# Trends for CIE-ISO-colour standards for input and output of all colour devices with relative CIELAB colour coordinates *rgb**

for this publication see: http://130.149.60.45/~farbmetrik/CIE_TC42_DFWG_14E.PDF

## Summary

DIN 33872-1 to 6 was published in 2010 and comes with test charts on CD for part 1 to 6, and in internet, see http://www.ps.bam.de/33872E. The output properties of these test charts are tested visually for the *softcopy* (display, projector) and the *hardcopy* (printer, offset, photographic) output.

For example the ISO committees TC159/SC4/WG2 *Visual display requirements* and ISO/IEC SC28 *Office systems* have asked the standard bodies CIE Division 1 and 8 by different resolutions between 2009 and 2014 to work on a visual human *RGB* colour space. The trends in standardization to such a colour space for example by different the CIE Reportership Reports R1-47, R1-57 and R8-09 are described. The advantages for example to solve the visual user wishes of DIN 33872-1 to -6 by colorimetry are given and may influence this CIE development.

## DIN 33872-1 to -6 and ouput dependence on colour workflow

In the DIN standard series DIN 33872-1 to -6 there is **no** statement that the output properties according to DIN-user wishes are **required**. However, many companies may consider how to *solve* the DIN-user wishes as an ***option*** for applications.

If one studies the user whishes then it is realized soon, that the *workflow* between the file and the output has at least four sources which usually support and sometimes block the user whishes. For example:

- the computer operating system
- the application software
- the device driver
- the hard- and software of the device

Therefore the workflow output of the test charts of DIN 33871-1 to -6 can either support the user wishes or block them.
The individual source of the problem may not be detected, because only the final output of a workflow with different components is studied.

For the output, the main questions and user wishes are:

- Is the output visually *equally spaced* for equally spaced *rgb* data *(Y/N)?* *(compare Fig. 1)*
- Are the *elementary* hues produced for the given *rgb* values *(Y/N)?* *(compare Fig. 2)*

**Example outputs of test charts and trends for CIE-ISO standards**

The following pages show two output examples of two DIN-test charts according to DIN 33872-2 and -5.

In addition each output example produces questions, see

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

in a DIN-form to be answered by the user.

Only visual evaluation is necessary to answer the DIN-questions.

The use of colour measurement equipment is an *option* to support colorimetric answers, for example in real office colour applications. More standardization is needed for these colorimetric *option*.

