Linear CIELAB – cmy* Color Workflow for the Color Office Devices and based on ISO/IEC 15775 and DIS ISO/IEC 19839-1 to 4

Klaus RICHTER, Prof. Dr.
Federal Institute of Materials Research and Testing (BAM)
Head of Project Group: Visual Methods and Image Reproduction for NDT
Unter den Eichen 87
D-12200 Berlin, Germany
email: klaus.richter@bam.de
internet: http://www.ps.bam.de or http://www.ps.bam.de/BAMCMY.PDF

Abstract

Four analog **ISO/IEC-test charts** according to **ISO/IEC 15775** are designed for the test of colour copiers. The International Standard ISO/IEC 15775 includes the LAB* (CIELAB) data and many cmy* data of the colours used in the test charts. The digital ISO/IEC-test chart files include mainly cmy* colour data but also LAB* data for the CIE-test colours and are available on the recommended web servers. The files have been used for the production of the ISO/IEC-test charts in Germany and Japan.

This paper uses **either *LAB** or *cmy** data in the digital files** and still the colour output is identical. With additional Output Linearisation (OL) the 16 step colour series are produced with equal spacing in CIELAB. The 16 step series are produced by linearized devices with an accuracy of less than 3 CIELAB units intended for the office environment. **The CIELAB colour difference is often reduced by a factor 3 to 5** for the 16 step series on the surface of the colour solid. For the CIE-test colours which are mainly located inside the colour solid the accuracy seems to be similar compared to the accuracy of the ISO/IEC-test chart productions in offset which is near 10 CIELAB units.

The **user requirement for a linear relationship between CIELAB data and cmy* data** is realised. This **linear CIELAB – cmy* colour workflow** for offices seems to be both simple and effective. The yellowness data y*=0.5 will produce a yellow in CIELAB space visually in the middle between white W and yellow Y. This is similar for the other series, e. g. white – black. Therefore there is agreement with the basic user requirement. The linear relationship between cmy* and CIELAB has many advantages for colour image technology. Slightly different output colours compared to the intended CIELAB colours can be corrected in the digital input file by using the linear CIELAB difference of the output and the intended CIELAB colour. The CIELAB – cmy* workflow is **linear** which may be compared to the **nonlinear** rgb workflow of the International Standards IEC 61966-X. The spacing of the rgb coordinates of the Standards IEC 61966-X is incompatible with the CIELAB spacing [7.1].

1. Introduction

The International Standard ISO/IEC 15775 Information technology – Office machines – Machines for colour image reproduction - *Method of specifying image reproduction of colour copying machines by analog test charts – Realisation and application* was prepared by DIN (as DIN 33866-2). DIN 33866-2 was published in 1998 and ISO/IEC 15775 in 1999 [2].

The committees ISO/IEC JTC1/SC28 and DIN-NI-28: Information technology, Office equipment have worked together to develop the International Standard ISO/IEC 15775 [2]. The German national standards DIN 33866-1 to 5 [1a], ISO/IEC 15775 and the Draft International Standards DIS ISO/IEC 19839-X [1b] are based on equivalent colour series. Both use **digital** and **analog** test charts and the same layout. Fig. 1 and 2 show the relationship of these standards and draft standards.

New colorimetric technologies of the BAM have been used to produce the first set of four DIN-test charts in offset printing (3600 dpi) which are in application for colour devices (for example copiers, printers, scanners and monitors). The first production of (Asian) ISO/IEC-test charts according to ISO/IEC 15775 have been produced in Japan by JBMA (Japan Business Machines Makers Association). In applications the devices including software are used for ISO/IEC-test chart input and output in three different combinations **analog - analog** (copiers), **digital - analog** (printers, monitors) and **analog - digital** (scanners, Photo-CD-systems), compare Fig. 1 and 2.

Input	Output	Input and output media and applications			Standard
		Input media	**Output media**	**Application**	**or Draft**
-	**-**	**-**	**-**	**Basis**	**ISO/IEC 19839-1**
analog	**analog**	ISO/IEC-test chart (hardcopy)	Hardcopy	**Copier**	**ISO/IEC 15775**
analog	**digital**	ISO/IEC-test chart (hardcopy)	File	**Scanner**	**ISO/IEC 19839-3**
digital	**analog**	ISO/IEC-test chart (file)	Hardcopy Softcopy	**Printer** **Monitor**	**ISO/IEC 19839-2** **ISO/IEC 19839-4**

MMTNKIE

Figure 1: Analog and digital ISO/IEC-test charts according to ISO/IEC 15775 and DIS ISO/IEC 19839-1 to -4.

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 Softcopy	**Printer** **Monitor**	**DIN 33866-3** **DIN 33866-5**

MMTNKDE

Figure 2: Analog and digital DIN-test charts according to DIN 33866-1 to -5

New colorimetric technologies of Germany and Japan have been used to produce the four DIN- and ISO/IEC-test charts in offset printing (3600 dpi) which are in application for colour devices now.

There are flat area lamps with the chromaticity of daylight D65, a luminance of 10 000 cd/m^2 and sizes between 15 and 21 Inches on the market. A transparent ISO/IEC-test chart on top of this equipment defines a reference monitor for comparison with display output.

2. Digital and analog ISO/IEC-test charts and reproduction

2.1 General

The **digital** and **analog** test charts for the assessment of copier outputs are defined in ISO/IEC 15775. The original digital file format *PostScript* (PS) is transformed to different equivalent formats, e. g. *Portable Document Format* (PDF) and these files with the intended colours have been used for the production of the analog ISO/IEC-test charts in Germany and Japan. According to ISO/IEC 15775 the **digital** ISO/IEC-test charts (digital files) are on the web servers, see the URL: http://www.ps.bam.de. **Analog** ISO/IEC-test charts according to ISO/IEC 15775 have been produced in reflectance and transmittance mode for D65.

2.2 Content of test charts

There are two achromatic ISO/IEC-test charts.The two chromatic ISO/IEC-test charts are defined by the three primary colours CMY and the three mixture colours OLV of the primary colours. Fig. 3 shows one chromatic ISO/IEC-test chart. The test chart includes a frame and picture area with different test elements like Siemens-stars, Landolt-rings and line screens. All colours in the standard are defined by CIELAB data based on the CIELAB coordinates of offset printing for D65 [3]. This paper will describe the methods to use the LAB* (CIELAB) data which are transformed to cmy* data in the test chart files.

2.3 Content of chromatic ISO/IEC-test chart no. 4 with *OLV*-colours

Figure 3: Frame and picture area of ISO/IEC-test chart no. 4 according to ISO/IEC 15775
Fig. 3 shows the layout of one of the four ISO/IEC-test charts.

