux in offices and CIE 184 specifies Indoor Daylight Illuminants iD65 and iD50. In Europe the use of daylight is recommended in offices, see DIN V 18599-4.

The standard illuminance of 500 lux produces a luminance of about 140 cd/m^2 on the white standard offset paper. LCD displays may have a higher white luminance, for example 320 cd/m^2 and CRT displays may have a lower luminance of 80 cd/m^2. Therefore the reflection of the ambient light on the monitor surface may vary by a factor 4.

The visual effect in appearance is large even if the reflection is only 2,5%. The lightness range between White and Black reduces from ΔL^* = 95,4 - 0,0 = 95,4 to 94,4 - 18,0 = 77,4. The is a reduction factor 0,82. At the same time the chroma in red–green and yellow–blue direction reduces by the same factor. The result is a colour gamut reduction by the factor 0,82 x 0,82 x 0,82 = 0,55. The loss of 45% of the visual colour gamut is avoided in the graphic arts area of ISO TC 130, see ISO 15076-1, by a reduction of the ambient illuminance from 500 lux to 32 lux and shutters around the CRTdisplay. This artificial situation is not allowed by ergonomic illumination standards in offices, see ISO 8995. If still colour management according to ISO 15076-1 is used then the efficiency of colour managment for the standard office situation with 2,5% reflection is reduced. The colour gamut and the efficiency is reduced by a factor 0,55.

In addition ISO 15076-1 request a D50 illumination in offices. In the standard case of 2,5% luminance reflection of the D50 illumination, the CIELAB chroma changes for White and Black towards yellow, but much more for Black. The CIELAB chroma C^*_{ab} changes from zero to about 2 for White and 10 for black. The tolerance is 3 according to ISO/IEC 15775 for colour copiers. Therefore the Black and the dark greys look very yellowish and the achromatic axis is tilted. ISO 15076-1 needs not to consider this problem because it assumes an illuminance of 32 lux compared to the standard office illuminance of 500 lux (15fold less compared to ISO 8995 and therefore 15fold less reflection).

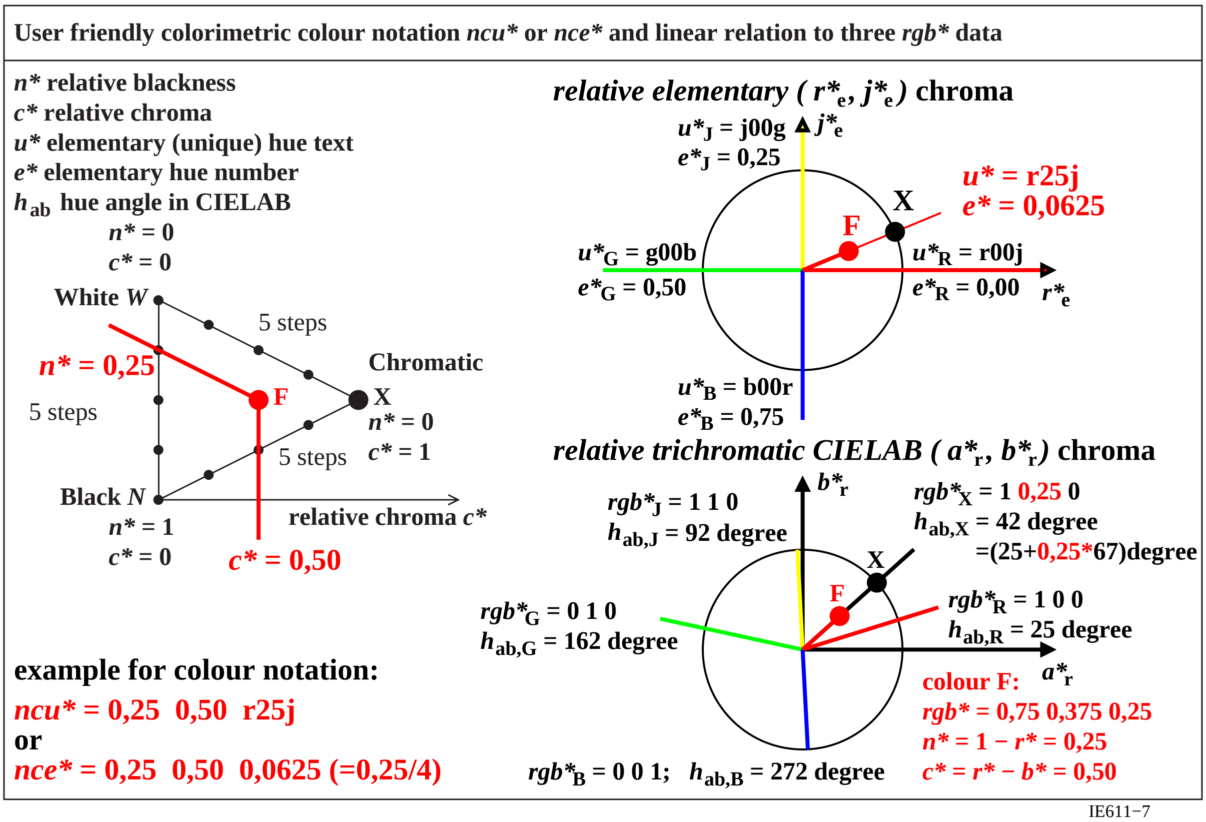


Figure 3 – Relations between colour coordinates *ncu**, ***rgb****, and CIELAB hue angle** h_{ab}

Fig. 3 shows the relations between the colour coordinates *ncu*, rgb** and the CIELAB hue angle $h_{ab.}$ A colour triangle of equal hue is shown on the left side and two hue circles on the right side. The hue spacing is different in a symmetrical elementary hue circle *(top right)* and compared to the spacing according to the CIELAB hue angle h_{ab} *(bottom right)*. The most chromatic colour is located together with Black *N* and White *W* on a hue triangle *(left)*. This is known from many colour order systems, for example of *Ostwald* (1925) and *NCS* (1970). The colours of equal blackness are located on lines parallel to the line W – X with the relative blackness ***n**** = 0. The blackness reaches ***n**** = 1 for black and therefore it is valid *n** = 0,25 for the colour F in Fig. 3. The relative chroma is ***c**** = 1 for the colour X and it is therefore *c** = 0,5 for the colour F in Fig. 3. The missing coordinates *rgb** are shifted by 25% from rgb^*_R = 1 0 0 for elementary Red *R* towards rgb^*_J = 1 1 0 for elementary Yellow *J*, see Fig. 3 *(top right).* The letters in red colour show the connection between

ncu* = 0,25 0,50 r25j and ***rgb**** = 0,75 0,375 0,25.

The use of equations (3) and (4) verifies

$n^* = 1 - max\ (r^*, g^*, b^*) \qquad = 1 - 0{,}75 \qquad = 0{,}25$

$c^* = max\ (r^*, g^*, b^*) - min\ (r^*, g^*, b^*) \qquad = 0{,}75 - 0{,}25 \qquad = 0{,}50$

If we use the elementary hue angles of CIE R1-47 we can calculate the elementary hue text ***u**** for any given CIELAB hue angle h_{ab} and vice versa. This has been realized in DIN 33872 and the *RECS* colour system. If the CIELAB chroma $C^*_{ab,Ma}$ and the lightness L^*_{Ma} of the maximum colour X = M_a is known, then it is valid for any colour F of the same CIELAB hue angle with the coordinates ($C^*_{ab,a,F}$, L^*_F):

$$c^* = C^*_{ab,a,F} / C^*_{ab,a,Ma} \qquad (5)$$

Blackness ***n**** can be calculated by the following equations with the CIELAB lightness ***L**** of the colours F, W, and N.

$$l^* = [\ L^*_F - L^*_N\ ]\ /\ [\ L^*_W - L^*_N\ ] \qquad (6)$$

$$t^* = l^* - c^*\ \{\ [\ L^*_{Ma} - L^*_N\ ]\ /\ [\ L^*_W - L^*_N\ ] - 0.5\ \} \qquad (7)$$

$$n^* = 1 - t^* - 0.5\ c^* \qquad (8)$$

Therefore if the CIELAB data LCH^*_F of any colour F and the CIELAB data LCH^*_{Ma} of the device Maximum colour M_a of the same hue are given, then the colour coordinates *rgb** and *ncu** can be calculated.

If the coordinates *rgb** are given then it is easy to calculate *ncu** and the CIELAB hue angle h_{ab}. For the missing CIELAB data LC^*_F of the sample colour the data LC^*_{Ma} of the Maximum colour Ma are necessary. For example for the *sRGB* color space according to IEC 91966-2-1and many other colour spaces of image technology the data LC^*_{Ma} are known as function of the CIELAB hue angle h_{ab}. Therefore if any data set of the three sets *rgb*, ncu*,* and *LCH** is given the other two can be calculated.

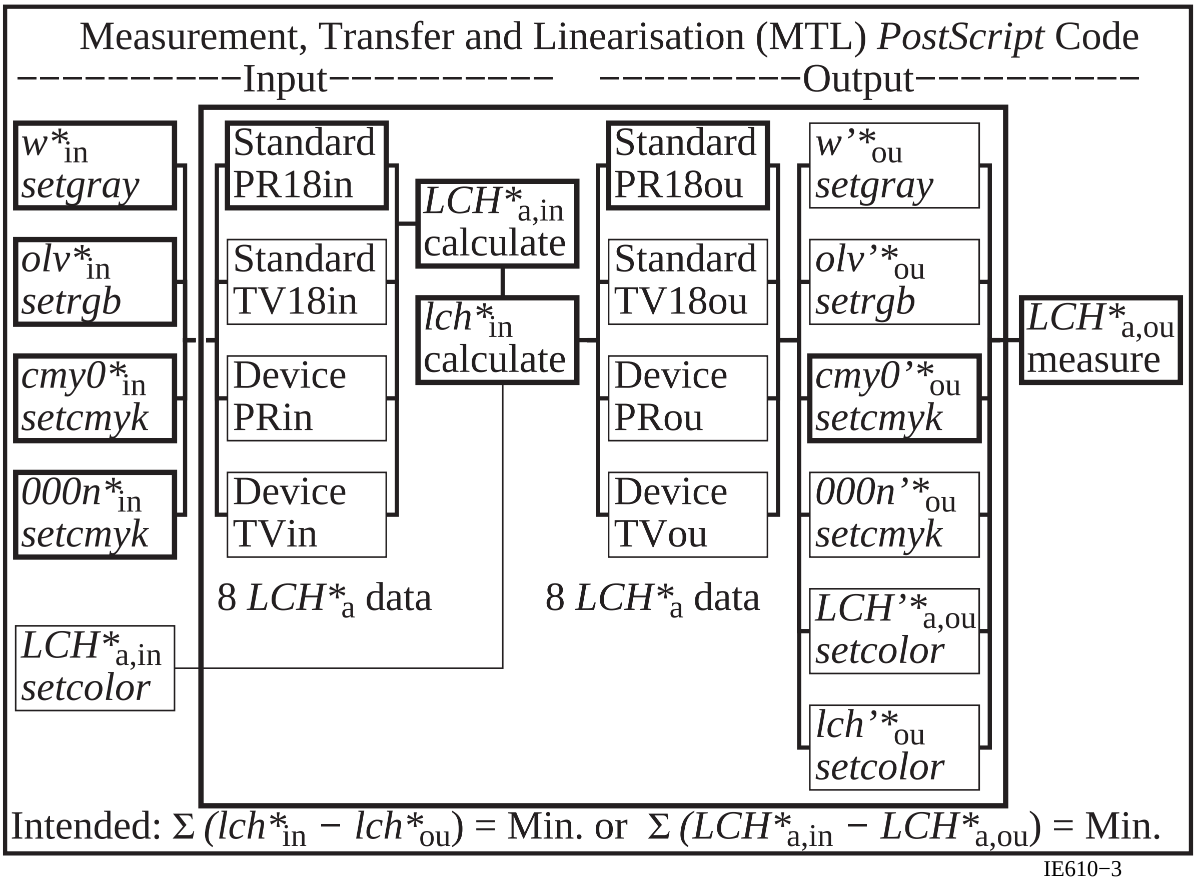
As a result of the discussion we can summarize as follows

A user friendly image technology shall take care of the viewing conditions in office application, especially the office illumination of 500 lux and the change of the CIELAB colour data by reflections on the display. In a worse case according to ISO 9241-306 the luminance produced by the projector display and the luminance of the daylight office may be the same. This will reduce the lightness range from 77,4 (=95,4–18,0) to 25,4 (=95,4–70,0). Then the colour gamut will decrease by the factor 0,3 x 0,3 x 0,3 = 0,027. This factor 0,027 is much less compared to factor 0,55 for the standard reflection 2,5%

There are user friendly visual coordinates *ncu** (relative blackness *n**, relative chroma *c** and elementary hue text *u**) which are connected to the visual *rgb** coordinates by equations. The visual *rgb** coordinates have the values *rgb** = 1 0 0, 1 1 0, 0 1 0, and 0 0 1 for the elementary hues Red *R*, Yellow *J*, Green *G*, and Blue *B*. For any colour device with known CIELAB data of the eight device colours *OYLCVMNW* there are equations which allow to calculate the *adapted* (and standard) CIELAB data LCH^*_a (lightness *L**, Chroma $C^*_{ab,a}$, and hue angle $h_{ab,a}$) for any triple of *rgb** data and vice versa.

In the next chapter the definitions of colour in image technology will be discussed. Visual *rgb* data called *rgb** (star-data) according to ISO/IEC 15775 are used. The use of the *rgb** data by *PS* or *PDF* operators and the calculated change to the inverse *rgb'** data (dash-star) for the intended output will be shown

4. Colour data change of *PostScript* colour operators between in and output



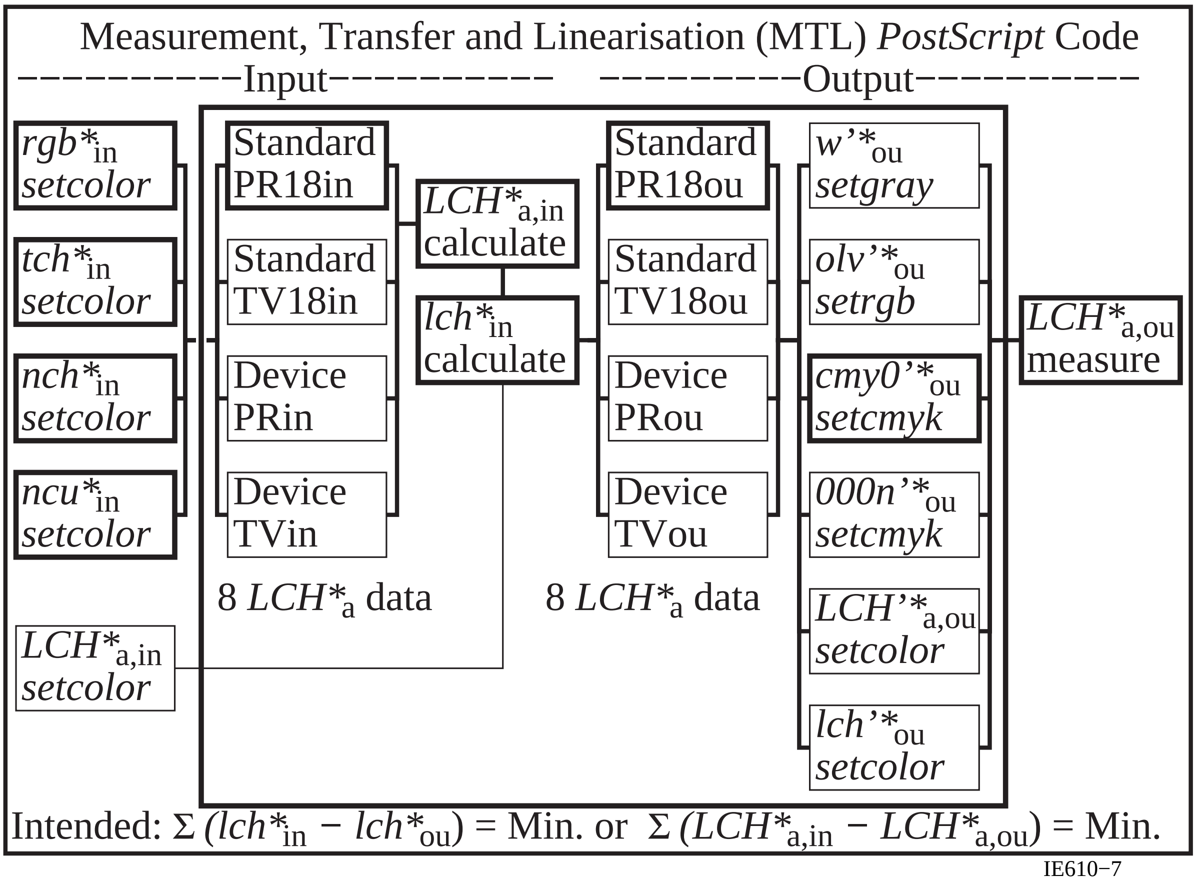


Figure 4 – Colour data change of *PostScript* operators between input and output in image technology

Fir. 4 shows different *PostScript* operators and for example the *rgb** colour data change of between input and output. The are different *PostScript* colour operators and corresponding *PDF* operators which are used in files of the format

PS and *PDF*. The format *PS* is used to create the figures and test charts of this document. The format *PDF* is created for example by the software *Adobe Acrobat Distiller 3* from the *PS* file format. The *PDF* format is mainly used in offices and the *PS* format additionally often in the graphic arts area.

Fig. 4 shows in the upper part the standard *PostScript* operators, for example *setgray, setrgbcolor,* and *setcmykcolor.* Up to four data in the range zero to one are necessary in front of the *PS* operator, for example *w*, olv* (rgb)*, and *cmy0** or *000n** (star data). For an intended linearized output, see ISO/IEC TR 19797, a special change to *w'*, olv'*,* and *cmy0'** or *000n'** (dash-star data) is necessary. The *PS* operator *setcolor* in the lower part of Fig. 4 can use modifications and functions of the coordinates *w*, olv* (rgb)*, and *cmy0** or *000n*,* for example the coordinates *ncu*.*

In the profile connection space (PCS) of colour management according to ISO 15076-1 the CIELAB data *LAB** or *LCH** are necessary to calculate an output transform, for example between the star-data *olv* (rgb)* and the dash-star-data *olv'* (rgb')*. For example for data projectors the display reflections changes according to ISO 9241-306 from 0% in a dark room up to about 50% in a daylight office. Therefore for displays the colour gamut may change from 100% to about 3%. The CIELAB data are measured and stored in the CIELAB Profile Connection Space (PCS). The PCS reserve a digital data range between -128 and 127 for *a** and *b** and between 0 and 255 for *L**. For example the *sRGB* colour space with a lightness range between 0 and 100 covers only 20% of the CIELAB PSC gamut according to CIE 168. This is the case for the System TLS00 of Table 2. If we consider the colour gamut reduction to 55% for the office colour condition then only 11% of the CIELAB PCS gamut is used. This is the case for the System TLS18 of Table 2. If in a worse case the luminance produced by the data projector and the daylight office illumination is the same, then only 0,2 x 0,027 = 0,06 or 0,6% of the CIELAB PCS is used. In other words the CIELAB data of the data projector are located only within 0,6% of the reserved CIELAB PCS data range. The efficiency of colour management according to ISO 15076-1 decreases to less then 1% for these office conditions. If one assumes nearly no reflections on the display as in the artificial graphic arts conditions the efficiency is reduced by a factor 5, if the sRGB colour space is used

The proposal of this paper is to use an alternate *RGB* PCS instead of the CIELAB PCS. This increases the efficiency by more than a factor 150 in a worse case and by a factor 9 if the standard sRGB space is used. The factor 9 appears because the triangle *RGB* coordinates describe the sRGB space directly and not by the more ineffective cartesian rectangular *LAB** coordinates. The improvement is included in the equations 1 to 8, which connects the *RGB* space defined by the 8 basic device colours by equations with the CIELAB space. There is an increase in efficiency if the colour data are given in a visual *RGB* space. The *RGB* data in the range 0 to 1 always fill the device space up to the device gamut limits. The CIELAB data fill only 0,6% of the CIELAB PCS in the case of the System TLS70, 12% in the case of TLS18, and 20% in case of TLS00.

In a Ph.D. thesis recently *Wagenknecht* has studied the accuracy of the colour output with different colour management methods. *Wagenknecht* has used the standard CIELAB PCS of different commercial software product and has simulated an *RGB* PCS. The accuracy of the CIELAB PCS was by a factor 2 to 3 worse compared to the method which simulates an *RGB* PCS.

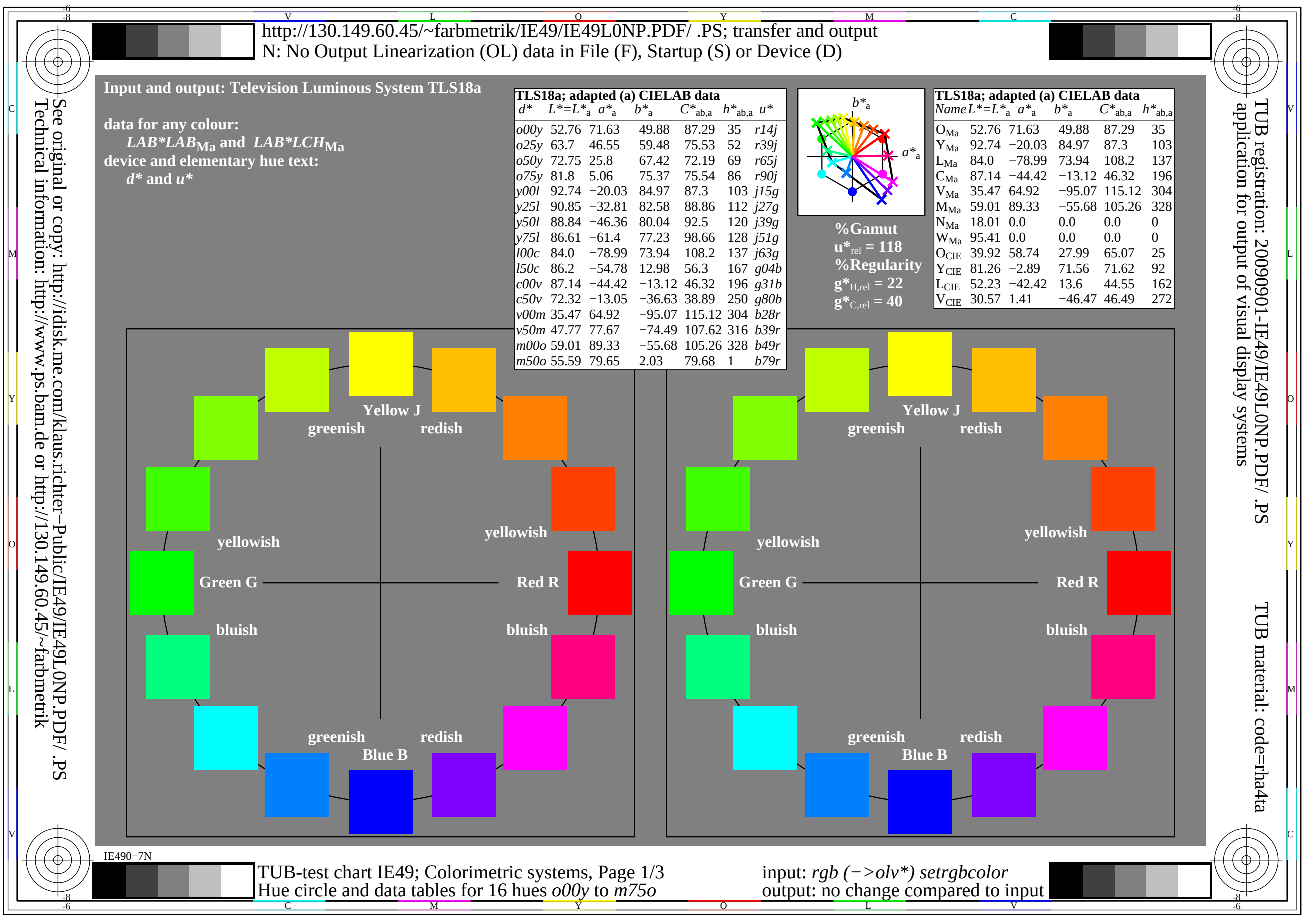
The most efficient method for colour management is therefore a direct transfer from the *olv* (rgb)* to the *olv'* (rgb')* data. This method is often called a device link transfer. In other words the *rgb* data and not the CIELAB data of a device have to be stored and transmitted. This increases the accuracy up to a factor 150 for the worse office condition TLS70. The equations (1) to (8) can be used for the calculation of the CIELAB data from the *rgb* data at any stage of the workflow. At least the CIELAB data of 8 reference colours *OYLCVM NW* are necessary for this calculations in both directions. A more general solution is the transmittance of the maximum data of a 48 step device colour circle and 9 grey step including Black and White, see Fig. 10 to 12.