# Trends for CIE-ISO-colour standards for input and output of all colour devices

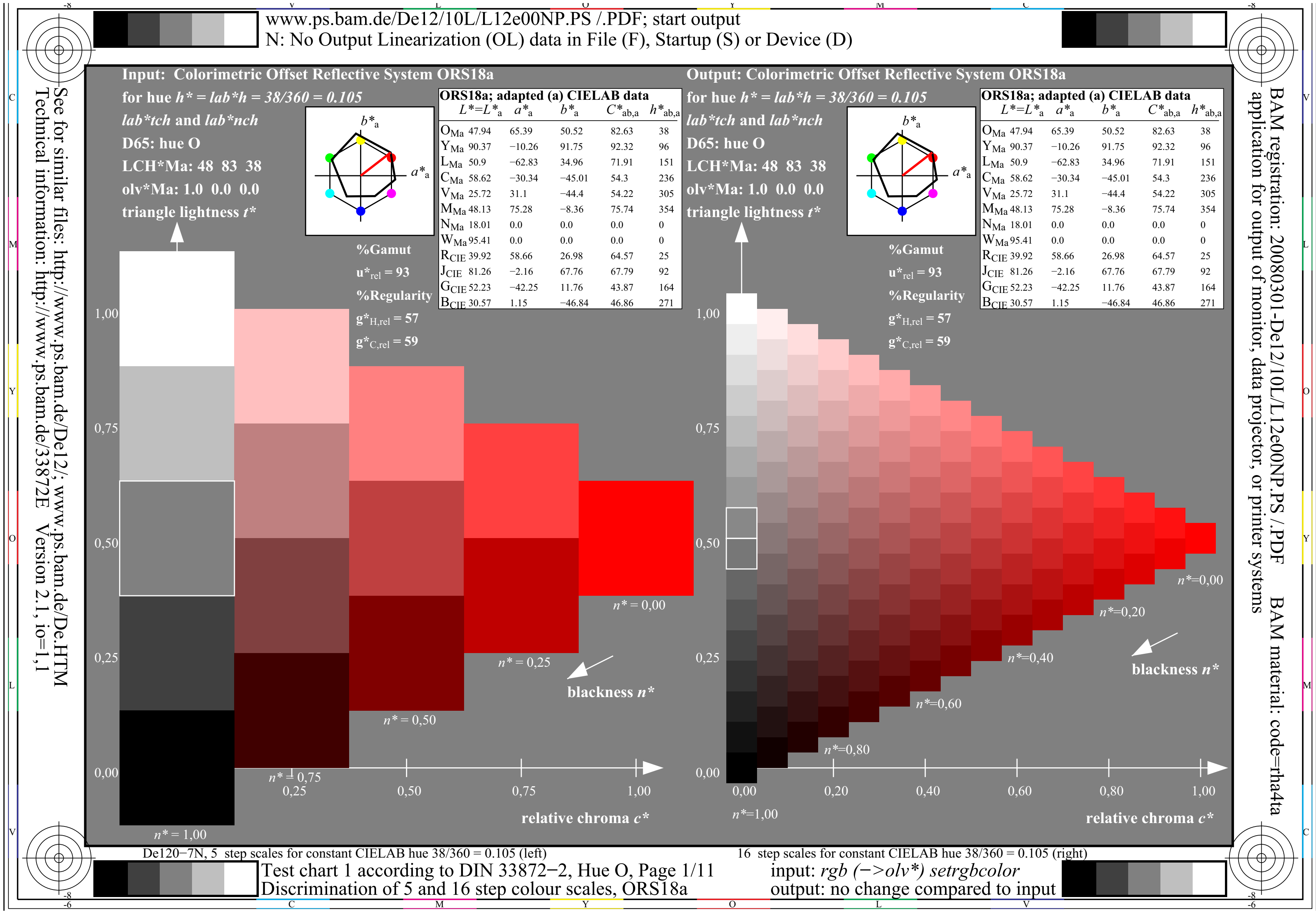
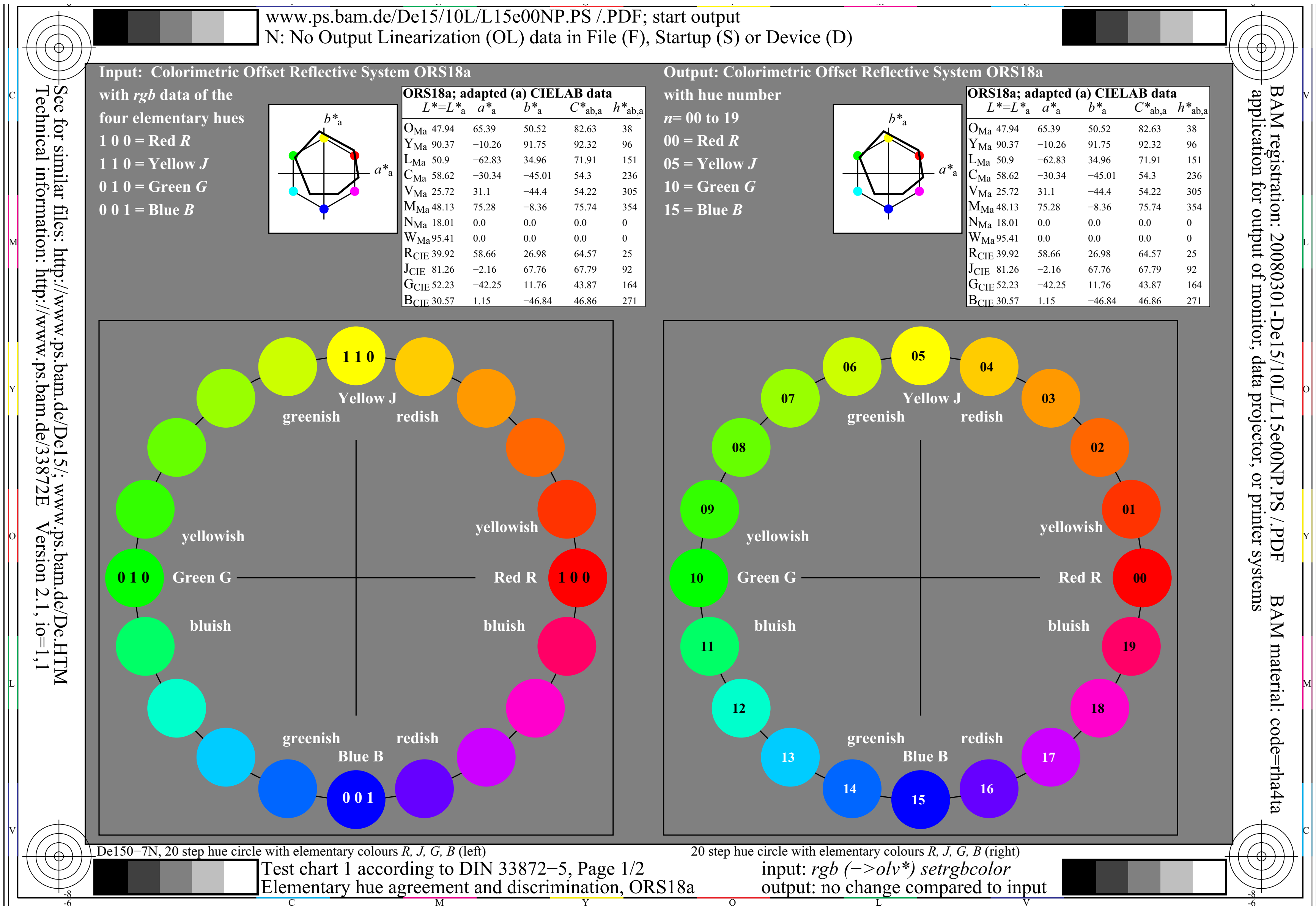



**Fig 1:** ***Equally spaced colour test*** **with test chart according to DIN 33872-2**

**Question: Produce the equally spaced** ***rgb*** **values equally spaced output series (Y/N) ?**

# Trends for CIE-ISO-colour standards for input and output of all colour devices




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 |


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**Fig 2: *Elementary hue output test* with test chart according to DIN 33872-5**