Basic test colour name	Intended CIELAB data CMYN (ISO 2846-1) Reference (r)			Intended CIELAB data RGB (ITU-R BT.709-2) Output (o)			CIELAB differences of test colours Difference (o-r)			CIELAB-test colour difference
	L^*_r	a^*_r	b^*_r	L^*_o	a^*_o	b^*_o	ΔL^*_{o-r}	Δa^*_{o-r}	Δb^*_{o-r}	ΔE^*_{ab}
C	58.62	−30.62	−42.74	86.88	−46.17	−13.56	28.26	−15.54	29.18	43.5
M	48.13	75.2	-6.79	57.3	94.35	−20.7	9.17	19.15	−13.9	25.38
Y	90.37	−11.15	96.17	92.66	−20.7	90.75	2.29	-9.54	-5.41	11.22
O	47.94	65.31	52.07	50.5	76.92	64.55	2.56	11.61	12.48	17.24
L	50.9	−62.96	36.71	83.63	−82.76	79.9	32.73	−19.79	43.19	57.69
V	25.72	31.45	−44.35	30.39	76.06	−103.59	4.67	44.61	−59.23	74.31
N	18.01	0.5	-0.46	1.57	0.0	0.0	−16.43	-0.49	0.47	16.45
W	95.41	-0.98	4.76	95.41	0.01	0.01	0.0	1.0	-4.74	4.85
Average CIELAB colour difference:								$\Delta E^*_{ab,m}$ =		*31.3*

INFDE031:DETA131.PS 2x2

Table 1: Intended printing (PR) and television (TV) colours and comparison
Fig. 3 shows a chromatic test chart and Table 1 shows the printing colours compared to the television colours defined in ITU-R BT709.2 for CIE-standard illuminant D65 and the 2° CIE standard observer. Table 1 shows the differences between the colours $CMYOLVNW_{PR}$ and $CMYOLVNW_{TV}$. There are differences up to ΔE^*_{ab} = 74 for the colour violet blue *V* (called blue *B* in television) and the average difference is $\Delta E^*_{ab,m}$ = 31,5. This is about ten times the difference which a user accepts as tolerance. The user often wishes a colorimetric reproduction and then the colour properties of the different devices must be linearized. This linearisation is often sufficient for a colorimeric reproduction in offices or serves as setup-state for colour management. In the following the linearized reproduction of the 16 step

equidistant colour series according to CIELAB will be described. The series between the colour White W and the six colours CMYOLV (Fig. B4 and D4) as well as the series between White W and Black N and the CIE-test colours (Fig. B3) will be managed. Either LAB* (CIELAB) or cmy* digital data can be used as input in the digital file. The reproduction tolerance seems to be within the agreed tolerances of 3 CIELAB units for the office environment for any office device and any computer operating system.

3. Reproduction processes analog – digital – analog

3.1 Analog - analog reproduction by a colour copier

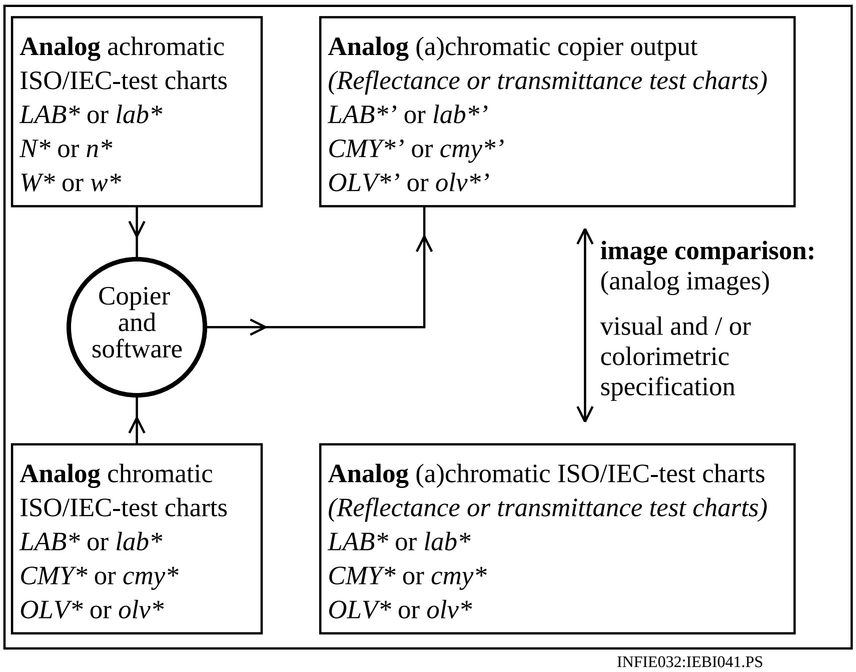


Figure 4: Colour output of the analog ISO/IEC-test charts on a colour copier

Fig. 4 shows the image comparison of the copier output with the original. Within the methods developed here it is possible to define the colours of the digital files with the different coordinate systems LAB* or CMY* data (absolute systems in capital letters) and lab* or cmy* data (relative systems in small letters). There are standard equations between the different coordinate systems defined in ISO/IEC 15775 and based on offset colours for D65. According to ISO/IEC 15775 and DIS ISO/IEC 19839-1 to 4 the device output of copiers, printers, scanners and monitors is compared with the reference. The reference may be analog (viewed colours as hardcopy or softcopy) or digital (as image file).

New CIELAB colour measurement devices with prices beginning as low as $500 (accuracy less than 3 CIELAB units) and new flat panel lamps (10000 cd/m^2) with transparent ISO/IEC-test charts on top allow to compare any colour device output visually or digital with the reference. There are new CIELAB cameras and scanners on the market which measure the image pixels in LAB*. In this paper we use the transformations between LAB* and cmy* defined in ISO/IEC 15775. So new technologies form the basis for the new Draft International Standards DIS ISO/IEC 19839-1 to -4. The author is editor of the different ISO/IEC standards in image technology and this paper describes the first time a LAB* – cmy* colour workflow for image technology based on ISO/IEC 15775.

This paper is therefore a further contribution to the many discussions in the committee ISO/IEC SC28 (Office Systems) during last three years and in the committee ISO SCIT (ISO Steering Committee for Image Technology). New discussions are determined for the ISO/IEC ballot resolution meeting (BRM) on DIS ISO/IEC 19839-X [1b] in October 2001. It is the wish as Editor to have as many countries as possible represented at this BRM. There are many conflicts between the user requirements and the image technology industry which had invested a lot in a device specific colour management solution based on the artifical luminous colours in Television. The spacing of the nonlinear coordinates rgb of this solution is incompatible with the CIELAB spacing. A comparison of the International Standards ISO/IEC 15775 and DIS ISO/IEC 18839 and IEC 61966-X is given in the paper [7.1].

