# Colour Definition and Workflow for relative affin Colour Image Reproduction in Offices

http://www.ps.bam.de/BAMWS07E.PDF
(34 pages,1 MByte)

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http://www.ps.bam.de

For this paper presented at the BAM-DIN-Workshop on Image Technology (Dec. 3, 2007) see the URL (34 pages, 1 MByte)
http://www.ps.bam.de/BAMWS07E.PDF

For a similar paper presented at a Kolloquium (TU Berlin, Dec. 5, 2007) in German see the URL (34 pages, 1 MByte)
http://www.ps.bam.de/TUKOL07G.PDF

A new German draft standard DIN E 33872-1 to 6:2007 on relative colour reproduction with many test charts is published. For titels and test charts see

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

The DIN-test charts are freely available on the web together with questions about output properties for monitor and/or printer output.

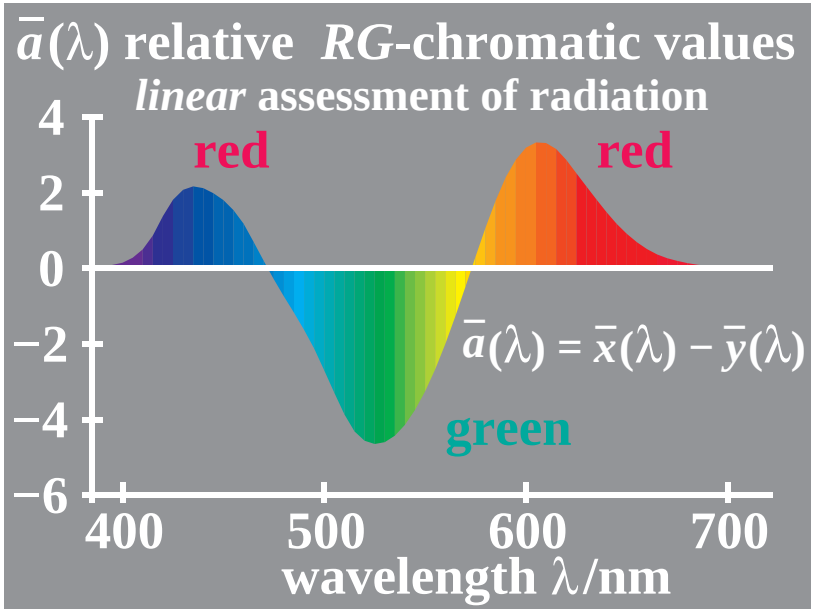
# Content of the first part

- Colour names according to ISO/IEC 15775
- Device and elementary colours
- Elementary colours and *rgb** colour coordinates
- Other relative colour coordinates, for example nce*
- Colour data in colorimetry and image technology
- User friendly colour notation
- Away from device to elementary colour data
- Relative affin colour management
- ICC colour mamangement according to ISO 15076-1

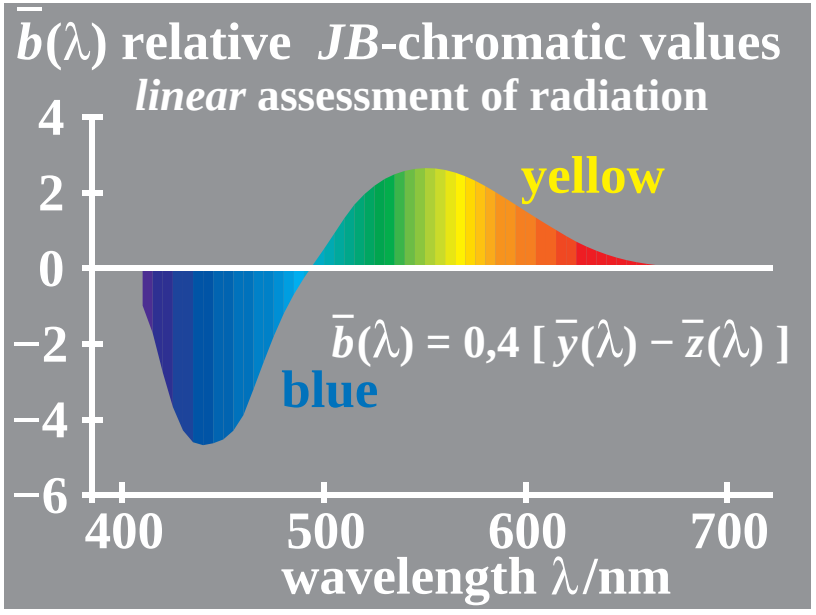
**Definition of elementary colours and spectral assessment**

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

YE980−3

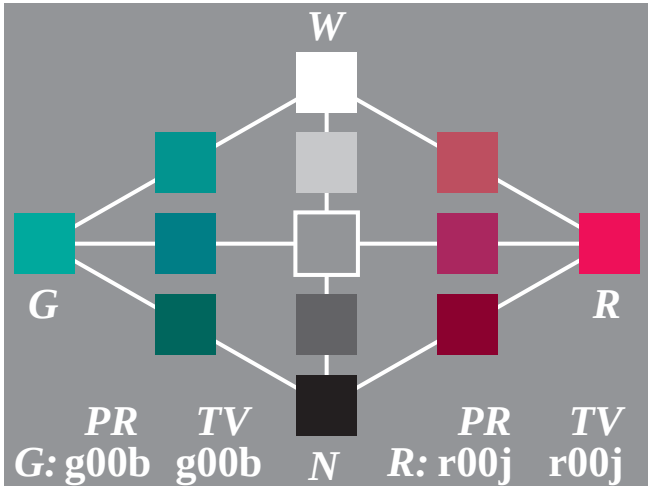



XE351−1

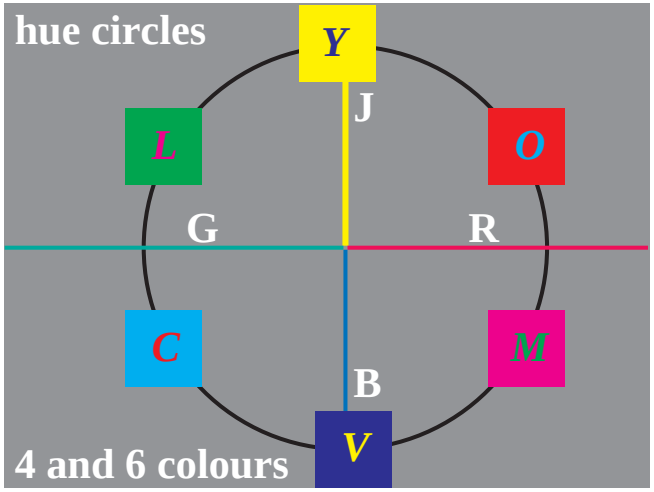



XE351−2

**Elementary hue circle and different hue planes**



ZE410−7



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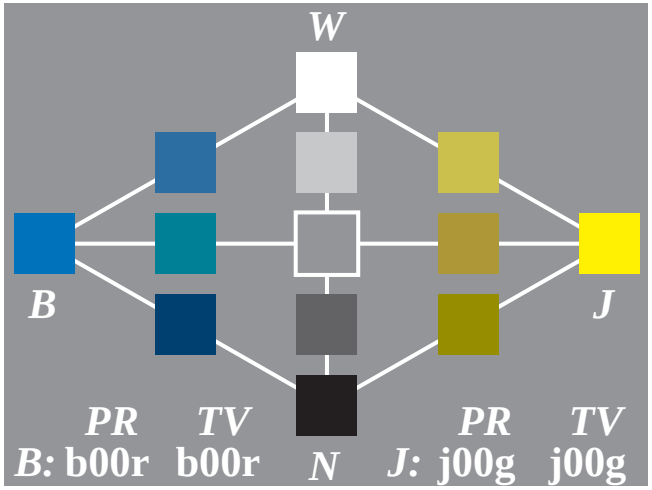

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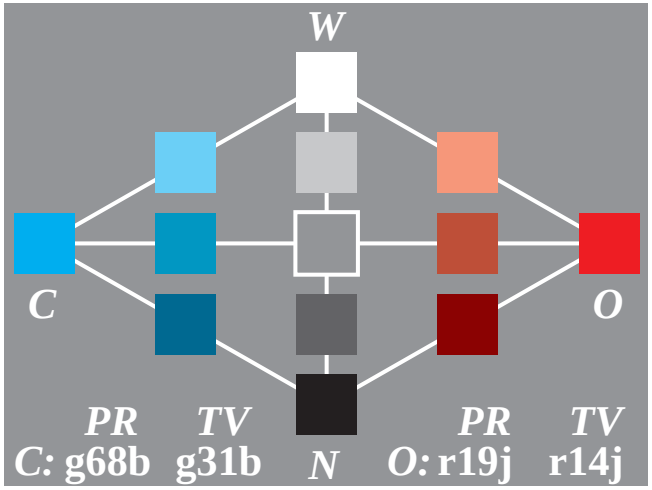

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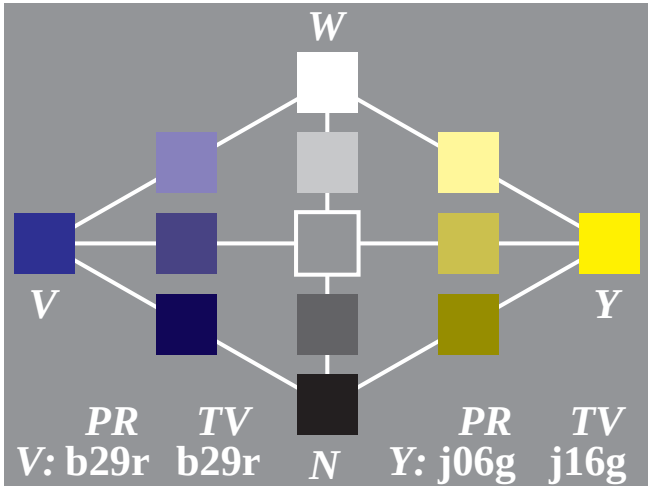
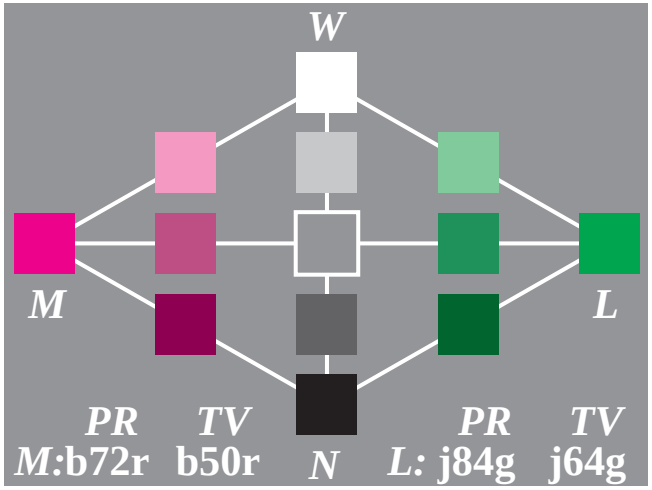


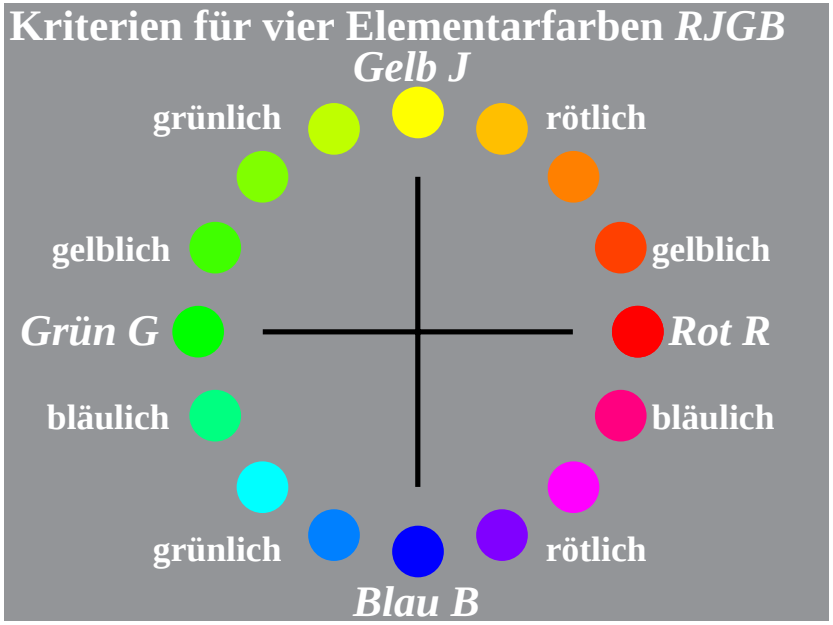
ZE410−5



ZE410−6

Colour order systems are based on a double cone with a circular basis *(Ostwald, NCS)*. The *Natural Colour System (NCS)* uses three coordinates *nce** (relative blackness *n**, relative chroma *c**, elementary hue *e**)

**Criteria for elementary colours and three different relative device colour data**

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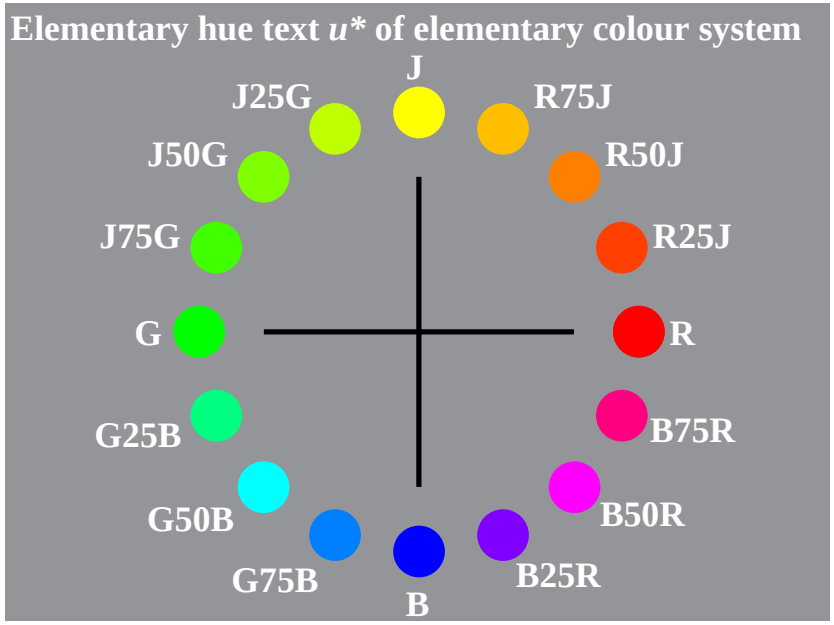


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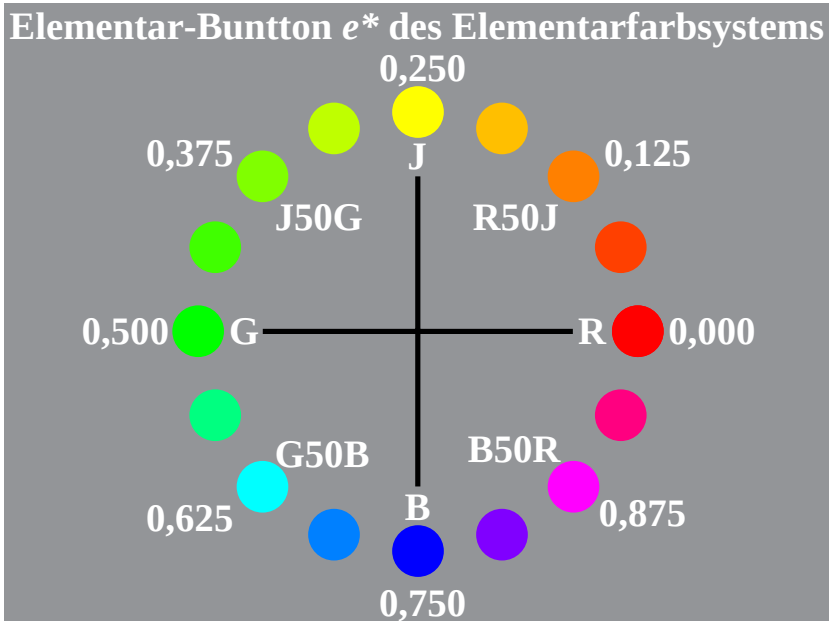


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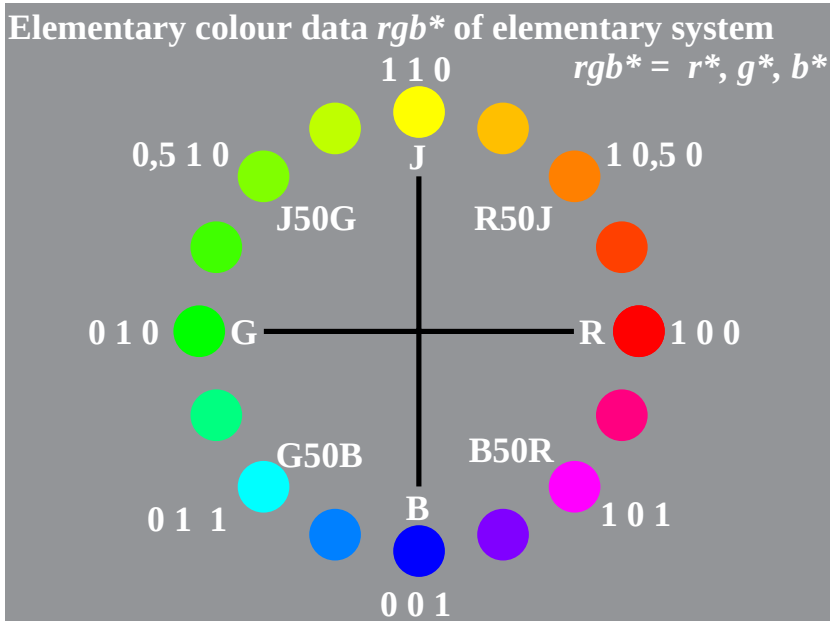
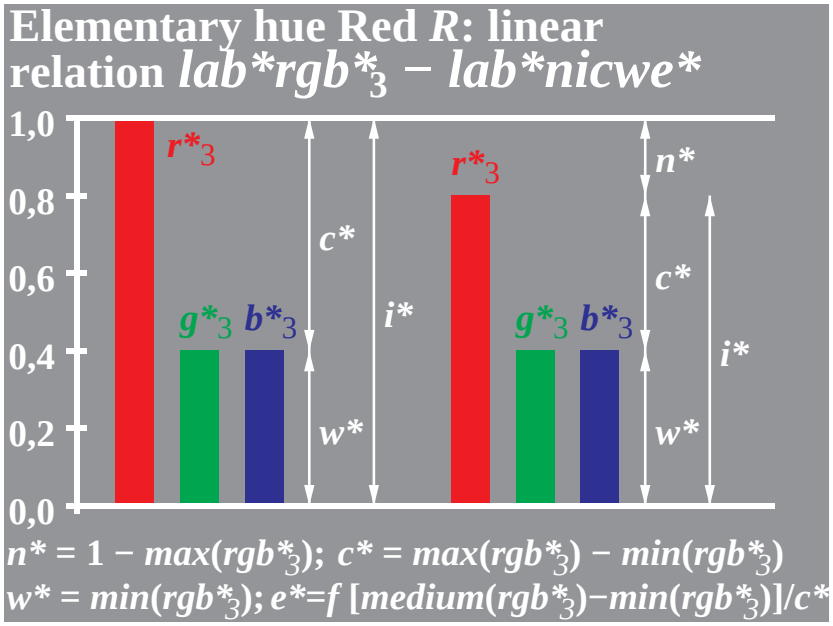