**Question: Produce the *rgb* values the elementary hues according to visual criteria (Y/N)?**

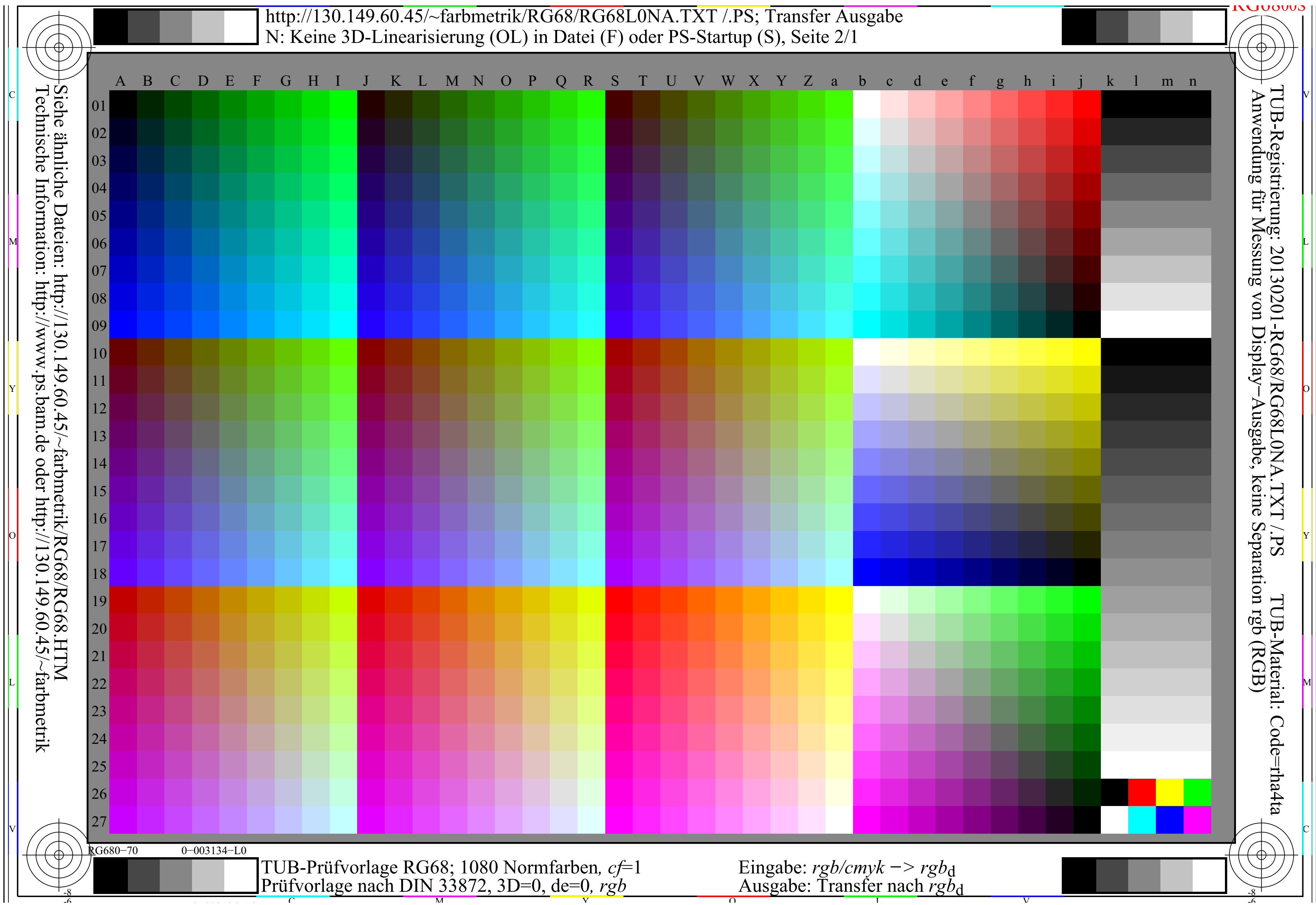


**Fig. 3: Test chart according to CIE R8-09 with 1080 colours defined by *rgb* values in file**

Fig. 3 includes 1080 colours. A *rgb* colour cube is defined by 729=9x9x9 colours. There is a 48 step hue circle within the 729 colours. In addition oponent hue planes and greys are shown.

# Trends for CIE-ISO-colour standards for input and output of all colour devices

| Input | Output | Input and output media and applications: Input media | Output media | Application | Technical Report (TR) or Standard | Method & Test: Linearization |
|---|---|---|---|---|---|---|
| – | – | – | – | **Basis** | **ISO/IEC TR 24705** | **DIN 33866−1**<br>**DIN 33872−1** |
| **analog** | **analog** | ISO/IEC-file<br>series equally spaced in *rgb* +<br>ISO/IEC-test chart (hardcopy)<br>series equally spaced in *LCh** | Hardcopy | **Copier** | **ISO/IEC 15775** | **DIN 33866−2**<br>**JIS X 6933** |
| **analog** | **digital** | ISO/IEC-test chart (hardcopy)<br>series equally spaced in *Lch** | File | **Scanner** | **ISO/IEC TR 24705** | **DIN 33866−4** |
| **digital** | **analog** | ISO/IEC-test chart (File)<br>series equally spaced in *rgb* | Hardcopy | **Printer** | **ISO/IEC TR 24705** | **DIN 33866−3**<br>**DIN 33872−2,4** |
| | | | Softcopy | **Display** | **ISO/IEC TR 24705**<br>**ISO 9241−306** | **DIN 33866−5**<br>**DIN 33872−2,4** |

The ISO/IEC-input linearisation method produces an ISO/IEC-file from an ISO/IEC-original scene:
Flower motiv with 16 equidistant grey steps, and 14 CIE-test colours according to CIE 13.3

The ISO/IEC-output linearisation method produces from an ISO/IEC-file a linearized display, offset or printer output:

**ISO/IEC-input linearisation method**

| Input | Output | Application | Technical Report (TR) or Standard |
|---|---|---|---|
| Original scene + CIE colours | ISO/IEC Image File | Reference Image File | **ISO/IEC 15775**<br>**ISO/IEC TR 24705** |

**ISO/IEC-output linearisation method**

| Input | Output media | Application | Technical Report (TR) or Standard |
|---|---|---|---|
| ISO/IEC File | Hardcopy | Printer | **ISO/IEC TR 19797** |
| ISO/IEC File | Softcopy | Display | **ISO 9241−306**<br>8 viewing conditions |
| ISO/IEC File | Softcopy | Display | **CIE R8−09: 2014**<br>device space +<br>device-independent<br>visual RGB* space |
| | Hardcopy | Offset | |
| | Hardcopy | Printer | |

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**Fig. 4: Standard documents with equally spaced *rgb* and *LCh** data for 16-step series**

Fig. 4 includes the connection between many International and National Standard documents.
The colour series have equal spacing in *rgb* in the file and equal spacing in *LCh** in the hardcopy.

## Output linearization according to CIE R8-09 and user test according to DIN 33872-1 to -6

**Colour device company which produces:**
display, data projector, printer, offset machine, ...

Device output of colour test chart according to DIN 33872-X or CIE R8-09 by two options:
option 1: automatic company device output
option 2: output according to CIE R8-09

**Linearization company:**
Measures 1080 user colours and produces ***linearization code according to CIE R8-09*** in driver or profile for user device

For the test charts of DIN 33872-1 to -6 see
http://www.ps.bam.de/33872E

For english text of DIN 33872 see
http://www.iso.org/scit (docum. N183−189)

For test chart with 1080 colours of CIE R8-09 see
http://130.49.60.45/~farbmetrik/RE68/RE68L0NP.PDF

For more technical information about CIE R8-09 see
http://130.49.60.45/~farbmetrik/outlin

**Visual output test for option 1 or 2**
with Y/N user questions of DIN 33872-2 to -6
(no colour measurement necessary)

**Agrees the output with the user wishes (Y/N)?**
If the answer is Yes (Y) then finish.
If No (N) agreement to the user wishes then:
look for a device with properties according to R8-09
or send (printed) output to a **linearization company.**
*Get back a device driver or profile which produces an output according to CIE R8-09.*

**Advantages of Output Linearization:**

– Device-independent hue output (CIE R1-47).
– Linear relation between *rgb** and CIELAB data.
– No loss of visual information for 16 step colour series on different colour devices.
– remark: for *rgb** colour specification in device-independent *RGB** colour space see CIE R1-57 & http://www.iso.org/scit (open document N275).

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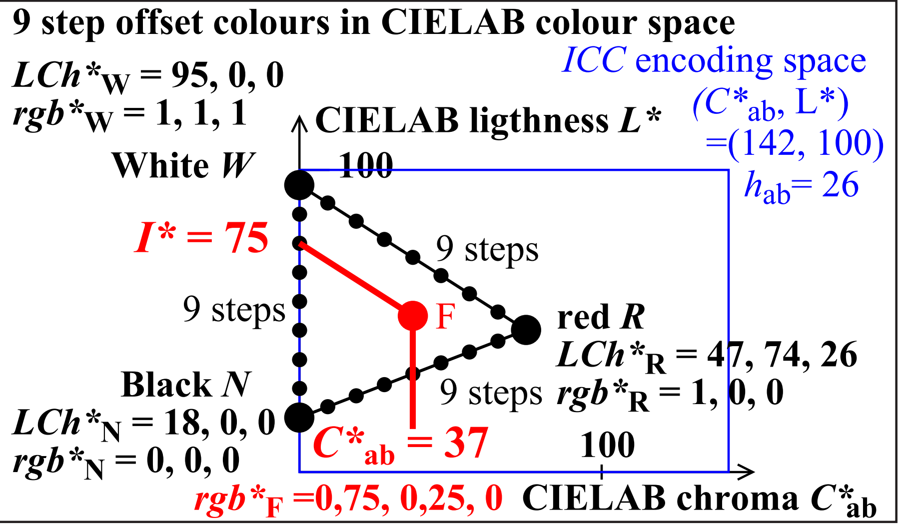
**Fig. 5: Output Linearization according to CIE R8-09 to realize user wishes of DIN 33872-X**
An automatic device company output, for example by the method of CIE R8-09, or profiles produced for users by *linearization companies* may solve the user wishes of DIN 33872-X.

**Offset *rgb** input data and *LCh** output data**

| Color | *rgb** | *LCh** |
|---|---|---|
| $R_e$ elementary red | **1 0 0** | 47, 74, **26** |
| $Y_e$ elementary yellow | **1 1 0** | 86, 88, **92** |
| $G_e$ elementary green | **0 1 0** | 53, 57, **164** |
| $B_e$ elementary blue | **0 0 1** | 42, 45, **271** |
| *N* black | **0 0 0** | 18, **0, 0** |
| *W* white | **1 1 1** | 95, **0, 0** |

*(data according to test chart DIN 33872-2, p. 9-12)*
*(CIELAB hue angles according to CIE R1−47)*