3.2 Analog – digital reproduction by CIELAB scanners and cameras

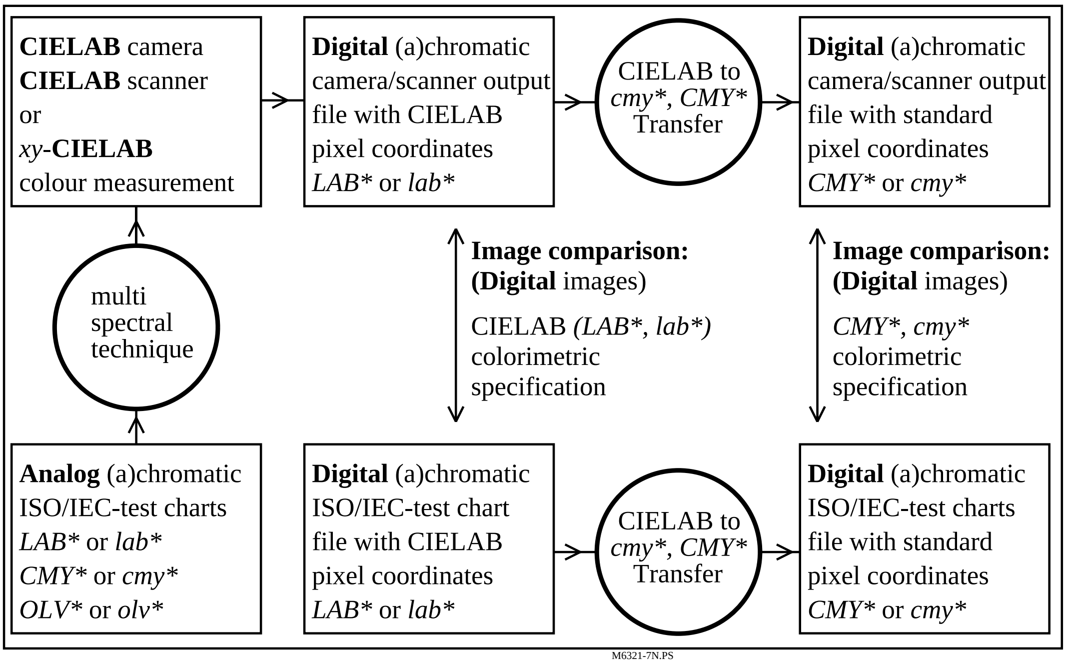


Figure 5: Ideal input scan with CIELAB cameras and CIELAB scanners as reference process

Fig. 5 shows the ideal scan process with CIELAB cameras or scanners. According to Fig. 5 a tool to transfer from the LAB* data to the cmy* data is very important. A solution will be described in the following. With this tool there are then different possibilities to compare the **digital** image files produced by CIELAB cameras or scanners with the **digital** files of the ISO/IEC-test charts. In Fig. 4 a similar comparison of the copier **analog** output with the **analog** reference ISO/IEC-test chart is given.

3.3 Digital – analog reproduction of PostScript by two nonlinear transforms

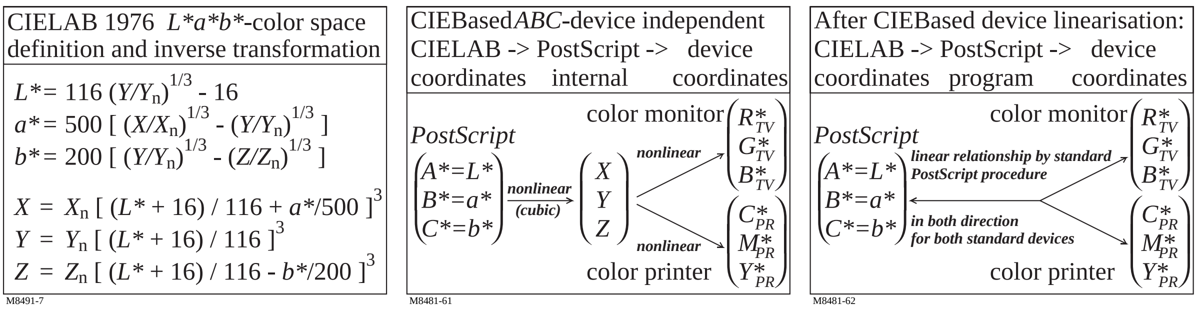


Figure 6: Digital – analog reproduction of PostScript by two nonlinear functions which are replaced by one linear function

Fig. 6 shows the mathematical relationship between the CIELAB 1976 data L*, a* and b* and the CIEXYZ 1931 data X, Y and Z (left). There is a CIE modification of the equation below Y=0,8 but such a low luminance factor Y data does not exist for reflective colours, e. g. black N has a luminance factor 2,5 which corresponds to the lightness L*=18. The CIEXYZ system is used as internal reference system in the *Adobe PostScript* programming language [6]. The middle figure shows the use of the CIE **nonlinear cubic transformation** from LAB* to XYZ and **another nonlinear transformation** between XYZ and the monitor device coordinates here called RGB* instead of OLV*. Such nonlinear transformations between XYZ and RGB* are used in the International Standards IEC 61966-X [7.1]. The RGB* spacing is incompatible with the CIELAB spacing and the visual perception. ISO/IEC 15775 and DIS ISO/IEC 19839-X use the much more simple and effective way to define the **device coordinates CMY* or cmy* and OLV* or olv* (RGB* or rgb*) as linear function of LAB*** (right). The use of two different nonlinear functions in IEC 61966-X and artificial rgb coordinates lead to basic problems of these standards discussed elsewhere [7.1]. The standard groups dealing with image technology in Germany have voted No on the RGB printer standard IEC 61996-7-1 in 2001. The US standard committee was unable to vote at all because of large disagreement of the different standard members on this IEC standard.

This paper use either the LAB* or cmy* coordinates in the digital files. A transformation to XYZ with the CIE equations is at any time possible.