5. Device and elementary hue circle with *olv*, rgb** and CIELAB *LCH** data

For the 2,5% luminance reflection on the monitor surface the CIELAB standard colour gamut will be studied in the following. The CIELAB *LCH** data and some relative CIELAB data, for example *lab*olv* = olv**, *lab* rgb* = rgb** and *lab*ncu* = ncu** will be given for a 16 step colour circle and for hue planes with 5- and 16-step colour series. The hue changes in the hue circle by 16 steps and there is no change in hue plane. For a linearized output according to ISO/ IEC TR 19797 in device space the hue angle between two neigboring colours differs in equal (25%) steps. It must be mentioned that any successful colour management method needs a device output linearization. Therefore the following linearization in device space and the following in elementary colour space is essential.

Many printer systems on the market do not fulfill the rules of ISO/IEC TR 19797. The output is often irregular and not continuous for equally spaced *rgb*-input data, see Fig. 19 *(top)*. Therefore these devices can not be used for a successful colour management. In case of *PostScript* printers there is often a work around. Often only the *cmy0* output is continuous and more linear compared to the *rgb* output. Fig. 5 to 8 include tables of the six standard device colours *OYLCVM* and Black *N* and White *W* for the device colour system TLS18a for 2,5% reflection compared to the white monitor. The device and elementary hue text is based on CIE R1-47. The CIELAB data describe the Maximum colours M_a at the colour gamut boundary. The values C^*_{ab} are different in the *standard* CIELAB space *LCH* (capital letters)* but relative chroma *lab*c* = c** is equal to 1 in the *relative* CIELAB space *lch* (small letters).*

Output Linearization of visual displays based on a human visual RGB* colour space



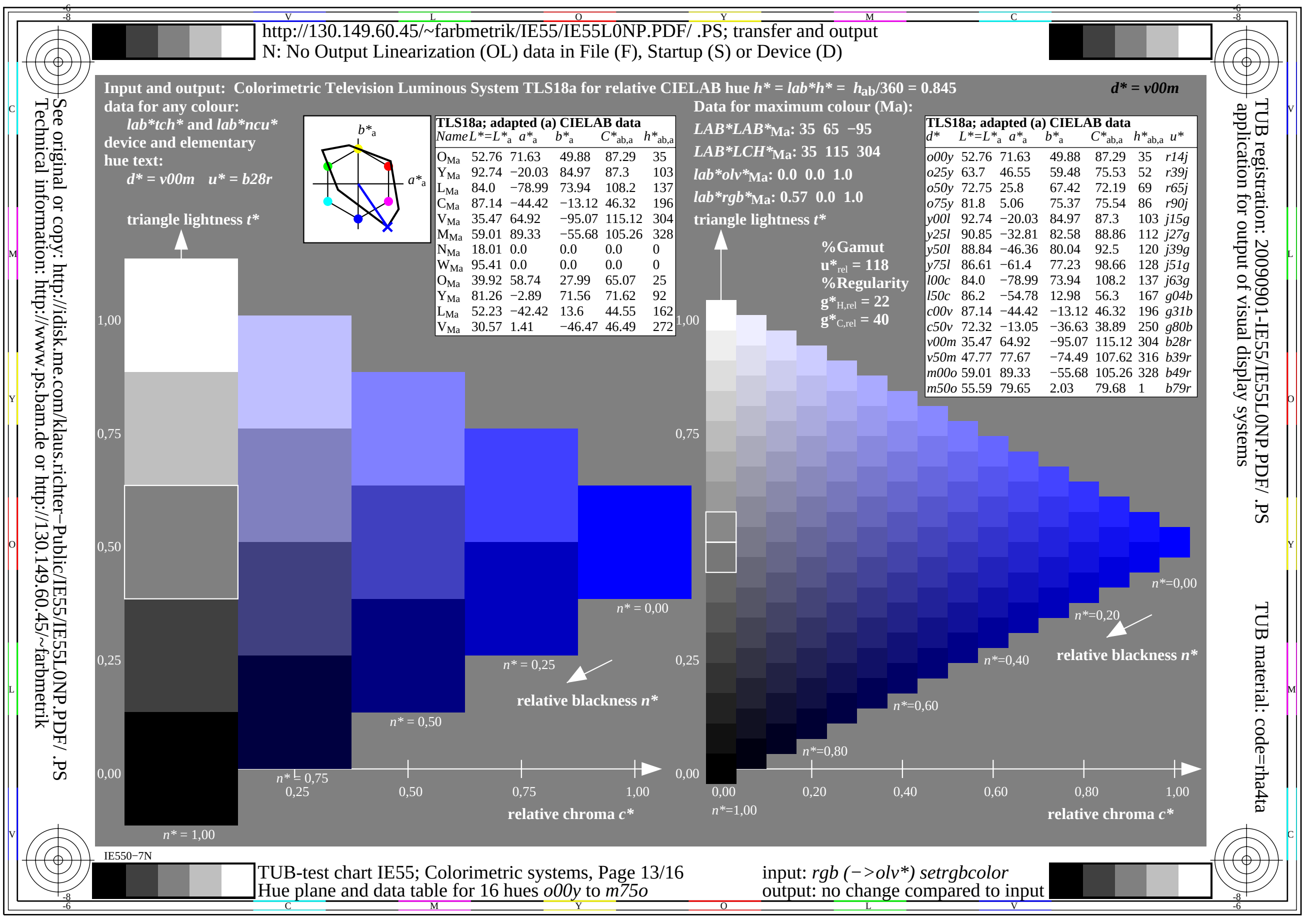
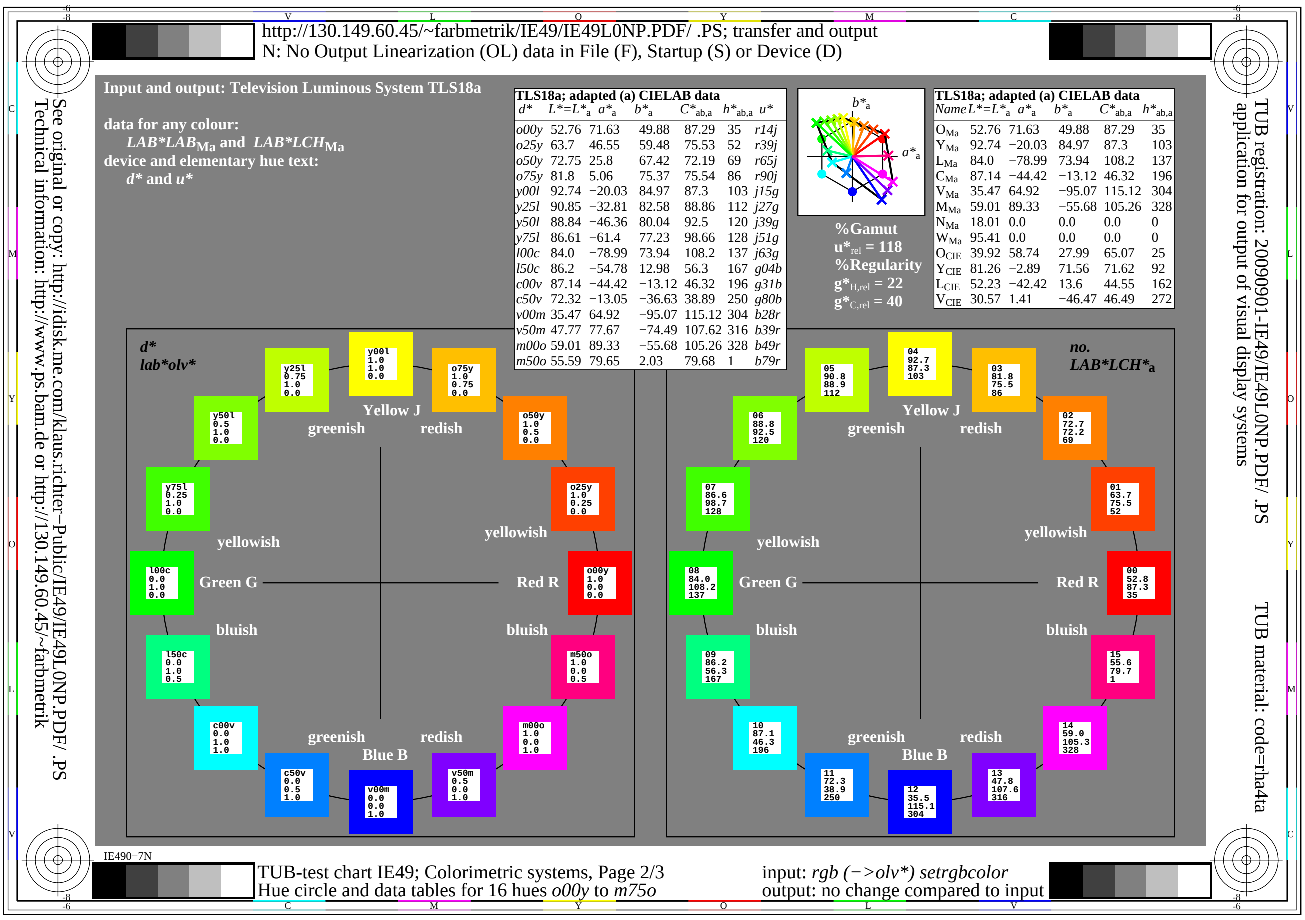


Figure 5 – Colour circle in device hue space and 5- and 16-step colour series for device hue *V = v00m*

Output Linearization of visual displays based on a human visual RGB* colour space



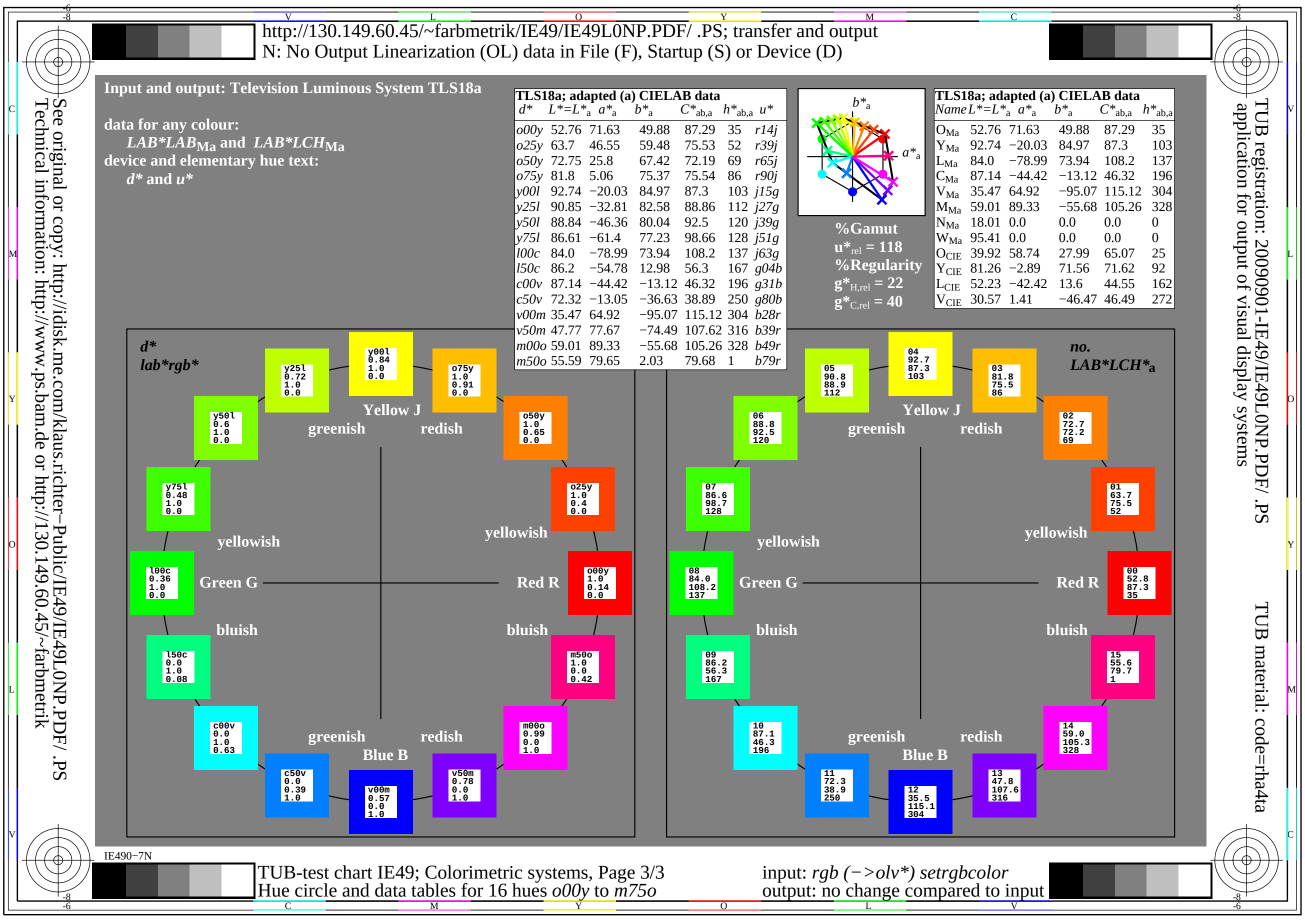
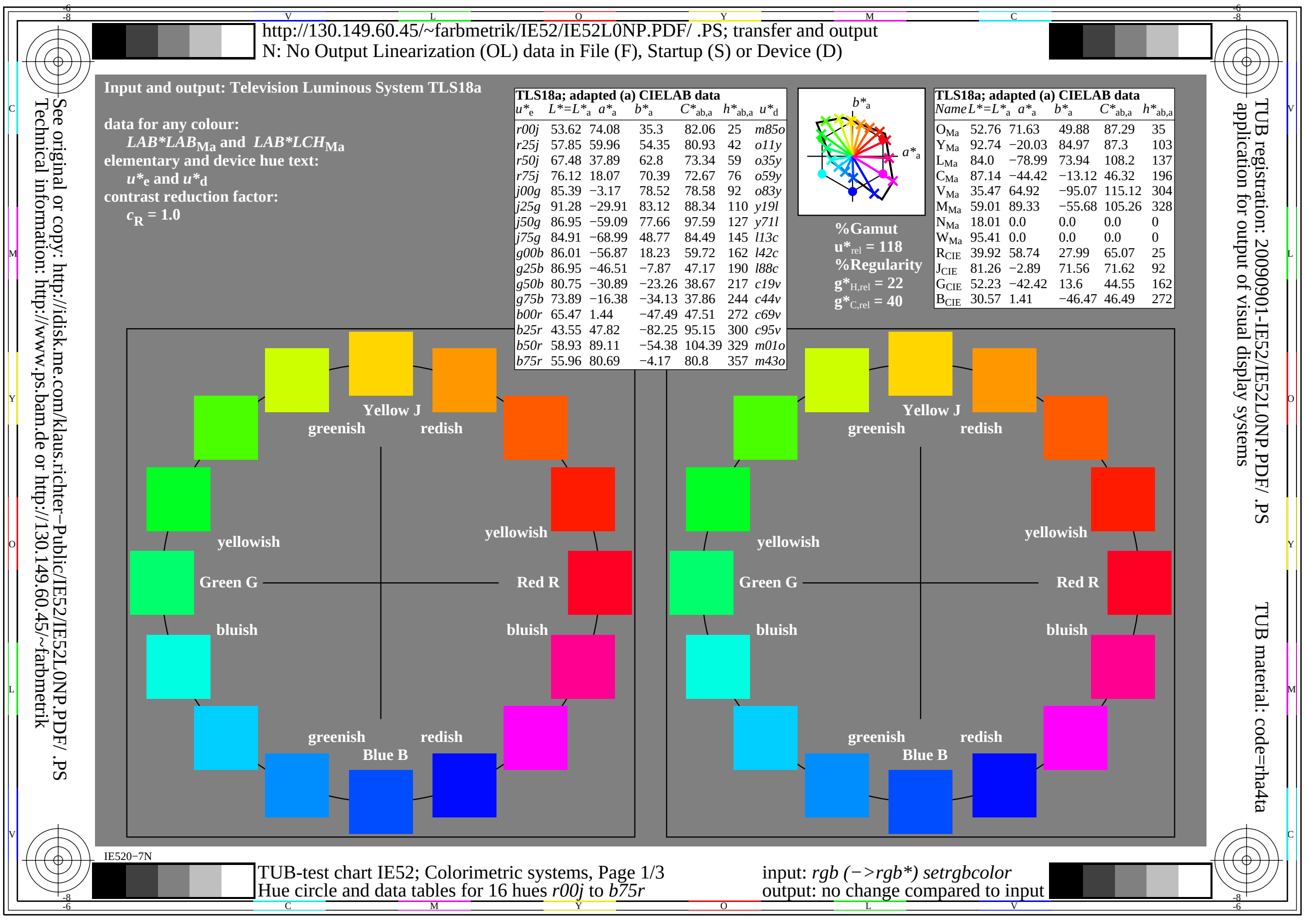


Figure 6 – 16-step colour circle in device space with device hue text *d between *o00y* and *m50o***

Output Linearization of visual displays based on a human visual RGB* colour space



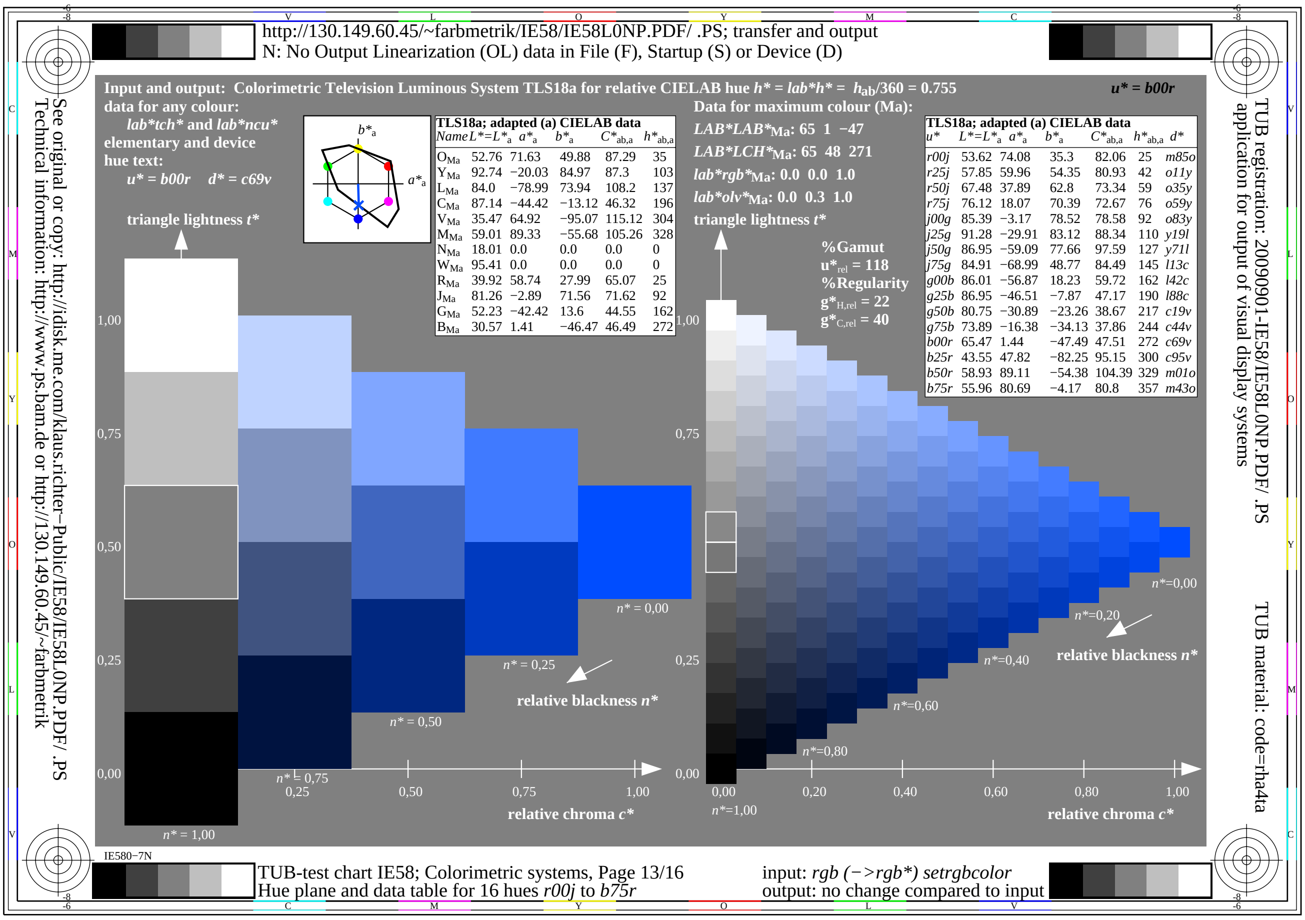
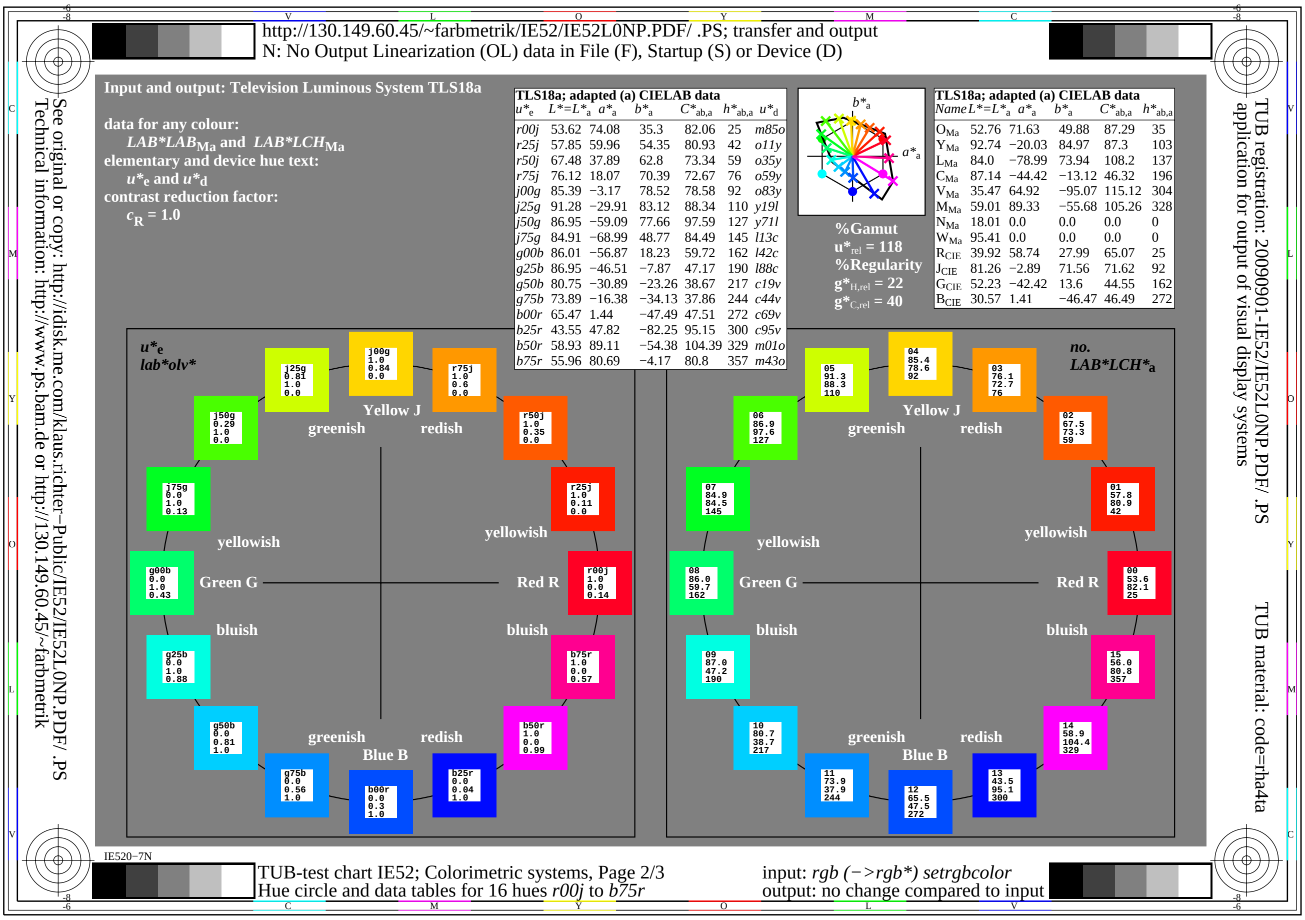