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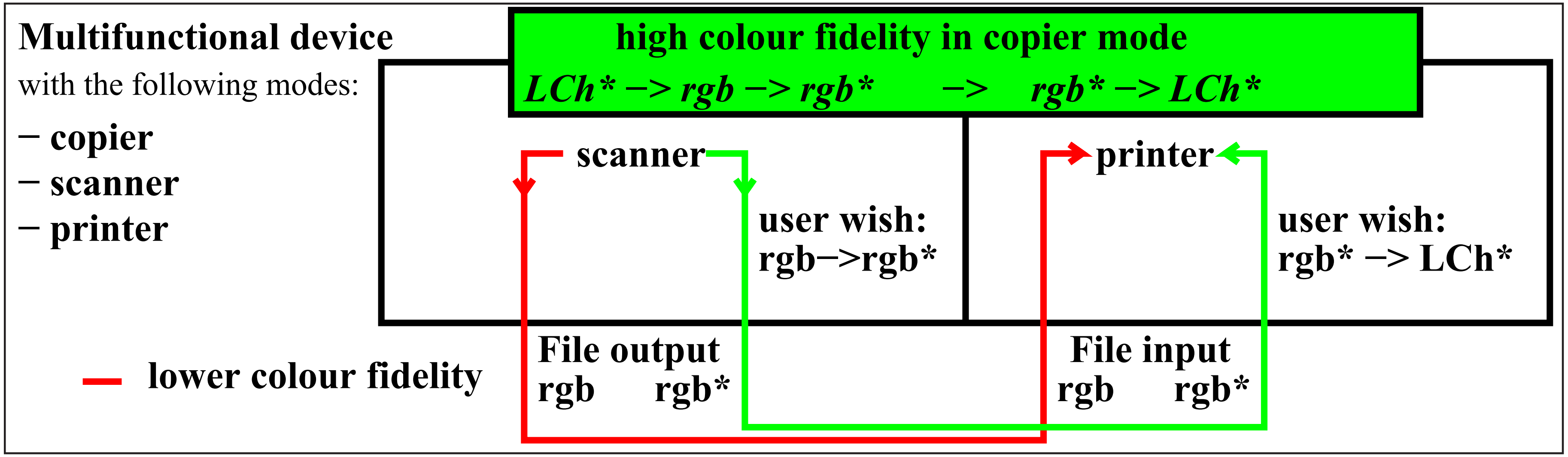


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**Fig. 6: *ICC* rectangle and *rgb** triangle coding (top) and *rgb->rgb** transfer for scan devices**

Fig. 6 compares the *ICC* rectangle with the *rgb** triangle coding. According to CIE 168 the *sRGB* triangle space fills 20% of the ICC coding space. The coding accuracy increases by *rgb** by a factor 5 which for example increases colour fidelity of multifunctional devices in scanning mode.

| **Development of relative device and visual colour spaces *sRGB* & *RGB**** | | |
|---|---|---|
| **Time scale** | **IEC: Display manufacturers and standard documents** | **CIE: Visual observers and standard documents** |
| 1950−1999 | **Colour television and colour CRT devices**<br><br>4 display device colours $RYGB_d$<br>CIELAB hue angles = 40, 102, 136, 306 | **Visual colour space CIELAB 1976**<br>$L^*, C^*_{ab}, h_{ab} = \mathbf{g_n}\,(XYZ)$ (CIE metric)<br>( $\mathbf{g_n}$ = nonlinear function)<br>Color rendering CIE 13<br>Test colours no. 9 to 12 = *RYGB*<br>CIELAB hue angles = 26, 92, 162, 272 |
| 2000−2009 | ***sRGB* (display) standard**<br>$rgb = \mathbf{f_n}\,(XYZ, L^*)$ (sRGB metric?)<br>( $\mathbf{f_n}$ = nonlinear function)<br>(the sRGB metric allows much freedom)<br>IEC 61966−2−1 (sRGB standard)<br>IEC 61966−X | ***relative device* CIELAB space**<br>$rgb^*_d = \mathbf{f_l}\,(L^*, C^*_{ab}, h_{ab,d})$ (CIE metric)<br>( $\mathbf{f_l}$ = linear function, d = any device)<br>DIN 33866−1 to 5, JIS 6933<br>ISO/IEC 15775, ISO/IEC TR 24705<br>ISO 9241−306:2009 Linearized display output for 8 room light reflections |
| 2010−20?? | IEC 61966−1 to 12 | ***relative elementary* CIELAB space**<br>CIE R1−47: CIE 13, no. 9 to 12 = $RYGB_e$<br>$rgb^*_e = \mathbf{g_l}\,(L^*, C^*_{ab}, h_{ab,e})$ (CIE metric)<br>( $\mathbf{g_l}$ = linear function, e = elementary)<br>DIN 33872−1 to 6<br>−> ISO/CIE ? |

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**Fig. 7: Development of *relative device* space *sRGB* and *visual* colour space *RGB****

Fig. 7 shows that only the *RGB** metric is visual, in contrast to *sRGB*. Output linearization for office displays is allready used at work places in ISO 9241-306:2009 and not a new requirement

**Posible time scale related to international standardization of DIN 33872−X**
*possible standard and market developments between 2009 and 2024*