CIEBased*ABC*-color space transformation *ABC** -> *XYZ*
CIELAB part 1: *ABC** -> *LMN**

A = DecodeA^* = {16 add 116 div}
B = DecodeB^* = {500 div}
C = DecodeC^* = {200 div}

$$\begin{pmatrix} L^* \\ M^* \\ N^* \end{pmatrix} = \begin{pmatrix} 1 & 1 & 0 \\ 1 & 0 & 0 \\ 1 & 0 & -1 \end{pmatrix} * \begin{pmatrix} A \\ B \\ C \end{pmatrix}$$

M8510-1

CIEBased*ABC*-color space transformation *ABC** -> *XYZ*
CIELAB part 2: *LMN** -> *XYZ*

L = DecodeL^* = {3 exp}
M = DecodeM^* = {3 exp}
N = DecodeN^* = {3 exp}

$$\begin{pmatrix} X \\ Y \\ Z \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix} * \begin{pmatrix} X_n & L \\ Y_n & M \\ Z_n & N \end{pmatrix}$$

M8510-2

CIELAB 1976 *L*a*b**-color space

```
[/CIEBasedABC<<  %Dict PostScript Level 2
  /MatrixABC [1 0 0 0 1 0 0 0 1]  %default
  /DecodeABC [{16 add 116 div} bind
     {500 div} bind  {200 div} bind ]
  /RangeABC [0 100 -128 127 -128 127] %Lab*
  /MatrixLMN [0.9505 0 0 0 1 0 0 0 1.0890]
  /DecodeLMN [{3 exp} {3 exp} {3 exp}]
  /RangeLMN [ 0 0.9505 0 1 0 1.0890] %D65
  /WhitePoint [0.9505 1 1.0890] %D65
  /BlackPoint [0 0 0] % default
>>]setcolorspace
```

M8510-3

Figure 7: PostScript transformation between CIELAB and CIEXYZ and corresponding PostScript Dictionary

Fig. 7 shows the transformation between the three coordinates LAB* which are called ABC* in PostScript and XYZ in two steps (left and middle). The transformations are included in the standard PostScript dictionary (right). The default data are shown. A change of the default data. e. g. the white point, the black point and the luminance factor Y range (2.5% to 88.6% for offset) lead to problems. The different PostScript devices (and the Adobe Acrobat Distiller) react very different, ignore the settings or produce an output error. Therefore we use for all the following outputs the default data of Fig. 7 (right) which produce according to our experience an output on every device.

The default data produce instead of the white output a slightly greyish colour and instead of the black colour a dark gray. This is **not** important as in this paper the LAB* data of the PS program code

LAB* setcolor

are transferred to the three cmy* data including zero for black N by

cmy0* setcmykcolor

The urgent need for this transformations comes from the new CIELAB scanners and cameras which “measure” the colours and store the LAB* data for the image pixels, compare Fig. 5. About 10 papers dealing with such devices were presented in June 2001 at the last AIC (International Colour Association) colour conference in Rochester, USA. Either for the spectral range between 400 and 700nm about 16 liquid crystal filters were used in front of black and white cameras or more than 3 colour filters (e. g. 6, 9, 12) were used with conventional scanners or cameras to produce or calculate LAB* pixel data. For instance the famous London National Galery has recently stored most of their paintings in LAB* colour space which such kind of scanners [8].

4. Linear scales in ISO/IEC-test charts according to ISO/IEC 15775

The produced colours series of ISO/IEC-test charts are **linear** in CIELAB colour space, e. g. between White *W* and cyan blue *C* for the 16 equally spaced steps both in *L** (lightness) and *C** (chroma).

Figure 8 shows the main six different colour series *(left)* and the additional series White - Black in the colour triangle *(right)*. All the series have been produced in analog ISO/IEC-test charts according to ISO/IEC 15775 by both DIN in Germany and JBMA in Japan.

For the **analog** test chart production the **digital** ISO/IEC-test charts are on recommended web servers which allows an output on the different devices such as printers and monitors. Some manufacturers of colour devices have changed their firmware (or the software in the device) to reach a linear input-output relationship for printers, scanners and others, if the digital and analog ISO/IEC-test charts are used.

Devices with approximately linear properties reproduce often the intended colours and then there is no need for colour management systems. In applications the setup-state for colour management us defined by linearized devices for both the analog - digital (e. g. scanners) input part and the digital - analog (e. g. printers) output part.

Therefore it is of large importance to develop linear relationships. In another paper [7.7| we started to linearize the digital - analog output process and the input process and finally the whole process from the analog input (original scene) to the analog output (colorimetric reproduction of the original scene). The direct use of LAB* data and the output of colours located within the colour solid was not considered.

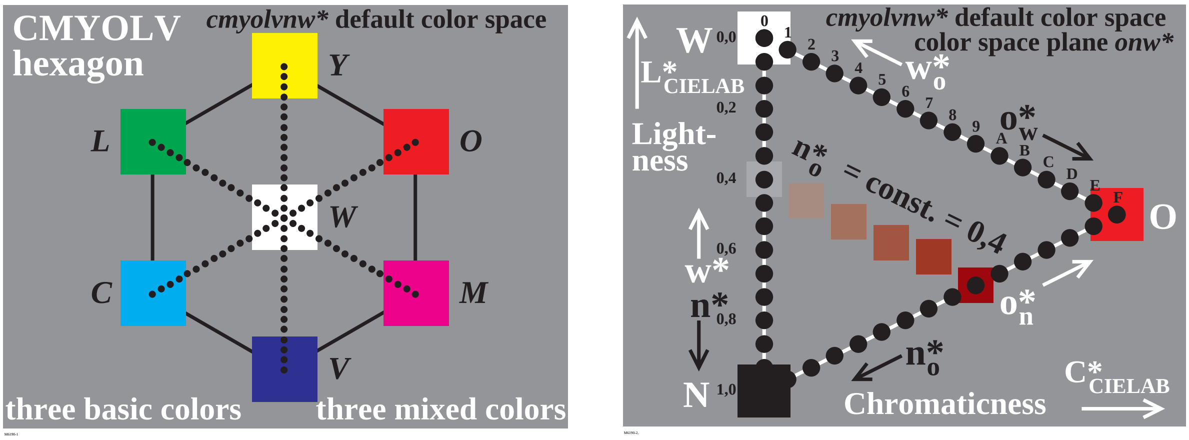


Figure 8: Hexagon of *CMYOLV* colours with 16 steps and colour triangle in the hue plane *N – O –W* with two 16 step series *W - O* and *W - N*

Figure 8 shows the main six different colour series *(left)* and in a hue plane the series White – Orange red (W – O) and White – Black (W – N) *(right)*.

The series between white and the six chromatic colours and black are often scaled very different. The intended output should be linearly related but often a more square (quadratic) relation and sometimes a square root relation appears by the output. The ideas of the International Standard ISO/IEC 15775 will now been applied to the printer, monitor and scanner area. In the following we will produce different model outputs and we will develop an automatic correction by the MTL (Measurement, Transfer and Linearisation) code. If we succeed to make the input – output relationship linear then it is possible to calculate any colour on the surface of the colour solid and inside the colour solid by linear equations.