Figure 7 – Colour circle in elementary space and 5- and 16-step colour series for elementary hue *B* = *b00r*



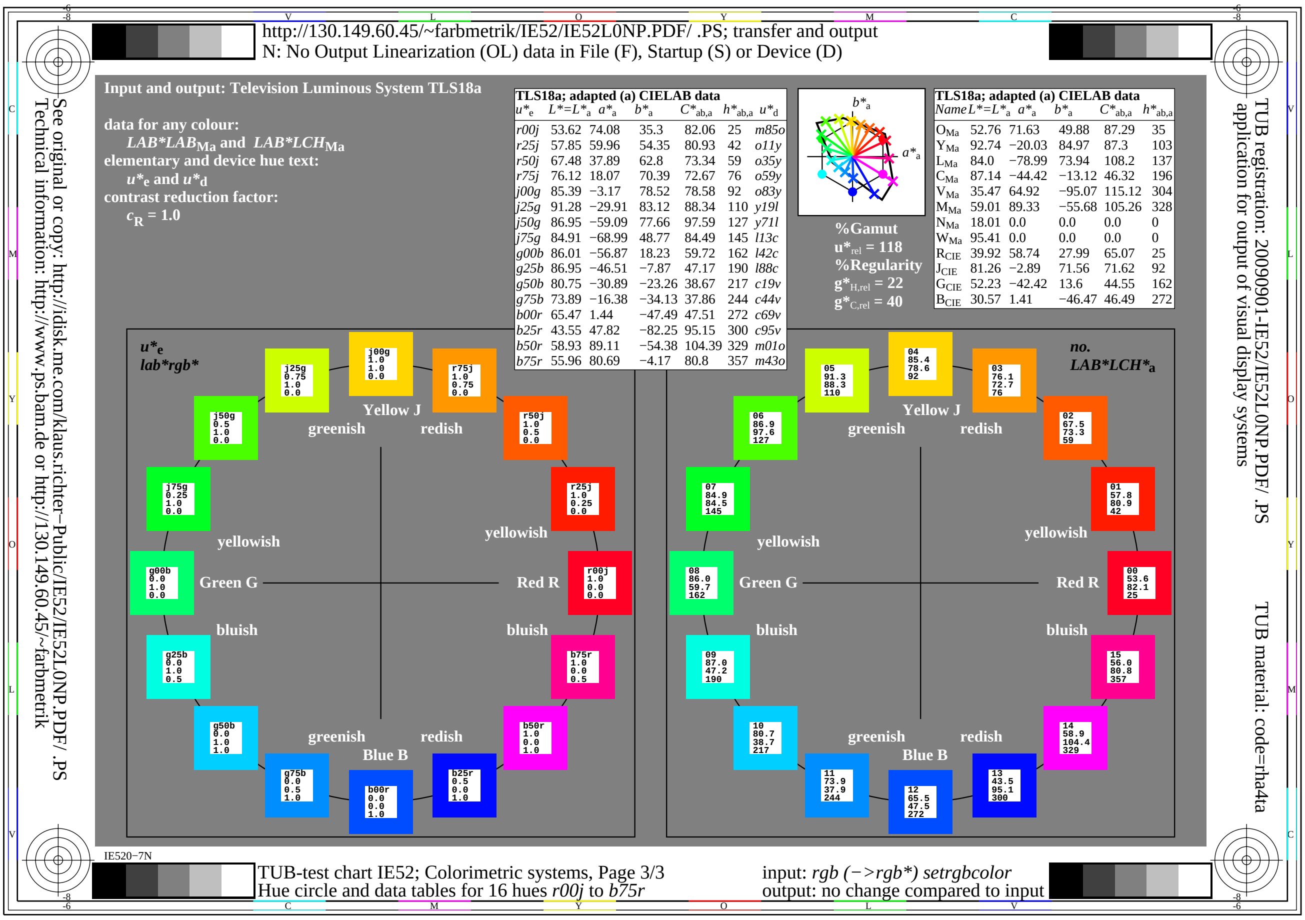


Figure 8 – 16-step colour circle in elementary hue space with elementary hue text *u between *r00j and b75r***

Output Linearization of visual displays based on a human visual RGB* colour space

Fig. 5 to 8 show a device and an elementary hue circle, and 5- and 16- step colour scales in device and elementary hue space. All data given are for the Television Luminous System TLS18 with L^*_N = 18 and L^*_W = 95.

Fig. 5 to 8 include tables of the CIELAB data of the 8 device and the 4 CIE reference colours of CIE R1-47 and CIE 13.3, which define the elementary hue angles 26, 92, 162, and 272 degrees for *RJGB* in CIELAB. The three intermediate colours, for example with the elementary hue text *r25j, r50j, r75j* are shifted in hue angle by (92-26)/4 = 17 degrees in the sector *R – J* and similar in the other four sectors. So for every CIELAB hue angle h_{ab} the elementary hue text *u** can be calculated and vice versa. Similar the *rgb** colour data of the elementary colour space can be calculated for the maximum colours. Always at least one of the three *rgb** data is 1 and one other is zero. The intermediate value of the remaining *rgb* value is 0,25, 0,50, or 0,75.

In the device space the hue angles and the *olv** data are similar shifted by 25%, 50% and 75% between the neighboring colours of the two sectors *O – Y* and *Y – L*. For the other four sectors *L – C, C – V, V– M,* and *M– O* the intermediate colours are shifted by 50% between two neighboring colours for a 16-step hue circle.

6. Colorimetric *standard* and *adapted* CIELAB data in a hue hexagon

The colorimetric data of television, printing and of elementary colours in an *adapted* and *relative* CIELAB chroma diagram are of special importance for the device output linearization.

The six chromatic colours *X=OYLCVM* and their linear mixtures create the maximum colours M_a. For each *adapted* CIELAB hue angle $h_{ab,a}$ there is a maximum colour M_a with defined CIELAB data L^*, $C^*_{ab,a}$, and $h^*_{ab,a}$.The linearization, for example according to ISO/IEC TR 19797, produces a 16 step equidistant colour series in the output.

For output linearization in device space it is recommended to measure a grid of 9x9x9 colours. This is common practice to define the colour gamut and the colour gamut boundary for colour management.

Fig. 9 shows the TUB-test chart IE00 with a 9x9x9 colour grid G *(top)* and the TUB-test chart IE32 with a 12x9x9 opponent colour grid O *(bottom)*. The top part shows in addition a 3x9x9 opponent colour grid O. Both parts show at the right side 9-step and 16-step grey scales which are defined by four *PS* operators and in addition the 8 basic colours at the end.

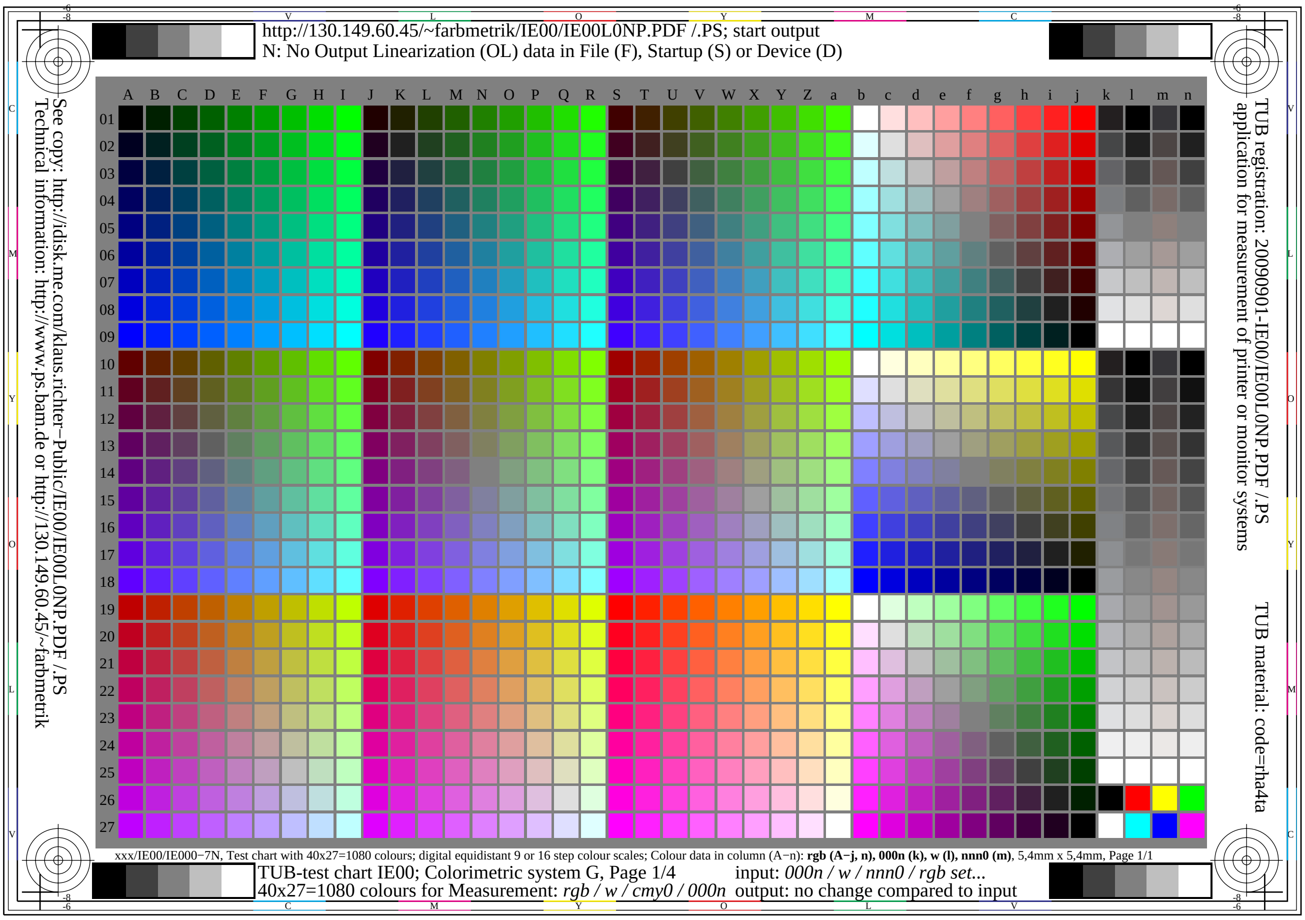
Fig. 10 shows for an LCD display (*Apple Cinema Display*, 2004) the measurement data of a 48 step hue circle. The number of hue samples in Fig. 10 is 3fold compared to the hue circle of Fig. 5

For the LCD display the colorimetric data for 48 colours of the device hue circle are given. In addition the data of a 9-step grey scale is given. In any application the chroma *a** and *b** of Black and White are all different from zero and all are different. Therefore a special adaptation method is necessary. Otherwise there is no way to define the CIELAB hue and to calculate the relative CIELAB data *lab**.

If the chroma C^*_{ab} of both Black *N* and White *W* is less than 3 then both colours appear achromatic. The data in Fig. 10 or 11 show a deviation which is twice of the tolerance of 3 CIELAB, but both Black *N* and White *W* may be still be accepted as achromatic. This has to be tested visually.

By the adaption method given, the tilted axis without adaption is shifted to the vertical axis in the *adapted* CIELAB space LCH^*_a *(index a)*. Still some grey colours have a chroma of about 2 for this device after application of the adaption method but this chroma value is below the accepted tolerance value of 3 according to ISO/IEC 15775.

Output Linearization of visual displays based on a human visual RGB* colour space



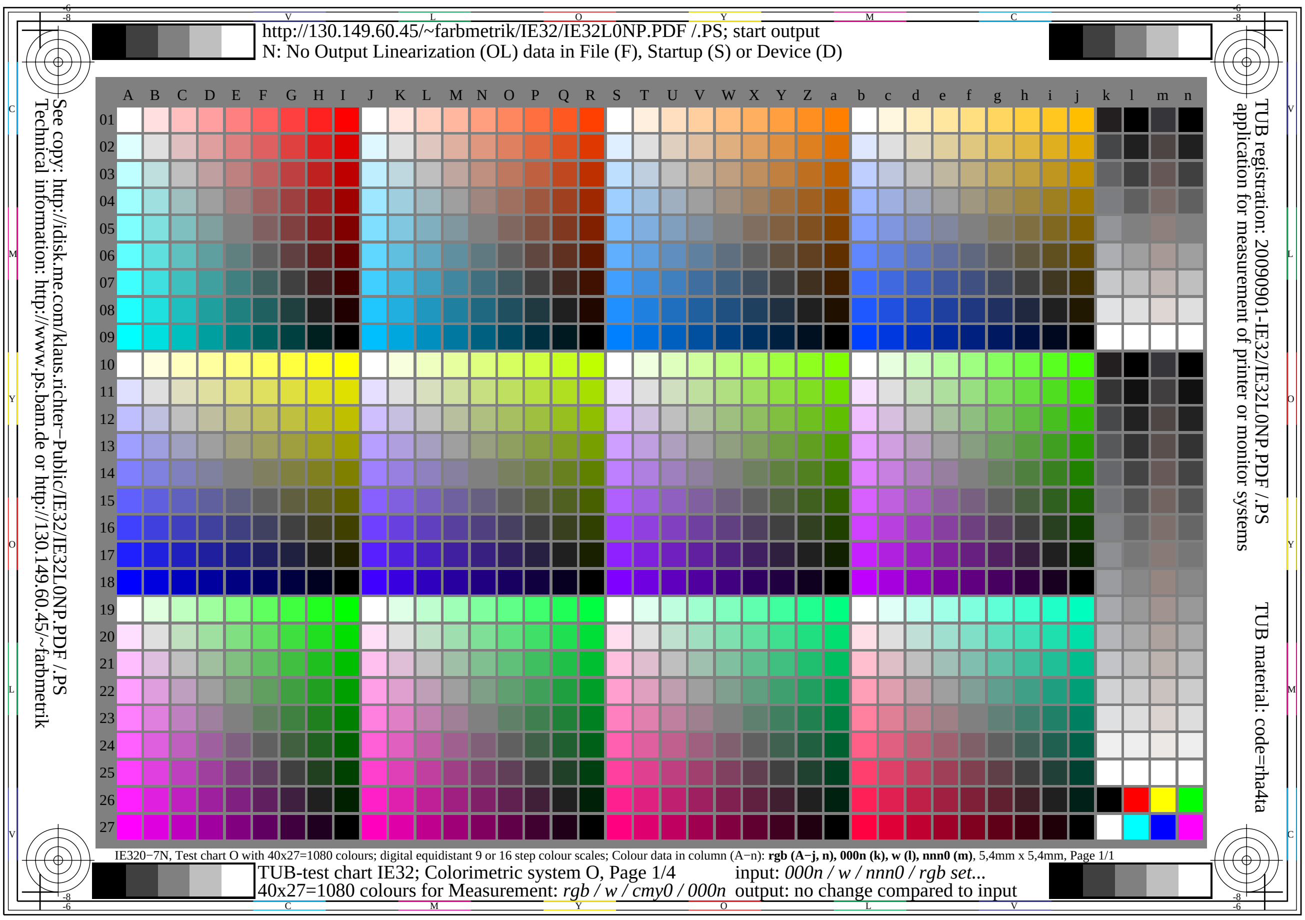
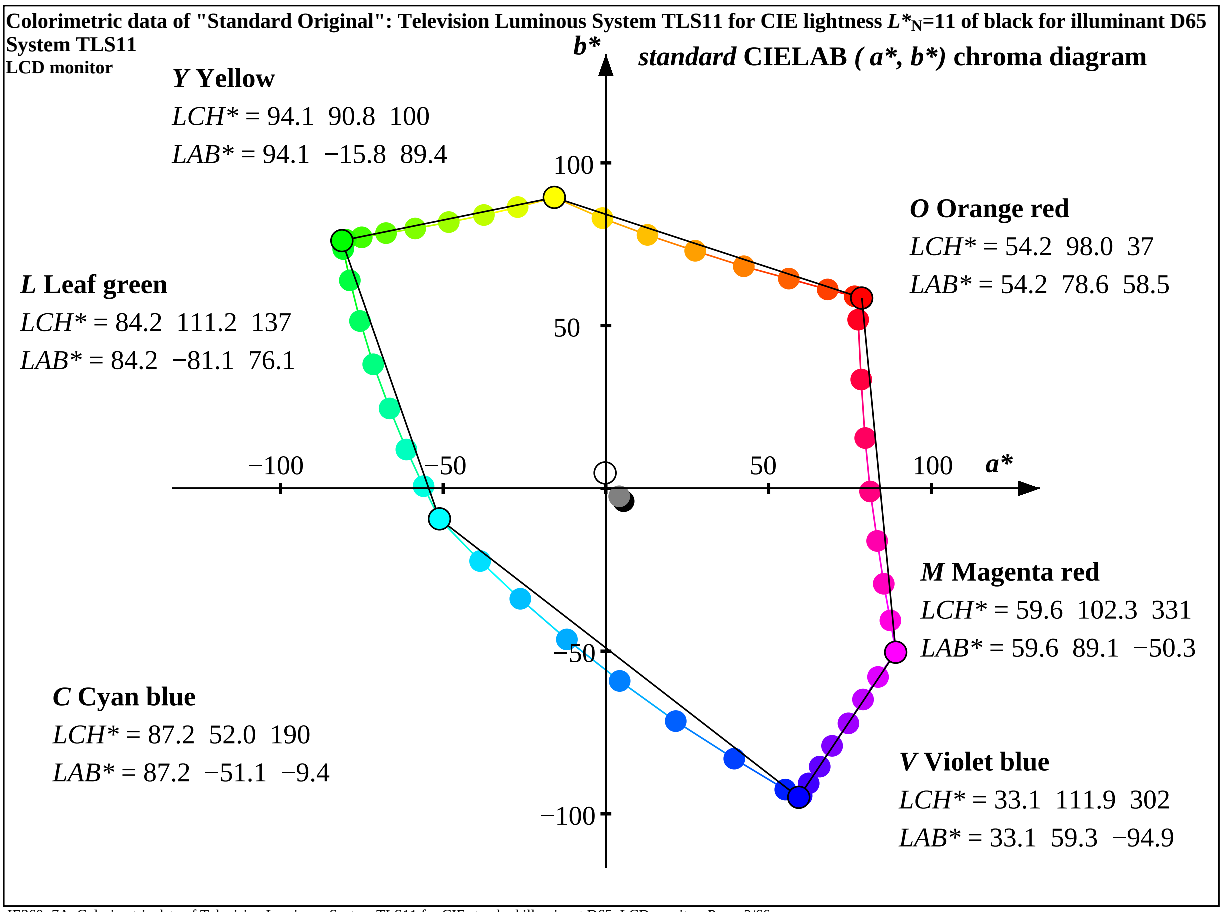


Figure 9 – TUB-test charts with x 9x9x9 colour grid G (top) and a 12x9x9 opponent colour grid O (bottom)



IE360−7A, Colorimetric data of Television Luminous System TLS11 for CIE standard illuminant D65; LCD monitor; Page: 2/66

Colorimetric data of "Standard Original": Television Luminous System TLS11 for CIE lightness L^*_N=11 of black for illuminant D65