**Time scale for Standard Development**

| 2009 | 2014 | 2019 | 2024 | |
|---|---|---|---|---|
| ● | | | | DIN 33872−1 to −6:2009 User wish satisfied (Yes/No)? |
| ● | | | | CIE R1−47:2009 with the four hue angles $h_{ab,e}$ = 26, 92, 162, and 271. |
| | ● | | | CIE R1−57:2013 with *rgb** coordinates for *Ostwald* colours. |
| | ● | | | CIE R8−09:2014? (long version) for output linearization of devices. |
| | | ● | | CIE Technical Report with four elementary hue angles $h_{ab,e}$ of $RYGB_e$. |
| | | ● | | CIE Technical Report with definition of visual *rgb** colour coordinates. |
| | | | ● | ISO/CIE Standard with four elementary hue angles $h_{ab,e}$ of $RYGB_e$. |
| | | | ● | ISO/CIE Standard with definition of the visual *RGB** colour space. |
| | | | ● | ISO/CIE Standards: Output Linearization for displays, offset, printers. |
| | | | ● | ISO/CIE Standards: Input Linearization for scanners and cameras. |

**Time scale for Market Development with the motivation of fast solutions for user wishes**

1. Use of DIN-test charts and the above CIE documents within new *rgb** workflow.
2. Production of *reference* test charts with CIE R8−09 for many output devices.
3. Use of *reference* test charts for colour calibration of scanners and cameras.
4. Optimizing the output-input-output linearization loop for *rgb** colour management.
5. 5-fold higher accuracy (triangle coding) for *Profile Connection Space RGB** instead of *CIELAB*.

| 2009 | 2014 | 2016 | 2018 | |
|---|---|---|---|---|
| | ● | | | Device Output Linearization, and production of test charts *rgb−>rgb**. |
| | | ● | | Linearized *reference* test charts for calibration of scanners & cameras. |
| | | ● | | Colour workflow loop output-input-output and calculation of accuracy. |
| | | | ● | Advantages & disadvantages of *rgb**; smooth transfer $rgb_{sRGB}$−>*rgb**. |

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**Fig. 8: Possible time scale related to international standardization of DIN 33872-X**
Fig. 8 include a possible time scale for a standard and market development. The market demand may not wait for new standards. Some mouse clicks seem to solve the user wishes.

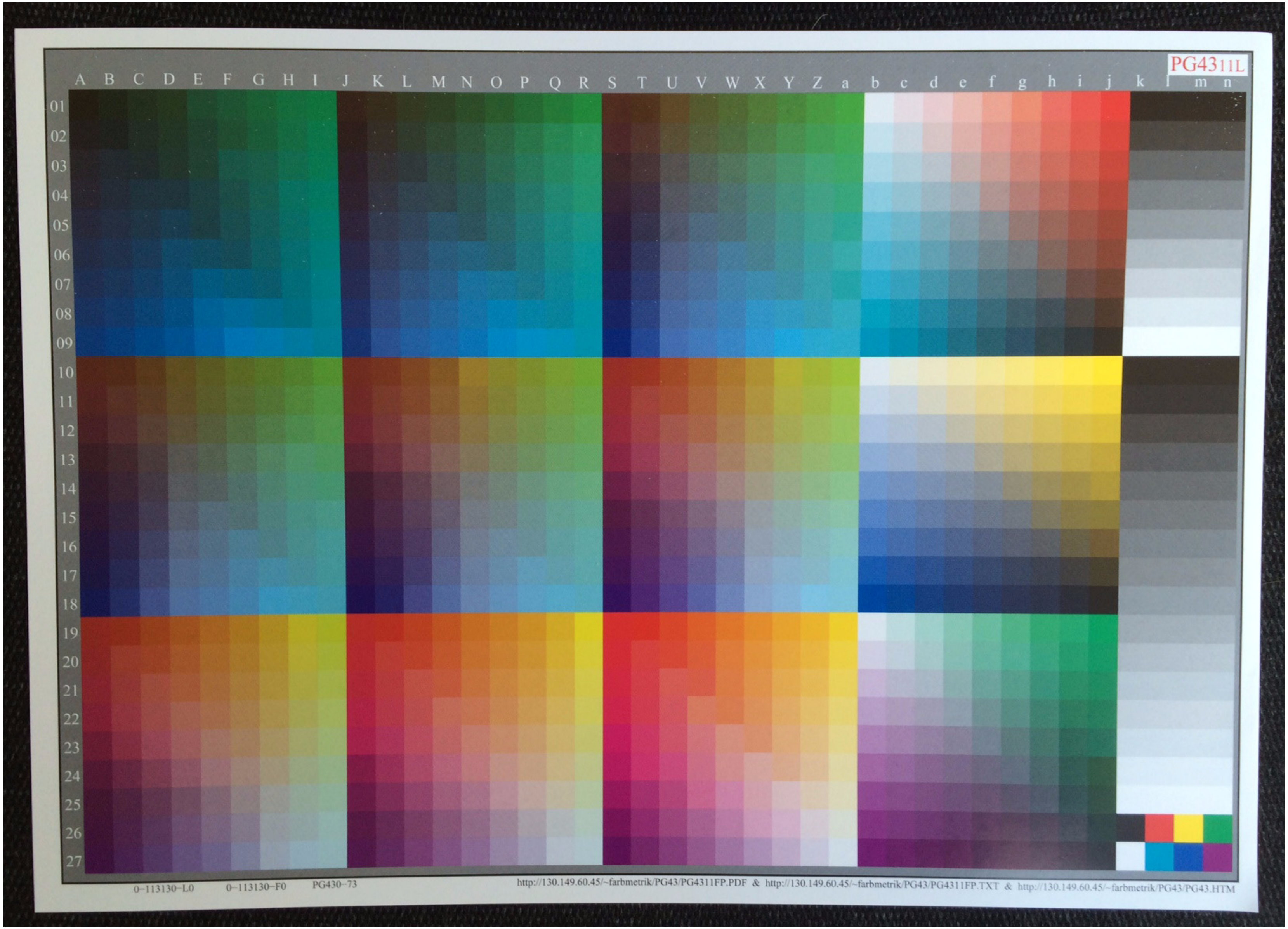


**Fig. 9: *iPhone* foto of the *rgb** linearized output in offset, Plate PG4311L, German edition**
Fig. 9 includes the 729 colours with known *rgb** and $L^*C^*_{ab}h_{ab}$ values in CIELAB. One can get 729 foto *rgb* data by many software. Use of a profile *rgb -> rgb** produces the original file colours.