5. Model output of 16 step LAB* colours and inverse correction.

N: w - x c**
LAB setcolor_to_*
cmy0 setcmykcolor*

	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F

Different colour coordinates of this colour series

Series N: w - x c** *Transfer: LAB*_to_cmy* and other colour coordinates:*

*LAB*PR18*	95.41	92.96	90.51	88.05	85.6	83.15	80.7	78.25	75.79	73.34	70.89	68.44	65.99	63.53	61.08	58.63
	-0.97	-2.95	-4.92	-6.9	-8.87	-10.85	-12.82	-14.8	-16.78	-18.75	-20.73	-22.7	-24.68	-26.66	-28.63	-30.61
	4.76	1.59	-1.56	-4.73	-7.89	-11.06	-14.23	-17.39	-20.56	-23.72	-26.89	-30.06	-33.22	-36.39	-39.55	-42.72
*cmy*wPR18*	0.0	0.07	0.13	0.2	0.27	0.33	0.4	0.47	0.53	0.6	0.67	0.73	0.8	0.87	0.93	1.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
*olv*nPR18*	1.0	0.93	0.87	0.8	0.73	0.67	0.6	0.53	0.47	0.4	0.33	0.27	0.2	0.13	0.07	0.0
	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
*nru*PR18*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.07	0.13	0.2	0.27	0.33	0.4	0.47	0.53	0.6	0.67	0.73	0.8	0.87	0.93	1.0
	b0.69r	g0.55b	g0.55b	g0.55b	g0.55b	g0.55b	g0.55b	g0.55b	g0.55b	g0.55b	g0.55b	g0.55b	g0.55b	g0.55b	g0.55b	g0.55b
*wte*PR18*	1.0	0.93	0.87	0.8	0.73	0.67	0.6	0.53	0.47	0.4	0.33	0.27	0.2	0.13	0.07	0.0
	1.0	1.03	1.07	1.1	1.13	1.17	1.2	1.23	1.27	1.3	1.33	1.37	1.4	1.43	1.47	1.5
	2.57	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

File http://www.ps.bam.de/DE48/X10/X11E00NP.PS/.PDF *for similar files, see http://www.ps.bam.de/DE48/DE48.HTM*

Part of Figure B4 of the ISO/IEC-test charts according to ISO/IEC 15775 and DIS ISO/IEC 19839-1 to 4

Figure 9: 16 step cyan series of Fig. B4 of the ISO/IEC-test charts and transformation from LAB* to cmy* and other *colour coordinates.

Fig. 9 and the following figures will show the 16 step series of the Fig. B4 of the ISO/IEC-test charts according to ISO/IEC 15775. Similar data for the other series are given by the URL in the figure.

The Red, Green, Blue device coordinates are called OLV*nTV18 and olv*nTV18 according to ISO/IEC 15775 and DIS ISO/IEC 19839-1 to -4. The other abbreviations are TV=Television and n=origin at black.

Fig. 9 shows examples of the different colour coordinates LAB*, cmy*, olv*, nru*, wte*. The coordinate system LAB* is device independent and the others are device dependent. The zero point of the device dependent system may be either white (index w) or black (index n). The abbreviation PR18 is used to indicate the print system (Offset) and the CIE lightness L*=18 for black is indicated. The standard transformations according to ISO/IEC 15775 are used and this transfer is defined by the **MTL code** (MTL=Measurement,Transfer and Linearisation) within the file. If we change in this MTL code one parameter ISYTEM from 0 to 1 then the device dependent television coordinates TV18 are calculated. If we change in this MTL code ISYSTEM to 2 then the actual device dependent transformations between LAB* and e. g. the printer cmy* are calculated. By default the printer lightness range, e. g. between L*=23 and 93, is equally spaced in the output according to the lightness L* of CIELAB.

The coordinates ncu* are similar to the coordinates of the Swedish natural colour system NCS. The coordinates used here are relative blackness n*, relative chromaticness c* and unique hueness u* which uses the letter r, g, b and j for the four unitary hues red, green, blue and yellow (j=french jeaune).

The coordinates wte* used here are relative whiteness w*, triangle lightness t* and eigencolour e*w. Relative whiteness w* and the eigencolour e*w are coordinates which are necessary for output linearisation inside the colour solid. The eigencolour e*w is equal to 1 for the whitish colours on the hexagon colour solid and equal to zero for the achromatic colours. For the colour with the eigencolour e*w equal to 1 the blackness n* is equal to 0. The blackness n* is equal 1 for the colour black N only but the eigencolour e*w is equal to 0 for the whole grey series between white W and black N.

Within the PostScript file the **MTL** (Measurement,Transfer and Linearisation) **code transfers from the LAB* to the cmy* coordinates** and to the other coordinates. For this the **MTL code uses a PostScript program code procedure LAB*_to_cmy***. This MTL PS code forms the file header and makes the calculations within the file if the device output is produced. There are at least three other methods to determine the output in the intended direction. This paper uses the **MTL code in the file header** but it can be stored instead in:

1. **The PS printer**
2. **The PostScript Printer Driver (PPD file)**
3. **The Adobe Acrobat Distiller Startup directory.**

The **MTL code** (MTL Measurement,Transfer and Linearisation) includes a Colour Measurement (CM) data table of the 128 standard colours, the Colour Coordinate Transfer (CT) code, the Input Linearisation (IL) code (for scanners) and the Output Linearisation (OL) code (for printers and monitors). In some output examples only parts of a general standard MTL code are used.

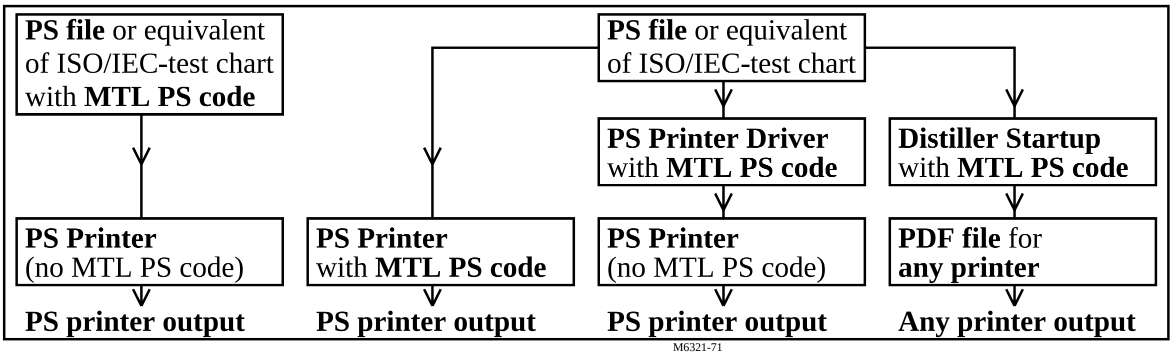


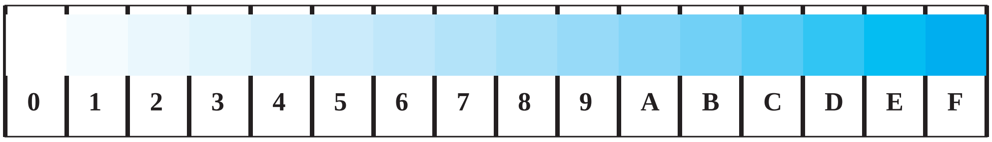
Figure 10: MTL (Measurement, Transfer and Linearisation) PS code and Printer Output

Fig. 10 shows the different possibilities how to use the MTL code within the CIELAB - cmy* colour workflow. The PS file of an ISO/IEC-test chart or only of one figure is used for output

Any PS file (according to our experience) which can be produced from **any application** on **any computer operating system** is **varied by this MTL code** in the same manner if this **MTL code is stored on one of the four different places:** the file, the PS printer device, the PPD file, the Distiller Startup, see Fig. 10

The Distiller Startup directory will add this code to the PS file to be distilled and will therefore change the produced PDF file. The produced PDF file will change the output on any device in the intended direction.