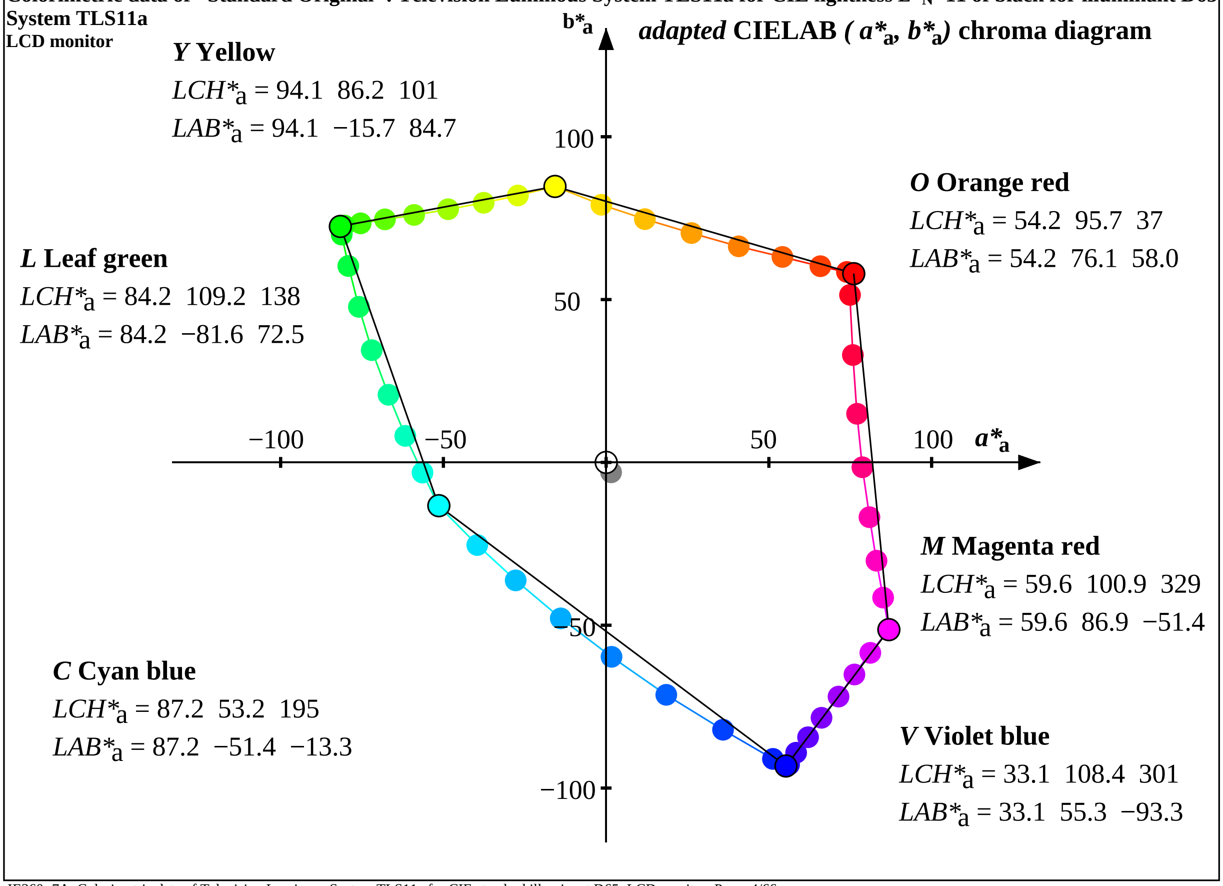
System TLS11
LCD monitor

	Color	$r=olv^*_1$	$g=olv^*_2$	$b=olv^*_3$	$L^*_c=LAB^*_{1c}$	$a^*_c=LAB^*_{2c}$	$b^*_c=LAB^*_{3c}$	$C^*_{ab,c}=LAB^*_{rc}$	$h_{ab,c}$	$X_c=XYZ_{1c}$	$Y_c=XYZ_{2c}$	$Z_c=XYZ_{3c}$	x_c	y_c	$Y_c/88.59$
00	o00y	1.0	0.0	0.0	54.21	78.64	58.52	98.03	37	42.14	22.17	3.33	0.623	0.3278	0.2503
01	o13y	1.0	0.125	0.0	54.91	76.45	59.02	96.58	38	42.42	22.84	3.44	0.6174	0.3325	0.2579
02	o25y	1.0	0.25	0.0	57.87	68.1	61.12	91.5	42	43.91	25.83	3.96	0.5958	0.3505	0.2916
03	o38y	1.0	0.375	0.0	62.22	56.16	64.44	85.47	49	46.26	30.66	4.75	0.5664	0.3754	0.3461
04	o50y	1.0	0.5	0.0	67.48	42.42	68.19	80.31	58	49.48	37.27	5.91	0.534	0.4022	0.4207
05	o63y	1.0	0.625	0.0	73.63	27.43	72.96	77.94	70	53.85	46.12	7.39	0.5016	0.4296	0.5206
06	o75y	1.0	0.75	0.0	80.08	12.73	77.89	78.93	81	59.14	56.82	9.2	0.4725	0.454	0.6414
07	o88y	1.0	0.875	0.0	86.52	−1.05	82.98	82.99	91	65.14	69.03	11.22	0.448	0.4748	0.7793
08	y00l	1.0	1.0	0.0	94.11	−15.83	89.38	90.77	101	73.43	85.54	13.8	0.425	0.4951	0.9655
09	y13l	0.875	1.0	0.0	92.0	−27.1	86.39	90.55	108	64.07	80.71	13.54	0.4047	0.5098	0.911
10	y25l	0.75	1.0	0.0	90.22	−37.49	83.97	91.96	115	56.47	76.78	13.28	0.3854	0.524	0.8667
11	y38l	0.625	1.0	0.0	88.56	−48.25	81.77	94.94	122	49.55	73.23	13.01	0.3649	0.5393	0.8266
12	y50l	0.5	1.0	0.0	87.07	−58.61	79.85	99.06	128	43.6	70.14	12.75	0.3447	0.5545	0.7917
13	y63l	0.375	1.0	0.0	85.89	−67.53	78.43	103.5	132	39.02	67.76	12.51	0.3271	0.568	0.7649
14	y75l	0.25	1.0	0.0	84.97	−74.95	77.13	107.56	136	35.55	65.95	12.4	0.3121	0.579	0.7444
15	y88l	0.125	1.0	0.0	84.37	−79.89	76.36	110.52	138	33.36	64.77	12.3	0.3021	0.5865	0.7312
16	l00c	0.0	1.0	0.0	84.21	−81.1	76.13	111.24	138	32.83	64.47	12.29	0.2996	0.5883	0.7278
17	l13c	0.0	1.0	0.125	84.25	−80.71	73.57	109.22	139	32.98	64.54	13.31	0.2976	0.5823	0.7285
18	l25c	0.0	1.0	0.25	84.35	−78.62	63.95	101.35	143	33.71	64.74	17.66	0.2903	0.5576	0.7308
19	l38c	0.0	1.0	0.375	84.61	−75.49	51.46	91.37	148	34.93	65.24	24.72	0.2797	0.5224	0.7365
20	l50c	0.0	1.0	0.5	84.97	−71.46	38.14	81.01	154	36.59	65.95	34.2	0.2676	0.4823	0.7444
21	l63c	0.0	1.0	0.625	85.43	−66.43	24.55	70.83	163	38.75	66.85	46.23	0.2552	0.4403	0.7546
22	l75c	0.0	1.0	0.75	85.97	−61.24	11.9	62.39	173	41.15	67.93	59.93	0.2435	0.4019	0.7668
23	l88c	0.0	1.0	0.875	86.54	−56.04	0.7	56.06	183	43.7	69.07	74.31	0.2336	0.3692	0.7796
24	c00v	0.0	1.0	1.0	87.18	−51.1	−9.41	51.97	195	46.37	70.38	89.45	0.2249	0.3413	0.7944
25	c13v	0.0	0.875	1.0	78.68	−38.63	−22.32	44.62	213	38.35	54.38	86.97	0.2134	0.3026	0.6138
26	c25v	0.0	0.75	1.0	71.08	−26.3	−33.97	42.97	233	32.33	42.3	84.93	0.2026	0.2651	0.4775
27	c38v	0.0	0.675	1.0	63.12	−11.97	−46.39	47.92	254	27.09	31.73	83.16	0.1908	0.2235	0.3582
28	c50v	0.0	0.5	1.0	54.95	4.19	−59.11	59.26	272	22.65	22.88	81.29	0.1786	0.1804	0.2582
29	c63v	0.0	0.375	1.0	47.37	21.46	−71.55	74.71	284	19.44	16.3	80.45	0.1673	0.1403	0.184
30	c75v	0.0	0.25	1.0	40.2	39.44	−83.05	91.95	294	16.99	11.37	79.32	0.1578	0.1056	0.1284
31	c88v	0.0	0.125	1.0	34.57	55.15	−92.53	107.73	299	15.49	8.29	79.02	0.1507	0.0806	0.0935
32	v00m	0.0	0.0	1.0	33.09	59.26	−94.9	111.9	301	15.11	7.58	78.79	0.1489	0.0747	0.0856
33	v13m	0.125	0.0	1.0	33.6	60.17	−94.39	111.95	301	15.63	7.82	79.26	0.1522	0.0761	0.0882
34	v25m	0.25	0.0	1.0	35.64	62.25	−90.58	109.92	303	17.57	8.82	78.88	0.1669	0.0838	0.0996
35	v38m	0.375	0.0	1.0	38.78	65.67	−85.41	107.74	306	20.9	10.53	79.21	0.1889	0.0952	0.1189
36	v50m	0.5	0.0	1.0	42.38	69.54	−79.14	105.36	310	25.19	12.75	79.11	0.2152	0.1089	0.1439
37	v63m	0.625	0.0	1.0	46.58	74.48	−72.19	103.73	315	31.01	15.7	79.49	0.2457	0.1244	0.1772
38	v75m	0.75	0.0	1.0	50.83	79.05	−64.9	102.28	320	37.61	19.12	79.55	0.276	0.1403	0.2158
39	v88m	0.875	0.0	1.0	54.98	83.66	−57.89	101.74	324	44.97	22.91	79.74	0.3046	0.1552	0.2586
40	m00o	1.0	0.0	1.0	59.56	89.09	−50.27	102.3	329	54.26	27.64	80.12	0.3349	0.1706	0.312
41	m13o	1.0	0.0	0.875	58.35	87.39	−40.57	96.35	334	51.59	26.33	65.42	0.3599	0.1837	0.2972
42	m25o	1.0	0.0	0.75	57.23	85.38	−29.34	90.29	340	49.04	25.16	51.28	0.3908	0.2005	0.284
43	m38o	1.0	0.0	0.675	56.14	83.38	−16.14	84.93	348	46.62	24.05	37.77	0.4299	0.2218	0.2715
44	m50o	1.0	0.0	0.5	55.19	81.22	−0.89	81.23	359	44.43	23.11	25.72	0.4764	0.2478	0.2609
45	m63o	1.0	0.0	0.375	54.35	79.62	15.44	81.1	11	42.67	22.31	16.14	0.526	0.275	0.2518
46	m75o	1.0	0.0	0.25	53.75	78.41	33.44	85.24	24	41.41	21.74	8.91	0.5747	0.3017	0.2454
47	m88o	1.0	0.0	0.125	53.35	77.5	51.81	93.22	34	40.55	21.37	4.23	0.613	0.323	0.2412
48	o00y	1.0	0.0	0.0	54.21	78.64	58.52	98.03	37	42.14	22.17	3.33	0.623	0.3278	0.2503
49	n00w	0.0	0.0	0.0	10.76	5.51	−3.96	6.79	0	1.34	1.23	1.71	0.3134	0.2867	0.0139
50	n13w	0.125	0.125	0.125	16.56	4.87	−3.31	5.9	169	2.33	2.21	2.86	0.3146	0.2988	0.025
51	n25w	0.25	0.25	0.25	30.75	4.15	−2.76	4.99	269	6.61	6.54	7.89	0.3142	0.311	0.0739
52	n38w	0.375	0.375	0.375	43.53	4.11	−2.65	4.9	292	13.48	13.52	15.89	0.3142	0.3152	0.1526
53	n50w	0.5	0.5	0.5	55.06	4.06	−2.42	4.73	297	22.73	22.99	26.55	0.3145	0.3181	0.2595
54	n63w	0.625	0.625	0.625	66.15	3.69	−1.8	4.11	298	34.83	35.52	40.18	0.3151	0.3214	0.401
55	n75w	0.75	0.75	0.75	76.28	3.24	−0.77	3.34	301	49.03	50.35	55.64	0.3163	0.3248	0.5683
56	n88w	0.875	0.875	0.875	85.51	2.1	0.82	2.26	299	64.62	67.02	71.95	0.3174	0.3292	0.7565
57	n99w	1.0	1.0	1.0	95.41	−0.21	4.78	4.79	0	84.08	88.59	89.43	0.3208	0.338	1.0

IE360−7A, Colorimetric data of Television Luminous System TLS11 for CIE standard illuminant D65; LCD monitor; Page: 1/66

Figure 10 – TLS11 measurement data of an LCD display in the standard CIELAB chroma diagram

Colorimetric data of "Standard Original": Television Luminous System TLS11a for CIE lightness L^*_N=11 of black for illuminant D65



IE360−7A, Colorimetric data of Television Luminous System TLS11a for CIE standard illuminant D65; LCD monitor; Page: 4/66

Colorimetric data of "Standard Original": Television Luminous System TLS11a for CIE lightness L^*_N=11 of black for illuminant D65

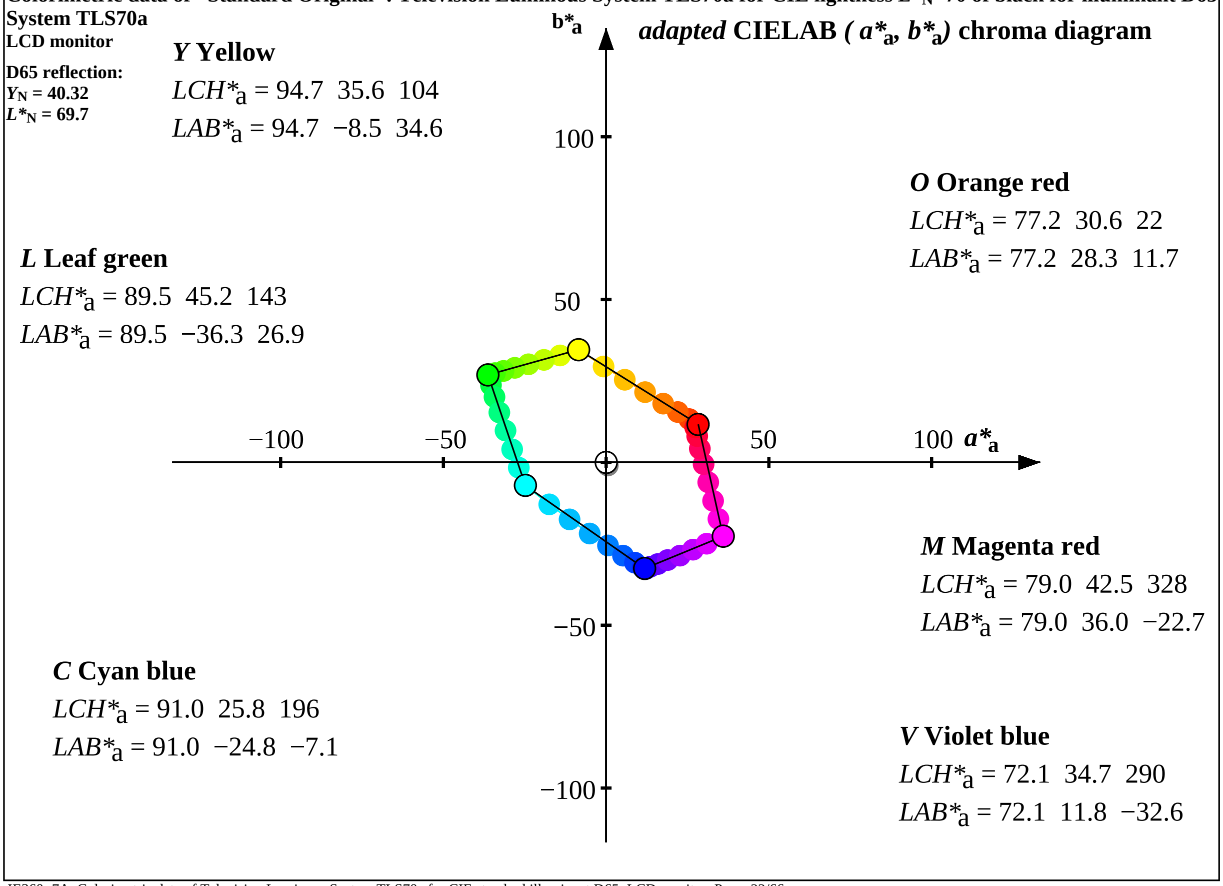
System TLS11a
LCD monitor

	Color	$r=olv^*_1$	$g=olv^*_2$	$b=olv^*_3$	$L^*_a=LAB^*_{1a}$	$a^*_a=LAB^*_{2a}$	$b^*_a=LAB^*_{3a}$	$C^*_{ab,a}=LAB^*_{ra}$	$h_{ab,a}$	$X_a=XYZ_{1a}$	$Y_a=XYZ_{2a}$	$Z_a=XYZ_{3a}$	x_a	y_a	$Y_a/88.59$
00	o00y	1.0	0.0	0.0	54.21	76.07	58.0	95.66	37	41.29	22.17	3.41	0.6174	0.3315	0.2503
01	o13y	1.0	0.125	0.0	54.91	73.93	58.43	94.23	38	41.58	22.84	3.54	0.6118	0.3361	0.2579
02	o25y	1.0	0.25	0.0	57.87	65.78	60.22	89.18	42	43.12	25.83	4.12	0.5901	0.3535	0.2916
03	o38y	1.0	0.375	0.0	62.22	54.13	63.09	83.13	49	45.55	30.66	5.03	0.5607	0.3774	0.3461
04	o50y	1.0	0.5	0.0	67.48	40.75	66.3	77.82	58	48.87	37.27	6.37	0.5283	0.4029	0.4207
05	o63y	1.0	0.625	0.0	73.63	26.18	70.43	75.13	70	53.36	46.12	8.1	0.496	0.4287	0.5206
06	o75y	1.0	0.75	0.0	80.08	11.91	74.7	75.64	81	58.8	56.82	10.24	0.4672	0.4515	0.6414
07	o88y	1.0	0.875	0.0	86.52	−1.44	79.12	79.13	91	64.97	69.03	12.67	0.4429	0.4707	0.7793
08	y00l	1.0	1.0	0.0	94.11	−15.7	84.73	86.17	101	73.49	85.54	15.81	0.4203	0.4892	0.9655
09	y13l	0.875	1.0	0.0	92.0	−27.11	81.96	86.33	108	64.06	80.71	15.42	0.3999	0.5038	0.911
10	y25l	0.75	1.0	0.0	90.22	−37.62	79.72	88.15	115	56.42	76.78	15.06	0.3806	0.5179	0.8667
11	y38l	0.625	1.0	0.0	88.56	−48.49	77.69	91.59	122	49.46	73.23	14.69	0.36	0.5331	0.8266
12	y50l	0.5	1.0	0.0	87.07	−58.96	75.93	96.14	128	43.48	70.14	14.35	0.3398	0.5481	0.7917
13	y63l	0.375	1.0	0.0	85.89	−67.96	74.63	100.94	132	38.89	67.76	14.04	0.3222	0.5615	0.7649
14	y75l	0.25	1.0	0.0	84.97	−75.44	73.43	105.28	136	35.4	65.95	13.88	0.3072	0.5723	0.7444
15	y88l	0.125	1.0	0.0	84.37	−80.42	72.71	108.42	138	33.21	64.77	13.75	0.2973	0.5797	0.7312
16	l00c	0.0	1.0	0.0	84.21	−81.64	72.51	109.2	138	32.68	64.47	13.72	0.2948	0.5815	0.7278
17	l13c	0.0	1.0	0.125	84.25	−81.25	69.95	107.21	139	32.83	64.54	14.83	0.2926	0.5752	0.7285
18	l25c	0.0	1.0	0.25	84.35	−79.15	60.31	99.51	143	33.55	64.74	19.49	0.2849	0.5497	0.7308
19	l38c	0.0	1.0	0.375	84.61	−76.0	47.79	89.79	148	34.78	65.24	27.01	0.2738	0.5136	0.7365
20	l50c	0.0	1.0	0.5	84.97	−71.95	34.43	79.78	154	36.44	65.95	37.07	0.2613	0.4729	0.7444
21	l63c	0.0	1.0	0.625	85.43	−66.89	20.8	70.06	163	38.61	66.85	49.78	0.2487	0.4306	0.7546
22	l75c	0.0	1.0	0.75	85.97	−61.66	8.09	62.2	173	41.02	67.93	64.21	0.2369	0.3923	0.7668
23	l88c	0.0	1.0	0.875	86.54	−56.43	−3.15	56.52	183	43.57	69.07	79.31	0.227	0.3598	0.7796
24	c00v	0.0	1.0	1.0	87.18	−51.44	−13.34	53.15	195	46.25	70.38	95.2	0.2184	0.3322	0.7944
25	c13v	0.0	0.875	1.0	78.68	−39.54	−25.37	46.99	213	38.06	54.38	91.34	0.2071	0.2959	0.6138
26	c25v	0.0	0.75	1.0	71.08	−27.73	−36.23	45.64	233	31.93	42.3	88.11	0.1967	0.2606	0.4775
27	c38v	0.0	0.675	1.0	63.12	−13.94	−47.83	49.84	254	26.61	31.73	85.14	0.1854	0.2212	0.3582
28	c50v	0.0	0.5	1.0	54.95	1.67	−59.7	59.74	272	22.1	22.88	82.09	0.1739	0.18	0.2582
29	c63v	0.0	0.375	1.0	47.37	18.43	−71.36	73.71	284	18.85	16.3	80.21	0.1634	0.1413	0.184
30	c75v	0.0	0.25	1.0	40.2	35.92	−82.13	89.65	294	16.36	11.37	78.1	0.1546	0.1074	0.1284
31	c88v	0.0	0.125	1.0	34.57	51.25	−91.02	104.47	299	14.84	8.29	77.05	0.1481	0.0827	0.0935
32	v00m	0.0	0.0	1.0	33.09	55.26	−93.24	108.4	301	14.45	7.58	76.63	0.1465	0.0768	0.0856
33	v13m	0.125	0.0	1.0	33.6	56.21	−92.78	108.49	301	14.96	7.82	77.15	0.1497	0.0782	0.0882
34	v25m	0.25	0.0	1.0	35.64	58.43	−89.19	106.63	303	16.87	8.82	77.06	0.1642	0.0859	0.0996
35	v38m	0.375	0.0	1.0	38.78	62.05	−84.34	104.72	306	20.16	10.53	77.8	0.1858	0.0971	0.1189
36	v50m	0.5	0.0	1.0	42.38	66.17	−78.44	102.63	310	24.4	12.75	78.19	0.2116	0.1105	0.1439
37	v63m	0.625	0.0	1.0	46.58	71.39	−71.92	101.35	315	30.18	15.7	79.14	0.2414	0.1256	0.1772
38	v75m	0.75	0.0	1.0	50.83	76.25	−65.07	100.25	320	36.76	19.12	79.78	0.271	0.1409	0.2158
39	v88m	0.875	0.0	1.0	54.98	81.14	−58.49	100.03	324	44.1	22.91	80.55	0.2989	0.1553	0.2586
40	m00o	1.0	0.0	1.0	59.56	86.88	−51.35	100.93	329	53.4	27.64	81.56	0.3284	0.17	0.312
41	m13o	1.0	0.0	0.875	58.35	85.1	−41.52	94.69	334	50.73	26.33	66.53	0.3533	0.1834	0.2972
42	m25o	1.0	0.0	0.75	57.23	83.02	−30.18	88.34	340	48.17	25.16	52.11	0.384	0.2006	0.284
43	m38o	1.0	0.0	0.675	56.14	80.94	−16.86	82.68	348	45.76	24.05	38.35	0.423	0.2224	0.2715
44	m50o	1.0	0.0	0.5	55.19	78.72	−1.52	78.73	359	43.58	23.11	26.11	0.4696	0.249	0.2609
45	m63o	1.0	0.0	0.375	54.35	77.06	14.91	78.48	11	41.82	22.31	16.39	0.5194	0.2771	0.2518
46	m75o	1.0	0.0	0.25	53.75	75.81	32.96	82.67	24	40.56	21.74	9.05	0.5685	0.3047	0.2454
47	m88o	1.0	0.0	0.125	53.35	74.87	51.38	90.8	34	39.71	21.37	4.32	0.6072	0.3268	0.2412
48	o00y	1.0	0.0	0.0	54.21	76.07	58.0	95.66	37	41.29	22.17	3.41	0.6174	0.3315	0.2503
49	n00w	0.0	0.0	0.0	10.76	0.0	0.0	0.01	0	1.17	1.23	1.34	0.3127	0.329	0.0139
50	n13w	0.125	0.125	0.125	16.56	−0.23	0.05	0.25	169	2.09	2.21	2.4	0.3119	0.3299	0.025
51	n25w	0.25	0.25	0.25	30.75	0.0	−0.86	0.87	269	6.22	6.54	7.36	0.3091	0.3252	0.0739
52	n38w	0.375	0.375	0.375	43.53	0.82	−2.07	2.24	292	12.97	13.52	15.63	0.308	0.3209	0.1526
53	n50w	0.5	0.5	0.5	55.06	1.55	−3.03	3.42	297	22.18	22.99	26.95	0.3076	0.3188	0.2595
54	n63w	0.625	0.625	0.625	66.15	1.93	−3.55	4.05	298	34.32	35.52	41.67	0.3077	0.3186	0.401
55	n75w	0.75	0.75	0.75	76.28	2.17	−3.58	4.19	301	48.64	50.35	58.62	0.3086	0.3195	0.5683
56	n88w	0.875	0.875	0.875	85.51	1.65	−2.93	3.37	299	64.42	67.02	76.71	0.3095	0.322	0.7565
57	n99w	1.0	1.0	1.0	95.41	0.0	0.0	0.01	0	84.2	88.59	96.46	0.3127	0.329	1.0