**Output − Input − Output: A loop for colour fidelity with the visual *rgb** and *LCh** CIELAB data**

**Produce a reference test chart with 729 CIELAB colours**
or buy one, or use PG4311L of *Colour and Colour Vision,*
see http://130.149.60.45/~farbmetrik/color

**Example: Linearized output in offset print**

Output linearization produces for 729=9·9·9 *rgb* input data the 729 *LCh** CIELAB output colours.

Produce the linearized output of page 2 of the file
http://130.149.60.45/~farbmetrik/RE68/RE68L0NP.PDF

Use document CIE R8−09 for output linearization, see for more information
http://130.149.60.45/~farbmetrik/outlin or
http://farbe.li.tu−berlin.de/outlin

**Offset *rgb** data input and *LCh** data output**

| **Color** | ***rgb**** | ***LCh**** |
|---|---|---|
| $R_e$ elementary red | **1 0 0** | 47, 74, **26** |
| $Y_e$ elementary yellow | **1 1 0** | 86, 88, **92** |
| $G_e$ elementary green | **0 1 0** | 53, 57, **164** |
| $B_e$ elementary blue | **0 0 1** | 42, 45, **271** |
| *N* black | **0 0 0** | 18, **0, 0** |
| *W* white | **1 1 1** | 95, **0, 0** |

*(data according to test chart DIN 33872-2, p. 9-12)*

**Use reference test chart with 729 CIELAB colours**

Colour scanners or cameras produce 729 *rgb* data.

Transfer the 729 *rgb* data to the 729 *rgb** data.

After the linearized input the 729 colour data *rgb** may be used again for the linearized output.

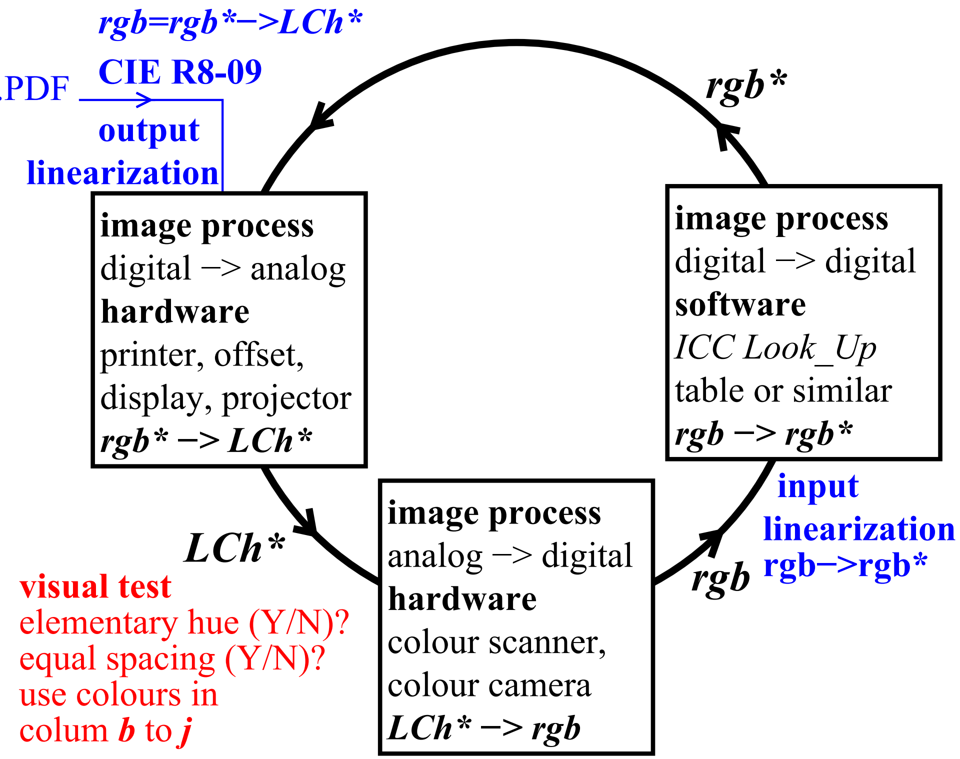


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**Fig. 10:** Output - Input - Output: A loop for colour fidelity with the visual *rgb** and *LCh** data
Fig. 10 includes available information for the *calibration* of colour *scanners* and *cameras*. A reference test chart in offset (PG4311L) is in the German version of an available booklet.