N: w* - x c* LAB* setcolor_to_ cmy0* setcmykcolor



*Different colour coordinates of this colour series; Model of square output *' (star-dash)*

Series N: w - x c** *Transfer: LAB*_to_cmy* and other colour coordinates:*

	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
LAB*'PR18	95.41	94.16	92.87	91.53	90.13	88.66	87.12	85.49	83.76	81.89	79.86	77.62	75.08	72.06	68.13	58.63
	-0.97	-1.97	-3.02	-4.1	-5.23	-6.41	-7.65	-8.96	-10.36	-11.86	-13.5	-15.3	-17.35	-19.78	-22.95	-30.61
	4.76	3.15	1.48	-0.24	-2.05	-3.94	-5.93	-8.04	-10.28	-12.68	-15.3	-18.2	-21.48	-25.38	-30.46	-42.72
cmy*'wPR18	0.0	0.0338	0.069	0.1055	0.1435	0.1834	0.2253	0.2696	0.3167	0.3674	0.4225	0.4834	0.5526	0.6346	0.7415	0.9996
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0001
olv*'nPR18	1.0001	0.9662	0.931	0.8945	0.8565	0.8166	0.7747	0.7304	0.6833	0.6326	0.5775	0.5166	0.4474	0.3654	0.2585	0.0004
	0.9999	0.9999	0.9999	0.9999	0.9999	0.9999	0.9999	0.9999	0.9999	0.9999	0.9999	0.9999	0.9999	0.9999	0.9999	0.9999
	1.0001	1.0001	1.0001	1.0001	1.0001	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9999
nru*'PR18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0001
	0.0001	0.0339	0.069	0.1055	0.1436	0.1834	0.2253	0.2696	0.3167	0.3674	0.4225	0.4834	0.5526	0.6346	0.7415	0.9996
	b0.69r	g0.55b	g0.55b	g0.55b	g0.55b	g0.55b	g0.55b	g0.55b	g0.55b	g0.55b	g0.55b	g0.55b	g0.55b	g0.55b	g0.55b	g0.55b
wte*'PR18	0.9999	0.9662	0.931	0.8945	0.8565	0.8166	0.7747	0.7304	0.6833	0.6326	0.5775	0.5166	0.4474	0.3654	0.2585	0.0004
	1.0002	1.017	1.0346	1.0528	1.0718	1.0918	1.1127	1.1348	1.1584	1.1837	1.2113	1.2417	1.2763	1.3173	1.3707	1.4997
	2.5722	1.002	1.0009	1.0005	1.0004	1.0003	1.0002	1.0001	1.0001	1.0001	1.0	1.0	1.0	1.0	1.0	0.9999

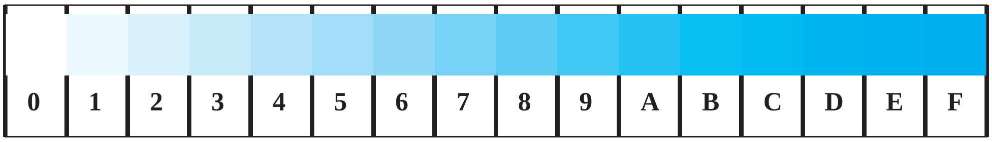
File http://www.ps.bam.de/DE48/X10/X21E00NP.PS/.PDF *for similar files, see http://www.ps.bam.de/DE48/DE48.HTM*

Part of Figure B4 of the ISO/IEC-test charts according to ISO/IEC 15775 and DIS ISO/IEC 19839-1 to 4

Figure 11: Cyan colours with transformation from the square (quadratic) LAB*' (star-dash) data to the cmy*' data.

Fig. 11 shows transformations from the square (quadratic) LAB*' (star-dash) data to the cmy*' data and to the data of other *'colour coordinates. It is assumed that the LAB*' (star-dash) data are defined by a square function. The nonlinear data are indicated using the red colour for the data output. If the accuracy is 0.01 units (2 digits) in cmy* then 4 digits are necessary in cmy*' both for either a square or square root model. Therefore 4 digits are used in the red data output here. One may found similar data for the three other series by the URL given in the figure.

N: w* - x c* LAB* setcolor_to_ cmy0* setcmykcolor



*Different colour coordinates of this colour series; Model of square output *' (star-dash) and correction by inverse square root input '* (dash-star)*

Series N: w - x c** *Transfer: LAB*_to_cmy* and other colour coordinates:*

	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
LAB*PR18	95.41	92.96	90.51	88.05	85.6	83.15	80.7	78.25	75.79	73.34	70.89	68.44	65.99	63.53	61.08	58.63
	-0.97	-2.95	-4.92	-6.9	-8.87	-10.85	-12.82	-14.8	-16.78	-18.75	-20.73	-22.7	-24.68	-26.66	-28.63	-30.61
	4.76	1.59	-1.56	-4.73	-7.89	-11.06	-14.23	-17.39	-20.56	-23.72	-26.89	-30.06	-33.22	-36.39	-39.55	-42.72
cmy*wPR18	0.0	0.07	0.13	0.2	0.27	0.33	0.4	0.47	0.53	0.6	0.67	0.73	0.8	0.87	0.93	1.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LAB*'PR18	95.41	90.67	86.26	82.17	78.41	74.98	71.87	69.09	66.64	64.51	62.72	61.25	60.1	59.28	58.79	58.63
(star-dash)	-0.97	-4.79	-8.35	-11.64	-14.67	-17.43	-19.94	-22.18	-24.15	-25.86	-27.31	-28.5	-29.42	-30.08	-30.47	-30.61
	4.76	-1.35	-7.05	-12.33	-17.18	-21.61	-25.62	-29.21	-32.38	-35.12	-37.44	-39.34	-40.82	-41.88	-42.51	-42.72
cmy'*wPR18	0.0	0.0338	0.069	0.1055	0.1435	0.1834	0.2253	0.2696	0.3167	0.3674	0.4225	0.4834	0.5526	0.6346	0.7415	0.9996
(dash-star)	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0001
LAB*PR18	95.41	92.96	90.51	88.05	85.6	83.15	80.7	78.25	75.79	73.34	70.89	68.44	65.99	63.53	61.08	58.63
	-0.97	-2.95	-4.92	-6.9	-8.87	-10.85	-12.82	-14.8	-16.78	-18.75	-20.73	-22.7	-24.68	-26.66	-28.63	-30.61
	4.76	1.59	-1.56	-4.73	-7.89	-11.06	-14.23	-17.39	-20.56	-23.72	-26.89	-30.06	-33.22	-36.39	-39.55	-42.72