ZE430−8

**Elementary colour coordinates *rgb** and relation to colour coordinates *nicme****

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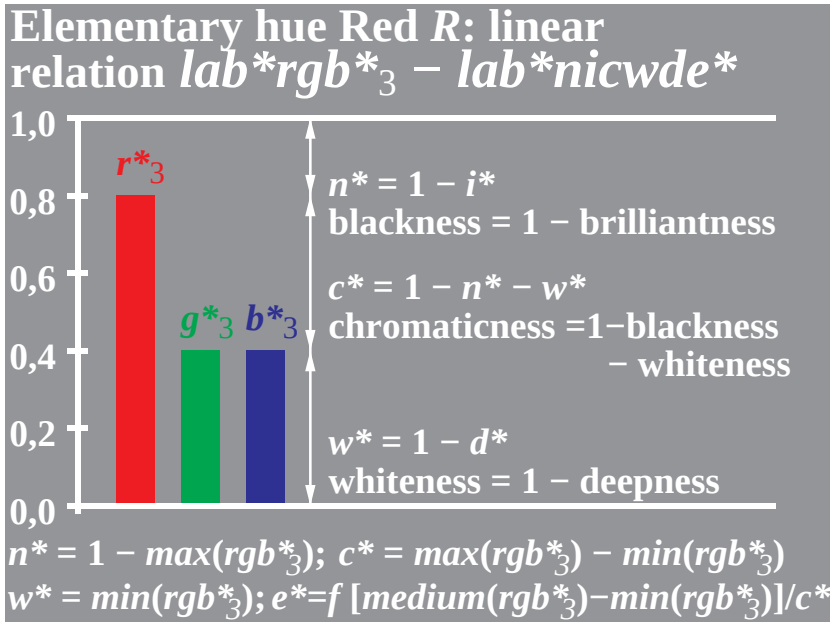


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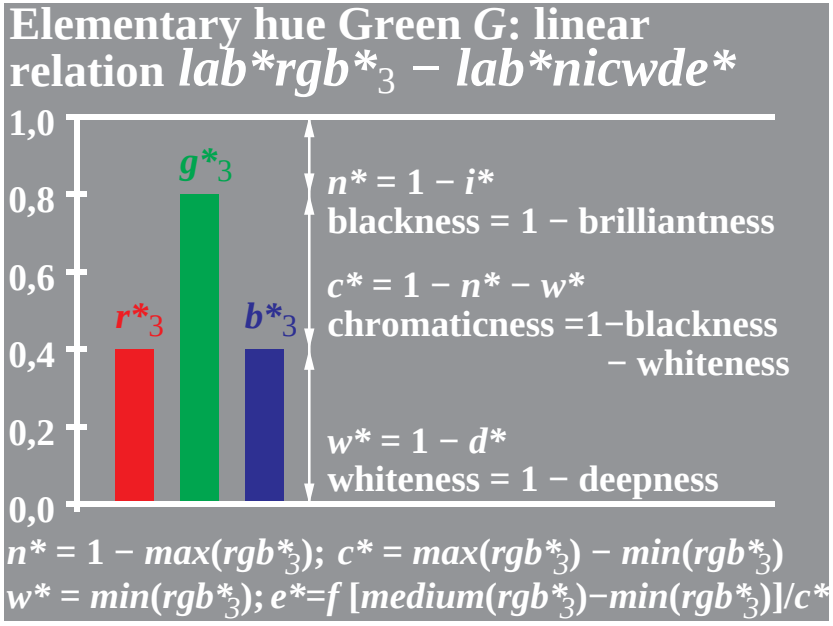
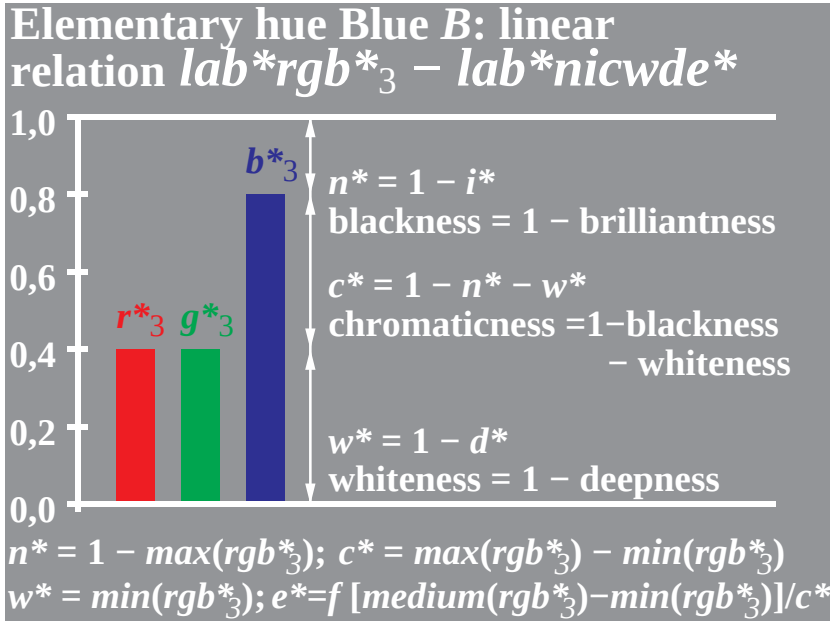



ZE430−3




ZE430−4

**Definition of more user friendly colour data *nce** and *rgb** and relation to *LCH** (CIELAB)**

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

***Aim: define user friendly connection***

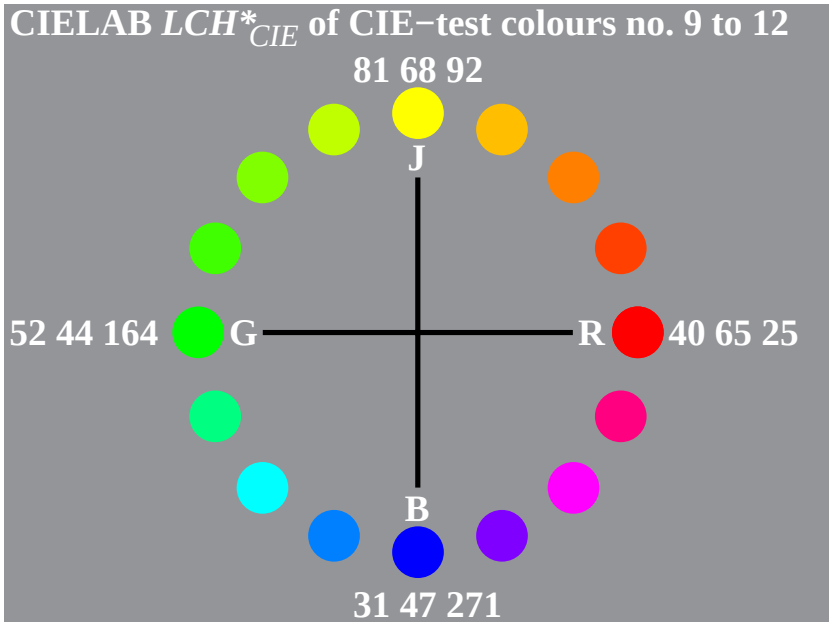
**New: Interpretation of the *rgb* colour data in the range 0 to 1 as elementary colour data $rgb^*_3$**

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

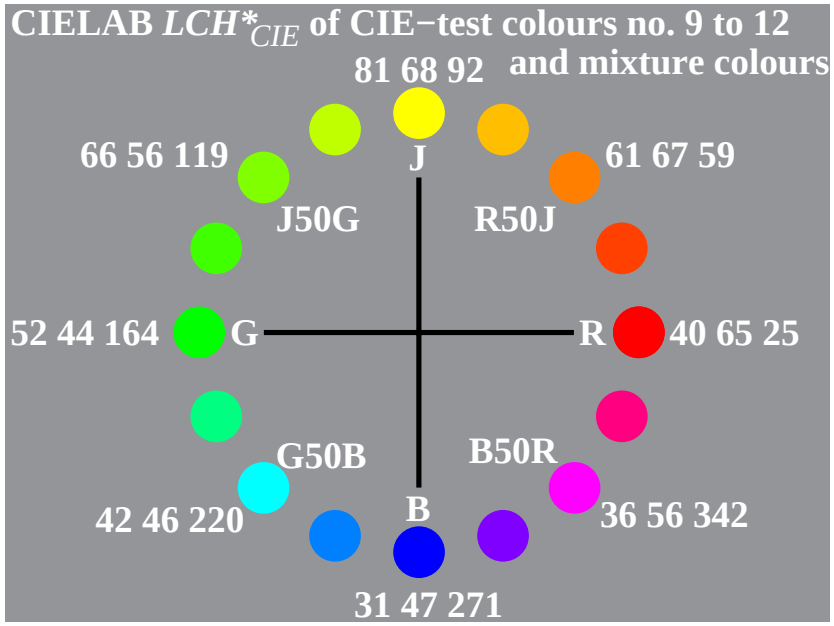
- $rgb^*_3 - L^*a^*b^*C^*_{ab}h_{ab}$ (CIELAB)
- $rgb - cmy$, $rgb^*_3 - cmy^*_3$ ("1-minus"-relation)
- $rgb^*_3 - nce^*$, $rgb^*_3 - ncu^*$

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

***LCH**** **device colour data of CIE-test colours no. 9 to 12 and *Miescher* elementary colours *RJGB***




ZE431−1

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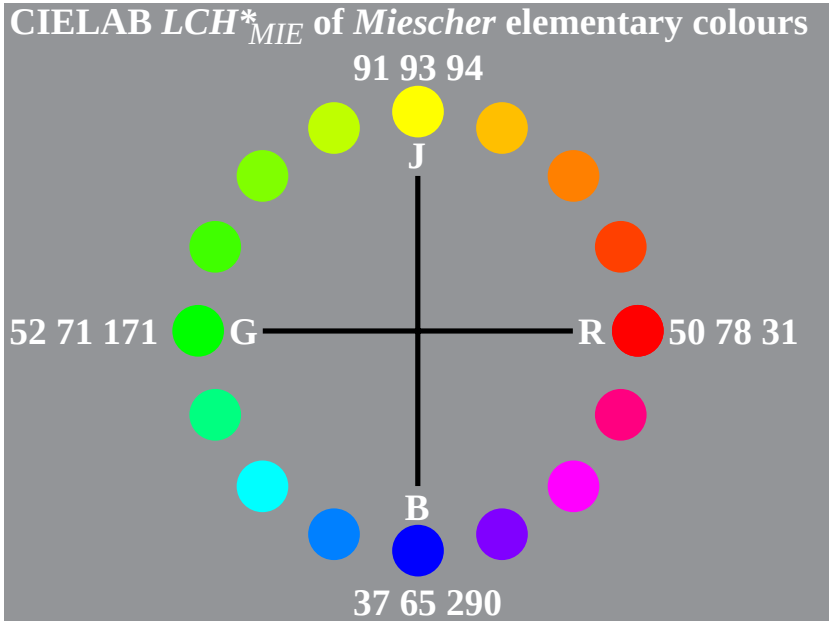


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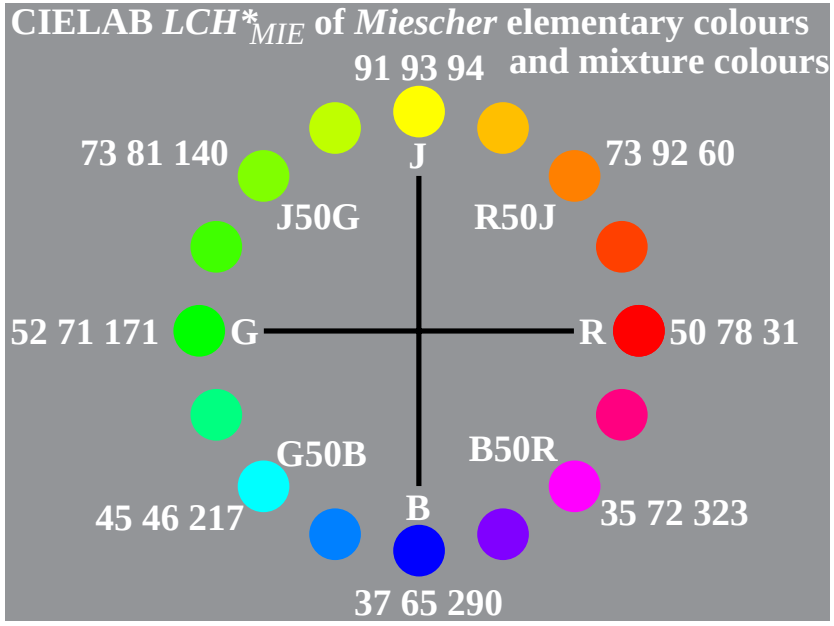
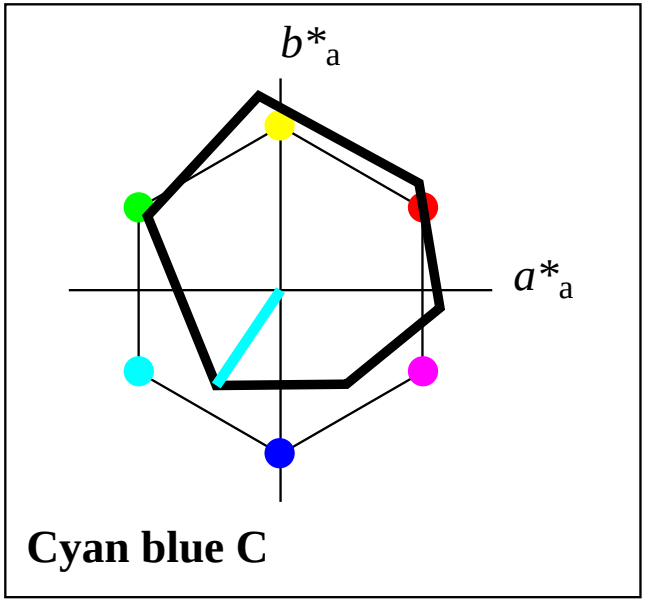


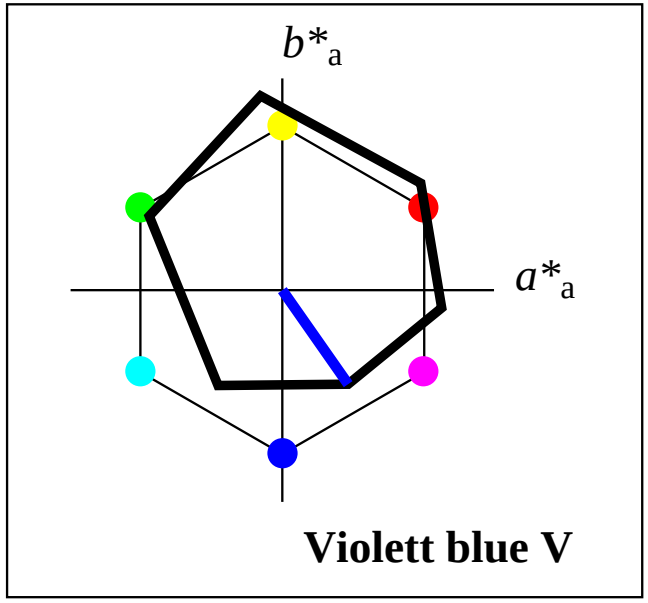

ZE431−4

**Device colour data of standard offset colour system ORS18**

| **ORS18: adapted (a) CIELAB data** | | | | | | **ORS18: relative device colour data** | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | $L^*=L^*_a$ | $a^*_a$ | $b^*_a$ | $C^*_{ab,a}$ | $h^*_{ab,a}$ | $rgb -> olv^*_3$ | | | $cmy^*_3$ | | |
| $O_{Ma}$ | 47.94 | 65.39 | 50.52 | 82.63 | 38 | 1.0 | 0.0 | 0.0 | 0.0 | 1.0 | 1.0 |
| $Y_{Ma}$ | 90.37 | −10.26 | 91.75 | 92.32 | 96 | 1.0 | 1.0 | 0.0 | 0.0 | 0.0 | 1.0 |
| $L_{Ma}$ | 50.9 | −62.83 | 34.96 | 71.91 | 151 | 0.0 | 1.0 | 0.0 | 1.0 | 0.0 | 1.0 |
| **$C_{Ma}$** | **58.62** | **−30.34** | **−45.01** | **54.3** | **236** | **0.0** | **1.0** | **1.0** | **1.0** | **0.0** | **0.0** |
| **$V_{Ma}$** | **25.72** | **31.1** | **−44.4** | **54.22** | **305** | **0.0** | **0.0** | **1.0** | **1.0** | **1.0** | **0.0** |
| $M_{Ma}$ | 48.13 | 75.28 | −8.36 | 75.74 | 354 | 1.0 | 0.0 | 1.0 | 0.0 | 1.0 | 0.0 |
| $N_{Ma}$ | 18.01 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | 0.0 | 0.0 | 1.0 | 1.0 | 1.0 |
| $W_{Ma}$ | 95.41 | 0.0 | 0.0 | 0.0 | 0 | 1.0 | 1.0 | 1.0 | 0.0 | 0.0 | 0.0 |




**Cyan blue C**

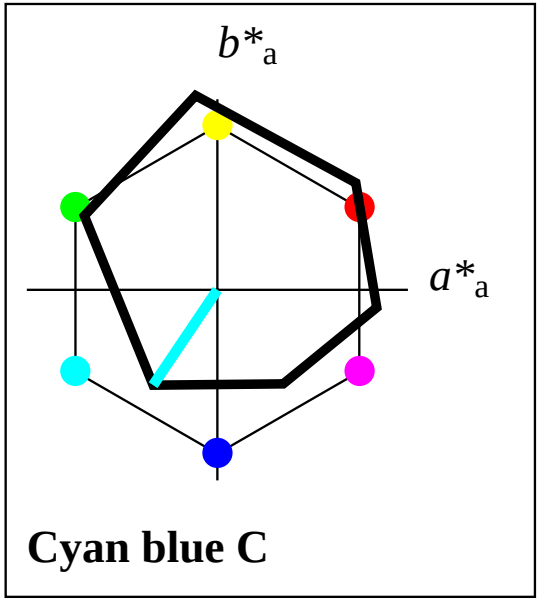


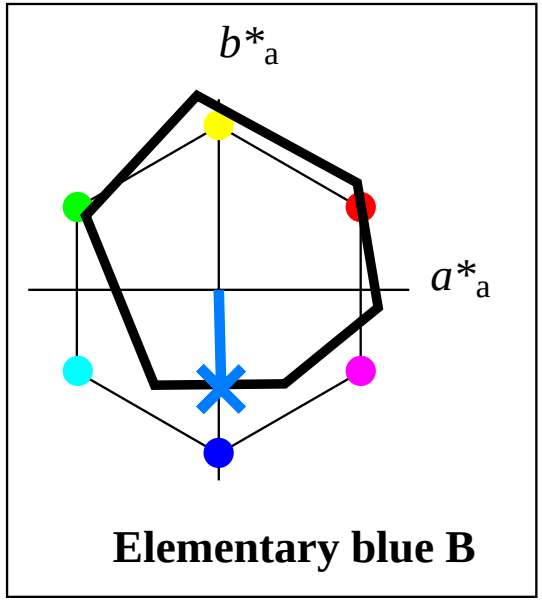

**Violett blue V**

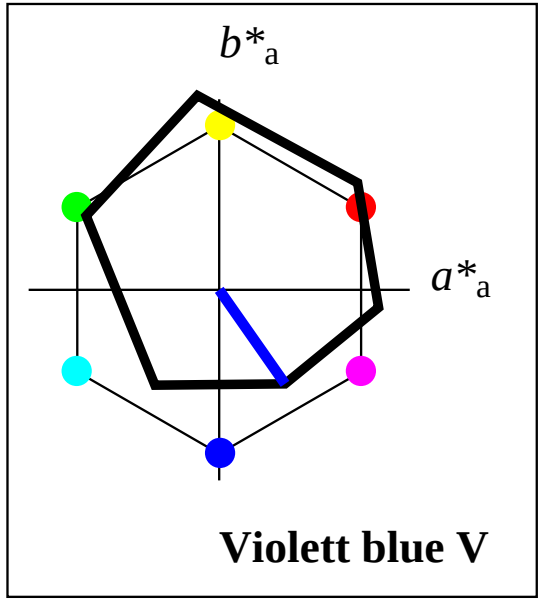
ZE440−1

**Elementary colour data for standard offset colour system ORS18**

| ORS18: adapted (a) CIELAB data | | | | | | ORS18: relative device colour data | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | $L^*=L^*_a$ | $a^*_a$ | $b^*_a$ | $C^*_{ab,a}$ | $h^*_{ab,a}$ | $rgb$ −> $rgb^*_3$ | | | $olv^*_3$ (device data) | | |
| R | 48.0 | 68.58 | 31.54 | 75.48 | 25 | 1.0 | 0.0 | 0.0 | 1.0 | 0.0 | 0.32 |
| R50J | 62.87 | 38.77 | 65.02 | 75.71 | 59 | 1.0 | 0.5 | 0.0 | 1.0 | 0.35 | 0.0 |
| J | 86.19 | −2.8 | 87.69 | 87.73 | 92 | 1.0 | 1.0 | 0.0 | 1.0 | 0.9 | 0.0 |
| J50G | 71.17 | −35.83 | 64.13 | 73.46 | 119 | 0.5 | 1.0 | 0.0 | 0.51 | 1.0 | 0.0 |
| G | 52.8 | −54.82 | 15.26 | 56.92 | 164 | 0.0 | 1.0 | 0.0 | 0.0 | 1.0 | 0.25 |
| G50B | 57.25 | −36.1 | −30.82 | 47.48 | 220 | 0.0 | 0.5 | 0.5 | 0.0 | 1.0 | 0.82 |
| **B** | **41.78** | **1.1** | **−44.7** | **44.72** | **271** | **0.0** | **0.0** | **1.0** | **0.0** | **0.49** | **1.0** |
| B50R | 40.78 | 60.78 | −20.18 | 64.05 | 342 | 0.5 | 0.0 | 1.0 | 0.67 | 0.0 | 1.0 |