IE360−7A, Colorimetric data of Television Luminous System TLS11a for CIE standard illuminant D65; LCD monitor; Page: 3/66

Figure 11 – TLS11a measurement data of a LCD display in the adapted CIELAB chroma diagram

Colorimetric data of "Standard Original": Television Luminous System TLS70a for CIE lightness L^*_N=70 of black for illuminant D65



IE360−7A, Colorimetric data of Television Luminous System TLS70a for CIE standard illuminant D65; LCD monitor; Page: 22/66

Colorimetric data of "Standard Original": Television Luminous System TLS70a for CIE lightness L^*_N=70 of black for illuminant D65

System TLS70a
LCD monitor

D65 reflection:
Y_N = 40.32
L^*_N = 69.7

	Color	$r=olv^*_1$	$g=olv^*_2$	$b=olv^*_3$	$L^*_a=LAB^*_{1a}$	$a^*_a=LAB^*_{2a}$	$b^*_a=LAB^*_{3a}$	$C^*_{ab,a}=LAB^*_{ab,a}$	$h_{ab,a}$	$X_a=XYZ_{1a}$	$Y_a=XYZ_{2a}$	$Z_a=XYZ_{3a}$	x_a	y_a	$Y_a/88.59$
00	o00y	1.0	0.0	0.0	77.22	28.3	11.69	30.62	22	60.49	51.89	45.05	0.3842	0.3296	0.5971
01	o13y	1.0	0.125	0.0	77.44	27.72	11.99	30.21	23	60.65	52.26	45.12	0.3838	0.3307	0.6014
02	o25y	1.0	0.25	0.0	78.41	25.53	13.32	28.8	28	61.5	53.91	45.44	0.3823	0.3352	0.6204
03	o38y	1.0	0.375	0.0	79.94	22.04	15.41	26.9	35	62.84	56.58	45.94	0.38	0.3422	0.6511
04	o50y	1.0	0.5	0.0	81.96	17.53	18.1	25.2	46	64.67	60.23	46.68	0.3769	0.351	0.6931
05	o63y	1.0	0.625	0.0	84.55	11.96	21.53	24.63	61	67.16	65.13	47.63	0.3733	0.362	0.7494
06	o75y	1.0	0.75	0.0	87.5	5.76	25.38	26.02	77	70.16	71.04	48.82	0.3692	0.3738	0.8174
07	o88y	1.0	0.875	0.0	90.68	−0.73	29.47	29.47	91	73.57	77.78	50.16	0.3651	0.386	0.8951
08	y00l	1.0	1.0	0.0	94.7	−8.44	34.63	35.65	104	78.28	86.9	51.9	0.3606	0.4003	1.0
09	y13l	0.875	1.0	0.0	93.55	−14.14	32.87	35.79	113	73.07	84.23	51.68	0.3496	0.4031	0.9693
10	y25l	0.75	1.0	0.0	92.6	−19.06	31.44	36.77	121	68.85	82.07	51.48	0.3402	0.4055	0.9443
11	y38l	0.625	1.0	0.0	91.73	−23.82	30.14	38.42	128	65.0	80.1	51.28	0.331	0.4079	0.9217
12	y50l	0.5	1.0	0.0	90.96	−28.08	29.0	40.38	134	61.7	78.4	51.09	0.3227	0.4101	0.9021
13	y63l	0.375	1.0	0.0	90.36	−31.51	28.14	42.25	138	59.16	77.08	50.92	0.3161	0.4118	0.887
14	y75l	0.25	1.0	0.0	89.9	−34.2	27.43	43.85	141	57.24	76.08	50.83	0.3108	0.4131	0.8754
15	y88l	0.125	1.0	0.0	89.59	−35.89	26.98	44.91	143	56.03	75.43	50.76	0.3075	0.414	0.868
16	l00c	0.0	1.0	0.0	89.52	−36.29	26.86	45.16	143	55.73	75.26	50.74	0.3067	0.4141	0.8661
17	l13c	0.0	1.0	0.125	89.53	−36.16	26.27	44.7	144	55.82	75.3	51.35	0.3059	0.4127	0.8665
18	l25c	0.0	1.0	0.25	89.59	−35.39	23.8	42.66	146	56.21	75.41	53.93	0.303	0.4064	0.8678
19	l38c	0.0	1.0	0.375	89.72	−34.27	20.06	39.71	150	56.89	75.69	58.09	0.2984	0.397	0.871
20	l50c	0.0	1.0	0.5	89.9	−32.79	15.36	36.22	155	57.81	76.08	63.64	0.2927	0.3851	0.8754
21	l63c	0.0	1.0	0.625	90.13	−30.89	9.82	32.42	162	59.01	76.58	70.67	0.2861	0.3713	0.8812
22	l75c	0.0	1.0	0.75	90.4	−28.88	4.01	29.17	172	60.34	77.17	78.64	0.2792	0.357	0.888
23	l88c	0.0	1.0	0.875	90.69	−26.8	−1.62	26.86	183	61.75	77.8	86.98	0.2726	0.3435	0.8953
24	c00v	0.0	1.0	1.0	91.02	−24.78	−7.1	25.79	196	63.23	78.53	95.76	0.2662	0.3306	0.9036
25	c13v	0.0	0.875	1.0	86.84	−17.45	−12.86	21.69	216	58.71	69.69	93.63	0.2644	0.3139	0.8019
26	c25v	0.0	0.75	1.0	83.45	−11.18	−17.5	20.78	237	55.32	63.01	91.84	0.2632	0.2998	0.7251
27	c38v	0.0	0.675	1.0	80.28	−5.05	−21.84	22.42	257	52.38	57.17	90.21	0.2622	0.2862	0.6579
28	c50v	0.0	0.5	1.0	77.45	0.53	−25.54	25.55	271	49.89	52.28	88.52	0.2616	0.2742	0.6016
29	c63v	0.0	0.375	1.0	75.23	5.18	−28.62	29.1	280	48.09	48.65	87.48	0.261	0.2641	0.5598
30	c75v	0.0	0.25	1.0	73.5	8.84	−30.79	32.04	286	46.72	45.92	86.31	0.2611	0.2566	0.5285
31	c88v	0.0	0.125	1.0	72.38	11.29	−32.3	34.23	289	45.87	44.22	85.73	0.2609	0.2515	0.5088
32	v00m	0.0	0.0	1.0	72.11	11.8	−32.58	34.66	290	45.66	43.83	85.5	0.2609	0.2505	0.5044
33	v13m	0.125	0.0	1.0	72.2	12.23	−32.64	34.87	291	45.94	43.96	85.79	0.2615	0.2502	0.5058
34	v25m	0.25	0.0	1.0	72.57	13.61	−31.97	34.75	293	47.0	44.52	85.74	0.2651	0.2511	0.5122
35	v38m	0.375	0.0	1.0	73.19	15.96	−31.19	35.04	297	48.81	45.46	86.15	0.2706	0.252	0.5231
36	v50m	0.5	0.0	1.0	73.99	18.86	−29.98	35.42	302	51.16	46.68	86.37	0.2777	0.2534	0.5372
37	v63m	0.625	0.0	1.0	75.02	22.68	−28.56	36.48	308	54.35	48.32	86.89	0.2867	0.2549	0.556
38	v75m	0.75	0.0	1.0	76.2	26.68	−26.79	37.82	315	57.99	50.21	87.24	0.2967	0.2569	0.5777
39	v88m	0.875	0.0	1.0	77.46	30.89	−24.91	39.69	321	62.04	52.3	87.67	0.3071	0.2589	0.6018
40	m00o	1.0	0.0	1.0	78.99	35.95	−22.67	42.51	328	67.18	54.91	88.23	0.3194	0.2611	0.6319
41	m13o	1.0	0.0	0.875	78.57	34.47	−17.35	38.59	333	65.7	54.19	79.92	0.3288	0.2712	0.6236
42	m25o	1.0	0.0	0.75	78.19	32.91	−11.79	34.97	340	64.29	53.54	71.96	0.3388	0.2821	0.6161
43	m38o	1.0	0.0	0.675	77.83	31.41	−6.05	31.99	349	62.96	52.93	64.35	0.3493	0.2937	0.6091
44	m50o	1.0	0.0	0.5	77.53	29.94	−0.48	29.94	359	61.75	52.41	57.59	0.3595	0.3052	0.6031
45	m63o	1.0	0.0	0.375	77.26	28.79	4.25	29.1	8	60.78	51.97	52.22	0.3684	0.315	0.598
46	m75o	1.0	0.0	0.25	77.07	27.96	8.08	29.1	16	60.09	51.65	48.16	0.3758	0.323	0.5944
47	m88o	1.0	0.0	0.125	76.95	27.37	10.68	29.38	21	59.62	51.45	45.55	0.3807	0.3285	0.592
48	o00y	1.0	0.0	0.0	77.22	28.3	11.69	30.62	22	60.49	51.89	45.05	0.3842	0.3296	0.5971
49	n00w	0.0	0.0	0.0	69.7	0.0	0.0	0.01	0	38.32	40.32	43.9	0.3127	0.329	0.464
50	n13w	0.125	0.125	0.125	70.08	−0.01	0.0	0.02	169	38.83	40.86	44.49	0.3127	0.3291	0.4702
51	n25w	0.25	0.25	0.25	71.73	0.0	−0.13	0.14	269	41.11	43.26	47.23	0.3124	0.3287	0.4978
52	n38w	0.375	0.375	0.375	74.26	0.2	−0.5	0.55	291	44.84	47.11	51.8	0.3119	0.3277	0.5421
53	n50w	0.5	0.5	0.5	77.49	0.5	−0.98	1.11	297	49.93	52.34	58.05	0.3114	0.3265	0.6023
54	n63w	0.625	0.625	0.625	81.44	0.76	−1.41	1.61	298	56.64	59.27	66.19	0.311	0.3255	0.682
55	n75w	0.75	0.75	0.75	85.74	0.99	−1.64	1.93	301	64.55	67.46	75.55	0.311	0.325	0.7763
56	n88w	0.875	0.875	0.875	90.17	0.83	−1.49	1.71	299	73.27	76.67	85.55	0.3111	0.3256	0.8823
57	n99w	1.0	1.0	1.0	95.41	0.0	0.0	0.01	0	84.2	88.59	96.46	0.3127	0.329	1.0194

n = 88.59 / (88.59 − 1.23) = 1.014

IE360−7A, Colorimetric data of Television Luminous System TLS70a for CIE standard illuminant D65; LCD monitor; Page: 21/66

Figure 12 – TTLS70a calculated data of a LCD display in the adapted CIELAB chroma diagram

7. Normalization method for displays between *standard* and *adapted* CIELAB

Usually for Black *N* and White *W* the chroma is different from zero. In addition because of in-device-stray light the luminance reflectance is about 1% of the white display. This was the case for the LCD display measured in Fig. 10. In the following a reference display TLS18 with the lightness L^*_N =18 for Black *N* is assumed. For this reference display the chroma of both Black *N* and White *W* is already zero. A transformation method for the calculation of the device colours *OYLCVM* in CIELAB is intended. This numerical method is presented in Fig. 13 and 14.

A silk glossy colour surface is studied, which is for example given for the standard offset colours on standard offset paper. In this case there is always a so called "white feet" for any colour including black, compare the reflection factor for a elementary colour Yellow *J* in Fig. 13. However, the elementary optimal colour J_o has no white feet. Mathematical reduction of the reflection by 2,5% and addition of 2,5% white light creates a "white feet" for the optimal colour. Some further total reduction may make the original elementary optimal colour Yellow J_o very similar to the surface colour Yellow *J*.

It has been shown, that a 2,5% change in luminance reflection changes the lightness from L^*_N = 0 to L^*_W = 18 for Black *N*. This is an appearance change by a factor 0,82. Something similar happens for the chroma of any colour if only 2,5% of white light is added. A large range can be produced by adding 8 different amounts of white light to any optimal colour or to any colour of an LCD display or a data projector. The result is shown in Fig. 14 for eight reflection conditions. The eight colour data are calculated for the eight spaces TLS(00/06/11/18/27/38/52/70)a.

Colorimetric "Standard data": Television Luminous System TLS18 for CIE lightness L^*_N=18 of black for illuminant D65

System TLS18	Color	$r=olv^*_1$	$g=olv^*_2$	$b=olv^*_3$	L^*	a^*	b^*	C^*_{ab}	h_{ab}	$X=XYZ_1$	$Y=XYZ_2$	$Z=XYZ_3$	x	y	$Y/88.59$
sRGB system	O (R)	1.0	0.0	0.0	52.76	71.63	49.88	87.29	35	37.89	20.83	4.41	0.6003	0.3299	0.2351
	Y	1.0	1.0	0.0	92.74	−20.03	84.97	87.3	103	68.67	82.37	14.66	0.4144	0.4971	0.9298
D65 reflection:	L (G)	0.0	1.0	0.0	84.0	−78.99	73.94	108.2	137	33.17	64.07	13.0	0.3009	0.5812	0.7231
	C	0.0	1.0	1.0	87.14	−44.42	−13.12	46.33	196	48.71	70.29	94.77	0.2279	0.3288	0.7934
Y_N = 2.52	V (B)	0.0	0.0	1.0	31.9	24.46	−37.38	44.68	303	9.36	7.04	23.5	0.2346	0.1764	0.0795
L^*_N = 18.01	M	1.0	0.0	1.0	59.01	89.33	−19.43	91.42	348	53.42	27.04	44.81	0.4265	0.2158	0.3052
	N	0.0	0.0	0.0	18.01	0.0	0.0	0.01	0	2.4	2.52	2.74	0.3127	0.329	0.0284
	W	1.0	1.0	1.0	95.41	0.0	0.0	0.01	0	84.2	88.59	96.46	0.3127	0.329	1.0
	N0	0.0	0.0	0.0	18.01	0.0	0.0	0.01	0	2.4	2.52	2.74	0.3127	0.329	0.0284
	W1	1.0	1.0	1.0	95.41	0.0	0.0	0.01	0	84.2	88.59	96.46	0.3127	0.329	1.0

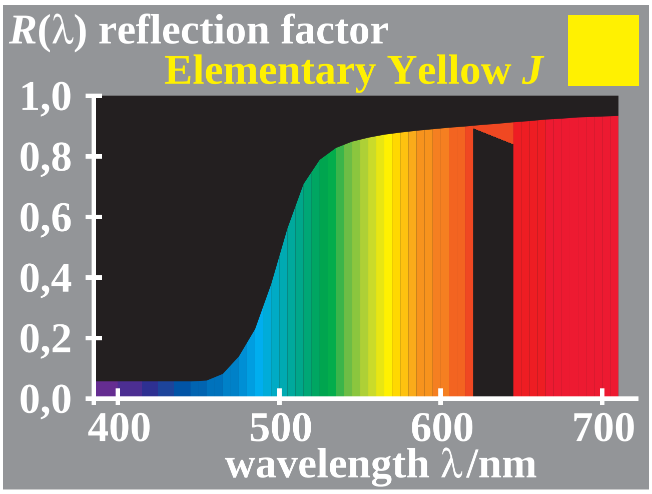
Colorimetric "Adapted data (a)": Television Luminous System TLS18a for CIE lightness L^*_N=18 of black for illuminant D65

System TLS18a	Color	$r=olv^*_1$	$g=olv^*_2$	$b=olv^*_3$	L^*_a	a^*_a	b^*_a	$C^*_{ab,a}$	$h_{ab,a}$	$X_a=XYZ_{1a}$	$Y_a=XYZ_{2a}$	$Z_a=XYZ_{3a}$	x_a	y_a	$Y_a/88.59$
sRGB system	O (R)	1.0	0.0	0.0	52.76	71.63	49.88	87.29	35	37.89	20.83	4.41	0.6003	0.3299	0.2351
	Y	1.0	1.0	0.0	92.74	−20.03	84.97	87.3	103	68.67	82.37	14.66	0.4144	0.4971	0.9298
D65 reflection:	L (G)	0.0	1.0	0.0	84.0	−78.99	73.94	108.2	137	33.17	64.07	13.0	0.3009	0.5812	0.7231
	C	0.0	1.0	1.0	87.14	−44.42	−13.12	46.33	196	48.71	70.29	94.77	0.2279	0.3288	0.7934
Y_N = 2.52	V (B)	0.0	0.0	1.0	31.9	24.46	−37.38	44.68	303	9.36	7.04	23.5	0.2346	0.1764	0.0795
L^*_N = 18.01	M	1.0	0.0	1.0	59.01	89.33	−19.43	91.42	348	53.42	27.04	44.81	0.4265	0.2158	0.3052
	N	0.0	0.0	0.0	18.01	0.0	0.0	0.01	0	2.4	2.52	2.74	0.3127	0.329	0.0284
	W	1.0	1.0	1.0	95.41	0.0	0.0	0.01	0	84.2	88.59	96.46	0.3127	0.329	1.0
	N0	0.0	0.0	0.0	18.01	0.0	0.0	0.01	0	2.4	2.52	2.74	0.3127	0.329	0.0284
	W1	1.0	1.0	1.0	95.41	0.0	0.0	0.01	0	84.2	88.59	96.46	0.3127	0.329	1.0

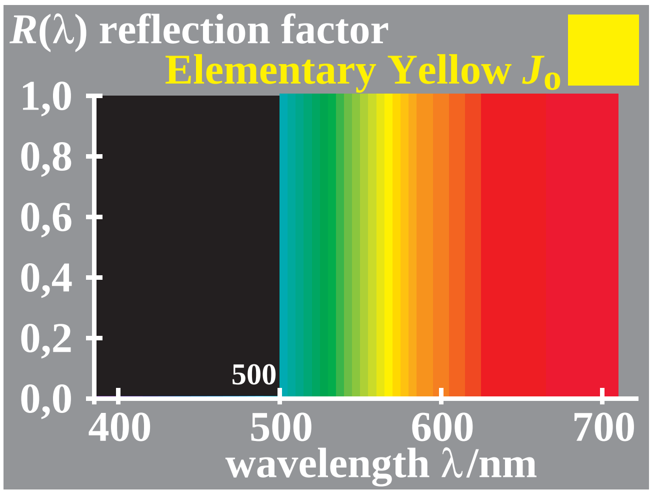
Colorimetric "Adapted data (a0)": Television Luminous System TLS00a0 for CIE lightness L^*_N=00 of black for illuminant D65

System TLS00a0	Color	$r=olv^*_1$	$g=olv^*_2$	$b=olv^*_3$	L^*_{a0}	a^*_{a0}	b^*_{a0}	$C^*_{ab,a0}$	$h_{ab,a0}$	$X_{a0}=XYZ_{1a0}$	$Y_{a0}=XYZ_{2a0}$	$Z_{a0}=XYZ_{3a0}$	x_{a0}	y_{a0}	$Y_{a0}/88.59$
sRGB system	O (R)	1.0	0.0	0.0	50.5	76.92	64.55	100.42	40	36.54=***k***(37.89−2.4)	18.84=***k***(20.83−2.52)	1.71=***k***(4.41−2.74)	0.64	0.33	0.2127
	Y	1.0	1.0	0.0	92.66	−20.68	90.75	93.08	103	68.22=***k***(68.67−2.4)	82.19=***k***(82.37−2.52)	12.27=***k***(14.66−2.74)	0.4193	0.5053	0.9278
D65 reflection:	L (G)	0.0	1.0	0.0	83.62	−82.74	79.9	115.03	136	31.68=***k***(33.17−2.4)	63.35=***k***(64.07−2.52)	10.55=***k***(13.0−2.74)	0.3	0.6	0.715
	C	0.0	1.0	1.0	86.88	−46.15	−13.54	48.11	196	47.67=***k***(48.71−2.4)	69.76=***k***(70.29−2.52)	94.72=***k***(94.77−2.74)	0.2247	0.3288	0.7874
Y_N = 0.0	V (B)	0.0	0.0	1.0	25.72	31.45	−44.28	54.32	305	7.17=***k***(9.36−2.4)	4.65=***k***(7.04−2.52)	21.37=***k***(23.5−2.74)	0.2161	0.1402	0.0525
L^*_N = 0.0	M	1.0	0.0	1.0	57.3	94.35	−20.68	96.59	348	52.52=***k***(53.42−2.4)	25.24=***k***(27.04−2.52)	43.3=***k***(44.81−2.74)	0.4339	0.2085	0.2849
	N	0.0	0.0	0.0	0.0	0.0	0.0	0.01	358	0.0=***k***(2.4−2.4)	0.0=***k***(2.52−2.52)	0.0=***k***(2.74−2.74)	0.0	0.0	0.0
k = 88.59 / (88.59 − 2.52)	W	1.0	1.0	1.0	95.41	0.0	0.0	0.01	0	84.2=***k***(84.2−2.4)	88.59=***k***(88.59−2.52)	96.46=***k***(96.46−2.74)	0.3127	0.329	1.0
= 1.029	N0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	358	0.0=***k***(2.4−2.4)	0.0=***k***(2.52−2.52)	0.0=***k***(2.74−2.74)	0.0	0.0	0.0
	W1	1.0	1.0	1.0	95.41	0.0	0.0	0.01	0	84.2=***k***(84.2−2.4)	88.59=***k***(88.59−2.52)	96.46=***k***(96.46−2.74)	0.3127	0.329	1.0

IE340−7A, Colorimetric data of Television Luminous System TLS18 for CIE standard illuminant D65; sRGB-System; Page: 1/3



IE100−2A



IE100−6A

Figure 13 – Television and elementary colours *J* and J_o in the *adapted* and *relative* CIELAB chroma diagram

Colorimetric "Adapted data (a0)": Television Luminous System TLS00a0 for CIE lightness L^*_N=00 of black for illuminant D65