File http://www.ps.bam.de/DE48/X10/X41E00NP.PS/.PDF *for similar files, see http://www.ps.bam.de/DE48/DE48.HTM*

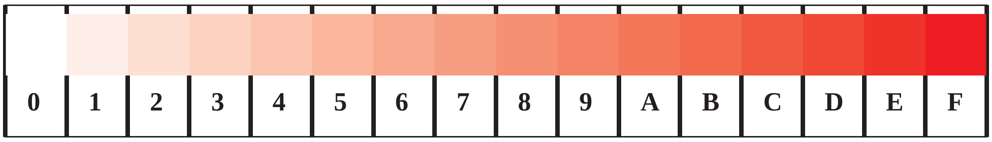
Part of Figure B4 of the ISO/IEC-test charts according to ISO/IEC 15775 and DIS ISO/IEC 19839-1 to 4

Figure 12: Cyan colours with transformation from LAB* to cmy* and inverse correction of the start output by the MTL code

Fig. 12 shows transformation from LAB* to cmy* and to other *colour coordinates. It is assumed that the start output data is LAB*' (star-dash) which is defined by a square root now. The start output of the square root LAB*' data are corrected in Fig. 12 by the MTL code. The output data LAB* are calculated by using the inverse cmy'* (dash-star) data, compare cmy*' (star-dash) in Fig. 11. Therefore then the input and output corresponds as intended.

If for a real device the device the output data give by measurement the square root output data LAB*' (star dash), then the default linear LAB* data in the MTL code must be replaced by the square root output data LAB*' and then the cmy'* (dash-star) data are calculated automatically by the MTL code. The corrections by the MTL code work for **any output data LAB*'** of the device. The LAB*' measurement data must define a monotone 16 step data set (the distance between the colour and white must continuously decrease in CIELAB space) which seems the case for any real device studied up to now.

N: w - x o**
LAB setcolor_to_*
cmy0 setcmykcolor*



*Different colour coordinates of this colour series; Model of square output *' (star-dash) and correction by inverse square root input '* (dash-star)*

Series N: w - x o** — *Transfer: LAB*_to_cmy* and other colour coordinates:*

	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
LAB*PR18	95.41	92.25	89.08	85.92	82.75	79.59	76.42	73.26	70.09	66.93	63.76	60.6	57.43	54.27	51.1	47.94
	-0.97	3.44	7.86	12.28	16.7	21.12	25.54	29.96	34.38	38.8	43.22	47.64	52.06	56.48	60.9	65.32
	4.76	7.91	11.07	14.22	17.38	20.53	23.69	26.84	30.0	33.15	36.31	39.46	42.61	45.77	48.92	52.08
cmy*wPR18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.07	0.13	0.2	0.27	0.33	0.4	0.47	0.53	0.6	0.67	0.73	0.8	0.87	0.93	1.0
	0.0	0.07	0.13	0.2	0.27	0.33	0.4	0.47	0.53	0.6	0.67	0.73	0.8	0.87	0.93	1.0
LAB*'PR18 (star-dash)	95.41	89.29	83.6	78.32	73.47	69.04	65.03	61.44	58.28	55.54	53.21	51.32	49.84	48.78	48.15	47.94
	-0.97	7.57	15.52	22.89	29.66	35.85	41.45	46.46	50.88	54.71	57.95	60.6	62.67	64.14	65.02	65.32
	4.76	10.86	16.54	21.79	26.63	31.05	35.04	38.62	41.77	44.51	46.82	48.71	50.19	51.24	51.87	52.08
cmy'*PR18 (dash-star)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0001	0.034	0.0691	0.1056	0.1437	0.1836	0.2255	0.2698	0.3169	0.3676	0.4227	0.4837	0.5528	0.6349	0.7419	1.0
	0.0	0.0338	0.069	0.1055	0.1436	0.1835	0.2254	0.2697	0.3169	0.3675	0.4226	0.4836	0.5528	0.6349	0.7418	1.0001
LAB*PR18	95.41	92.25	89.08	85.92	82.75	79.59	76.42	73.26	70.09	66.93	63.76	60.6	57.43	54.27	51.1	47.94
	-0.97	3.44	7.86	12.28	16.7	21.12	25.54	29.96	34.38	38.8	43.22	47.64	52.06	56.48	60.9	65.32
	4.76	7.91	11.07	14.22	17.38	20.53	23.69	26.84	30.0	33.15	36.31	39.46	42.61	45.77	48.92	52.08

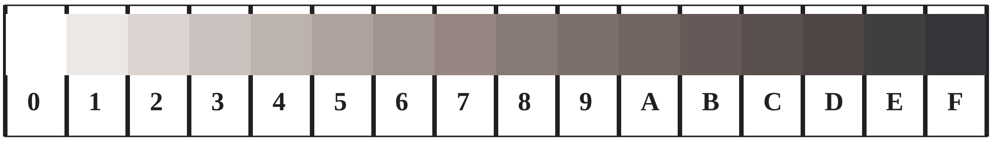
File http://www.ps.bam.de/DE49/X10/X41E00NP.PS/.PDF — *for similar files, see http://www.ps.bam.de/DE49/DE49.HTM*

Part of Figure D4 of the ISO/IEC-test charts according to ISO/IEC 15775 and DIS ISO/IEC 19839-1 to 4

Figure 13: Orange red colours with transformation from LAB* to cmy* and inverse correction of the start output by the MTL code.

Fig. 13 is similar to Fig. 12. Instead of the cyan series the orange red o* series is used. The device square root data LAB*' are corrected by the MTL code to the data LAB*. So again the input and output corresponds.