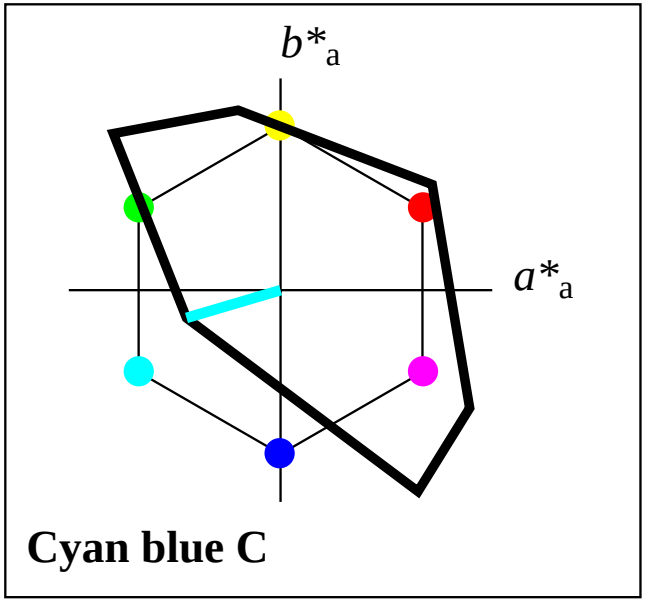



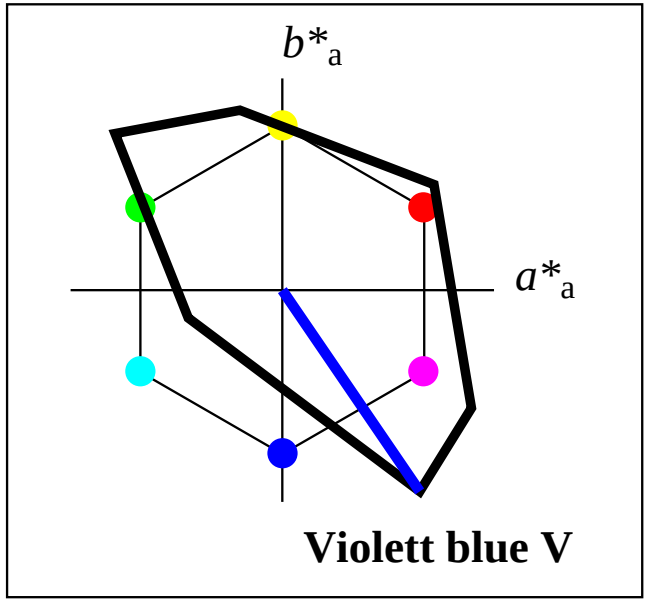

ZE440−2

**Device colour data of standard television colour system TLS18**

| **TSL18: adapted (a) CIELAB data** | | | | | | **TSL18: relative device colour data** | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | $L^*=L^*_a$ | $a^*_a$ | $b^*_a$ | $C^*_{ab,a}$ | $h^*_{ab,a}$ | $rgb -> olv^*_3$ | | | $cmy^*_3$ | | |
| $O_{Ma}$ | 52.76 | 71.63 | 49.88 | 87.29 | 35 | 1.0 | 0.0 | 0.0 | 0.0 | 1.0 | 1.0 |
| $Y_{Ma}$ | 92.74 | −20.02 | 84.97 | 87.3 | 103 | 1.0 | 1.0 | 0.0 | 0.0 | 0.0 | 1.0 |
| $L_{Ma}$ | 84.0 | −78.98 | 73.94 | 108.2 | 137 | 0.0 | 1.0 | 0.0 | 1.0 | 0.0 | 1.0 |
| **$C_{Ma}$** | **87.14** | **−44.41** | **−13.11** | **46.32** | **196** | **0.0** | **1.0** | **1.0** | **1.0** | **0.0** | **0.0** |
| **$V_{Ma}$** | **35.47** | **64.92** | **−95.06** | **115.12** | **304** | **0.0** | **0.0** | **1.0** | **1.0** | **1.0** | **0.0** |
| $M_{Ma}$ | 59.01 | 89.33 | −55.67 | 105.26 | 328 | 1.0 | 0.0 | 1.0 | 0.0 | 1.0 | 0.0 |
| $N_{Ma}$ | 18.01 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | 0.0 | 0.0 | 1.0 | 1.0 | 1.0 |
| $W_{Ma}$ | 95.41 | 0.0 | 0.0 | 0.0 | 0 | 1.0 | 1.0 | 1.0 | 0.0 | 0.0 | 0.0 |




**Cyan blue C**

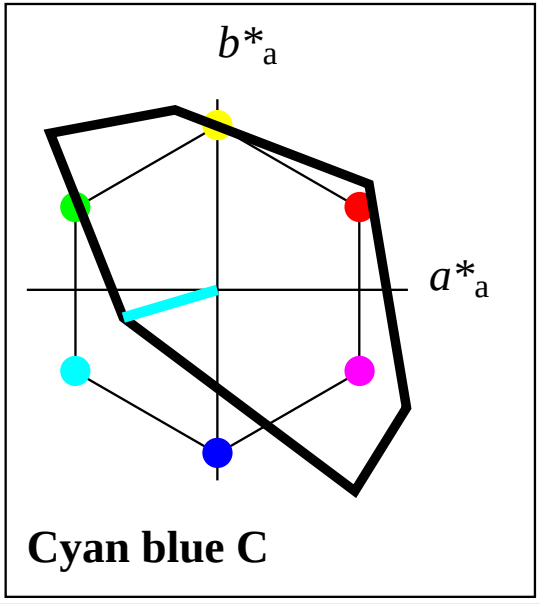


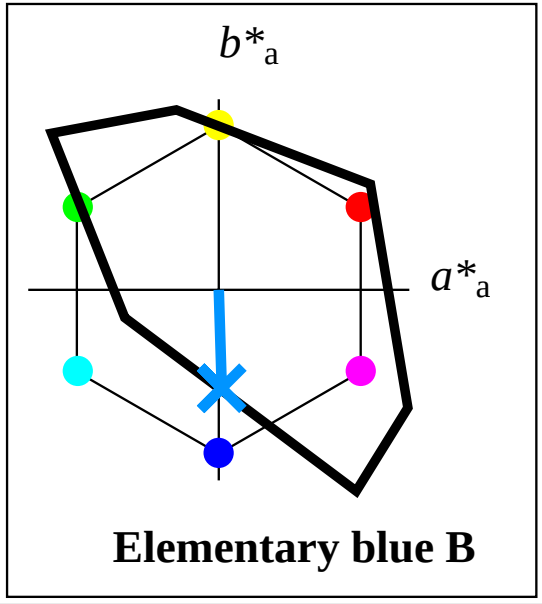

**Violett blue V**

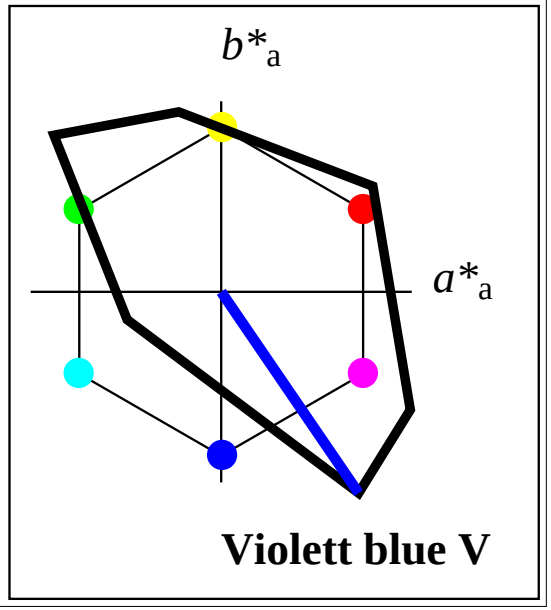
ZE440−7

**Elementary colour data for standard television colour system TLS18**

| TSL18: adapted (a) CIELAB data | | | | | | TSL18: relative device colour data | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | $L^*=L^*_a$ | $a^*_a$ | $b^*_a$ | $C^*_{ab,a}$ | $h^*_{ab,a}$ | $rgb$ −> $rgb^*_3$ | | | $olv^*_3$ (device data) | | |
| R | 53.62 | 74.08 | 35.3 | 82.06 | 25 | 1.0 | 0.0 | 0.0 | 1.0 | 0.0 | 0.14 |
| R50J | 68.43 | 35.7 | 63.63 | 72.97 | 61 | 1.0 | 0.5 | 0.0 | 1.0 | 0.39 | 0.0 |
| J | 85.39 | −3.16 | 78.52 | 78.58 | 92 | 1.0 | 1.0 | 0.0 | 1.0 | 0.82 | 0.0 |
| J50G | 89.35 | −42.92 | 80.69 | 91.4 | 118 | 0.5 | 1.0 | 0.0 | 0.61 | 1.0 | 0.0 |
| G | 86.01 | −56.86 | 18.23 | 59.72 | 162 | 0.0 | 1.0 | 0.0 | 0.0 | 1.0 | 0.64 |
| G50B | 80.29 | −29.91 | −23.97 | 38.35 | 219 | 0.0 | 0.5 | 0.5 | 0.0 | 0.87 | 1.0 |
| **B** | **65.47** | **1.44** | **−47.48** | **47.51** | **272** | **0.0** | **0.0** | **1.0** | **0.0** | **0.58** | **1.0** |
| B50R | 57.25 | 84.34 | −25.9 | 88.23 | 343 | 0.5 | 0.0 | 1.0 | 1.0 | 0.0 | 0.72 |

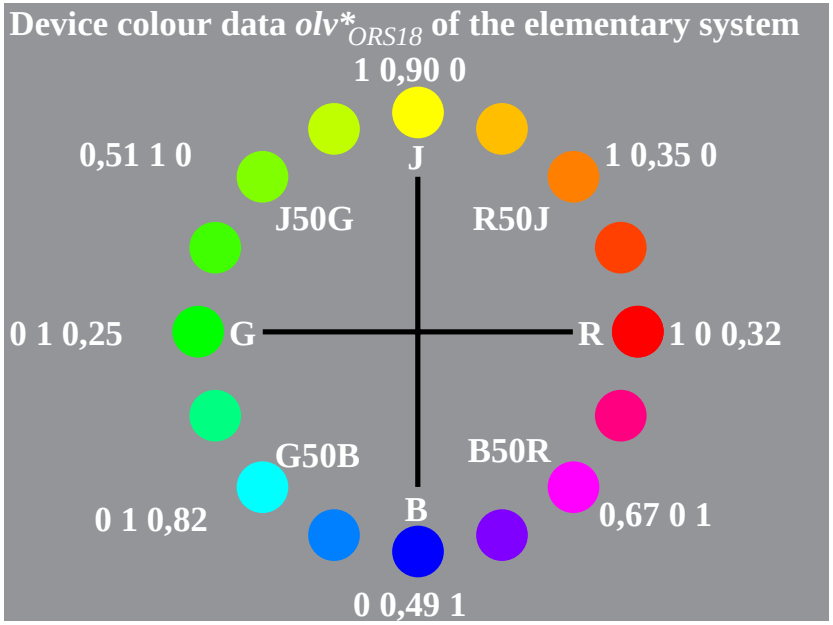


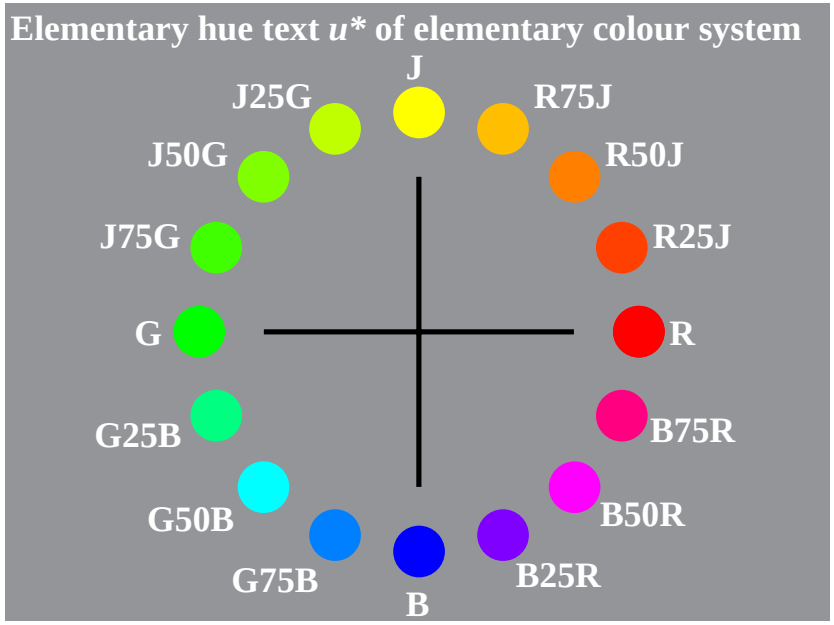




ZE440−8

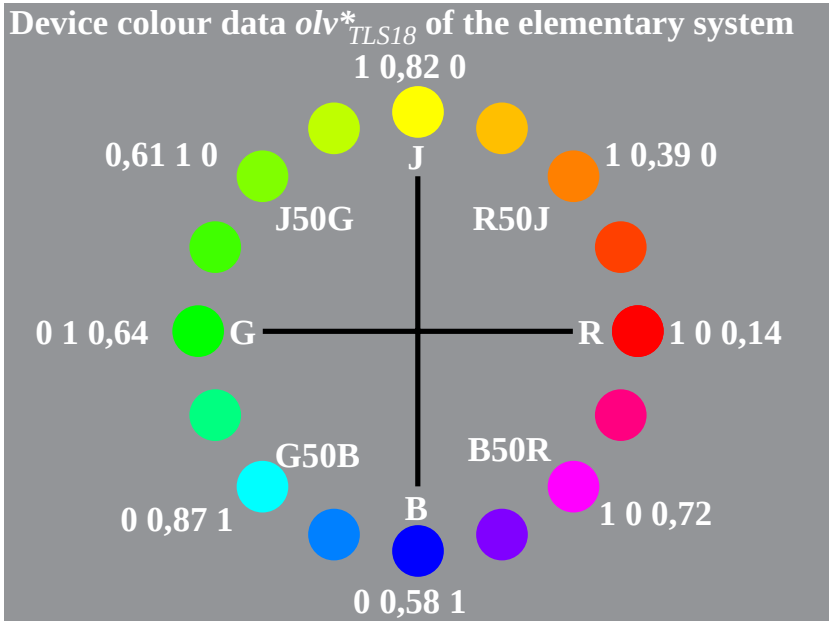
**Device colour data LCH* of standard offset colour system ORS18 to produce elementary colours**



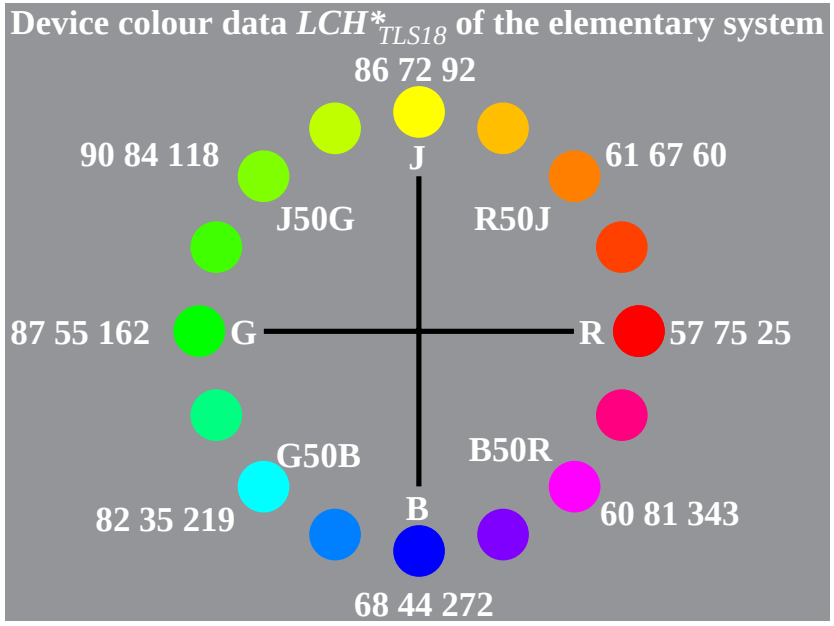

ZE431−5




ZE430−6




ZE431−7




ZE431−8

**Input data *rgb* =(1, 0, 0), (1, 1, 0), (0, 1, 0), (0, 0, 1) intended for elementary colour output**

www.ps.bam.de/XE63/10L/L63E00NP.PS/.PDF; start output
N: No Output Linearization (OL) data in File (F), Startup (S) or Device (D)

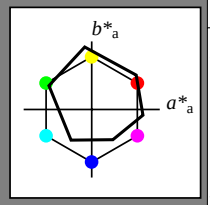
See for similar files: http://www.ps.bam.de/XE63/; www.ps.bam.de/XE.HTM
Technical information: http://www.ps.bam.de Version 2.1, io=1,1

BAM registration: 20070301-XE63/10L/L63E00NP.PS/.PDF BAM material: code=rha4ta
application for output of monitor, data projector, or printer systems