System TLS00a0	Color	$r=olv^*_1$	$g=olv^*_2$	$b=olv^*_3$	L^*_{a0}	a^*_{a0}	b^*_{a0}	$C^*_{ab,a0}$	$h_{ab,a0}$	$X_{a0}=XYZ_{1a0}$	$Y_{a0}=XYZ_{2a0}$	$Z_{a0}=XYZ_{3a0}$	x_{a0}	y_{a0}	$Y_{a0}/88.59$
sRGB system	O (R)	1.0	0.0	0.0	50.5	76.92	64.55	100.42	40	36.54=k(37.89−2.4)	18.84=k(20.83−2.52)	1.71=k(4.41−2.74)	0.64	0.33	0.2127
	Y	1.0	1.0	0.0	92.66	−20.68	90.75	93.08	103	68.22=k(68.67−2.4)	82.19=k(82.37−2.52)	12.27=k(14.66−2.74)	0.4193	0.5053	0.9278
D65 reflection:	L (G)	0.0	1.0	0.0	83.62	−82.74	79.9	115.03	136	31.68=k(33.17−2.4)	63.35=k(64.07−2.52)	10.55=k(13.0−2.74)	0.3	0.6	0.715
	C	0.0	1.0	1.0	86.88	−46.15	−13.54	48.11	196	47.67=k(48.71−2.4)	69.76=k(70.29−2.52)	94.72=k(94.77−2.74)	0.2247	0.3288	0.7874
Y_N = 0.0	V (B)	0.0	0.0	1.0	25.72	31.45	−44.28	54.32	305	7.17=k(9.36−2.4)	4.65=k(7.04−2.52)	21.37=k(23.5−2.74)	0.2161	0.1402	0.0525
L^*_N = 0.0	M	1.0	0.0	1.0	57.3	94.35	−20.68	96.59	348	52.52=k(53.42−2.4)	25.24=k(27.04−2.52)	43.3=k(44.81−2.74)	0.4339	0.2085	0.2849
	N	0.0	0.0	0.0	0.0	0.0	0.0	0.01	358	0.0=k(2.4−2.4)	0.0=k(2.52−2.52)	0.0=k(2.74−2.74)	0.0	0.0	0.0
k = 88.59 / (88.59 − 2.52)	W	1.0	1.0	1.0	95.41	0.0	0.0	0.01	0	84.2=k(84.2−2.4)	88.59=k(88.59−2.52)	96.46=k(96.46−2.74)	0.3127	0.329	1.0
= 1.029	N0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	358	0.0=k(2.4−2.4)	0.0=k(2.52−2.52)	0.0=k(2.74−2.74)	0.0	0.0	0.0
	W1	1.0	1.0	1.0	95.41	0.0	0.0	0.01	0	84.2=k(84.2−2.4)	88.59=k(88.59−2.52)	96.46=k(96.46−2.74)	0.3127	0.329	1.0

Calculated colorimetric data: Television Luminous Systems TLSxxa for CIE lightness L^*_N=00, 06, 11, 18 of black for illuminant D65

System TLS00a	Color	$r=olv^*_1$	$g=olv^*_2$	$b=olv^*_3$	L^*_a	a^*_a	b^*_a	$C^*_{ab,a}$	$h_{ab,a}$	$X_a=XYZ_{1a}$	$Y_a=XYZ_{2a}$	$Z_a=XYZ_{3a}$	x_a	y_a	$Y_a/88.59$
sRGB system	O (R)	1.0	0.0	0.0	50.5	76.92	64.55	100.42	40	36.54(=36.54n+0.0)	18.84(=18.84n+0.0)	1.71(=1.71n+0.0)	0.64	0.33	0.2127
	Y	1.0	1.0	0.0	92.66	−20.68	90.75	93.08	103	68.22(=68.22n+0.0)	82.19(=82.19n+0.0)	12.27(=12.27n+0.0)	0.4193	0.5053	0.9278
D65 reflection:	L (G)	0.0	1.0	0.0	83.62	−82.74	79.9	115.03	136	31.68(=31.68n+0.0)	63.35(=63.35n+0.0)	10.55(=10.55n+0.0)	0.3	0.6	0.715
	C	0.0	1.0	1.0	86.88	−46.15	−13.54	48.11	196	47.67(=47.67n+0.0)	69.76(=69.76n+0.0)	94.72(=94.72n+0.0)	0.2247	0.3288	0.7874
Y_N = 0.0	V (B)	0.0	0.0	1.0	25.72	31.45	−44.28	54.32	305	7.17(=7.17n+0.0)	4.65(=4.65n+0.0)	21.37(=21.37n+0.0)	0.2161	0.1402	0.0525
L^*_N = 0.0	M	1.0	0.0	1.0	57.3	94.35	−20.68	96.59	348	52.52(=52.52n+0.0)	25.24(=25.24n+0.0)	43.3(=43.3n+0.0)	0.4339	0.2085	0.2849
	N	0.0	0.0	0.0	0.0	0.0	0.0	0.0	358	0.0(=0.0n+0.0)	0.0(=0.0n+0.0)	0.0(=0.0n+0.0)	0.0	0.0	0.0
n = (88.59 − 0.0) / 88.59	W	1.0	1.0	1.0	95.41	0.0	0.0	0.0	0	84.2(=84.2n+0.0)	88.59(=88.59n+0.0)	96.46(=96.46n+0.0)	0.3127	0.329	1.0
= 1.0	N0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	358	0.0(=0.0n+0.0)	0.0(=0.0n+0.0)	0.0(=0.0n+0.0)	0.0	0.0	0.0
	W1	1.0	1.0	1.0	95.41	0.0	0.0	0.0	0	84.2(=84.2n+0.0)	88.59(=88.59n+0.0)	96.46(=96.46n+0.0)	0.3127	0.329	1.0

System TLS06a	Color	$r=olv^*_1$	$g=olv^*_2$	$b=olv^*_3$	L^*_a	a^*_a	b^*_a	$C^*_{ab,a}$	$h_{ab,a}$	$X_a=XYZ_{1a}$	$Y_a=XYZ_{2a}$	$Z_a=XYZ_{3a}$	x_a	y_a	$Y_a/88.59$
sRGB system	O (R)	1.0	0.0	0.0	51.08	75.54	59.69	96.28	38	36.88(=36.54n+0.6)	19.34(=18.84n+0.63)	2.39(=1.71n+0.69)	0.6293	0.33	0.2183
	Y	1.0	1.0	0.0	92.68	−20.51	89.24	91.57	103	68.33(=68.22n+0.6)	82.24(=82.19n+0.63)	12.87(=12.27n+0.69)	0.4181	0.5032	0.9283
D65 reflection:	L (G)	0.0	1.0	0.0	83.72	−81.79	78.32	113.25	136	32.05(=31.68n+0.6)	63.53(=63.35n+0.63)	11.16(=10.55n+0.69)	0.3003	0.5952	0.7171
	C	0.0	1.0	1.0	86.94	−45.72	−13.43	47.66	196	47.93(=47.67n+0.6)	69.89(=69.76n+0.63)	94.73(=94.72n+0.69)	0.2255	0.3288	0.7889
Y_N = 0.63	V (B)	0.0	0.0	1.0	27.44	29.31	−42.29	51.46	305	7.72(=7.17n+0.6)	5.25(=4.65n+0.63)	21.9(=21.37n+0.69)	0.2214	0.1506	0.0593
L^*_N = 5.69	M	1.0	0.0	1.0	57.74	93.06	−20.36	95.27	348	52.75(=52.52n+0.6)	25.69(=25.24n+0.63)	43.68(=43.3n+0.69)	0.432	0.2104	0.2899
	N	0.0	0.0	0.0	5.69	0.0	0.0	0.0	357	0.6(=0.0n+0.6)	0.63(=0.0n+0.63)	0.69(=0.0n+0.69)	0.3127	0.329	0.0071
n = (88.59 − 0.63) / 88.59	W	1.0	1.0	1.0	95.41	0.0	0.0	0.0	0	84.2(=84.2n+0.6)	88.59(=88.59n+0.63)	96.46(=96.46n+0.69)	0.3127	0.329	1.0
= 0.993	N0	0.0	0.0	0.0	5.69	0.0	0.0	0.0	357	0.6(=0.0n+0.6)	0.63(=0.0n+0.63)	0.69(=0.0n+0.69)	0.3127	0.329	0.0071
	W1	1.0	1.0	1.0	95.41	0.0	0.0	0.0	0	84.2(=84.2n+0.6)	88.59(=88.59n+0.63)	96.46(=96.46n+0.69)	0.3127	0.329	1.0

System TLS11a	Color	$r=olv^*_1$	$g=olv^*_2$	$b=olv^*_3$	L^*_a	a^*_a	b^*_a	$C^*_{ab,a}$	$h_{ab,a}$	$X_a=XYZ_{1a}$	$Y_a=XYZ_{2a}$	$Z_a=XYZ_{3a}$	x_a	y_a	$Y_a/88.59$
sRGB system	O (R)	1.0	0.0	0.0	51.65	74.21	55.83	92.86	37	37.22(=36.54n+1.2)	19.84(=18.84n+1.26)	3.06(=1.71n+1.37)	0.6191	0.33	0.2239
	Y	1.0	1.0	0.0	92.7	−20.35	87.77	90.1	103	68.44(=68.22n+1.2)	82.28(=82.19n+1.26)	13.46(=12.27n+1.37)	0.4168	0.5011	0.9288
D65 reflection:	L (G)	0.0	1.0	0.0	83.81	−80.85	76.81	111.52	136	32.42(=31.68n+1.2)	63.71(=63.35n+1.26)	11.77(=10.55n+1.37)	0.3005	0.5904	0.7191
	C	0.0	1.0	1.0	87.01	−45.28	−13.33	47.22	196	48.19(=47.67n+1.2)	70.02(=69.76n+1.26)	94.74(=94.72n+1.37)	0.2263	0.3288	0.7904
Y_N = 1.26	V (B)	0.0	0.0	1.0	29.02	27.48	−40.49	48.95	304	8.27(=7.17n+1.2)	5.85(=4.65n+1.26)	22.44(=21.37n+1.37)	0.2262	0.16	0.066
L^*_N = 11.0	M	1.0	0.0	1.0	58.17	91.8	−20.04	93.96	348	52.97(=52.52n+1.2)	26.14(=25.24n+1.26)	44.05(=43.3n+1.37)	0.4301	0.2122	0.295
	N	0.0	0.0	0.0	10.99	0.0	0.0	0.0	358	1.2(=0.0n+1.2)	1.26(=0.0n+1.26)	1.37(=0.0n+1.37)	0.3127	0.329	0.0142
n = (88.59 − 1.26) / 88.59	W	1.0	1.0	1.0	95.41	0.0	0.0	0.0	0	84.2(=84.2n+1.2)	88.59(=88.59n+1.26)	96.46(=96.46n+1.37)	0.3127	0.329	1.0
= 0.986	N0	0.0	0.0	0.0	10.99	0.0	0.0	0.0	358	1.2(=0.0n+1.2)	1.26(=0.0n+1.26)	1.37(=0.0n+1.37)	0.3127	0.329	0.0142
	W1	1.0	1.0	1.0	95.41	0.0	0.0	0.0	0	84.2(=84.2n+1.2)	88.59(=88.59n+1.26)	96.46(=96.46n+1.37)	0.3127	0.329	1.0

System TLS18a	Color	$r=olv^*_1$	$g=olv^*_2$	$b=olv^*_3$	L^*_a	a^*_a	b^*_a	$C^*_{ab,a}$	$h_{ab,a}$	$X_a=XYZ_{1a}$	$Y_a=XYZ_{2a}$	$Z_a=XYZ_{3a}$	x_a	y_a	$Y_a/88.59$
sRGB system	O (R)	1.0	0.0	0.0	52.76	71.63	49.88	87.29	35	37.89(=36.54n+2.4)	20.83(=18.84n+2.52)	4.41(=1.71n+2.74)	0.6003	0.3299	0.2351
	Y	1.0	1.0	0.0	92.74	−20.03	84.97	87.3	103	68.67(=68.22n+2.4)	82.37(=82.19n+2.52)	14.66(=12.27n+2.74)	0.4144	0.4971	0.9298
D65 reflection:	L (G)	0.0	1.0	0.0	84.0	−78.99	73.94	108.2	137	33.17(=31.68n+2.4)	64.07(=63.35n+2.52)	13.0(=10.55n+2.74)	0.3009	0.5812	0.7231
	C	0.0	1.0	1.0	87.14	−44.42	−13.12	46.33	196	48.71(=47.67n+2.4)	70.29(=69.76n+2.52)	94.77(=94.72n+2.74)	0.2279	0.3288	0.7934
Y_N = 2.52	V (B)	0.0	0.0	1.0	31.9	24.46	−37.38	44.68	303	9.36(=7.17n+2.4)	7.04(=4.65n+2.52)	23.5(=21.37n+2.74)	0.2346	0.1764	0.0795
L^*_N = 18.01	M	1.0	0.0	1.0	59.01	89.33	−19.43	91.42	348	53.42(=52.52n+2.4)	27.04(=25.24n+2.52)	44.81(=43.3n+2.74)	0.4265	0.2158	0.3052
	N	0.0	0.0	0.0	18.01	0.0	0.0	0.0	357	2.4(=0.0n+2.4)	2.52(=0.0n+2.52)	2.74(=0.0n+2.74)	0.3127	0.329	0.0284
n = (88.59 − 2.52) / 88.59	W	1.0	1.0	1.0	95.41	0.0	0.0	0.0	0	84.2(=84.2n+2.4)	88.59(=88.59n+2.52)	96.46(=96.46n+2.74)	0.3127	0.329	1.0
= 0.972	N0	0.0	0.0	0.0	18.01	0.0	0.0	0.0	357	2.4(=0.0n+2.4)	2.52(=0.0n+2.52)	2.74(=0.0n+2.74)	0.3127	0.329	0.0284
	W1	1.0	1.0	1.0	95.41	0.0	0.0	0.0	0	84.2(=84.2n+2.4)	88.59(=88.59n+2.52)	96.46(=96.46n+2.74)	0.3127	0.329	1.0

IE340−7A, Colorimetric data of Television Luminous System TLS18a for CIE standard illuminant D65; sRGB-System; Page: 2/3

Colorimetric "Adapted data (a0)": Television Luminous System TLS00a0 for CIE lightness L^*_N=00 of black for illuminant D65

System TLS00a0	Color	$r=olv^*_1$	$g=olv^*_2$	$b=olv^*_3$	L^*_{a0}	a^*_{a0}	b^*_{a0}	$C^*_{ab,a0}$	$h_{ab,a0}$	$X_{a0}=XYZ_{1a0}$	$Y_{a0}=XYZ_{2a0}$	$Z_{a0}=XYZ_{3a0}$	x_{a0}	y_{a0}	$Y_{a0}/88.59$
sRGB system	O (R)	1.0	0.0	0.0	50.5	76.92	64.55	100.42	40	36.54=k(37.89−2.4)	18.84=k(20.83−2.52)	1.71=k(4.41−2.74)	0.64	0.33	0.2127
	Y	1.0	1.0	0.0	92.66	−20.68	90.75	93.08	103	68.22=k(68.67−2.4)	82.19=k(82.37−2.52)	12.27=k(14.66−2.74)	0.4193	0.5053	0.9278
D65 reflection:	L (G)	0.0	1.0	0.0	83.62	−82.74	79.9	115.03	136	31.68=k(33.17−2.4)	63.35=k(64.07−2.52)	10.55=k(13.0−2.74)	0.3	0.6	0.715
	C	0.0	1.0	1.0	86.88	−46.15	−13.54	48.11	196	47.67=k(48.71−2.4)	69.76=k(70.29−2.52)	94.72=k(94.77−2.74)	0.2247	0.3288	0.7874
Y_N = 0.0	V (B)	0.0	0.0	1.0	25.72	31.45	−44.28	54.32	305	7.17=k(9.36−2.4)	4.65=k(7.04−2.52)	21.37=k(23.5−2.74)	0.2161	0.1402	0.0525
L^*_N = 0.0	M	1.0	0.0	1.0	57.3	94.35	−20.68	96.59	348	52.52=k(53.42−2.4)	25.24=k(27.04−2.52)	43.3=k(44.81−2.74)	0.4339	0.2085	0.2849
	N	0.0	0.0	0.0	0.0	0.0	0.0	0.01	358	0.0=k(2.4−2.4)	0.0=k(2.52−2.52)	0.0=k(2.74−2.74)	0.0	0.0	0.0
k = 88.59 / (88.59 − 2.52)	W	1.0	1.0	1.0	95.41	0.0	0.0	0.01	0	84.2=k(84.2−2.4)	88.59=k(88.59−2.52)	96.46=k(96.46−2.74)	0.3127	0.329	1.0
= 1.029	N0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	358	0.0=k(2.4−2.4)	0.0=k(2.52−2.52)	0.0=k(2.74−2.74)	0.0	0.0	0.0
	W1	1.0	1.0	1.0	95.41	0.0	0.0	0.01	0	84.2=k(84.2−2.4)	88.59=k(88.59−2.52)	96.46=k(96.46−2.74)	0.3127	0.329	1.0

Calculated colorimetric data: Television Luminous Systems TLSxxa for CIE lightness L^*_N=27, 33, 52, 70 of black for illuminant D65

System TLS27a	Color	$r=olv^*_1$	$g=olv^*_2$	$b=olv^*_3$	L^*_a	a^*_a	b^*_a	$C^*_{ab,a}$	$h_{ab,a}$	$X_a=XYZ_{1a}$	$Y_a=XYZ_{2a}$	$Z_a=XYZ_{3a}$	x_a	y_a	$Y_a/88.59$
sRGB system	O (R)	1.0	0.0	0.0	54.88	66.84	41.69	78.78	32	39.25(=36.54n+4.79)	22.81(=18.84n+5.04)	7.1(=1.71n+5.49)	0.5675	0.3298	0.2575
	Y	1.0	1.0	0.0	92.82	−19.39	79.81	82.13	104	69.12(=68.22n+4.79)	82.56(=82.19n+5.04)	17.06(=12.27n+5.49)	0.4097	0.4893	0.9319
D65 reflection:	L (G)	0.0	1.0	0.0	84.37	−75.39	68.76	102.04	138	34.66(=31.68n+4.79)	64.78(=63.35n+5.04)	15.44(=10.55n+5.49)	0.3017	0.5639	0.7313
	C	0.0	1.0	1.0	87.4	−42.72	−12.7	44.58	197	49.75(=47.67n+4.79)	70.83(=69.76n+5.04)	94.82(=94.72n+5.49)	0.231	0.3288	0.7995
Y_N = 5.04	V (B)	0.0	0.0	1.0	36.8	20.12	−32.47	38.2	302	11.55(=7.17n+4.79)	9.43(=4.65n+5.04)	25.64(=21.37n+5.49)	0.2478	0.2022	0.1064
L^*_N = 26.85	M	1.0	0.0	1.0	60.64	84.61	−18.27	86.56	348	54.33(=52.52n+4.79)	28.84(=25.24n+5.04)	46.32(=43.3n+5.49)	0.4195	0.2227	0.3255
	N	0.0	0.0	0.0	26.85	0.0	0.0	0.0	0	4.79(=0.0n+4.79)	5.04(=0.0n+5.04)	5.49(=0.0n+5.49)	0.3127	0.329	0.0569
n = (88.59 − 5.04) / 88.59	W	1.0	1.0	1.0	95.41	0.0	0.0	0.0	0	84.2(=84.2n+4.79)	88.59(=88.59n+5.04)	96.46(=96.46n+5.49)	0.3127	0.329	1.0
= 0.943	N0	0.0	0.0	0.0	26.85	0.0	0.0	0.0	0	4.79(=0.0n+4.79)	5.04(=0.0n+5.04)	5.49(=0.0n+5.49)	0.3127	0.329	0.0569
	W1	1.0	1.0	1.0	95.41	0.0	0.0	0.0	0	84.2(=84.2n+4.79)	88.59(=88.59n+5.04)	96.46(=96.46n+5.49)	0.3127	0.329	1.0

System TLS38a	Color	$r=olv^*_1$	$g=olv^*_2$	$b=olv^*_3$	L^*_a	a^*_a	b^*_a	$C^*_{ab,a}$	$h_{ab,a}$	$X_a=XYZ_{1a}$	$Y_a=XYZ_{2a}$	$Z_a=XYZ_{3a}$	x_a	y_a	$Y_a/88.59$
sRGB system	O (R)	1.0	0.0	0.0	58.77	58.45	31.73	66.5	28	41.96(=36.54n+9.58)	26.78(=18.84n+10.08)	12.49(=1.71n+10.98)	0.5166	0.3297	0.3023
	Y	1.0	1.0	0.0	92.98	−18.11	70.81	73.09	104	70.03(=68.22n+9.58)	82.92(=82.19n+10.08)	21.85(=12.27n+10.98)	0.4006	0.4744	0.936
D65 reflection:	L (G)	0.0	1.0	0.0	85.11	−68.58	60.02	91.14	139	37.65(=31.68n+9.58)	66.22(=63.35n+10.08)	20.33(=10.55n+10.98)	0.3032	0.5332	0.7475
	C	0.0	1.0	1.0	87.92	−39.42	−11.87	41.19	197	51.83(=47.67n+9.58)	71.9(=69.76n+10.08)	94.92(=94.72n+10.98)	0.237	0.3288	0.8116
Y_N = 10.08	V (B)	0.0	0.0	1.0	44.52	14.84	−25.65	29.64	300	15.94(=7.17n+9.58)	14.2(=4.65n+10.08)	29.91(=21.37n+10.98)	0.2654	0.2365	0.1603
L^*_N = 37.99	M	1.0	0.0	1.0	63.71	75.92	−16.19	77.63	348	56.13(=52.52n+9.58)	32.44(=25.24n+10.08)	49.35(=43.3n+10.98)	0.407	0.2352	0.3662
	N	0.0	0.0	0.0	37.99	0.0	0.0	0.0	0	9.58(=0.0n+9.58)	10.08(=0.0n+10.08)	10.98(=0.0n+10.98)	0.3127	0.329	0.1138
n = (88.59 − 10.08) / 88.59	W	1.0	1.0	1.0	95.41	0.0	0.0	0.0	0	84.2(=84.2n+9.58)	88.59(=88.59n+10.08)	96.46(=96.46n+10.98)	0.3127	0.329	1.0
= 0.886	N0	0.0	0.0	0.0	37.99	0.0	0.0	0.0	0	9.58(=0.0n+9.58)	10.08(=0.0n+10.08)	10.98(=0.0n+10.98)	0.3127	0.329	0.1138
	W1	1.0	1.0	1.0	95.41	0.0	0.0	0.0	0	84.2(=84.2n+9.58)	88.59(=88.59n+10.08)	96.46(=96.46n+10.98)	0.3127	0.329	1.0