| **Agreement *(Y/N)* of CIELAB $h_{ab}$ with IEC 61966-2-1 and CIE R1-47** | | | | | |
|---|---|---|---|---|---|
| | **reference: device colours** $R_{d,sRGB}$ | $Y_{d,sRGB}$ | $G_{d,sRGB}$ | $B_{d,sRGB}$ | **NOTES** visual standard deviation $v_{SD}$ |
| **definition for display output in IEC 61966−2−1** | 40 +/− 4<br>40 +/− 8 | 103 +/− 4<br>103 +/− 8 | 136 +/− 4<br>136 +/− 8 | 306 +/− 8<br>306 +/− 16 | 1 x $v_{SD}$<br>2 x $v_{SD}$<br>data see [1], Tab. B.2 |
| **measurement of printer output *rgb* in file** | 34 *N*(−2)<br>34 ***Y*** | 100 ***Y***<br>100 ***Y*** | 146 *N*(+8)<br>146 *N*(+2) | 264 *N*(−34)<br>264 *N*(−26) | 1 x $v_{SD}$; 1 x ***Y***<br>**2 x $v_{SD}$; 2 x *Y***<br>data see [1], Fig. 32 |
| **measurement of printer output *cmy0* in file** | 34 *N*(−2)<br>34 ***Y*** | 100 ***Y***<br>100 ***Y*** | 153 *N*(+15)<br>153 *N*(+9) | 300 ***Y***<br>300 ***Y*** | 1 x $v_{SD}$; 2 x ***Y***<br>2 x $v_{SD}$; 3 x ***Y***<br>data see [1], Fig. 33 |
| | **reference: elementary colours** $R_e$ | $Y_e$ | $G_e$ | $B_e$ | **NOTES** visual standard deviation $v_{SD}$ |
| **definition for any output in CIE R1−47** | 26 +/− 4<br>26 +/− 8 | 92 +/− 4<br>92 +/− 8 | 162 +/− 4<br>162 +/− 8 | 272 +/− 8<br>272 +/− 16 | 1 x $v_{SD}$<br>2 x $v_{SD}$<br>data see CIE R1−47 |
| **measurement of printer output *rgb* in file** | 34 *N*(+4)<br>34 ***Y*** | 100 *N*(+4)<br>100 ***Y*** | 146 *N*(−12)<br>146 *N*(−8) | 264 *N*(−4)<br>264 ***Y*** | 1 x $v_{SD}$; 0 x ***Y***<br>**2 x $v_{SD}$; 3 x *Y***<br>data see [1], Fig. 32 |
| **measurement of printer output *cmy0* in file** | 34 *N*(+4)<br>34 ***Y*** | 100 *N*(+4)<br>100 ***Y*** | 153 *N*(−5)<br>153 *N*(−1) | 300 *N*(+20)<br>300 *N*(+12) | 1 x $v_{SD}$; 0 x ***Y***<br>2 x $v_{SD}$; 2 x ***Y***<br>data see [1], Fig. 33 |

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**Fig. 11:** Agreement (Y/N) of CIELAB hue angle $h_{ab}$ with IEC 61966-2-1 and CIE R1-47
If *rgb* data are in the file, then the output of an example printer of a leading printer company agrees for blue more with the hue angle of CIE R1-47 ($h_{ab}$=272) compared to IEC 61966-2-1.

# References

CIE 15:2008, Colorimetry

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

CIE R1-47:2009, Hue angles of elementary colours, and CIE R1-57:2012, Border between luminous and blackish colours, see for download under MINUTES & REPORTS http://div1.cie.co.at

CIE R8-09:2014, Output Linearization for printers and displays - Reportership Report, under CIE processing (Sept. 2014), for CIE Division 8 members see CIE COLLTOOL

ISO EN DIN 9241-306:2009, Ergonomics of human system interaction – Part 306: Field Assessment methods for electronic visual displays

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

ISO 15076-1:2011, Image technology colour management -- Architecture, profile format and data structure -- Part 1: Based on ICC.1:2004-10

ISO/IEC 15775:2006, Information Technology – Office machines – Method of specifying image reproduction of colour copying machines by analog test charts – Realization and application, for accuracy of the test chart see *Ito, Takashi* (2004), JBMIA, Introduction of JIS X 6933 & ISO/IEC 15775-compliant Color Test Charts for Copying Machines of ISO/IEC JTC1/SC28, see the URL (2.1 MByte, 35 pages), http://www.ps.bam.de/info04/ITO04.PDF

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 22028-1:2007, Photography and graphic technology -- Extended colour encodings for digital image storage, manipulation and interchange -- Part 1: Architecture and requirements (see in addition NWI proposal ISO 17231-3:Consideration scene referred imaging applications)

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

DIN 33872-1 to -6:2010, Information technology - Office machines - Method of specifying relative colour reproduction with YES/NO criteria - Part 1: Classification, terms and principles - Part 2: Test charts for output properties - Testing of discriminability of 5 and 16 step colour series - Part 3: Test charts for output properties - Testing of equality for four equivalent grey definitions and discriminability of the 16 grey steps - Part 4: Test charts for output properties - Testing of equality for two equivalent colour definitions with 5 and 16 step colour series- Part 5: Test charts for output properties - Testing of elementary hue agreement and hue discriminability - Part 6: Test charts for output properties - Testing of the equivalent spacing and of the regular chromatic spacing. For the test charts according to DIN 33872-1 to -6 see http://www.ps.bam.de/33872E, For an english version of all parts, see http://www.iso.org/scit, download documents N 183 to 189.

Richter, Klaus (2008), Ergonomic color image technology with high visual and material efficiency based on elementary (unique) hues, pages 259-264, Sixteenth Color Imaging Conference, Final Program and Proceedings 2008, Nov. 10-15, Portland, Oregon, USA

Richter, Klaus (2009), Output Linearization in CIELAB for visual displays with 8 different Luminance reflections of indoor illuminants, Light and Lighting Conference with special emphasis on LEDs and Solid state lighting, Proceedings, Budapest 2009, 10 pages, no. PwDaS-39 on CD

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