**Input: Colorimetric Offset Reflective System ORS18a**

**with *rgb* data of the four elementary hues**

**1 0 0 = Red *R***
**1 1 0 = Yellow *J***
**0 1 0 = Green *G***
**0 0 1 = Blue *B***



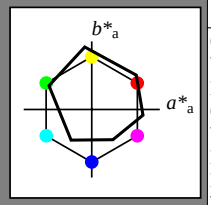

**ORS18a; adapted (a) CIELAB data**

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

**Output: Colorimetric Offset Reflective System ORS18a**

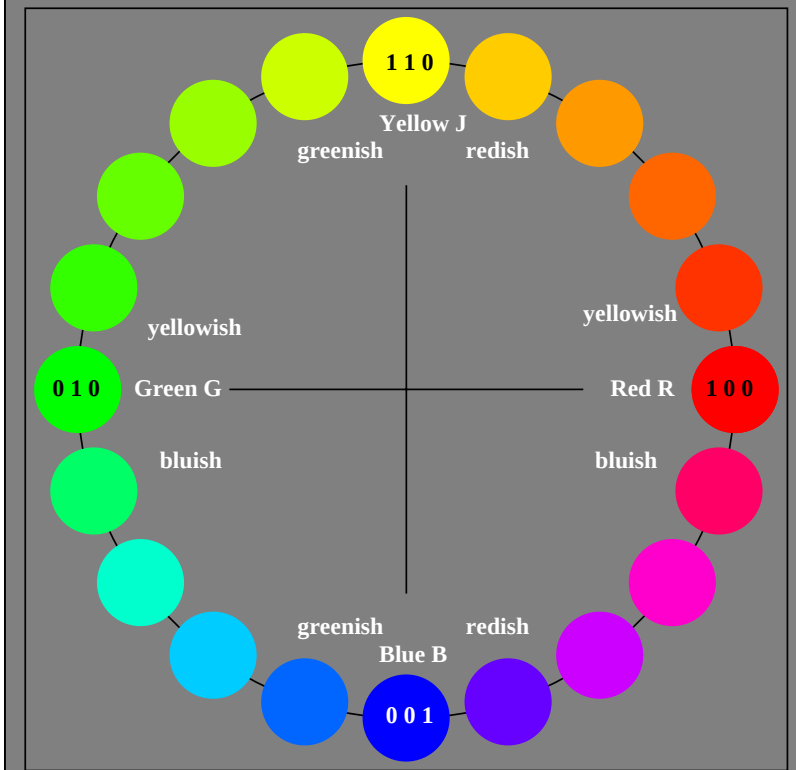
**with hue number *n*= 00 to 19**

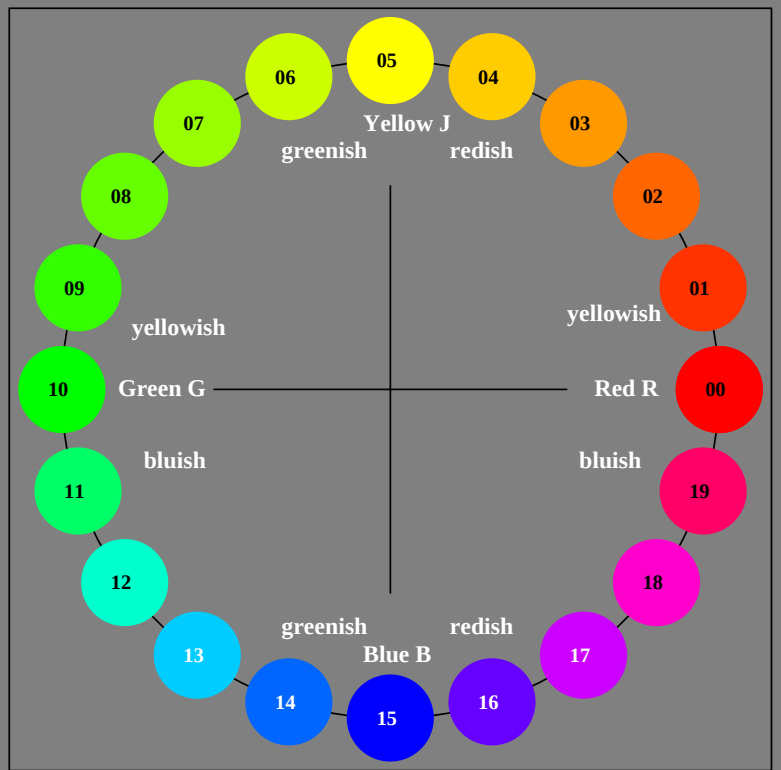
**00 = Red *R***
**05 = Yellow *J***
**10 = Green *G***
**15 = Blue *B***




**ORS18a; adapted (a) CIELAB data**

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




XE630−7N, 20 step hue circle with elementary colours *R, J, G, B* (left)

20 step hue circle with elementary colours *R, J, G, B* (right)

BAM-test chart XE63; Relative colour reproduction, ORS18
Elementary hue agreement and discrimination, Page 1/2

input: *rgb (->olv*) setrgbcolor*
output: no change compared to input

**5 step and 16 step colour scales in the Natural Colour Connection Space (NCCS)**

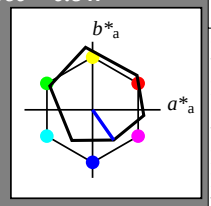
www.ps.bam.de/XE70/10L/L70E04NP.PS/.PDF; start output
N: No Output Linearization (OL) data in File (F), Startup (S) or Device (D)

See for similar files: http://www.ps.bam.de/XE70/; www.ps.bam.de/XE.HTM
Technical information: http://www.ps.bam.de Version 2.1, io=1,1

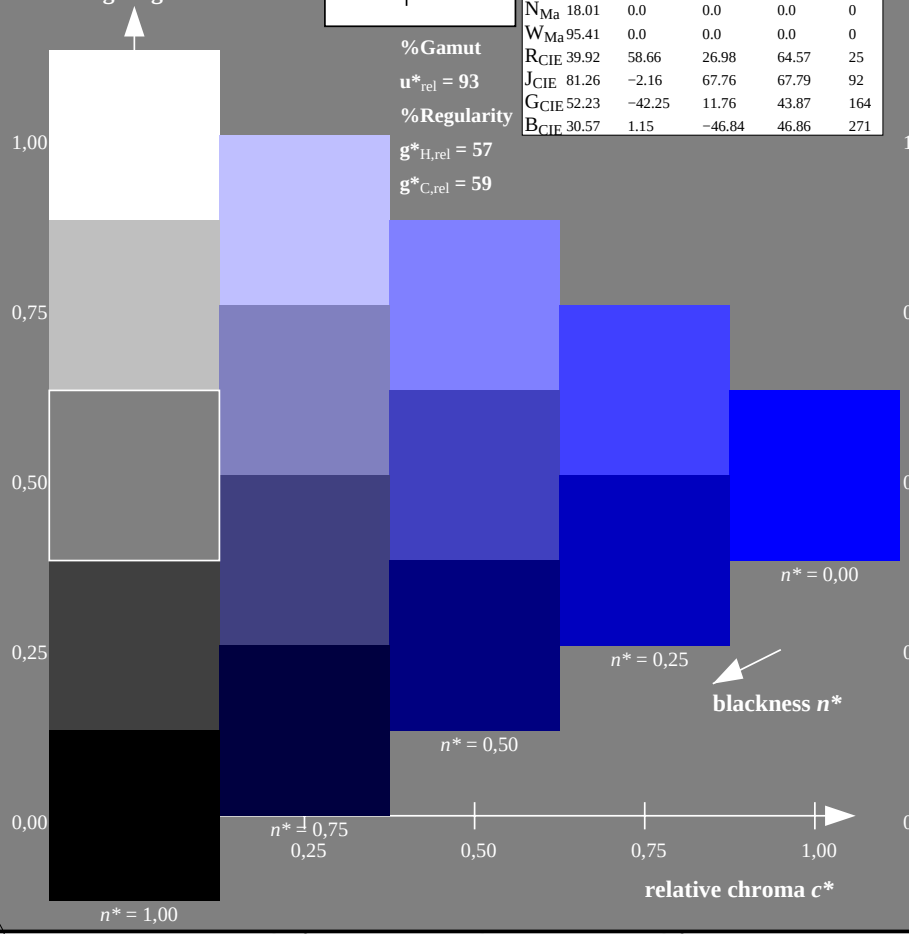
BAM registration: 20070301-XE70/10L/L70E04NP.PS/.PDF BAM material: code=rha4ta
application for output of monitor, data projector, or printer systems

**Input: Colorimetric Offset Reflective System ORS18a**

for hue *h** = *lab*h* = 305/360 = 0.847
*lab*tch* and *lab*nch*
D65: hue V
LCH*Ma: 26 54 305
olv*Ma: 0.0 0.0 1.0
triangle lightness *t**




%Gamut
u*rel = 93
%Regularity
g*H,rel = 57
g*C,rel = 59

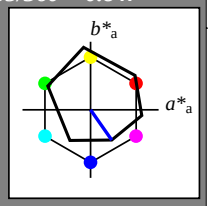



**ORS18a; adapted (a) CIELAB data**

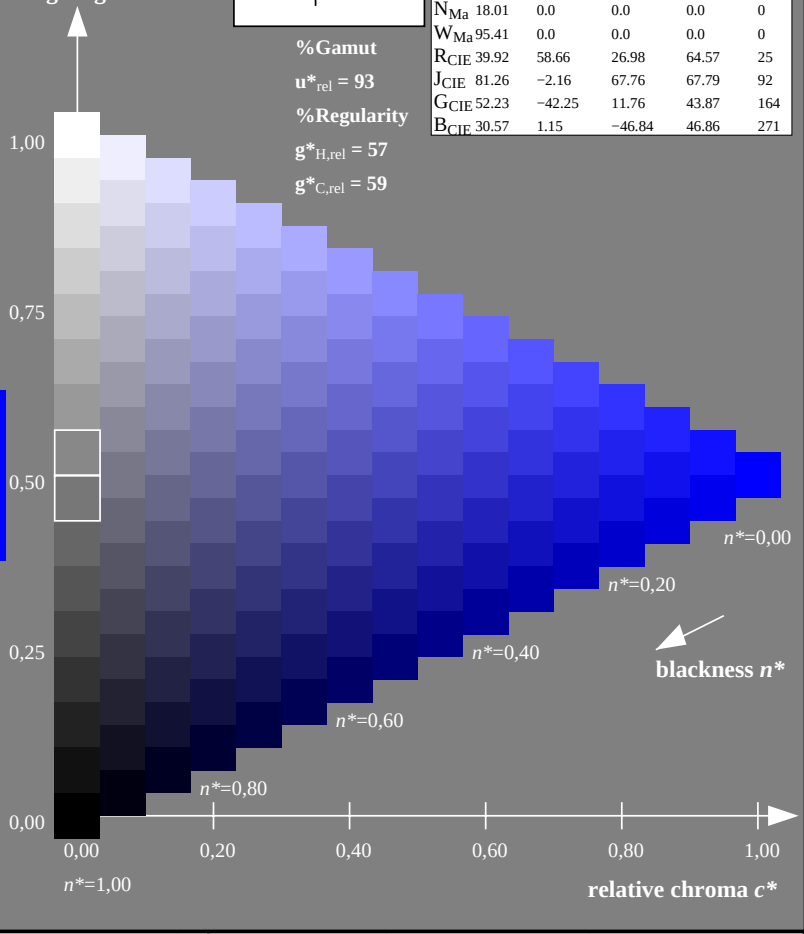
| | L*=L*a | a*a | b*a | C*ab,a | h*ab,a |
|---|---|---|---|---|---|
| $O_{Ma}$ | 47.94 | 65.39 | 50.52 | 82.63 | 38 |
| $Y_{Ma}$ | 90.37 | −10.26 | 91.75 | 92.32 | 96 |
| $L_{Ma}$ | 50.9 | −62.83 | 34.96 | 71.91 | 151 |
| $C_{Ma}$ | 58.62 | −30.34 | −45.01 | 54.3 | 236 |
| $V_{Ma}$ | 25.72 | 31.1 |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

**Output: Colorimetric Offset Reflective System ORS18a**

for hue *h** = *lab*h* = 305/360 = 0.847
*lab*tch* and *lab*nch*
D65: hue V
LCH*Ma: 26 54 305
olv*Ma: 0.0 0.0 1.0
triangle lightness *t**




%Gamut
u*rel = 93
%Regularity
g*H,rel = 57
g*C,rel = 59



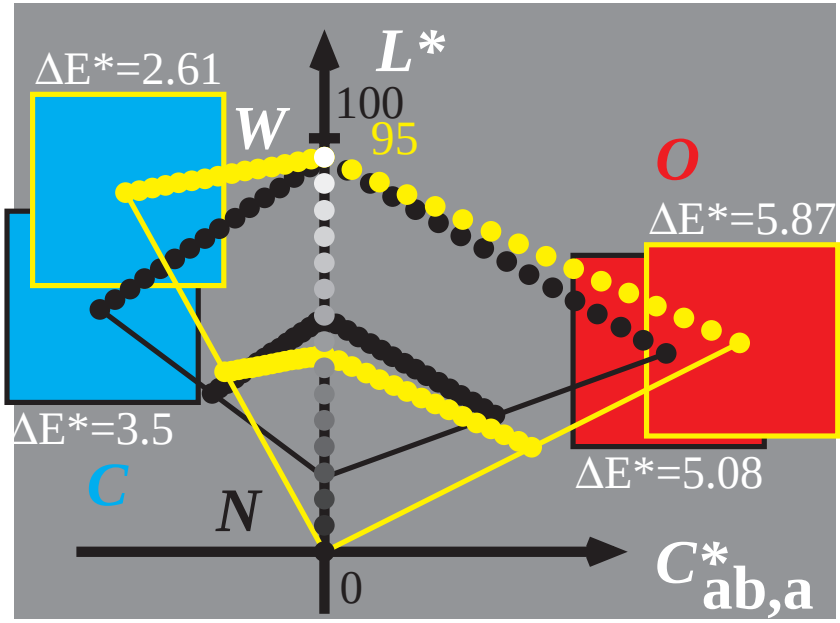

**ORS18a; adapted (a) CIELAB data**

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

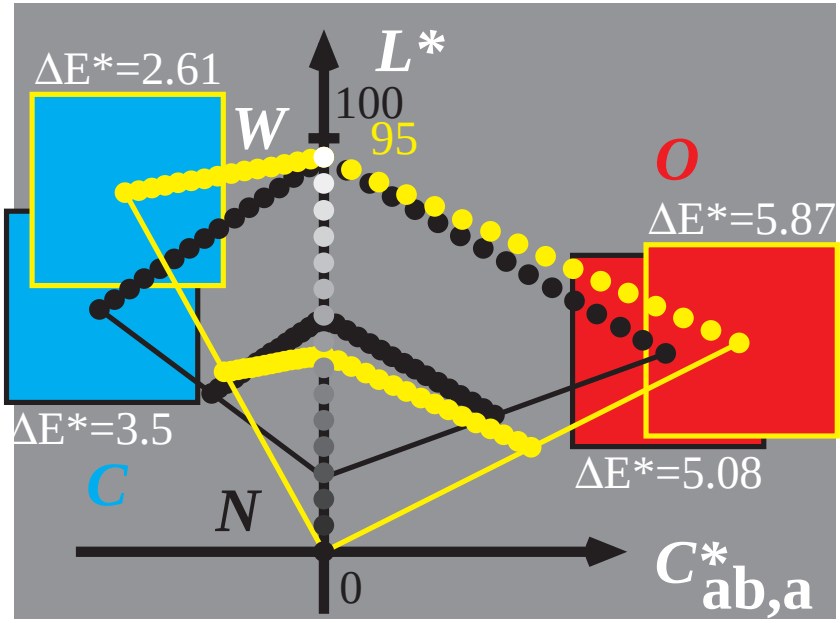
XE700−7N, 5 step scales for constant CIELAB hue 305/360 = 0.847 (left)
165 step scales for constant CIELAB hue 305/360 = 0.847 (right)

BAM-test chart XE70; Relative colour reproduction, ORS18
Discrimination of 5 and 16 step colour scales, Page 5/11 (V)
input: *rgb (->olv*) setrgbcolor*
output: no change compared to input

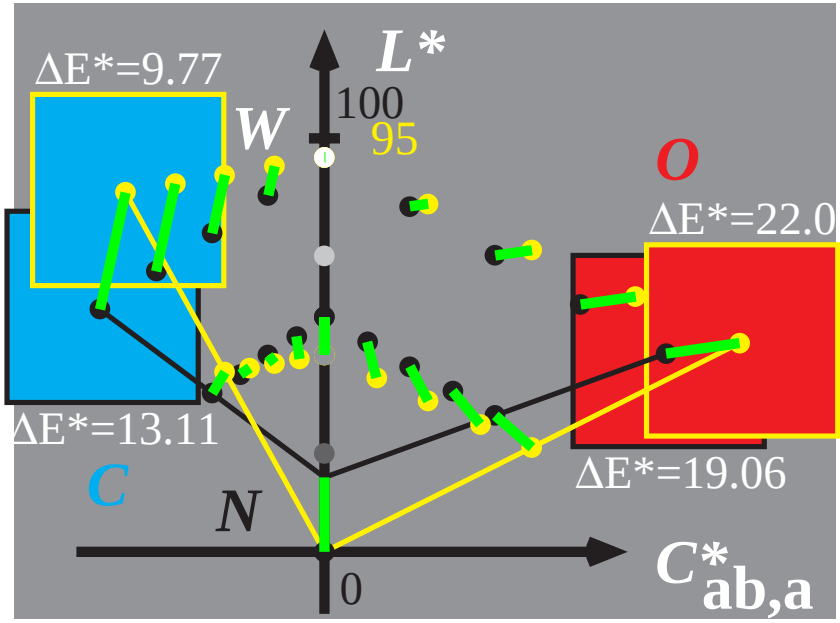
**Hue planes of three standard devices ORS18, TLS00 and TSL28 *(top)* and affin colour management**



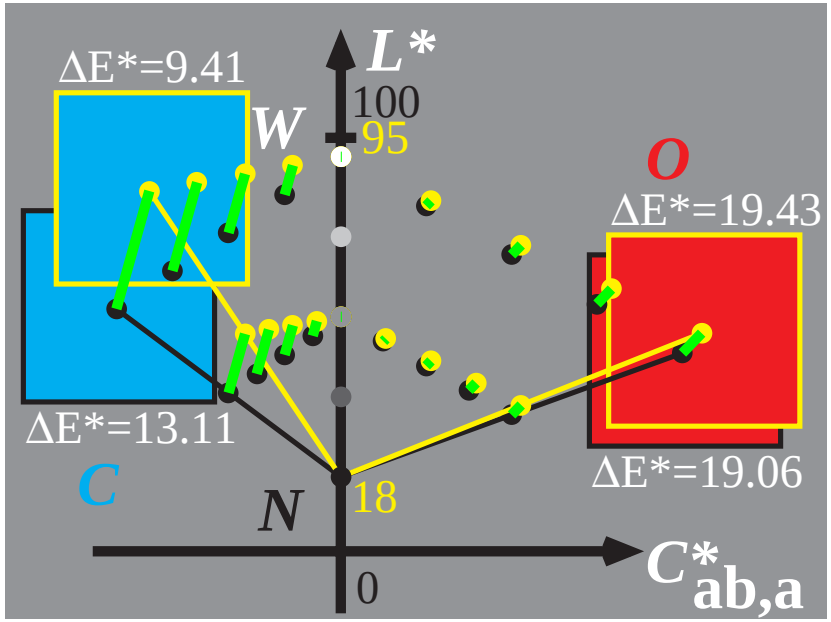

ZE421−1




ZE421−1

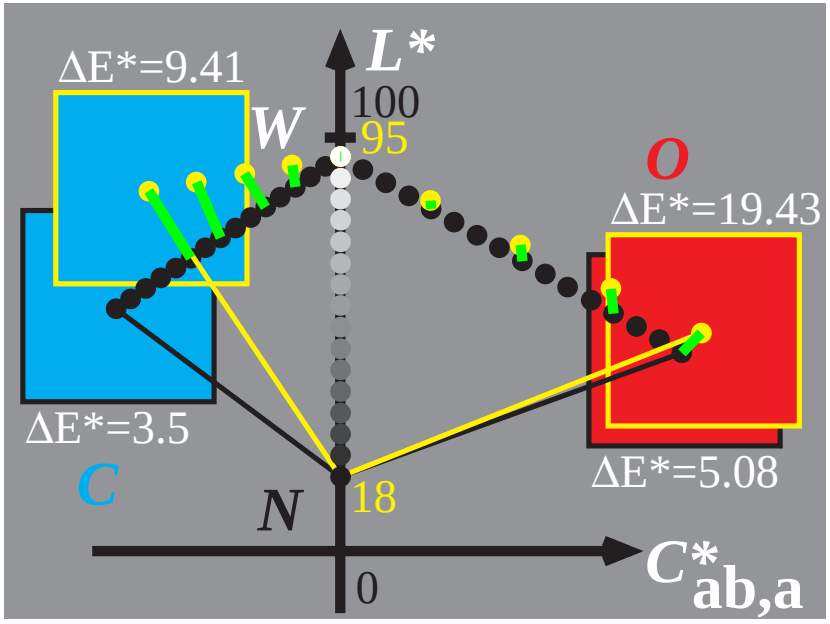



ZE421−3

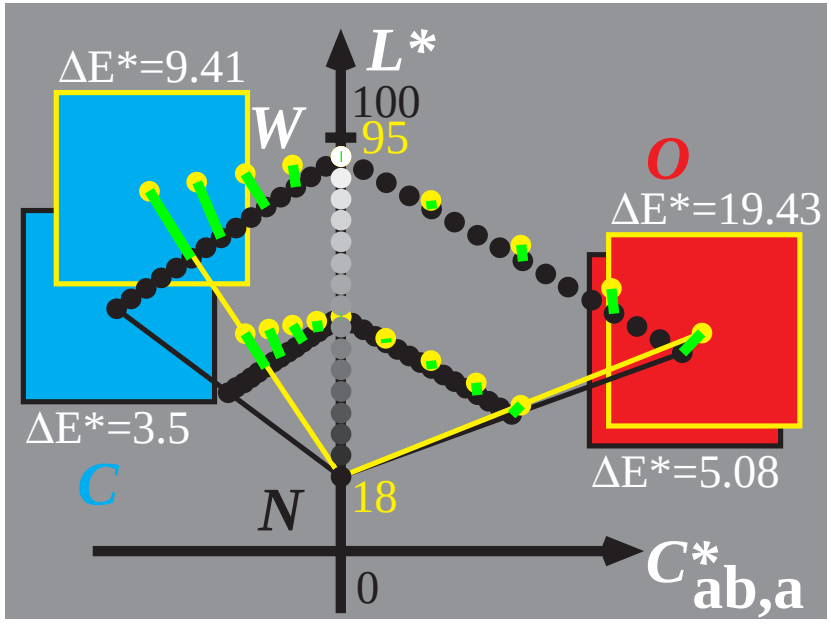



ZE421−4

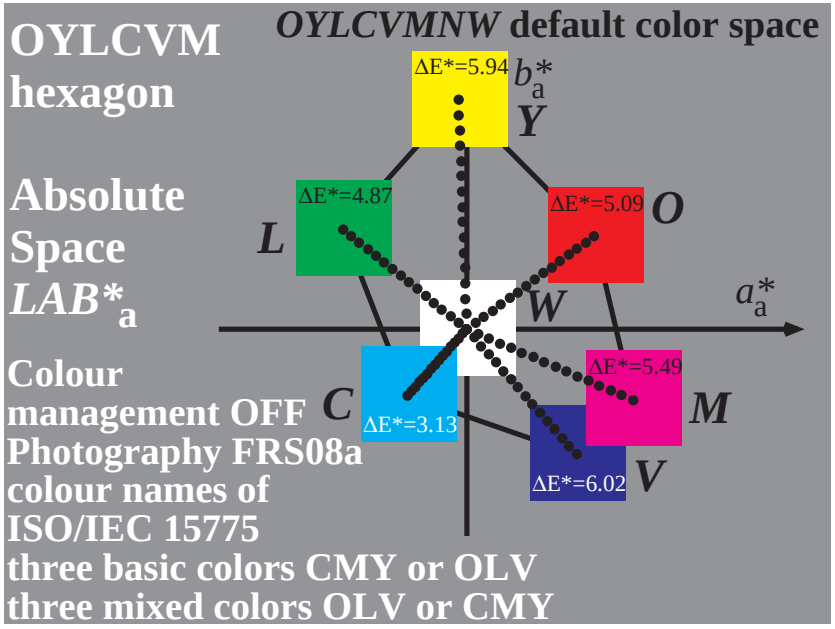
**ICC-colour management according to ISO 15706-1 which clipps colours and reduces the output gamut**