System TLS52a	Color	$r=olv^*_1$	$g=olv^*_2$	$b=olv^*_3$	L^*_a	a^*_a	b^*_a	$C^*_{ab,a}$	$h_{ab,a}$	$X_a=XYZ_{1a}$	$Y_a=XYZ_{2a}$	$Z_a=XYZ_{3a}$	x_a	y_a	$Y_a/88.59$
sRGB system	O (R)	1.0	0.0	0.0	65.53	45.06	20.98	49.71	25	47.38(=36.54n+19.16)	34.72(=18.84n+20.16)	23.27(=1.71n+21.95)	0.4497	0.3295	0.3919
	Y	1.0	1.0	0.0	93.3	−15.61	56.27	58.4	106	71.85(=68.22n+19.16)	83.65(=82.19n+20.16)	31.43(=12.27n+21.95)	0.3844	0.4475	0.9442
D65 reflection:	L (G)	0.0	1.0	0.0	86.55	−56.31	46.52	73.05	140	43.63(=31.68n+19.16)	69.09(=63.35n+20.16)	30.1(=10.55n+21.95)	0.3055	0.4838	0.7799
	C	0.0	1.0	1.0	88.94	−33.19	−10.24	34.75	197	55.98(=47.67n+19.16)	74.04(=69.76n+20.16)	95.12(=94.72n+21.95)	0.2487	0.3289	0.8358
Y_N = 20.16	V (B)	0.0	0.0	1.0	55.84	9.42	−17.5	19.88	298	24.7(=7.17n+19.16)	23.75(=4.65n+20.16)	38.46(=21.37n+21.95)	0.2842	0.2733	0.2681
L^*_N = 52.02	M	1.0	0.0	1.0	69.22	60.95	−12.72	62.27	348	59.73(=52.52n+19.16)	39.65(=25.24n+20.16)	55.4(=43.3n+21.95)	0.3859	0.2562	0.4476
	N	0.0	0.0	0.0	52.02	0.0	0.0	0.0	0	19.16(=0.0n+19.16)	20.16(=0.0n+20.16)	21.95(=0.0n+21.95)	0.3127	0.329	0.2276
n = (88.59 − 20.16) / 88.59	W	1.0	1.0	1.0	95.41	0.0	0.0	0.0	0	84.2(=84.2n+19.16)	88.59(=88.59n+20.16)	96.46(=96.46n+21.95)	0.3127	0.329	1.0
= 0.772	N0	0.0	0.0	0.0	52.02	0.0	0.0	0.0	0	19.16(=0.0n+19.16)	20.16(=0.0n+20.16)	21.95(=0.0n+21.95)	0.3127	0.329	0.2276
	W1	1.0	1.0	1.0	95.41	0.0	0.0	0.0	0	84.2(=84.2n+19.16)	88.59(=88.59n+20.16)	96.46(=96.46n+21.95)	0.3127	0.329	1.0

System TLS70a	Color	$r=olv^*_1$	$g=olv^*_2$	$b=olv^*_3$	L^*_a	a^*_a	b^*_a	$C^*_{ab,a}$	$h_{ab,a}$	$X_a=XYZ_{1a}$	$Y_a=XYZ_{2a}$	$Z_a=XYZ_{3a}$	x_a	y_a	$Y_a/88.59$
sRGB system	O (R)	1.0	0.0	0.0	76.43	26.27	10.57	28.31	22	58.23(=36.54n+38.32)	50.59(=18.84n+40.32)	44.83(=1.71n+43.9)	0.379	0.3292	0.571
	Y	1.0	1.0	0.0	93.93	−10.77	34.63	36.27	107	75.49(=68.22n+38.32)	85.11(=82.19n+40.32)	50.58(=12.27n+43.9)	0.3575	0.403	0.9606
D65 reflection:	L (G)	0.0	1.0	0.0	89.32	−35.81	27.64	45.25	142	55.58(=31.68n+38.32)	74.84(=63.35n+40.32)	49.65(=10.55n+43.9)	0.3087	0.4156	0.8447
	C	0.0	1.0	1.0	90.93	−21.96	−7.08	23.09	198	64.3(=47.67n+38.32)	78.33(=69.76n+40.32)	95.51(=94.72n+43.9)	0.27	0.3289	0.8841
Y_N = 40.32	V (B)	0.0	0.0	1.0	71.46	4.57	−9.01	10.11	297	42.23(=7.17n+38.32)	42.86(=4.65n+40.32)	55.54(=21.37n+43.9)	0.3003	0.3047	0.4837
L^*_N = 69.7	M	1.0	0.0	1.0	78.5	37.52	−7.58	38.28	349	66.94(=52.52n+38.32)	54.07(=25.24n+40.32)	67.49(=43.3n+43.9)	0.3551	0.2868	0.6103
	N	0.0	0.0	0.0	69.7	0.0	0.0	0.0	0	38.32(=0.0n+38.32)	40.32(=0.0n+40.32)	43.9(=0.0n+43.9)	0.3127	0.329	0.4551
n = (88.59 − 40.32) / 88.59	W	1.0	1.0	1.0	95.41	0.0	0.0	0.0	0	84.2(=84.2n+38.32)	88.59(=88.59n+40.32)	96.46(=96.46n+43.9)	0.3127	0.329	1.0
= 0.545	N0	0.0	0.0	0.0	69.7	0.0	0.0	0.0	0	38.32(=0.0n+38.32)	40.32(=0.0n+40.32)	43.9(=0.0n+43.9)	0.3127	0.329	0.4551
	W1	1.0	1.0	1.0	95.41	0.0	0.0	0.0	0	84.2(=84.2n+38.32)	88.59(=88.59n+40.32)	96.46(=96.46n+43.9)	0.3127	0.329	1.0

IE340−7A, Colorimetric data of Television Luminous System TLS18a for CIE standard illuminant D65; sRGB-System; Page: 3/3

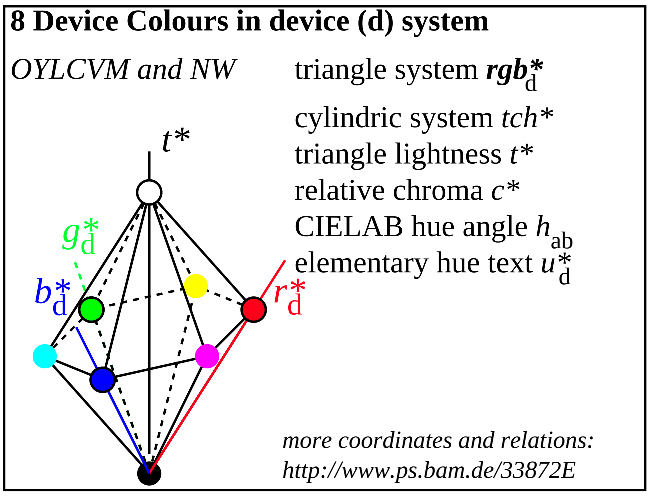
Figure 14 – Calculation of colorimetric data of Television Luminous Systems TLS(00/06/11/18/27/38/52/70)a

Fig. 13 and 14 show the mathematical method how to calculate the data of the Television Luminance System TLS00a by a factor *k*, For this calculation the data of the Television System TLS18a are given.

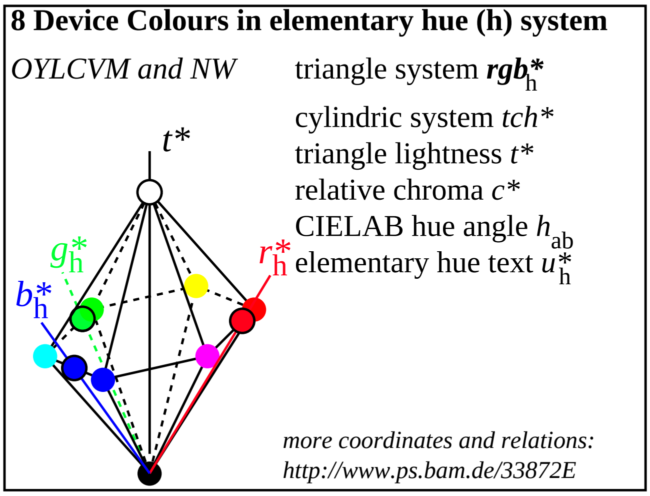
In Fig. 14 the data of seven other Television Luminance Systems TLS(06/11/18/27/38/52/70)a are calculated from the data of the Television Luminance System TLS00a. In application the measurement data TLSxx in standard CIELAB shall be first transferred to adapted data TLSxxa in adapted CIELAB and then transferred to the reflection free data TLS00a. An example for a real LCD display is given in the Fig. 10 and 12. In Fig. 10 the original measurement data are given and this system is called TLS11 according to the lightness L^*_N =11 for black *N*. In Fig. 11 the system is adapted for Black *N* and White *W* and called TLS11a. However, the chroma of all grey colour is not exactly at the achromatic point. It has to be tested if this deviation is visually acceptable. In Fig. 12 the data of the system TLS70a are calculated. The chroma gamut is reduced by a factor 0,3 in one dimension and by a factor 0,3 x 0,3 = 0,09 in two dimensions.

8. Device hue coordinates *olv** and elementary hue coordinates *rgb**

The 6 device colours *OYLCVM* define together with Black *N* and White *W* a double cone with a hexagon as basis. In application this hexagon is irregular. For example the hue differences between two neighboring colours may vary by a factor 1 to 3. For example the smallest hue angle difference may be between *V* and *M* and the largest hue angle difference may be between *C* and V, compare Fig. 17.



IE151-2N

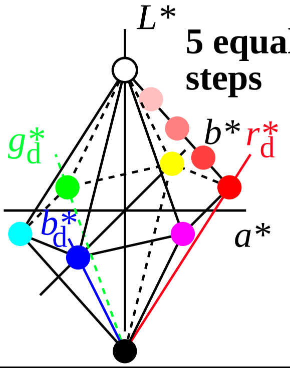


IE151-4N

Figure 15 – Double cone with a hexagon basis and for device and elementary hues

Fig. 15 shows two identical double cones with a hexagon basis and coordinates according to device and elementary hues rgb^*_d and rgb^*_h. For most devices, including the standard *sRGB* device and the *LCD* device in Fig. 12 to 14, the elementary hue angles in CIELAB are located between *M* and *O* for Red *R*, between *L* and *C* for Green *G*, and between *C* and *V* for Blue *B*, compare Fig. 15.

8 Device (d) colours in CIELAB: *OYLCVM* and *NW*



5 equal steps

Hexagon-triangle system based on device (d) colours: $\boldsymbol{rgb^*_d = olv^*}$
with **linear relations** between $\boldsymbol{rgb^*_d}$ and ***LCH****
(compare linear relations between rgb_{sRGB} *and L*)*

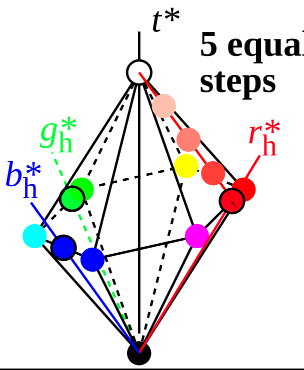
Equations rgb^*_d − *LCH** in both directions have been published, see:
Richter, CIE-Proceedings, Beijing, 2008, Volume 3 und DIN 33872-1

Three equations (tables) are needed for office applications:

$\boldsymbol{rgb_d}$ **− *LCH*’*** output a 9x9x9 grid of equally spaced rgb_d-input data
$\boldsymbol{rgb^*_d}$ **− *LCH**** a 9x9x9 grid of equally spaced data rgb^*_d and *LCH**
$\boldsymbol{rgb'_d}$ **− *LCH**** ***Device output linearisation by*** $\boldsymbol{rgb_d \to rgb'_d}$

IE161-3N

8 Device (d) colours, 4 elementary hues (h) in CIELAB: *OYLCVM, NW,* $\boldsymbol{RJGB_e}$



5 equal steps

Hexagon-triangle system based on device (d) colours: $\boldsymbol{rgb^*_d = olv^*}$
with **linear relations** between $\boldsymbol{rgb^*_d}$ **− *LCH****, and $\boldsymbol{rgb^*_h}$ **− *LCH****
(compare linear relations between rgb_{sRGB} *and L*)*

Equations rgb^*_h − *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:

$\boldsymbol{rgb_d}$ **− *LCH*’*** output a 9x9x9 grid of equally spaced rgb_d-input data
$\boldsymbol{rgb^*_h}$ **− *LCH**** a 9x9x9 grid of equally spaced data rgb^*_h and *LCH**
$\boldsymbol{rgb'_h}$ **− *LCH**** ***Device output linearisation by*** $\boldsymbol{rgb_d \to rgb'_h}$

IE161-5N

Figure 16 – Linear relations *olv* – LCH and *rgb* – LCH** for linearization for visual display output**

Fig. 16 shows linear relations *olv* – LCH** and *rgb* – LCH** for linearization of the visual display output with device and elementary hues and measured nonlinear relations rgb_d – *LCH*’* (star-dash-data).

It is intended, that the output of the 5-step colour series between Orange red *O* and White *W* is equally spaced in both the *standard* and the *adapted* CIELAB space. The *olv** input data vary for this series in equal steps. Then there is a linear relation between the *olv** data in this hue plane and the LCH^*_a data.

This ideal case with linear relations is rare but for example approximately true for the standard offset output. For displays and printers one can linearize the output.

At first there is a set of equations which define the ideal case. If the display hue circles and the corresponding coordinates are studied, then of course for the six device colours the *olv** coordinates have for the six device colours *OYLCVM* the values 1 0 0, 1 1 0, 0 1 0, 0 1 1, 0 0 1, 1 0 1 and define together with Black *N* and White *W* the gamut boundary, see for example the *olv** and CIELAB data in Fig. 13 for the system TLS18a.

The TUB-test chart IE00 is used to measure the device colours for the grid G with 9x9x9 colours. All measured CIELAB data are within the same part of the CIELAB PCS defined by the above *olv** -LCH^*_a relation. Therefore the theoretical and the practical part of the CIELAB gamut boundary will match in three dimensions and of course also in any hue plane.

The ICC colour management according to ISO 15076-1 offers an option called “absolute colour management” which is usually not used. This ICC method can calculate the *olv’** (dash-star) data to reach the intended equally spaced 5- or 16-step output in any hue plane.

Mathematically for any triple of *olv** data (star-data) there is a triple of *olv’** data (dash-star-data) to reach the intended output. Therefore the problem is solved with a table

olv* -> olv”* (for example to be calculated by own methods or by absolute ICC colour management for any device)

The question arises if this method is applicable for the eight standard reflections of the ambient light on the display surface. The answer is yes. Of course the gamut boundary size in CIELAB decreases from 100% to 2,7% between TLS00 and TLS70. This will reduce also the accuracy by the same amount but the accuracy can be increased again if the *olv** to *olv'** transformation is transmitted directly.

So eight tables *olv** –> *olv'** can be calculated for the eight Television Luminous Systems

TLS00a, TLS06a, TLS11a, TLS18a

TLS27a, TLS38a,TLS52a, TLS70a

They are device dependent and constant. All eight tables may be included in the device and used as eight options. In office application the most important table is for the standard 2,5% reflection (system TLS18) and not for the condition with 0% reflection (system TLS00).

This is the end of the description of the output linearization method in device hue space.

The additional problem to interpret the *rgb* colour input in elementary hue space and to produce a device independent hue output leads to similar tables *rgb** - > *rgb'**.

This step is simple. If already the table *olv** -> *olv'** exists, then the CIELAB hue angle can be calculated for any *rgb** value. For any *rgb** value additionally relative chroma *c** and relative blackness *n** can be calculated according to the equations (1) to (4). Similar, for any CIELAB hue angle the *olv** data of the Maximum colour M_a can be calculated. Together with the calculated *c** and *n** value the triple of *olv'** data (dash-star) is defined.

So finally eight tables *rgb** - > *olv'** can be calculated for the eight Television Luminous Systems

TLS00a, TLS06a, TLS11a TLS18a

TLS27a, TLS38a,TLS52a, TLS70a

for the elementary hue output.

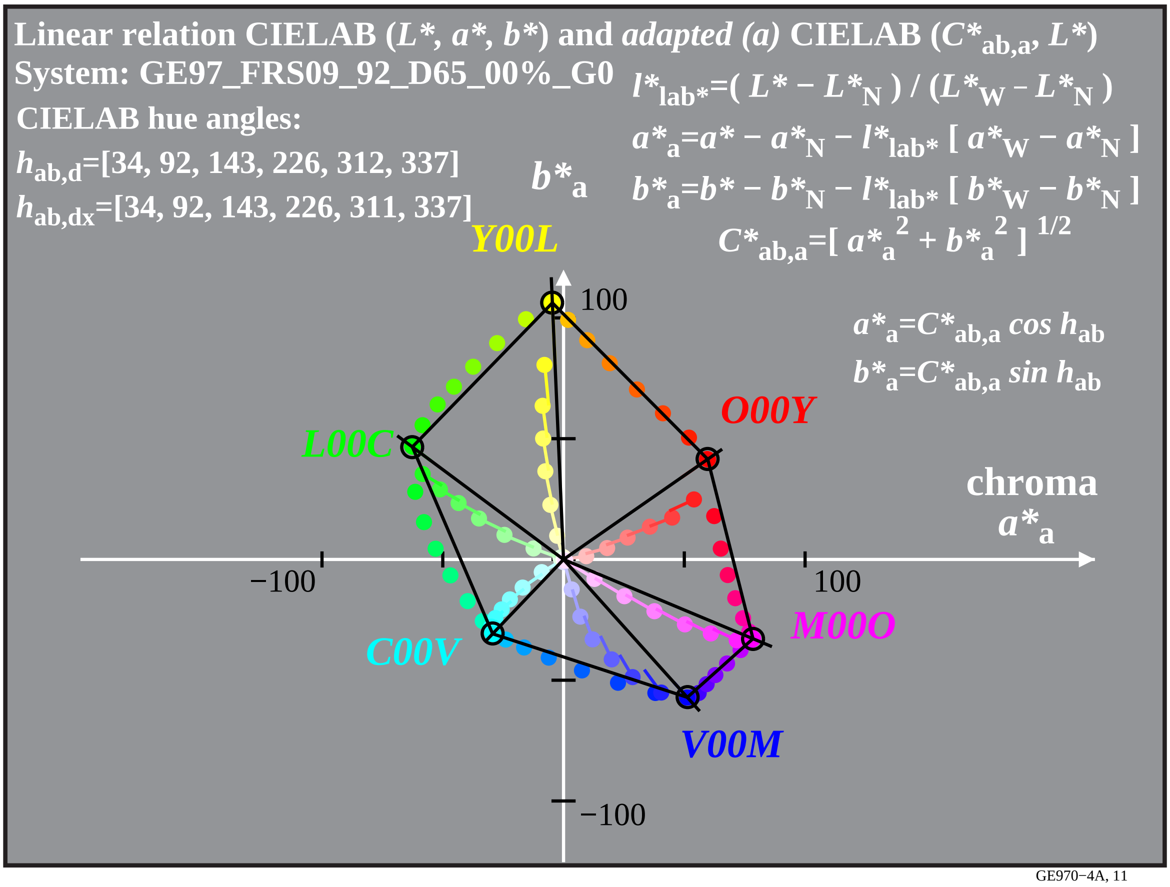
The efficiency may increase by a factor 150 if only *rgb*-data are transmitted instead of CIELAB data.

If colour managementaccording to ISO 15076-1 is developed further and allows an *RGB* PCS, then the device independent visual *RGB* colour space based on the report CIE R1-47:2009 is a good choice. The efficiency may increase by up to a factor 150 with this improved ICC colour management for visual displays an ambient daylight reflection at the display surface.

At present for the standard system TLS18a the application of ICC colour management with the CIELAB PCS may reduce the efficiency by a factor 0,11 compared to the intended *RGB* PCS. The factor 0,11 is determined by the factor 0,2 of the used CIELAB coding size and the colour gamut reduction by a factor 0,55 with the ambient light reflection of 2,5% on the monitor surface. The combination 0,2 x 0,55 of both factors both leads to the factor 0,11.

In other words if rgb data with a colorimetric connection to the CIELAB data of the eight colours *OYLCVMNW* are used, then the efficiency may increase by a factor 9 (=1/0,11) for the standard office condition with a 2,5% reflection (TLS18a) and the standard offset system (ORS18). For the system TLS70 the efficiency in increased by a factor 150.

9. Example output linearization for *device* and *elementary* hue output



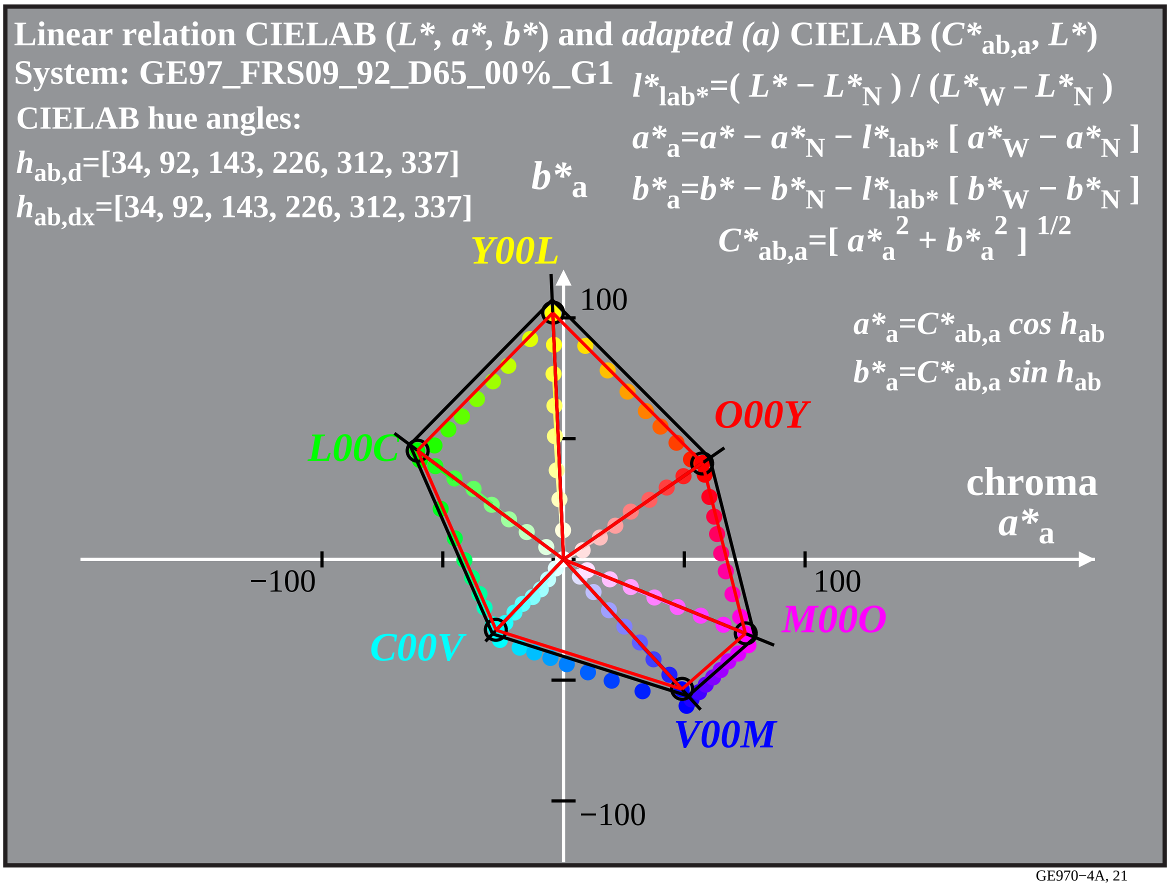
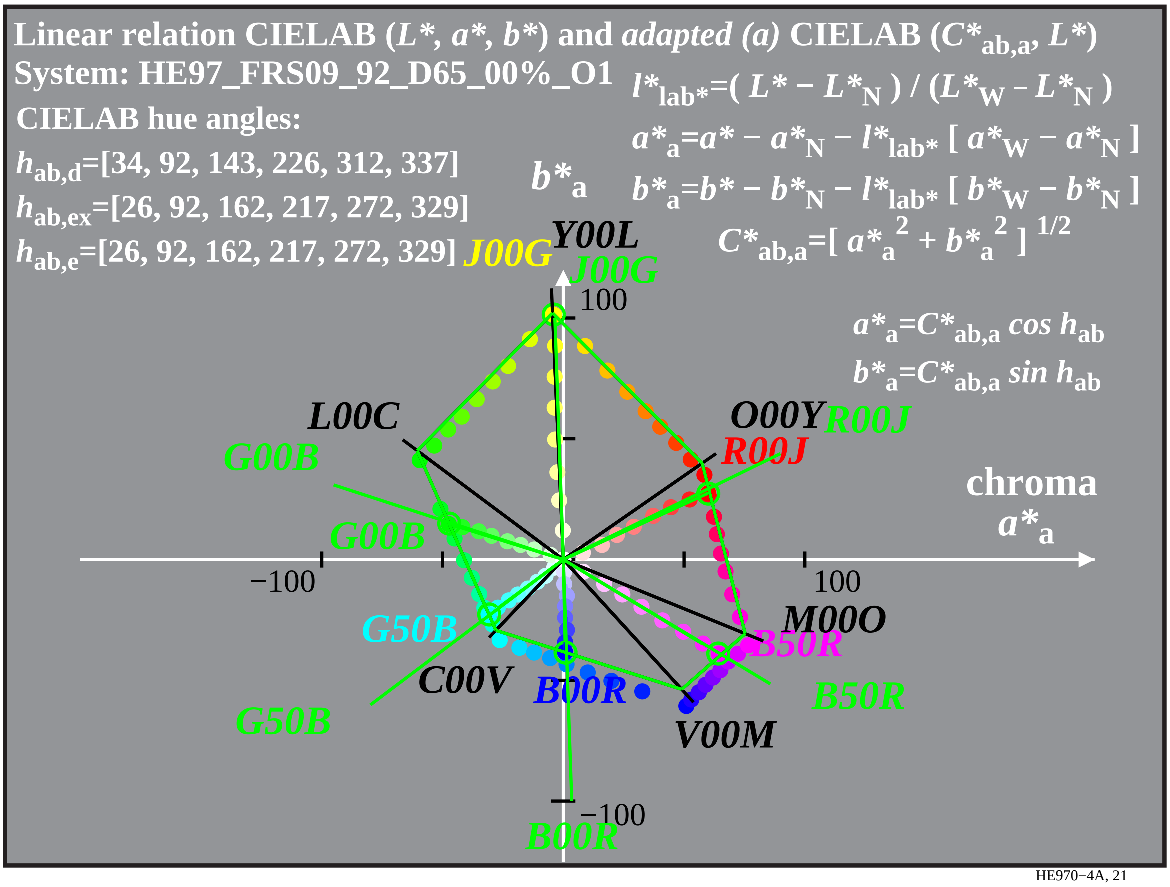


Figure 17 – Start and linearized device hue output in adapted CIELAB (a^*_a, b^*_a) for a photo printer

Fig. 17 shows the start and linearized device hue output in adapted CIELAB (a^*_a, b^*_a) for a photo printer.