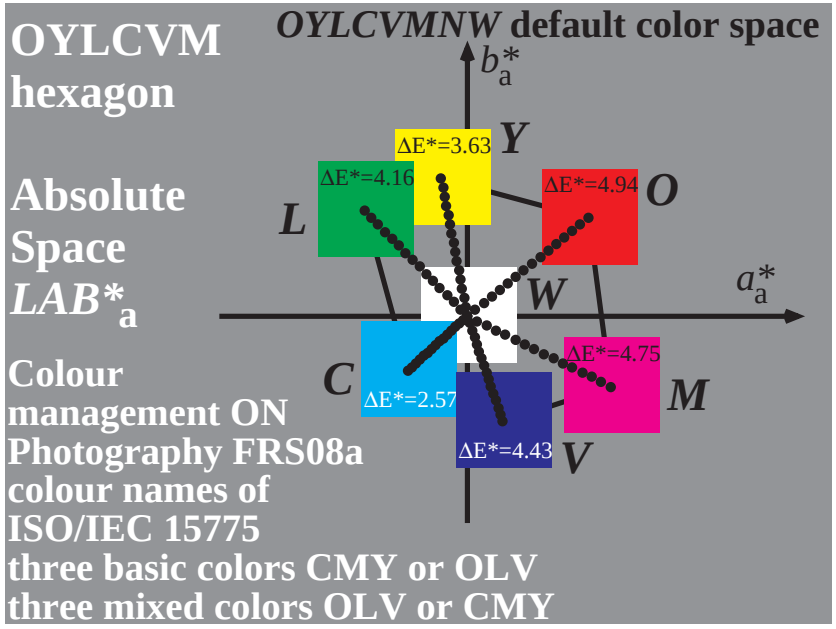

ZE421−5




ZE421−6




ZE140−1




ZE140−2

# Colour Workflow

- equally spaced output in CIELAB for *rgb* and equivalent *cmyn* input.

- equal output in CIELAB for equivalent *rgb* and *cmyn* input ("1-minus-relation between *rgb* and *cmy0*").

- more chromatic and less chromatic output

- workflow for printer output with PS and other printers

- high material efficiency by output linearisation

- high material efficiency by appropriate colour separation

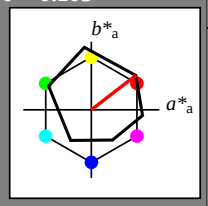
**Intended equal output of device hue red with data *rgb* = (1, 0, 0) and *cmy0* = (0, 1 , 1, 0)**

www.ps.bam.de/XE62/10L/L62E00NP.PS/.PDF; start output
N: No Output Linearization (OL) data in File (F), Startup (S) or Device (D)

See for similar files: http://www.ps.bam.de/XE62/; www.ps.bam.de/XE.HTM
Technical information: http://www.ps.bam.de Version 2.1, io=1,1

BAM registration: 20070301-XE62/10L/L62E00NP.PS/.PDF BAM material: code=rha4ta
application for output of monitor, data projector, or printer systems

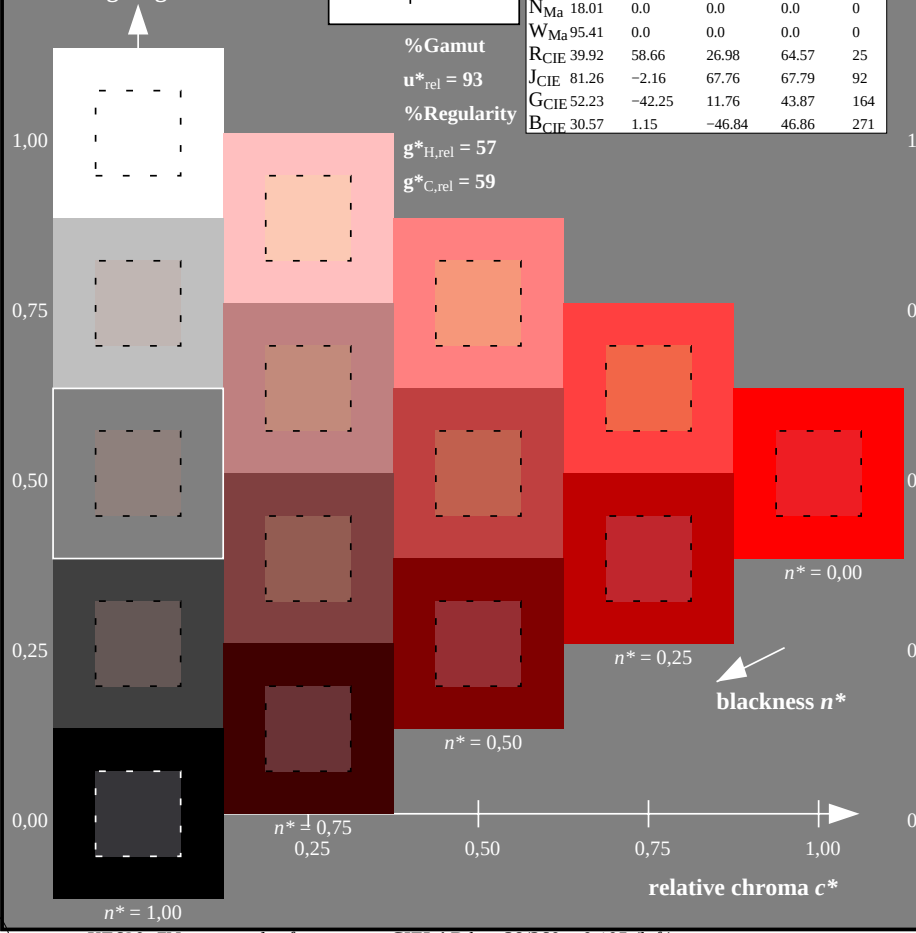
**Input: Colorimetric Offset Reflective System ORS18a**
**for hue *h** = *lab*h* = 38/360 = 0.105**
***lab*tch* and *lab*nch***
**D65: hue O**
**LCH*Ma: 48 83 38**
**olv*Ma: 1.0 0.0 0.0**
**triangle lightness *t****




%Gamut
$u^*_{rel}$ = 93
%Regularity
$g^*_{H,rel}$ = 57
$g^*_{C,rel}$ = 59

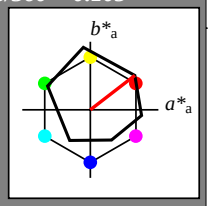
**ORS18a; adapted (a) CIELAB data**

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




XE620−7N, step scales for constant CIELAB hue 38/360 = 0.105 (left)

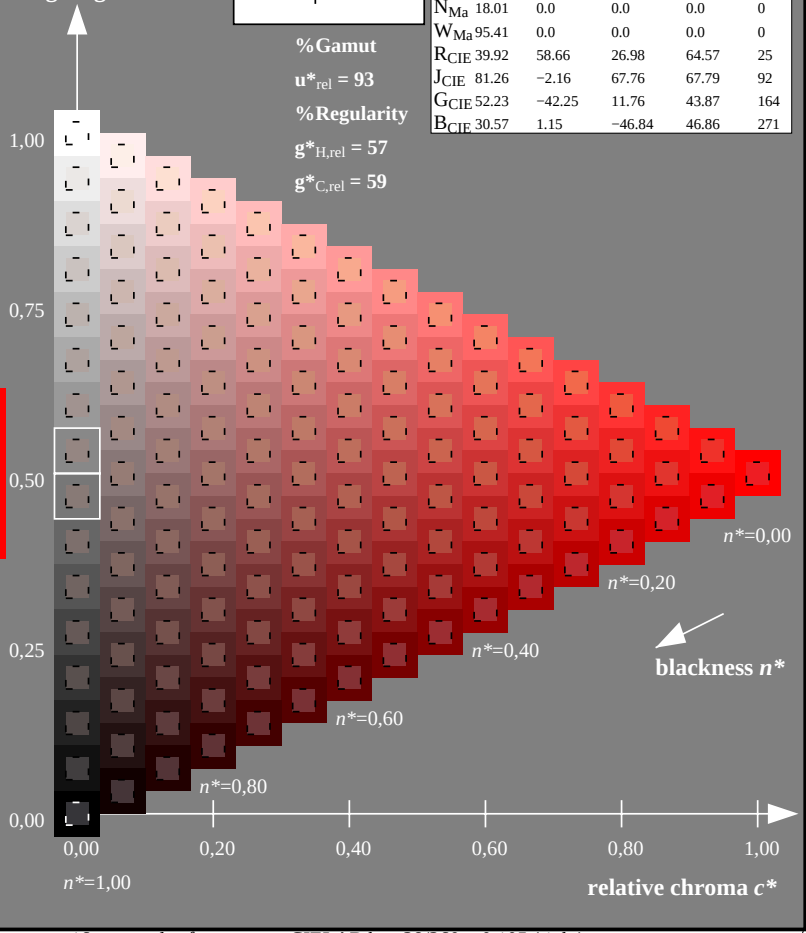
**Output: Colorimetric Offset Reflective System ORS18a**
**for hue *h** = *lab*h* = 38/360 = 0.105**
***lab*tch* and *lab*nch***
**D65: hue O**
**LCH*Ma: 48 83 38**
**olv*Ma: 1.0 0.0 0.0**
**triangle lightness *t****




%Gamut
$u^*_{rel}$ = 93
%Regularity
$g^*_{H,rel}$ = 57
$g^*_{C,rel}$ = 59

**ORS18a; adapted (a) CIELAB data**

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



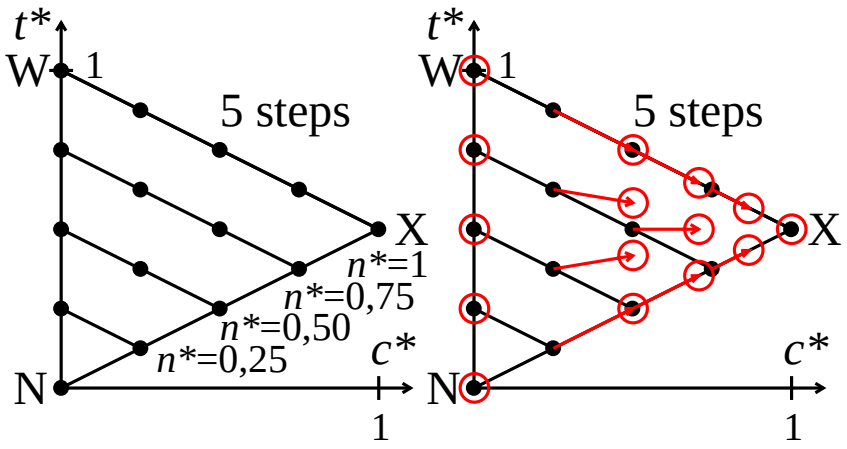

16 step scales for constant CIELAB hue 38/360 = 0.105 (right)

BAM-test chart XE62; Relative colour reproduction, ORS18
Equality for two colour definitions, Page 1/11 (O)

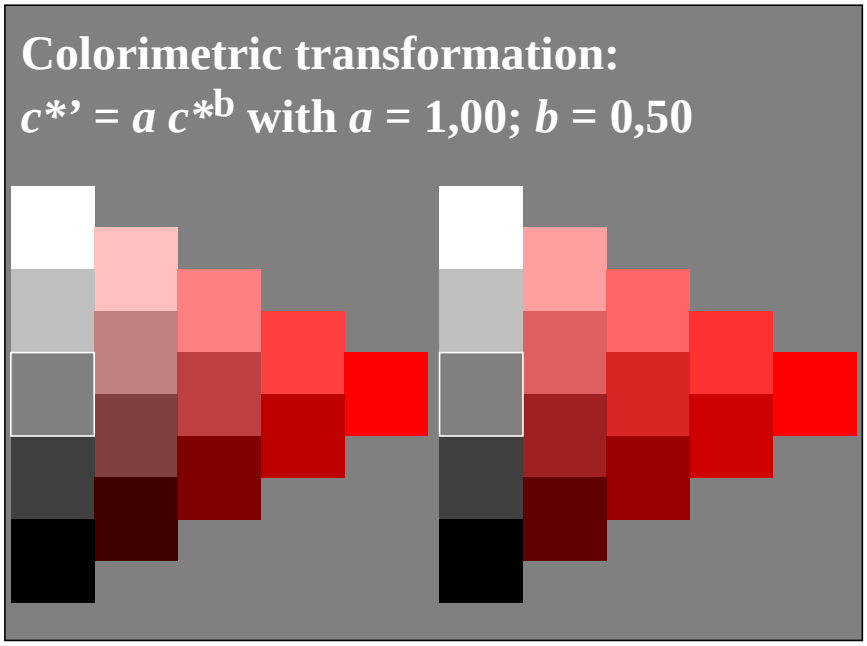
input: *cmy0-center*, *rgb-background*
output: no change compared to input

**Example for an equally spaced and a more chromatic *(top)* and less chromatic *(bottom)* output**

**Colorimetric transformation:**
**$c^{*\prime} = a\, c^{*b}$ with $a$ = 1,00; $b$ = 0,50**

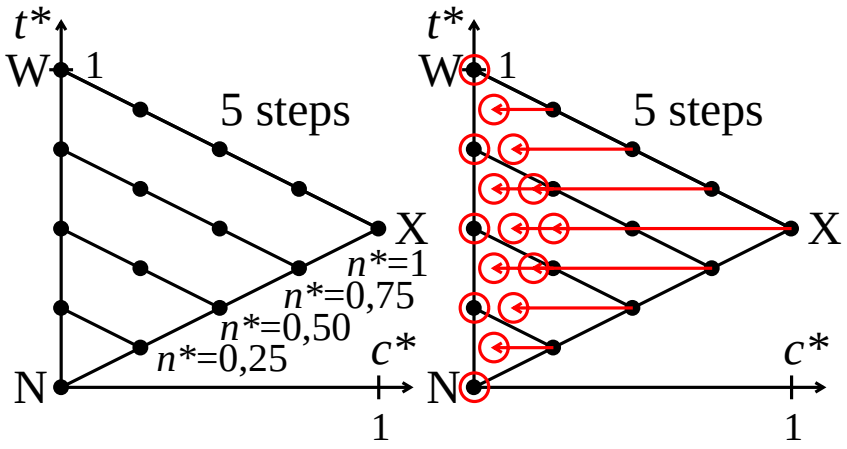



ZE320−5

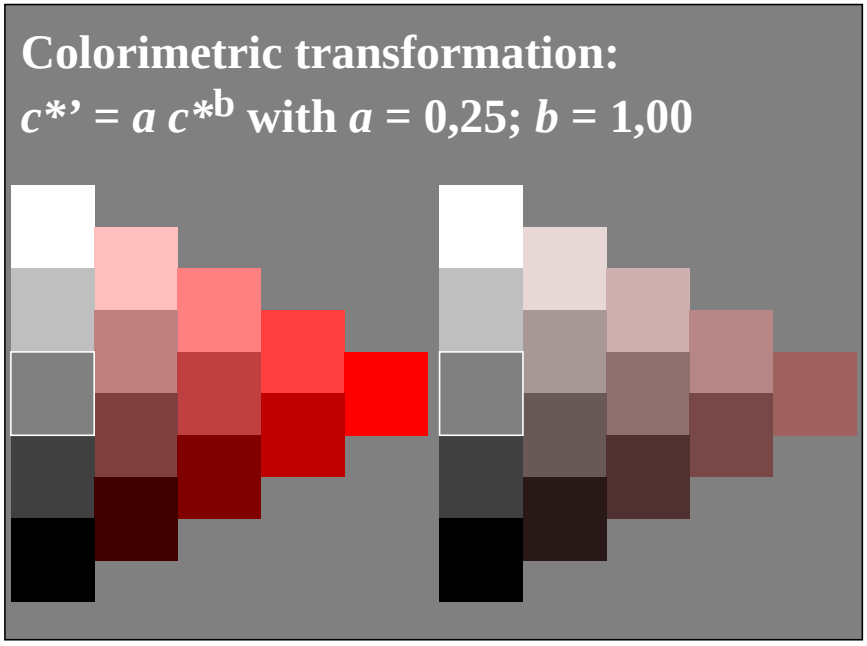



ZE320−6

**Colorimetric transformation:**
**$c^{*\prime} = a\, c^{*b}$ with $a$ = 0,25; $b$ = 1,00**

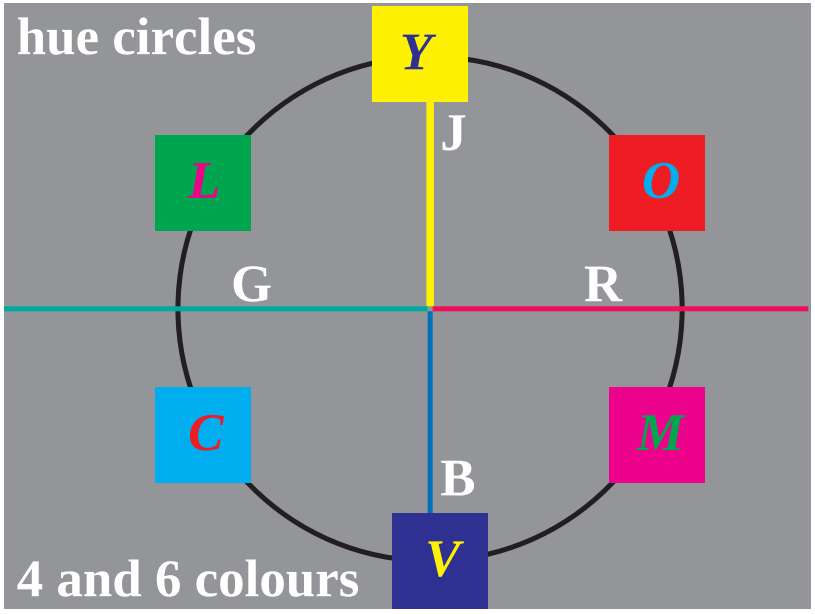



ZE321−5

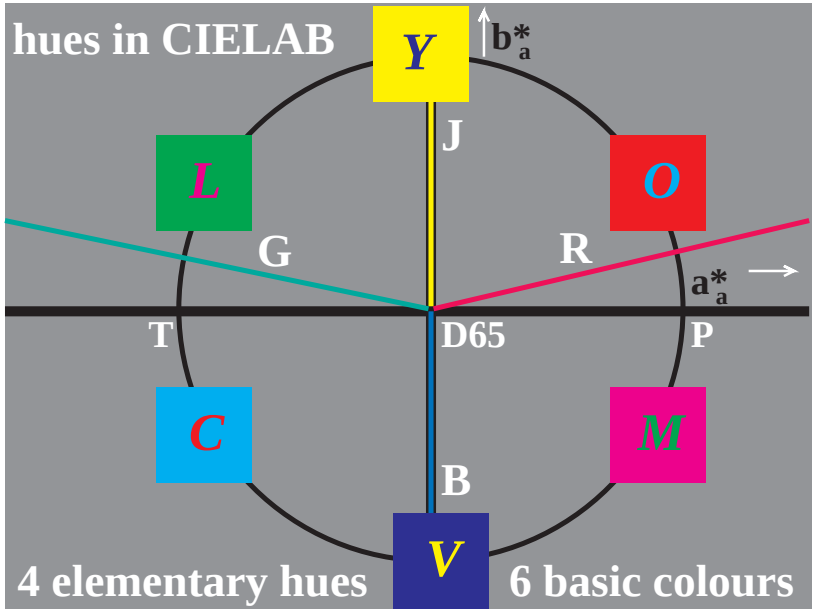



ZE321−6

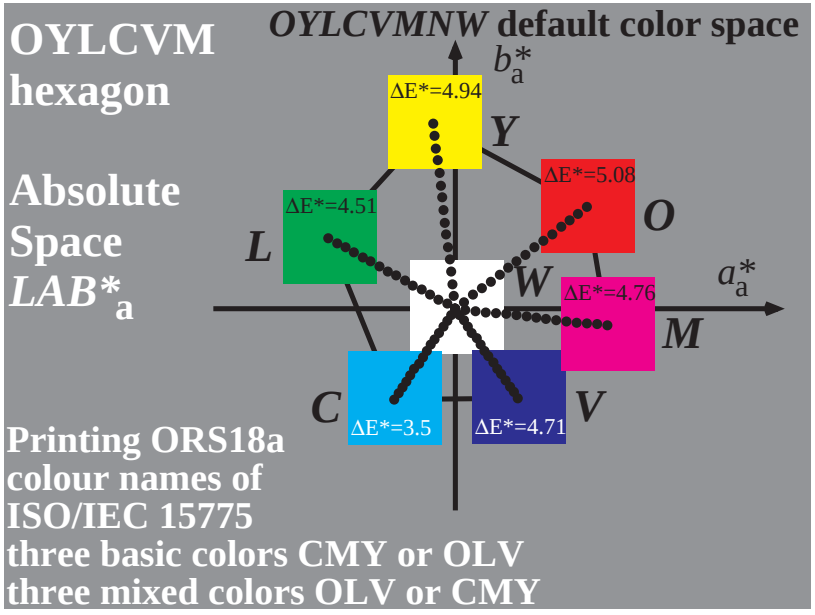
**Symmetric hue circle and elementary and device colour in CIELAB colour space**



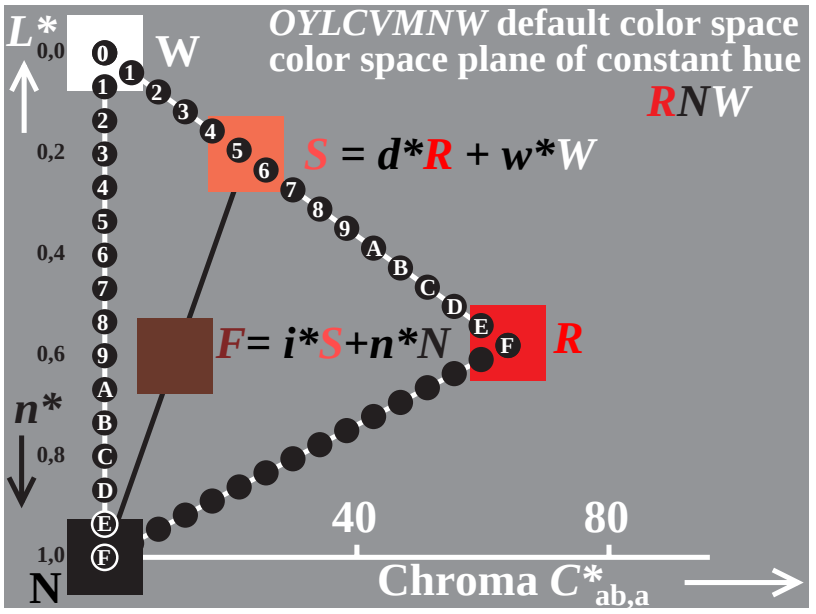

ZE410−3




ZE410−2

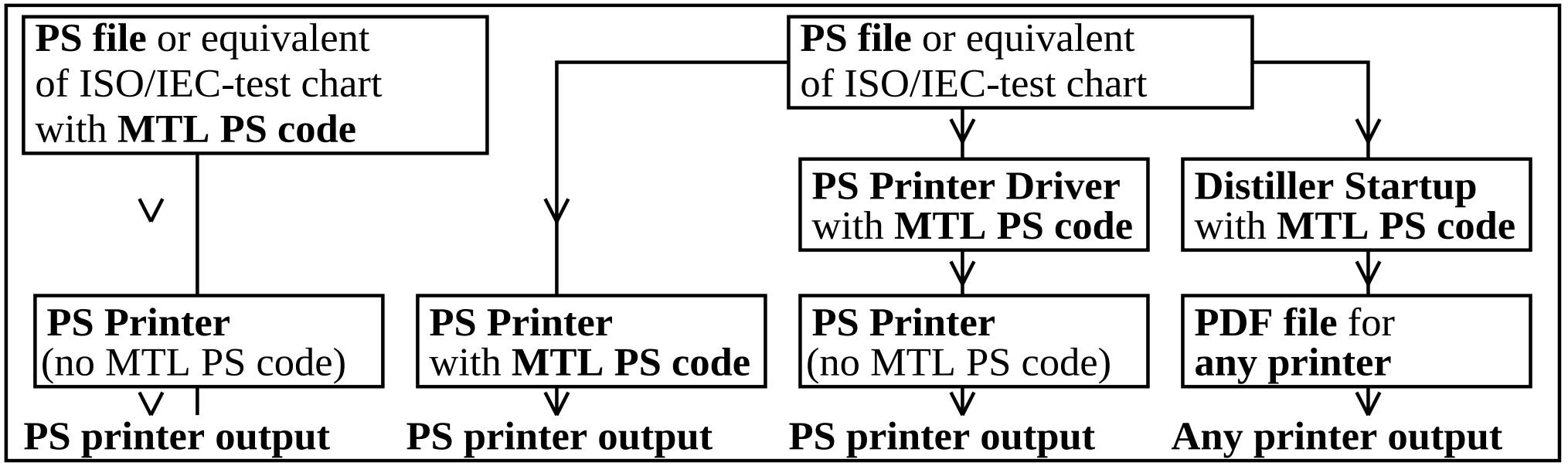



ZE420−1

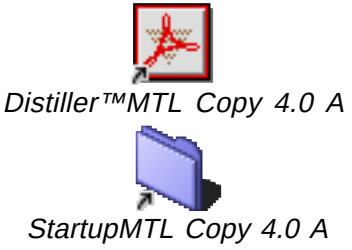



ZE411−6

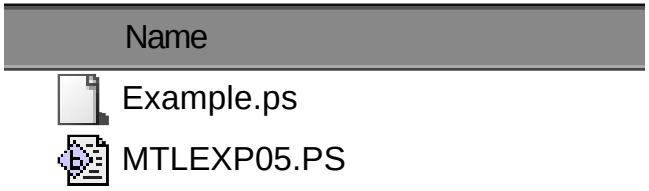
**Colour workflow for printer output and filter to produce new PDF file for output**



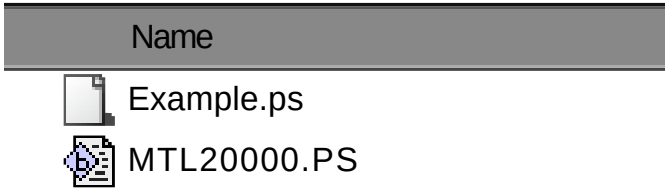







```
%MTLEXP05.PS
/MTLsetgray {setgray} bind def
/setgray {0.5 exp MTLsetgray} def
```



**Absolute and relative affin colour reproduction**

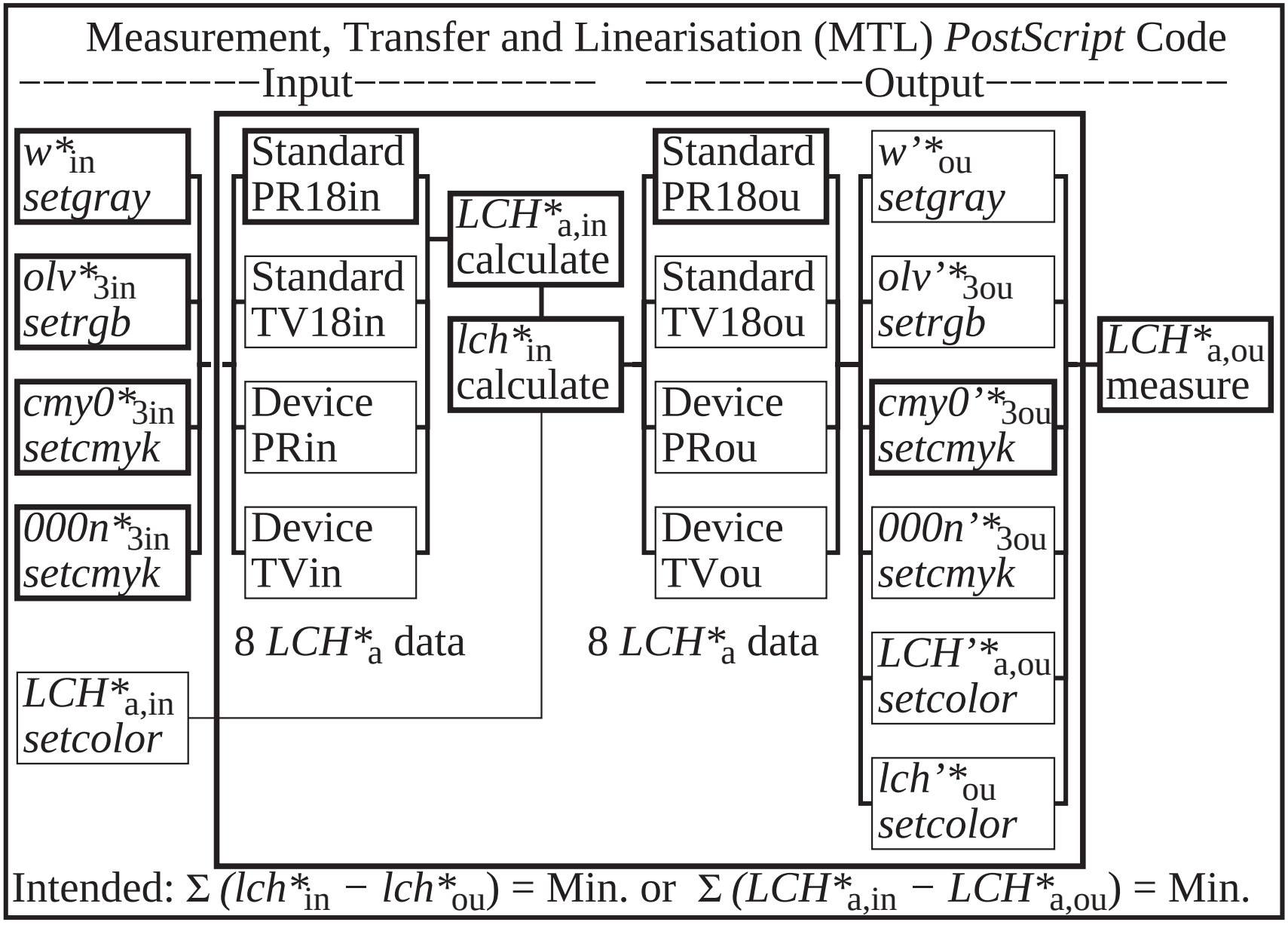
## Two Methods for Colour Comparison

**User needs of professionals and others:**
Absolute (professionals) und relative colorimetric reproduction

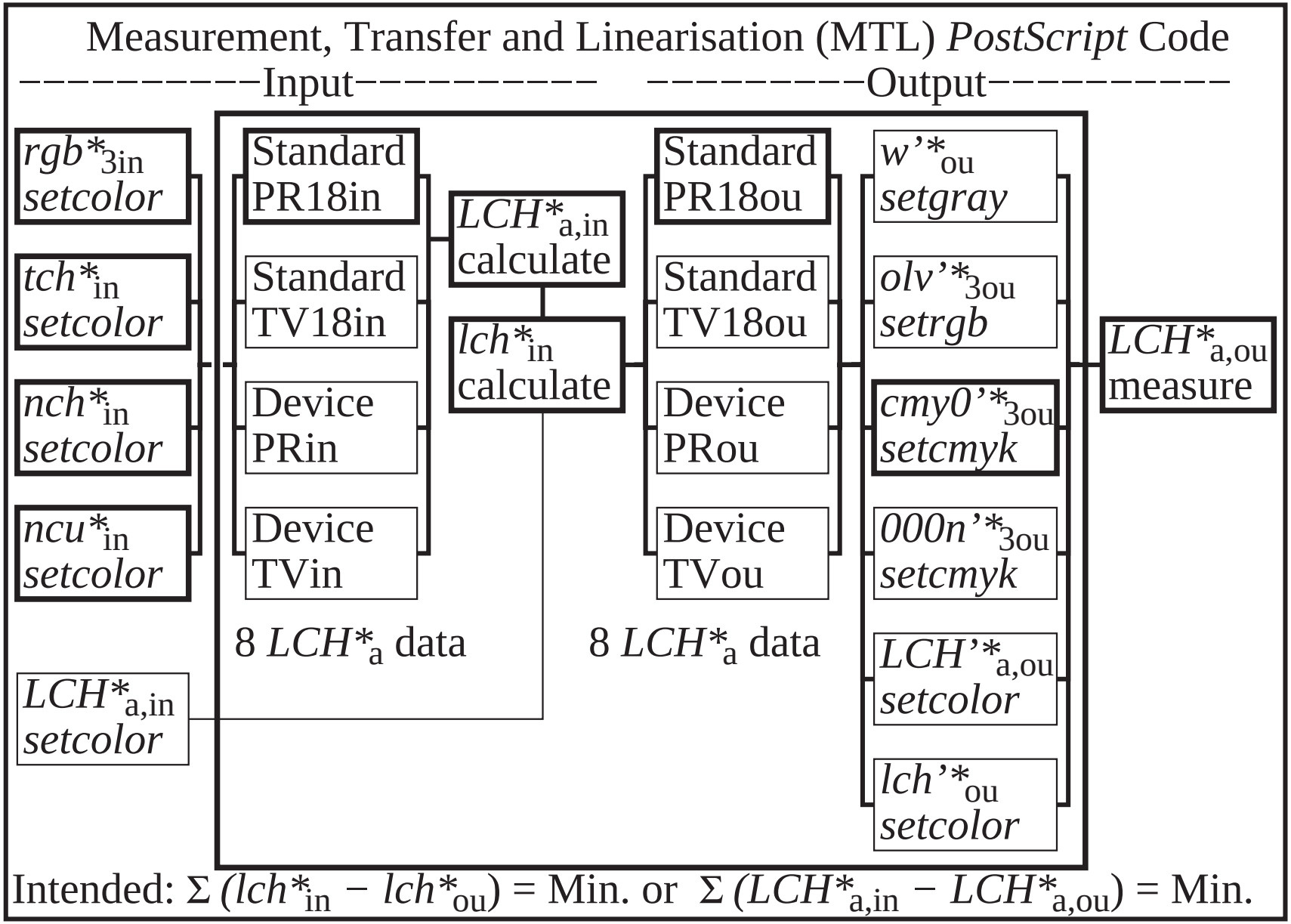
**Advantages and disadvantages:**

| | | |
|---|---|---|
| ***Absolute* CIELAB data**<br>$h_{ab}$ hue<br>$C^*_{ab}$ chroma<br>L* lightness | Visual comparison softcopy − hardcopy<br>Test of agreement with test files | **Advantage:**<br>Colorimetric reproduction of hue, chroma, lightness<br>**Disadvantage:**<br>Colour spaces of TV and Print show differences, often important colour **areas are clipped** |
| ***Relative* CIELAB data**<br>$h_{ab}$ hue<br>c* relative chroma<br>n* relative blackness | Test of visual equal relative spacing of either softcopy or hardcopy<br>Test of equal spacing with test files | **Advantage:**<br>Colorimetric reproduction of hue, *relative* chroma and *relative* lightness<br>Colour spaces of TV and Print show differences, No colour areas **are clipped**<br>**Disadvantage:**<br>Tolerable small changes of chroma and lightness |

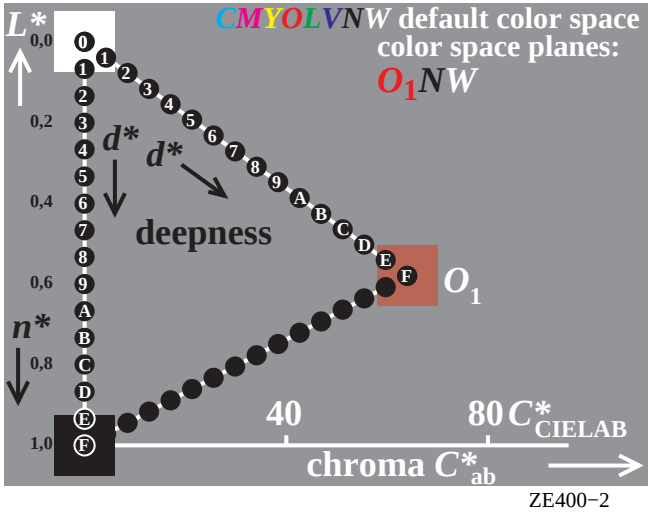
**Colour workflow according to ISO/IEC TR 19797**



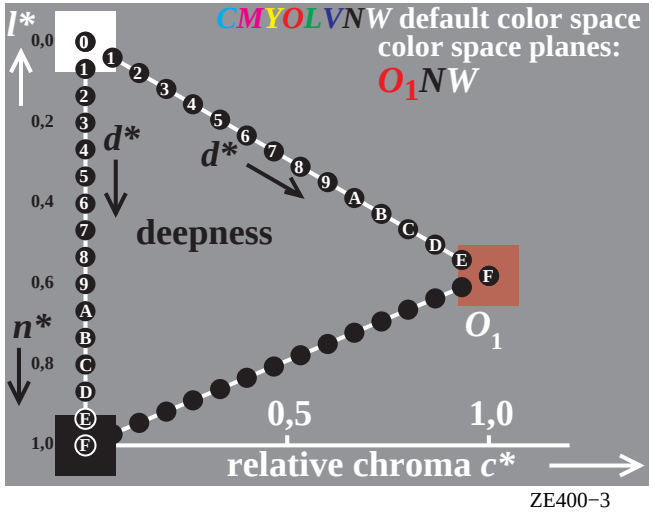
**Colour workflow according to ISO/IEC TR 19797 with new colour data, for example *rgb****