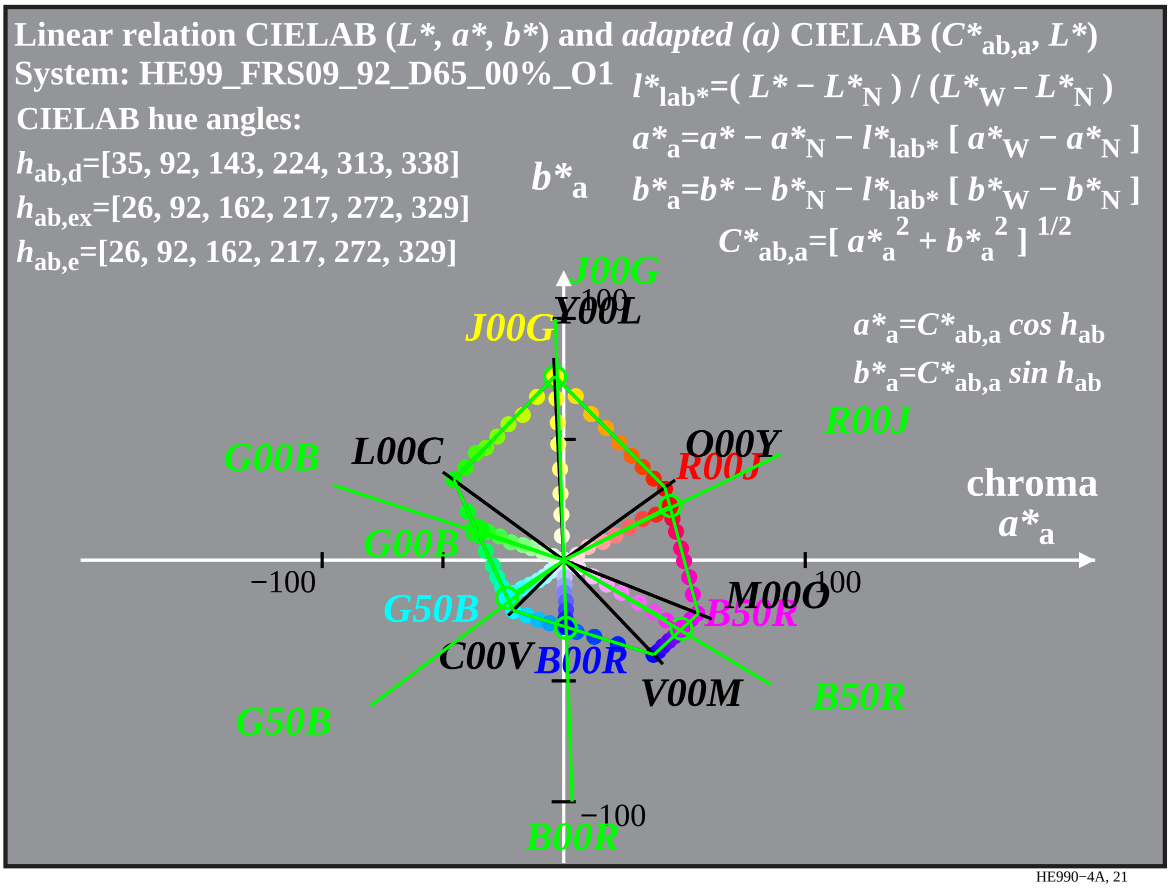
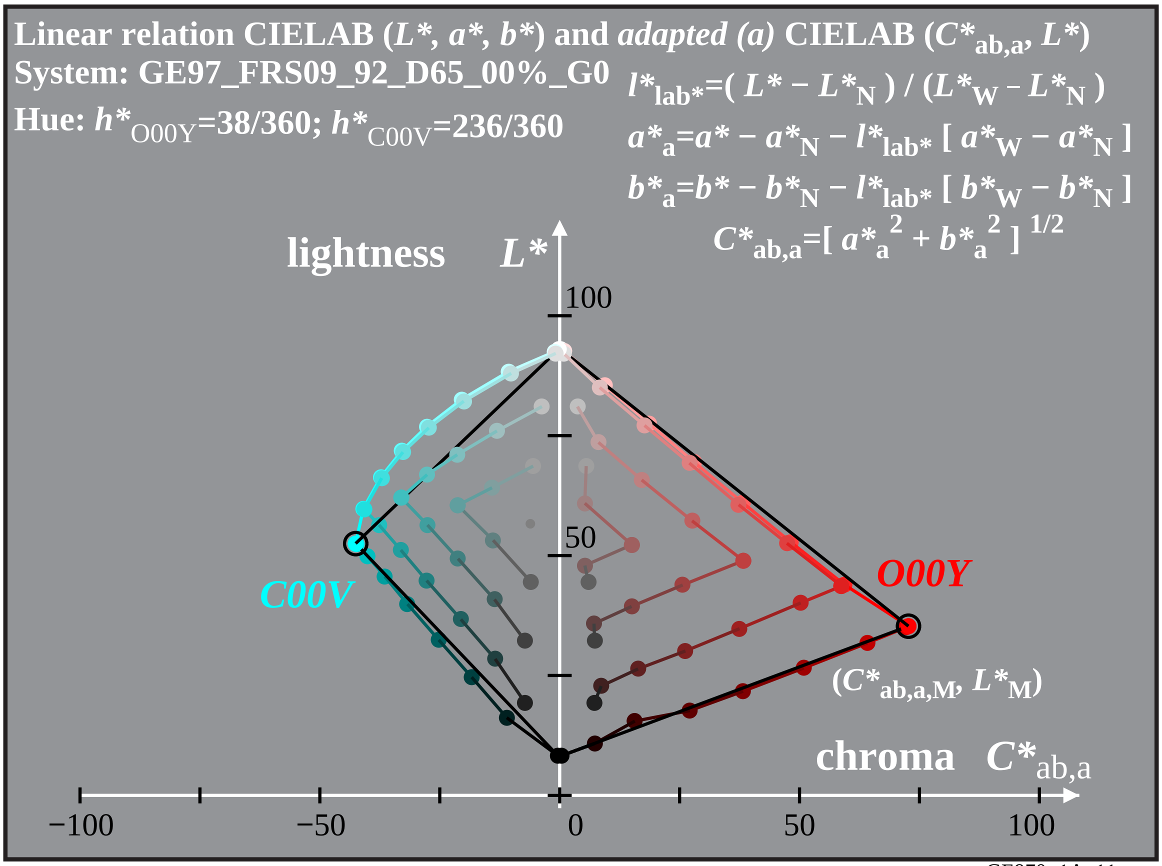


Figure 18 – Two linearized elementary hue outputs in adapted CIELAB (a^*_a, b^*_a) for a photo printer

Fig. 18 shows the two linearized elementary hue outputs in adapted CIELAB (a^*_a, b^*_a) for a photo printer. The bottom figure is calculated for a chroma contrast range of 70% instead of 100%.



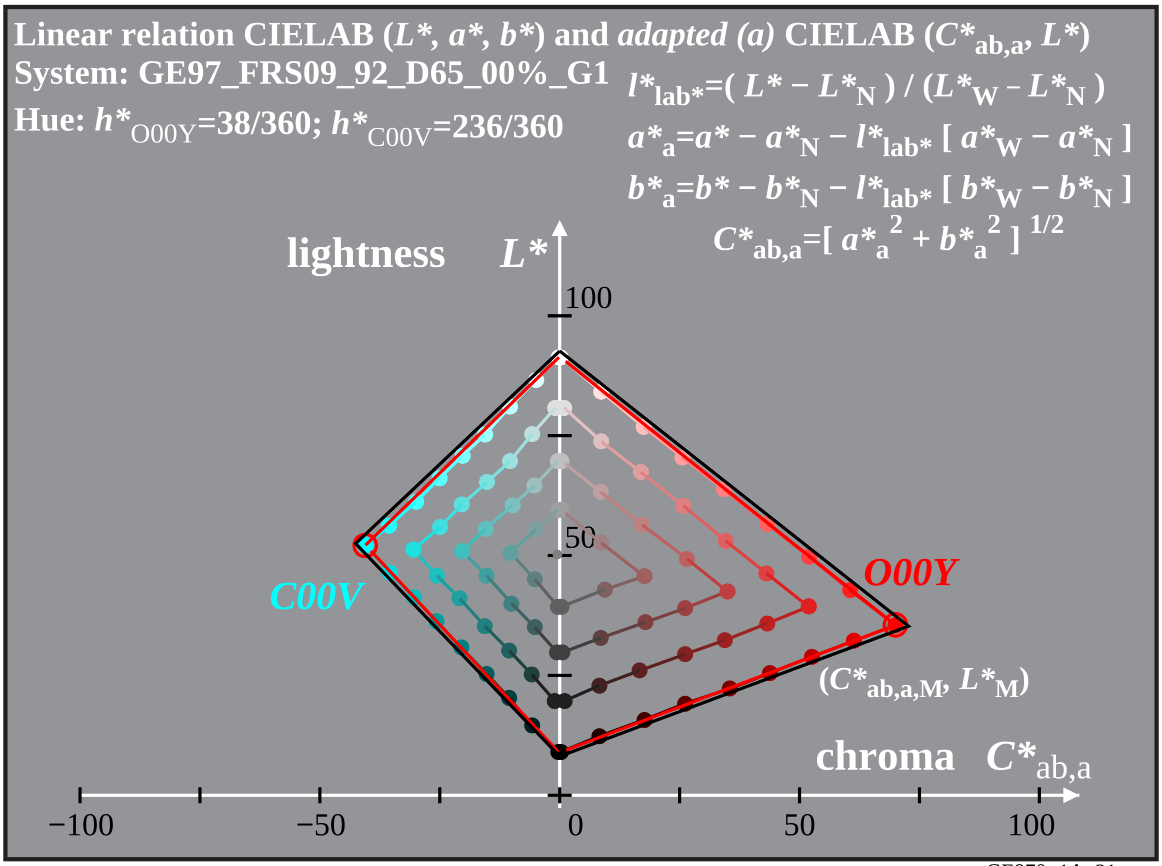


Figure 19 – Start and linearized device hue output in adapted CIELA B (C^*_{ab}, L^*) plane for a photo printer

Figures 17 to 19 show examples for the start and linearized output in the adapted CIELAB diagram (a^*_a, b^*_a) and the device hue plane *O – C* in the adapted CIELAB diagram (C^*_{ab}, L^*).

10. Summary

This paper proposes test charts and test methods for colour output of visual displays at office work places. The colour test chart allow a visual evaluation and a colorimetric specification of the colour output of the visual displays at office work places.

The so called "absolute colour management" according to ISO 15076-1 with a CIELAB *Profile Connection Space (PCS)* may be used to produce a linearized device output for equally spaced *rgb*-input data. The efficiency of this method is limited. For example the sRGB colour space according to IEC 61966-2-1 fills the CIELAB coding space by a factor 0,2 according to CIE 168. This factor is further reduced by a factor 0,55 for the standard display with *L**=18 instead with *L**=0 for Black *N* which is the ideal case according to IEC 61966-2-1 (System TLS00).

Therefore the colour management according to ISO 15076-1 has an efficiency defined by a factor 0,11 (=0,2 x 0,55) for the standard daylight reflections on the display surface. The method defined here increases the efficiency by a factor 9 (=1/0,11) for the standard condition. Large reflections may occur for standard screens in the daylight office, for example for data projectors and displays of mobile phones and digital cameras. In the worse case of ISO 9241-306 (System TLS70) the new method increases the efficiency by a factor 150.

ISO 15076-1 recommends an ambient luminance between 32 and 64 lux to avoid any CIELAB data change by the display reflections. This recommendation does not consider the standard office illumination of 500 lux and the European regulations (see DIN V 18599-4) to work in a daylight office which produces in any application larger reflections.

The application of a human visual *RGB** colour system which is device independent in hue is proposed here. This visual *RGB** system is based on recent proposals of the CIELAB h_{ab} hue angles of the elementary colours. The Report CIE R1-47 of CIE division 1: "Vision and Colour" defines the four elementary hue angles 26, 92, 162, and 272 degree in CIELAB for the four elementary colours Red *R*, Yellow *J*, Green *G,* and Blue *B*. These definitions are used in the standard series DIN 33872-1 to -6 (in print): Information technology - Office machines - Method of specifying relative colour reproduction with YES/NO criteria.

A colour output linearization method for visual displays and for eight reflections of the ambient light on the display surface is described here, similar as the one for Black *N* and White *W* in ISO 9241-306. The output linearization method can fulfill the criteria of DIN 33872 to produce visually equally spaced 5- and 16-step colour series and an elementary hue angle agreement in the output for equally spaced *rgb*-input data. The advantages for colour management of visual displays are discussed.

11. ISO-CIE-trend towards a 3D human visual *RGB** colour system

The human visual *RGB** colour system is presently only specified by the hue angles of the elementary colours. This is sufficient for nearly all applications of image technology. The device output linearization and the device independent hue output on any colour device is a large step forward.

However, the human visual *RGB** colour system used here is only device independent in one dimension. The *Natural Colour System NCS* includes already in addition the two human visual coordinates relative blackness *n** and relative chroma *c** for the other 2 dimensions. A relation between *ncu** and *rgb** in both directions is shown in Fig. 3.

Therefore for a more effective visual colour communication a 3-dimensional human visual *RGB** colour system seems very important for the field of image technology. This 3D human visual *RGB** colour system will include in addition the CIELAB chroma C^*_{ab} and the lightness *L** of the elementary colours. There are at least three solutions of this problem. One can use the four hue angles defined in CIE R1-47 and specify the CIELAB data C^*_{ab} and *L** for these for hue angles:

1. by use of the optimal colours of maximum chroma for D65.
2. by use of the *NCS* colours of maximum chroma for D65
3. by new visual evaluations of the human visual relative blackness *n** and relative chroma *c** of a high chroma colour circle, for example of the 16 step colour circle of the RECS colour system.

Some people do believe that the accuracy of point three is too low. However there are three methods mentioned here and one can make a compromise between the three. There are many compromises in vision, for example the agreement of a visual relative photopic luminance efficiency function $V(\lambda)$ in lighting technology.

In addition physiological models of the visual human system as requested. Some physiological models are given in a book of *Valberg* (2005) and in the report CIE R1-47. This report will appear soon at the CIE-web site of CIE Division 1, see

http://www.cie.co.at/div1/

12. References

Standards and similar documents

CIE13.3:1995: Colour rendering – Method of measuring and specifying colour rendering of light source

CIE15:2004: Colorimetry, 3rd edition

DIN EN IEC 61966-2-1: 2005, Multimedia-Systeme und Geräte – Farbmessung und Farbmanagement – part 2.1: Farbmanagement, *RGB*-Vorgabe-Farbraum – sRGB

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 analog test charts – Realisation and application and ISO/IEC 15775:1999/Amd 1:2005.

ISO/IEC TR 19797:2004, Information technology – Office machines – Device output of 16 colour scales, output linearization method (LM) and specification of the reproduction properties. For information and test charts according to ISO/IEC TR 19797 see

http://www.ps.bam.de/19797TE

ISO/IEC TR 24705:2005, Information technology – Office machines – Machines for colour image reproduction – Method of specifying image reproduction of colour devices by digital and analog test charts. For information and test charts according to ISO/IEC TR 24705 see

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ISO 22028-1:2004, Photography and graphic technology – Extended colour encodings for digital image storage, manipulation and interchange – Part 1: Architecture and requirements.

ISO/TS 22028-2:2005, Photography and graphic technology – Extended colour encodings for digital image storage, manipulation and interchange – Part 2: Reference output medium metric *RGB* colour image encoding (*ROMM RGB*)

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NOTE: The elementary hues are often called unique hues. They are in hue identical with the elementary colours of DIN 33872. The elementary colours of the *Natural Colour System NCS* also have the elementary hues.

Richter, K. (1969), Antagonistische Signale beim Farbensehen und ihr Zusammenhang mit der empfindungsgemäßen Farbordnung, Dissertation, Universität Basel.

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Richter, K. (1985), BAM-Forschungsbericht no. 115, Farbempfindungsmerkmal Elementarbuntton und Buntheitsabstände als Funktion von Farbart und Leuchtdichte von In- und Umfeld, 118 pages, ISBN 3-88314-420-7

Richter, K. (1996), Computergrafik und Farbmetrik - Farbsysteme, *PostScript* und geräteunabhängige CIE-Farben, VDE-Verlag, 288 pages with about 500 colour figures and many additional references, see

http://www.ps.bam.de/buche

Richter, K. (2007). Colorimetric model of logarithmic colour spaces LMSLAB, Part II, The Proceedings of the 26th Session of the CIE, 2007, Beijing, Proceedings Volume 2.pdf, 199-230

Richter, K. (2008a) Colorimetric supplement to DIN 33872-1 to -6, see (1 MB, 41 pages)

http://www.ps.bam.de/D33872-AE.PDF

Richter, K. (2008b), Relative Elementary Colour Sytem RECS as digital and analog colour atlas (36 pages with about 2000 colour samples), Short information and order possibilities, 1 page, 100 KByte

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Witt, J. (2006), Farbmetrische Methoden zur Herstellung von Prüfvorlagen für Farbkopierer, Farbscanner und Farbmonitore, Dissertation, TU Berlin, Fakultät IV, Elektrotechnik und Informatik, 177 pages, see the URL (178 pages, 8 MByte, PDF format)

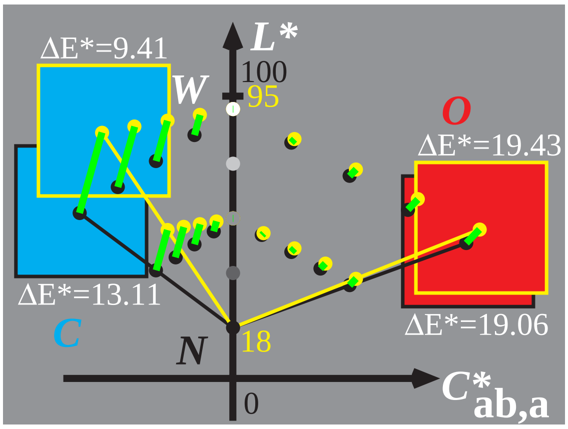
http://opus.kobv.de/tuberlin/volltexte/2006/1363/

Wagenknecht, H. (2009), Farbmetrische Verarbeitung von Bilddaten von Scanner-Systemen mit geeigneten Pruefvorlagen und Druckerausgabe (only in German with english abstract), Dissertation, Berlin University of Technology, Fakulty IV, Elektrotechnik and Informatik, see the URL (132 pages, 6,3 MByte, PDF format)

http://opus.kobv.de/tuberlin/volltexte/2009/2291/

Remarks to the images (figures and tables) and test charts shown is this paper:

The images of this paper and others in DIN and ISO/IEC standard documents of the editor *Klaus Richter* often have under the *figure a number*, for example “YE731-8“, compare the following figure:



Part 4 IE631−4

In this case the figure and similar figures may be found under an URL which is build either by the BAM-, the TUB- or the web-author server address, see one of the three addresses

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

http://130.149.60.45/~farbmetrik/

http://web.me.com/klaus.richter/

and the first *four* alphanumeric letters, for example YE73 for the above figure. *Similar figures* of the *relative affine image reproduction* may be found in this case under the URL:
http://web.me.com/klaus.richter/IE63

On one of the server pages there is usually a link which allows to download the page “YE73“, and the figure “YE730-8“ in the formats *Adobe PostScript (PS)* or *Portable Document (PDF, Version 1.3)*.

A survey of many *figures* which are created during the same time period may be found under the URL which is build by the server address and the first *two* alphanumeric letters “IE“.

Therefore *similar figures* may be found in this case under the URL:
http://web.me.com/klaus.richter/IE.HTM

Additional images may be found under the addresses which may begin instead of “I“ by any other letter between “A to Z“ and end instead of “E” for English with the letter “G“ for German, for example “GG“:
http://web.me.com/klaus.richter/GG.HTM

The ISO-, DIN-, BAM- and TUB-test charts include a frame. With many browsers and PDF-readers all links in the image frame are active, see for example the link in Fig. 5 (top side)

http://130.149.60.45/~farbmetrik/IE00/IE00L0NP.PDF

or the link in Fig. 5 (left side)

http://web.me.com/klaus.richter/IE00/IE00L0NP.PDF

or the link in Fig. 5 (left side)

http://www.ps.bam.de

or the link in Fig. 5 (left side)

http://130.149.60.45/~farbmetrik