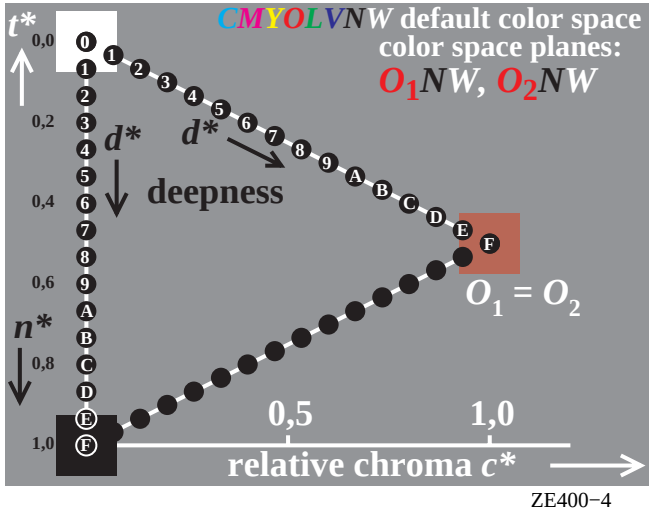
**Relative equidistant colour input and output of 16 step colour series**



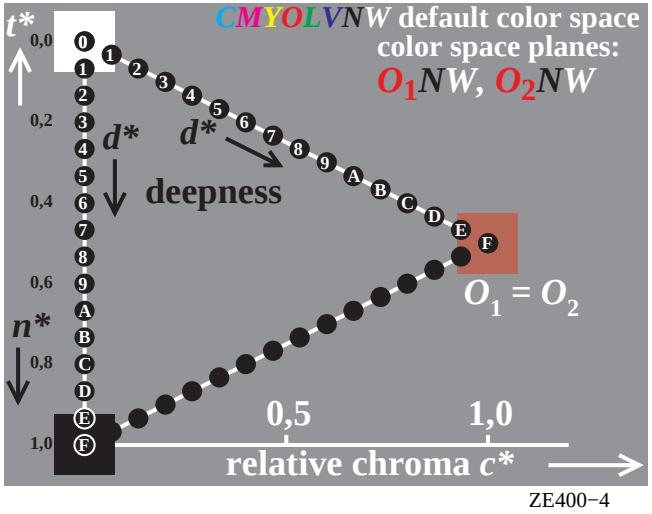

Absolute CIELAB input space:
lightness *L**
chroma $C^*_{ab}$



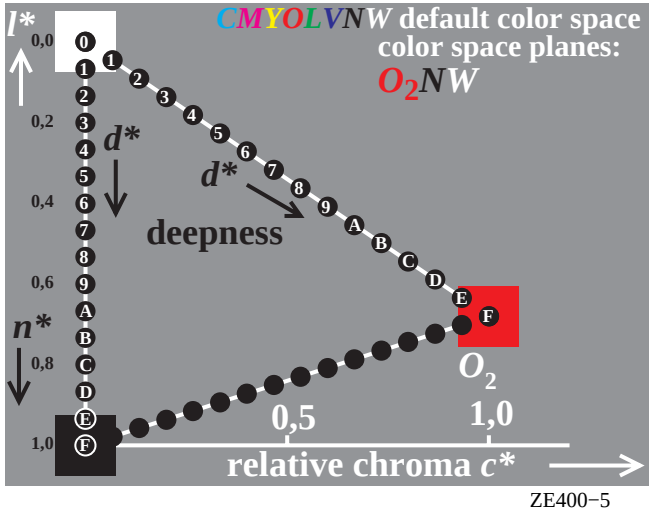

Relative CIELAB input space:
relative lightness *l**
relative chroma *c**



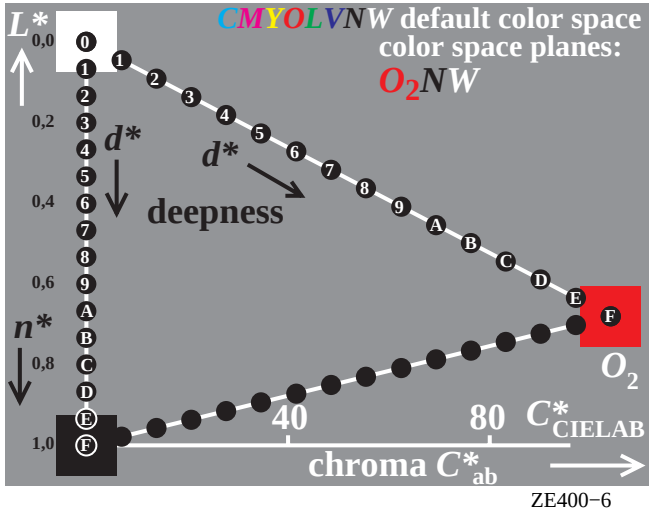

Natural Colour Connection Space:
relative triangle lightness *t**
relative chroma *c**




Natural Colour Connection Space:
relative triangle lightness *t**
relative chroma *c**




Relative CIELAB output space:
relative lightness *l**
relative chroma *c**

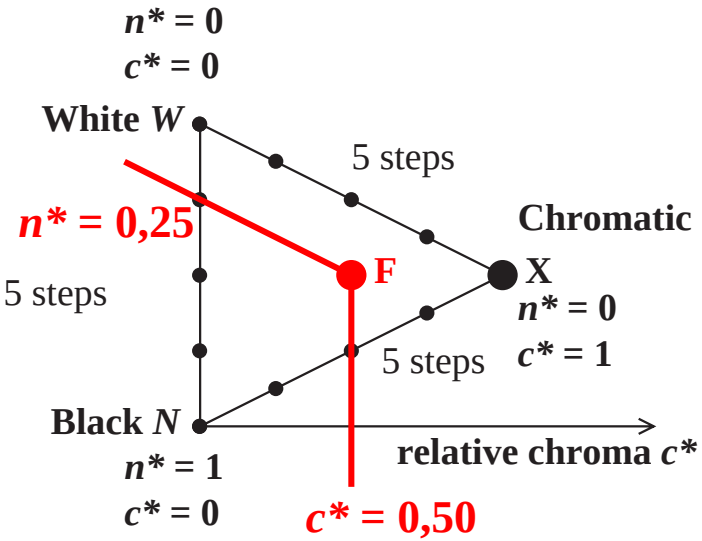



Absolute CIELAB output space:
lightness *L**
chroma $C^*_{ab}$

**User friendly relative colorimetric colour notation with elementary colour cocrdinates *ncu****

**User friendly colorimetric colour notation *ncu** and linear relation to three $rgb^*_3$ data**

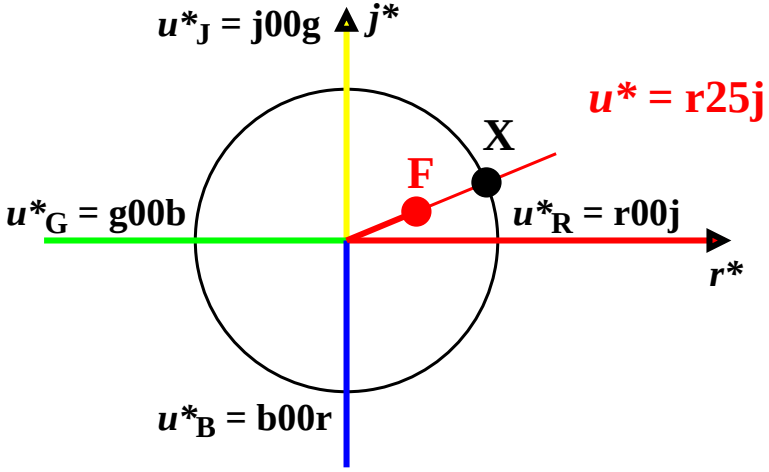
***n** relative blackness*
***c** relative chroma*
***u** elementary (unique) hue text*



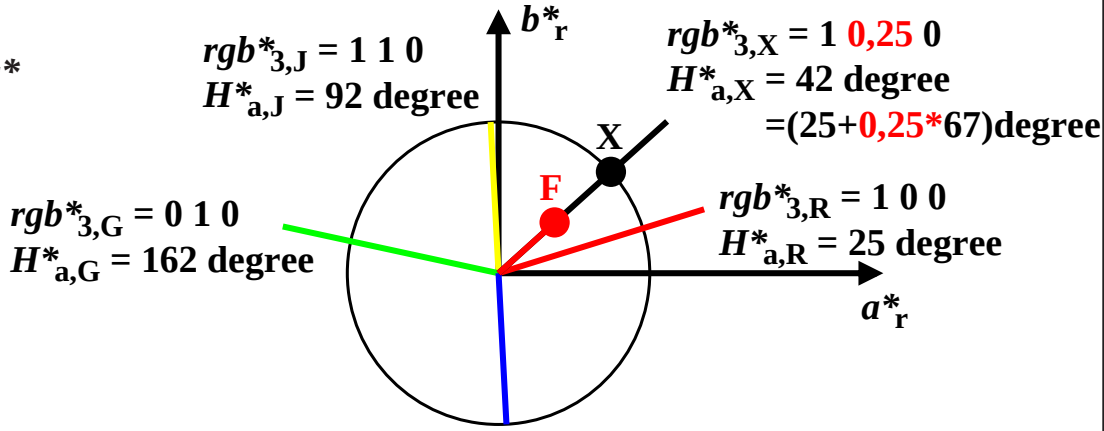

**example for colour notation:**

***ncu** = 0,25 0,50 r25j*

***relative opponent ( r*, j*)* chroma**




***relative trichromatic CIELAB ( a*r, b*r)* chroma**




$rgb^*_{3,B}$ = 0 0 1; $H^*_{a,B}$ = 272 degree

**9 and 16 step colour scales of elementary hue Blue *B***

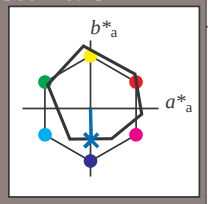
www.ps.bam.de/ZE62/10L/L62E00NP.PS/.PDF, Page 20/60; ORS18; transfer and output
N: No Output Linearization (OL) data in File (F), Startup (S) or Device (D)

See for similar files: http://www.ps.bam.de/ZE62/; www.ps.bam.de/ZE.HTM
Technical information: http://www.ps.bam.de Version 2.1, io=1,1

BAM registration: 20071001-ZE62/10L/L62E00NP.PS/.PDF BAM material: code=rha4ta
application for evaluation and measurement of printer or monitor systems

**Input: Colorimetric Offset Reflective System ORS18**

**for hue *h** = *lab*h* = 271/360 = 0.754**
***lab*tch* and *lab*nch***
**D65: hue B**
**LCH*Ma: 42 45 271**
**olv*Ma: 0.0 0.49 1.0**

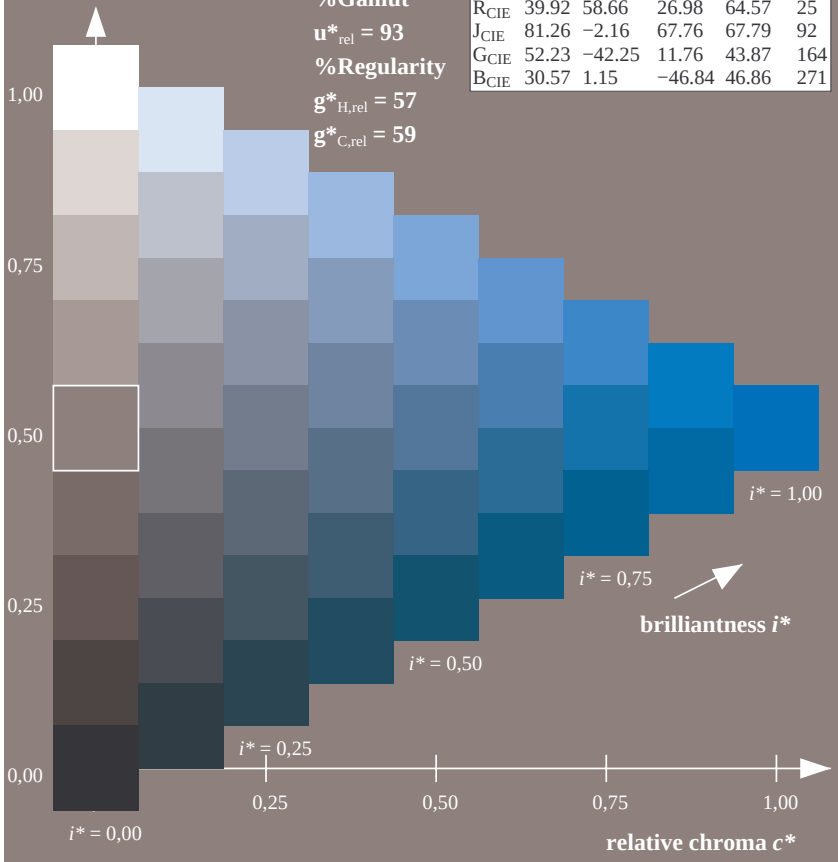



**ORS18; adapted (a) CIELAB data**

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

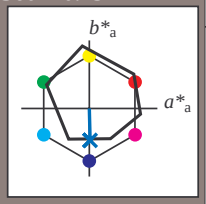
**triangle lightness *t****

**%Gamut**
**$u^*_{rel}$ = 93**
**%Regularity**
**$g^*_{H,rel}$ = 57**
**$g^*_{C,rel}$ = 59**




**Output: Colorimetric Offset Reflective System ORS18**

**for hue *h** = *lab*h* = 271/360 = 0.754**
***lab*tch* and *lab*nch***
**D65: hue B**
**LCH*Ma: 42 45 271**
**olv*Ma: 0.0 0.49 1.0**

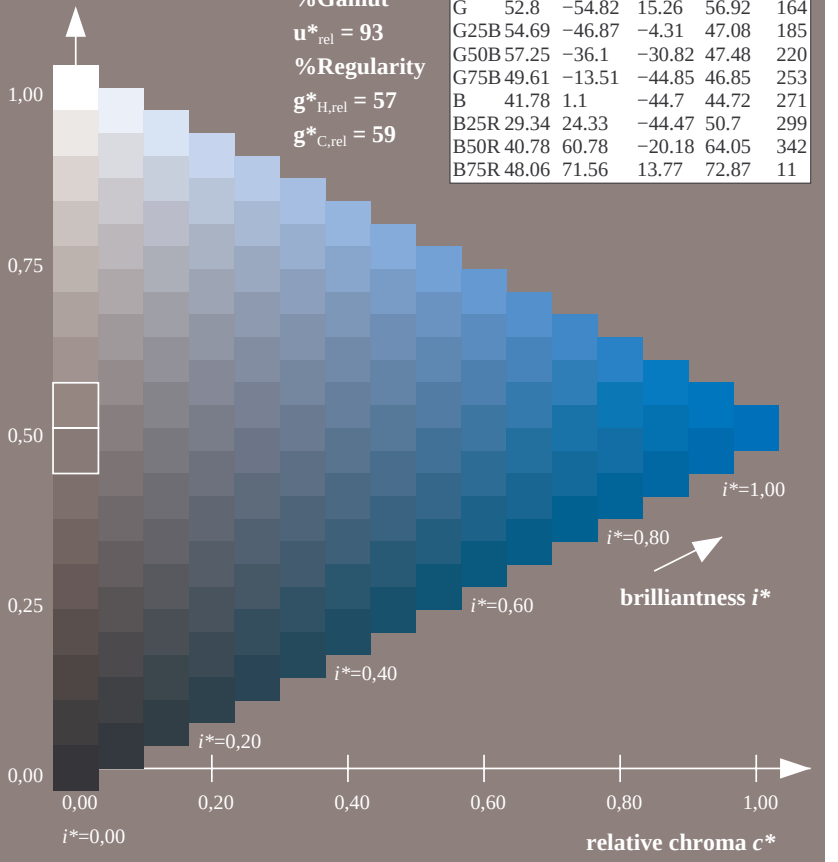



**ORS18; adapted (a) CIELAB data**

| | $L^*=L^*_a$ | $a^*_a$ | $b^*_a$ | $C^*_{ab,a}$ | $h^*_{ab,a}$ |
|---|---|---|---|---|---|
| R | 48.0 | 68.58 | 31.54 | 75.48 | 25 |
| R25J | 50.11 | 61.52 | 52.63 | 80.96 | 41 |
| R50J | 62.87 | 38.77 | 65.02 | 75.71 | 59 |
| R75J | 74.87 | 17.37 | 76.69 | 78.63 | 77 |
| J | 86.19 | −2.8 | 87.69 | 87.73 | 92 |
| J25G | 84.01 | −18.73 | 82.6 | 84.7 | 103 |
| J50G | 71.17 | −35.83 | 64.13 | 73.46 | 119 |
| J75G | 56.99 | −54.71 | 43.72 | 70.05 | 141 |
| G | 52.8 | −54.82 | 15.26 | 56.92 | 164 |
| G25B | 54.69 | −46.87 | −4.31 | 47.08 | 185 |
| G50B | 57.25 | −36.1 | −30.82 | 47.48 | 220 |
| G75B | 49.61 | −13.51 | −44.85 | 46.85 | 253 |
| B | 41.78 | 1.1 | −44.7 | 44.72 | 271 |
| B25R | 29.34 | 24.33 | −44.47 | 50.7 | 299 |
| B50R | 40.78 | 60.78 | −20.18 | 64.05 | 342 |
| B75R | 48.06 | 71.56 | 13.77 | 72.87 | 11 |

**triangle lightness *t****

**%Gamut**
**$u^*_{rel}$ = 93**
**%Regularity**
**$g^*_{H,rel}$ = 57**
**$g^*_{C,rel}$ = 59**

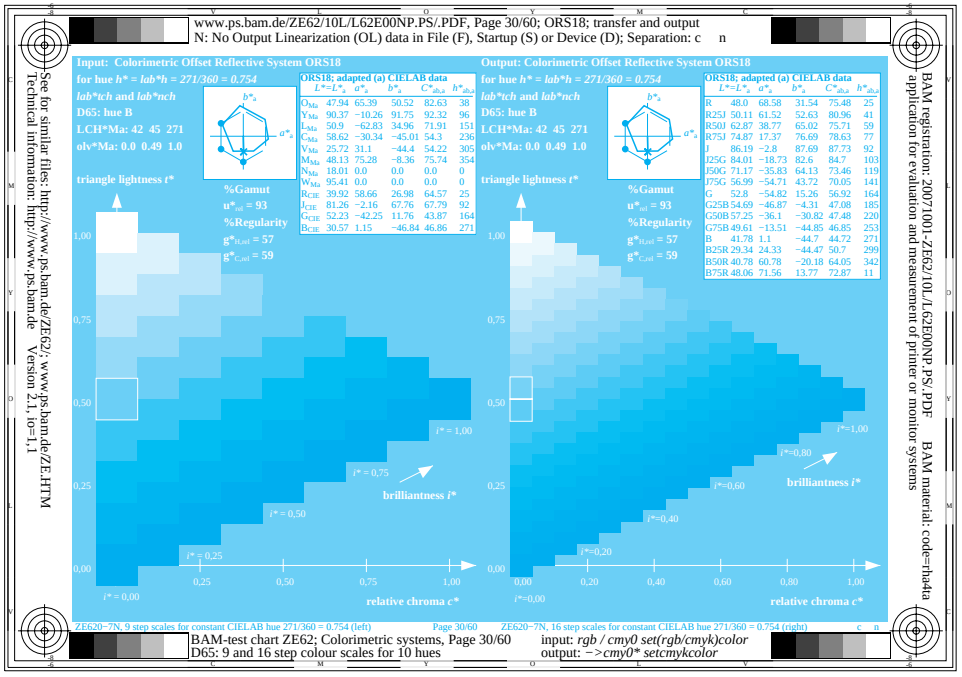


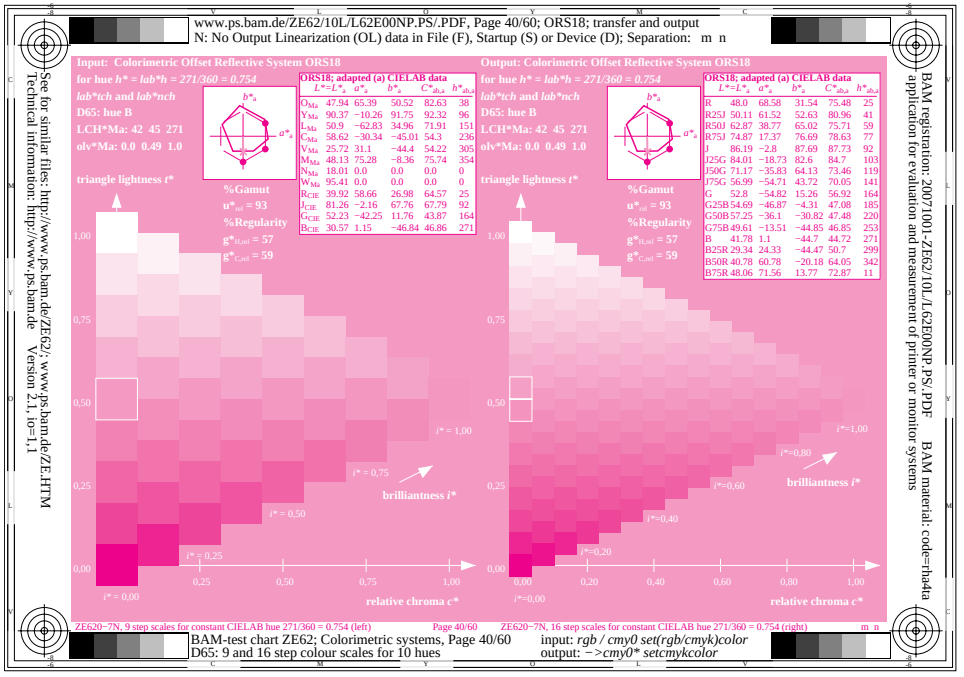

ZE620−7N, 9 step scales for constant CIELAB hue 271/360 = 0.754 (left) Page 20/60 ZE620−7N, 16 step scales for constant CIELAB hue 271/360 = 0.754 (right)

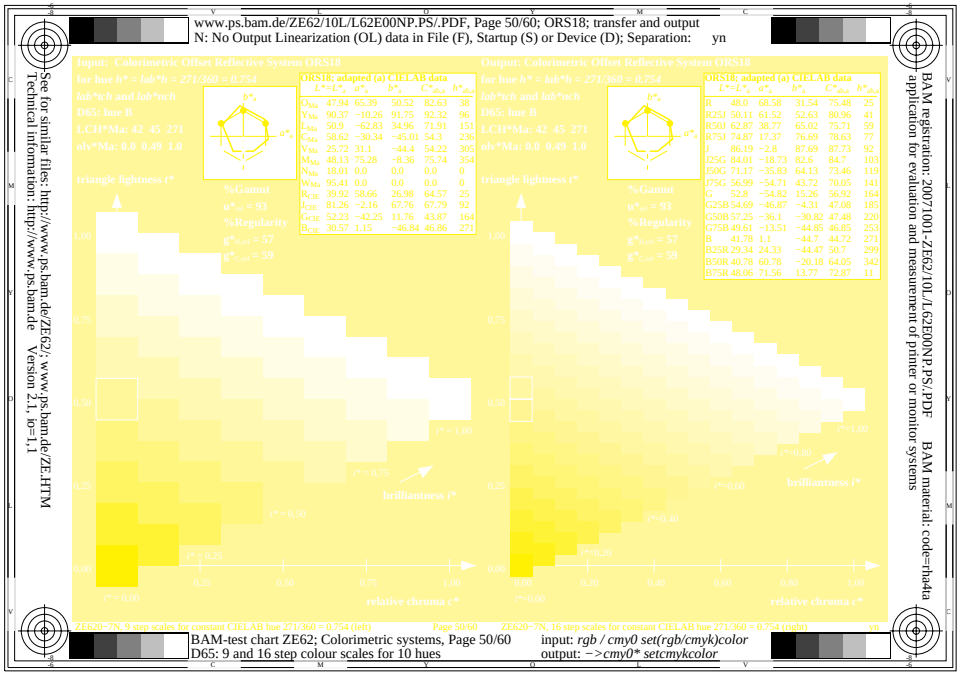
BAM-test chart ZE62; Colorimetric systems, Page 20/60
D65: 9 and 16 step colour scales for 10 hues

input: *rgb / cmy0 set(rgb/cmyk)color*
output: *−>cmy0* setcmykcolor*

## 4 colour separation for Blue *B* with low material efficiency using only chromatic colorants



**9 and 16 step colour scales of device colour Orange red *O***

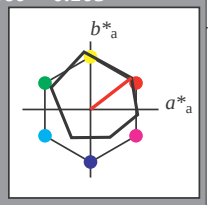
www.ps.bam.de/ZE82/10L/L82E00NP.PS/.PDF, Page 11/60; ORS18; transfer and output
N: No Output Linearization (OL) data in File (F), Startup (S) or Device (D)

See for similar files: http://www.ps.bam.de/ZE82/; www.ps.bam.de/ZE.HTM
Technical information: http://www.ps.bam.de Version 2.1, io=1,1

BAM registration: 20071001-ZE82/10L/L82E00NP.PS/.PDF BAM material: code=rha4ta
application for evaluation and measurement of printer or monitor systems

**Input: Colorimetric Offset Reflective System ORS18**

**for hue *h** = *lab*h* = 38/360 = 0.105**
***lab*tch* and *lab*nch***
**D65: hue O**
**LCH*Ma: 52 76 38**
**olv*Ma: 1.0 0.0 0.0**

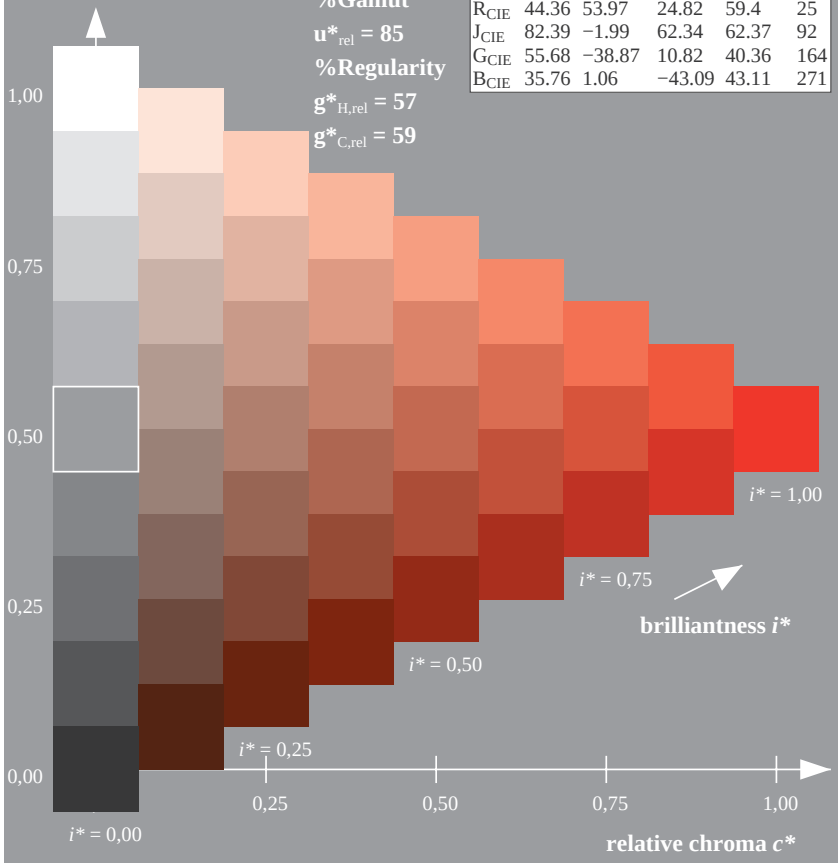



**ORS18; adapted (a) CIELAB data**

| | $L^*=L^*_a$ | $a^*_a$ | $b^*_a$ | $C^*_{ab,a}$ | $h^*_{ab,a}$ |
|---|---|---|---|---|---|
| $O_{Ma}$ | 51.74 | 60.16 | 46.48 | 76.02 | 38 |
| $Y_{Ma}$ | 90.77 | −9.44 | 84.41 | 84.94 | 96 |
| $L_{Ma}$ | 54.46 | −57.8 | 32.16 | 66.15 | 151 |
| $C_{Ma}$ | 61.56 | −27.91 | −41.41 | 49.95 | 236 |
| $V_{Ma}$ | 31.3 | 28.61 | −40.85 | 49.88 | 305 |
| $M_{Ma}$ | 51.91 | 69.26 | −7.69 | 69.68 | 354 |
| $N_{Ma}$ | 24.2 | 0.0 | 0.0 | 0.0 | 0 |
| $W_{Ma}$ | 95.41 | 0.0 | 0.0 | 0.0 | 0 |
| $R_{CIE}$ | 44.36 | 53.97 | 24.82 | 59.4 | 25 |
| $J_{CIE}$ | 82.39 | −1.99 | 62.34 | 62.37 | 92 |
| $G_{CIE}$ | 55.68 | −38.87 | 10.82 | 40.36 | 164 |
| $B_{CIE}$ | 35.76 | 1.06 | −43.09 | 43.11 | 271 |

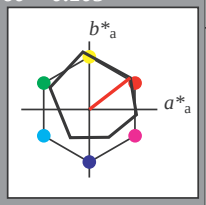
**triangle lightness *t****

**%Gamut**
**$u^*_{rel}$ = 85**
**%Regularity**
**$g^*_{H,rel}$ = 57**
**$g^*_{C,rel}$ = 59**




**Output: Colorimetric Offset Reflective System ORS18**

**for hue *h** = *lab*h* = 38/360 = 0.105**
***lab*tch* and *lab*nch***
**D65: hue O**
**LCH*Ma: 52 76 38**
**olv*Ma: 1.0 0.0 0.0**

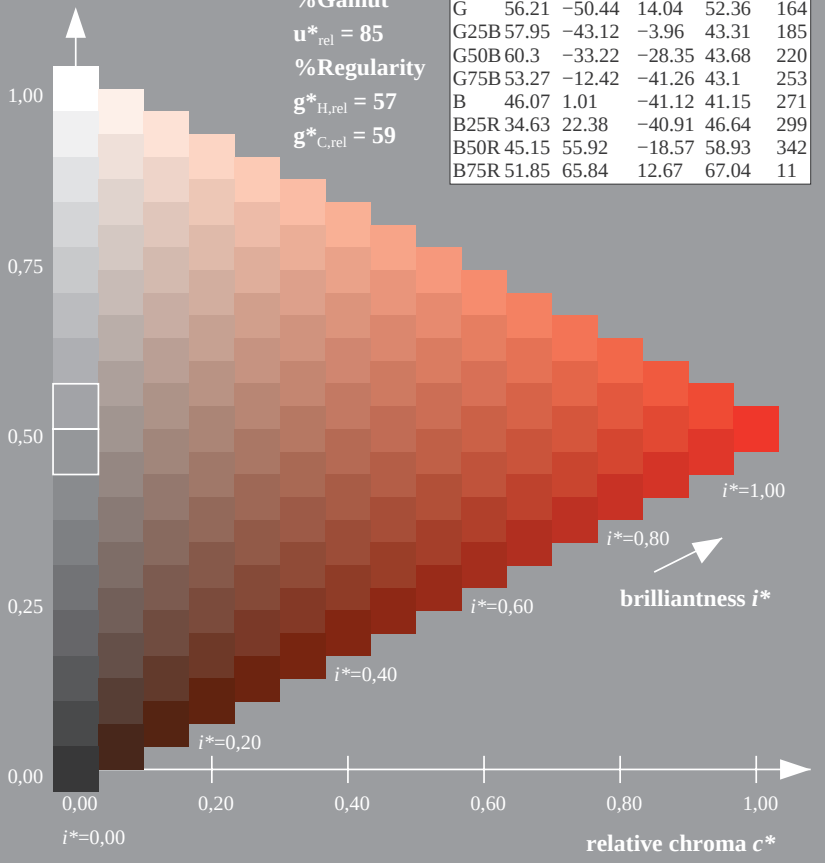



**ORS18; adapted (a) CIELAB data**

| | $L^*=L^*_a$ | $a^*_a$ | $b^*_a$ | $C^*_{ab,a}$ | $h^*_{ab,a}$ |
|---|---|---|---|---|---|
| R | 51.79 | 63.09 | 29.02 | 69.44 | 25 |
| R25J | 53.73 | 56.6 | 48.42 | 74.48 | 41 |
| R50J | 65.47 | 35.67 | 59.82 | 69.65 | 59 |
| R75J | 76.51 | 15.98 | 70.55 | 72.34 | 77 |
| J | 86.93 | −2.58 | 80.67 | 80.71 | 92 |
| J25G | 84.92 | −17.23 | 75.99 | 77.92 | 103 |
| J50G | 73.11 | −32.96 | 59.0 | 67.58 | 119 |
| J75G | 60.06 | −50.34 | 40.22 | 64.44 | 141 |
| G | 56.21 | −50.44 | 14.04 | 52.36 | 164 |
| G25B | 57.95 | −43.12 | −3.96 | 43.31 | 185 |
| G50B | 60.3 | −33.22 | −28.35 | 43.68 | 220 |
| G75B | 53.27 | −12.42 | −41.26 | 43.1 | 253 |
| B | 46.07 | 1.01 | −41.12 | 41.15 | 271 |
| B25R | 34.63 | 22.38 | −40.91 | 46.64 | 299 |
| B50R | 45.15 | 55.92 | −18.57 | 58.93 | 342 |
| B75R | 51.85 | 65.84 | 12.67 | 67.04 | 11 |

**triangle lightness *t****

**%Gamut**
**$u^*_{rel}$ = 85**
**%Regularity**
**$g^*_{H,rel}$ = 57**
**$g^*_{C,rel}$ = 59**

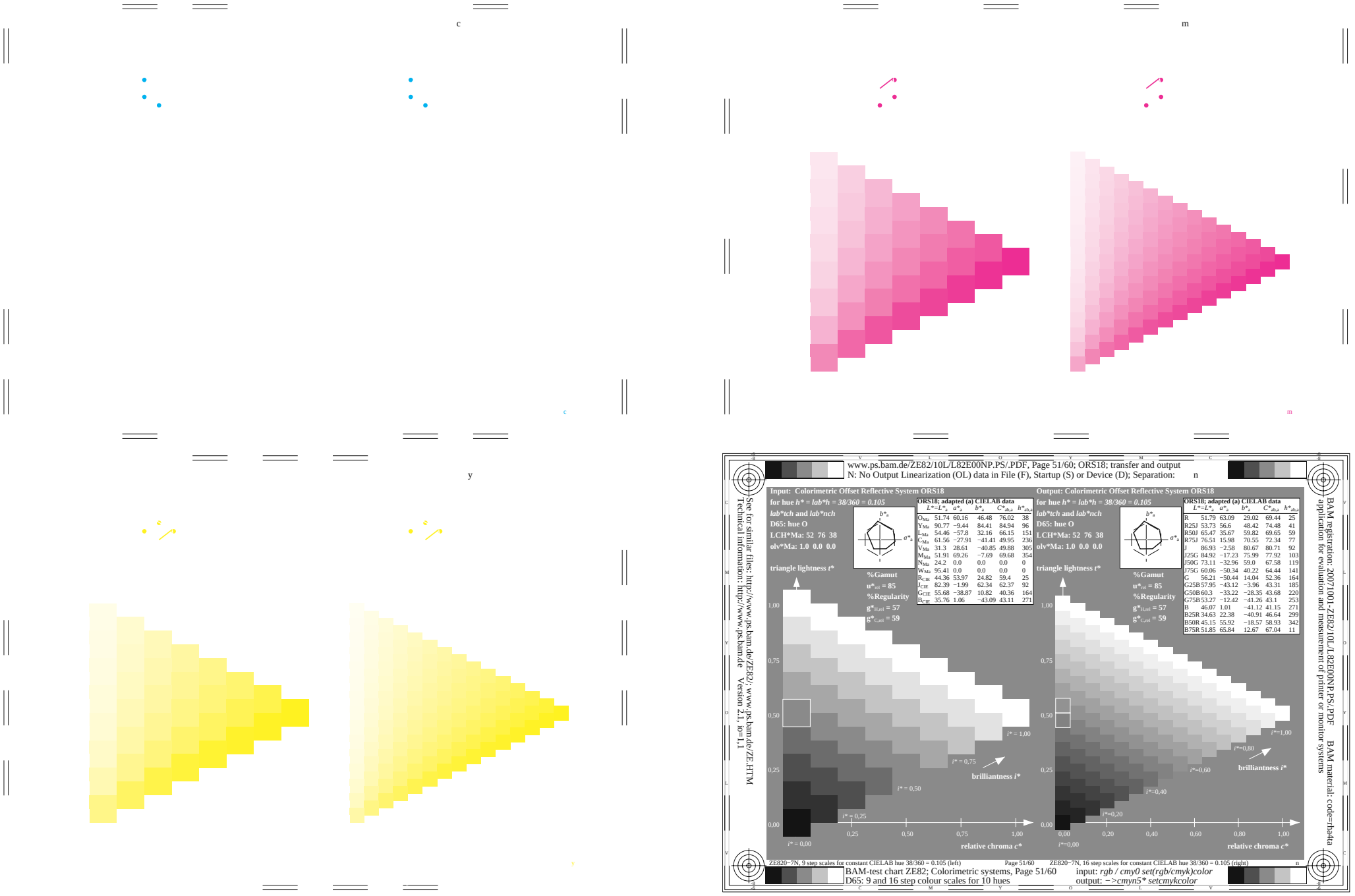



ZE820−7N, 9 step scales for constant CIELAB hue 38/360 = 0.105 (left) Page 11/60 ZE820−7N, 16 step scales for constant CIELAB hue 38/360 = 0.105 (right)

BAM-test chart ZE82; Colorimetric systems, Page 11/60
D65: 9 and 16 step colour scales for 10 hues

input: *rgb / cmy0 set(rgb/cmyk)color*
output: *−>cmyn5* setcmykcolor*

**4 colour separation of Orange red *O* with high material efficiency using the black colorant**



# Summary

- Device dependent colour systems
- Elementary colour systems
- User friendly *rgb** and *ncu** *(icu*)* colour coordinates
- Colorimetric connection with CIELAB for any device
- Output with high visual efficiency (16 output steps are equally spaced) based on output linearisation
- Output with high material efficiency (grey is printed by the black and not with chromatic colorants) based on improved separation technologies

- More examples are shown in the poster session

I thank especially Dr. Jens Witt, Dr. Stefan Jaeger, Hans Wagenknecht, Philipp Kittelmann and Bern Muschik for the scientic and other help and promotion of this paper

## References and links to publications and test charts

CIE 170-1:2006, Fundamental chromaticity diagram with physiological axes - Part 1 CIE 15: 2004, Colorimetry

ISO/IEC 15775:1999, Information Technology – Office Systems – Method for specifying image reproduction of colour copying machines by analog test charts – Realisation and application, Editor: K. Richter.

ISO/IEC TR 19797:2004, Information Technology – Office Systems – Device output of 16-step colour scales, output linearization method (LM) and specification of the reproduction properties, Editor: K. Richter, 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 Systems – Method of specifying image reproduction of colour devices by digital and analog test charts, Editor: K. Richter, For Information and test charts according to ISO/IEC TR 24505 see
http://www.ps.bam.de/24705TE

Hurvich, Leo. M (1981), Colour Vision, Sinauer Associates Inc, Sunderland, Massachusetts, ISBN 0 87893-336-0

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German standards and international standard documents for colorimetric image technology

| Input | Output | Input and output media and applications | | | Standard |
|---|---|---|---|---|---|
| | | Input media | Output media | Application | |
| – | – | – | – | **Basis** | **DIN 33866−1** |
| **analog** | **analog** | DIN-test chart (hardcopy) | Hardcopy | **Copier** | **DIN 33866−2** |
| **analog** | **digital** | DIN-test chart (hardcopy) | File | **Scanner** | **DIN 33866−4** |
| **digital** | **analog** | DIN-test chart (file) | Hardcopy<br>Softcopy | **Printer**<br>**Monitor** | **DIN 33866−3**<br>**DIN 33866−5** |

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| Input | Output | Input and output media and applications | | | Technical Report (TR) or Standard |
|---|---|---|---|---|---|
| | | Input media | Output media | Application | |
| – | – | – | – | **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<br>Softcopy | **Printer**<br>**Monitor** | **ISO/IEC TR 24705**<br>**ISO/IEC TR 24705** |

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