N: w - x cmy**
LAB setcolor_to_*
cmy0 setcmykcolor*



*Different colour coordinates of this colour series; Model of square output *' (star-dash) and correction by inverse square root input '* (dash-star)*

Series N: w - x cmy** — *Transfer: LAB*_to_cmy* and other colour coordinates:*

	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
LAB*PR18	95.41	90.25	85.09	79.93	74.77	69.61	64.45	59.29	54.13	48.97	43.81	38.65	33.49	28.33	23.17	18.01
	-0.97	-0.87	-0.77	-0.67	-0.58	-0.48	-0.38	-0.28	-0.18	-0.08	0.01	0.11	0.2	0.3	0.4	0.5
	4.76	4.41	4.06	3.72	3.37	3.02	2.67	2.32	1.98	1.63	1.28	0.93	0.58	0.24	-0.1	-0.45
cmy*wPR18	0.0	0.07	0.13	0.2	0.27	0.33	0.4	0.47	0.53	0.6	0.67	0.73	0.8	0.87	0.93	1.0
	0.0	0.07	0.13	0.2	0.27	0.33	0.4	0.47	0.53	0.6	0.67	0.73	0.8	0.87	0.93	1.0
	0.0	0.07	0.13	0.2	0.27	0.33	0.4	0.47	0.53	0.6	0.67	0.73	0.8	0.87	0.93	1.0
LAB*'PR18 (star-dash)	95.41	85.43	76.15	67.55	59.63	52.41	45.87	40.03	34.87	30.39	26.61	23.51	21.11	19.39	18.35	18.01
	-0.97	-0.78	-0.6	-0.44	-0.29	-0.15	-0.02	0.08	0.18	0.26	0.34	0.39	0.44	0.47	0.49	0.5
	4.76	4.09	3.46	2.88	2.35	1.86	1.42	1.02	0.68	0.38	0.12	-0.08	-0.24	-0.36	-0.43	-0.45
cmy'*PR18 (dash-star)	0.0	0.0338	0.069	0.1055	0.1436	0.1834	0.2253	0.2696	0.3168	0.3675	0.4226	0.4836	0.5527	0.6348	0.7418	1.0
	0.0001	0.034	0.0691	0.1056	0.1437	0.1835	0.2254	0.2697	0.3169	0.3676	0.4227	0.4836	0.5528	0.6349	0.7418	1.0
	0.0	0.0339	0.069	0.1055	0.1436	0.1835	0.2254	0.2697	0.3169	0.3676	0.4227	0.4836	0.5528	0.6349	0.7419	1.0001
LAB*PR18	95.41	90.25	85.09	79.93	74.77	69.61	64.45	59.29	54.13	48.97	43.81	38.65	33.49	28.33	23.17	18.01
	-0.97	-0.87	-0.77	-0.67	-0.58	-0.48	-0.38	-0.28	-0.18	-0.08	0.01	0.11	0.2	0.3	0.4	0.5
	4.76	4.41	4.06	3.72	3.37	3.02	2.67	2.32	1.98	1.63	1.28	0.93	0.58	0.24	-0.1	-0.45

File http://www.ps.bam.de/DE49/X10/X44E00NP.PS/.PDF — *for similar files, see http://www.ps.bam.de/DE49/DE49.HTM*

Part of Figure D4 of the ISO/IEC-test charts according to ISO/IEC 15775 and DIS ISO/IEC 19839-1 to 4

Figure 14: Grey colours with transformation from LAB* to cmy* and inverse correction of the start output by the MTL code.

Fig. 14 is similar to Fig. 12 and 13. The achromatic grey series is used here. The device square root data LAB*' are corrected by the MTL code to the data LAB*. So again the input and output corresponds.

The Figures 12 to 14 are of much importance for both the users and the manufacturers. The user will get a 16 step equally spaced device output if the manufacturer installs within the printer or the printer driver the MTL code which includes the start output measurement data LAB*'. If the user is still not satisfied with this default data the user can update using his own additional MTL code for his paper or his application.

6. Output of *LAB** (CIELAB) and *cmy** standard colours

The ISO/IEC-test chart include 8 colour series of 16 steps each in Fig. B4 and D4 of the ISO/IEC-test charts 2 and 4.

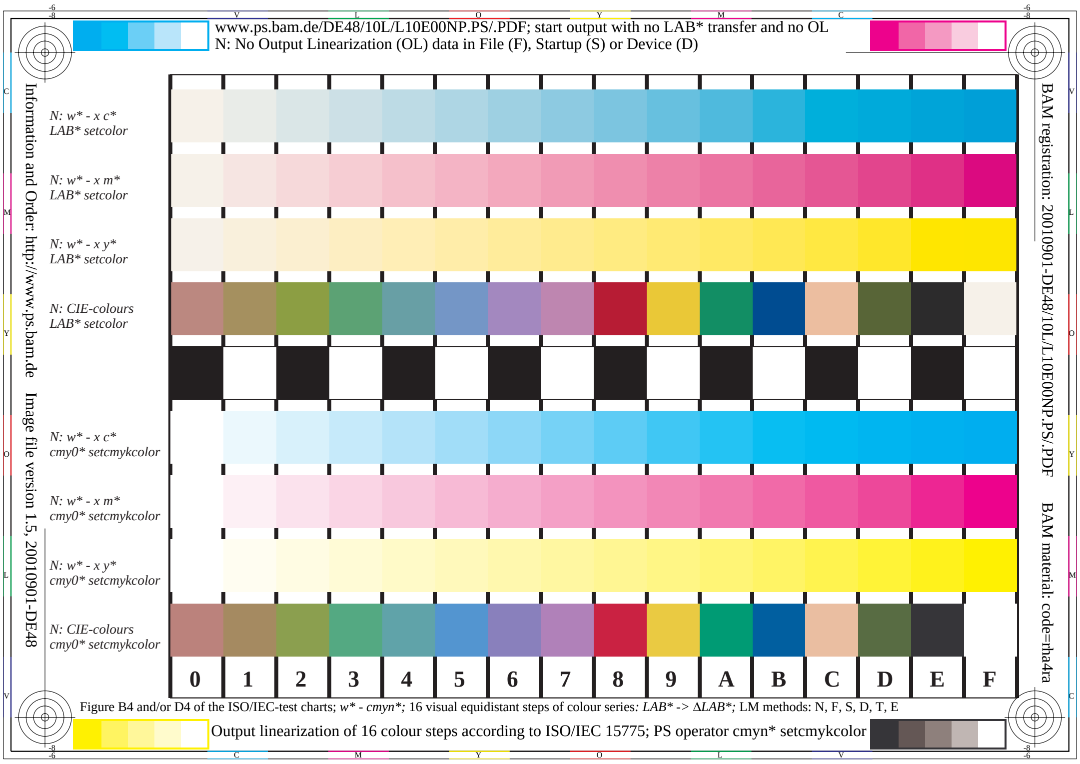


Figure 15: Use of LAB* setcolor and cmy0* setcmykcolor for the 48 cmy* standard colours and the 16 CIE-test colours of the ISO/IEC-test charts no. 2.

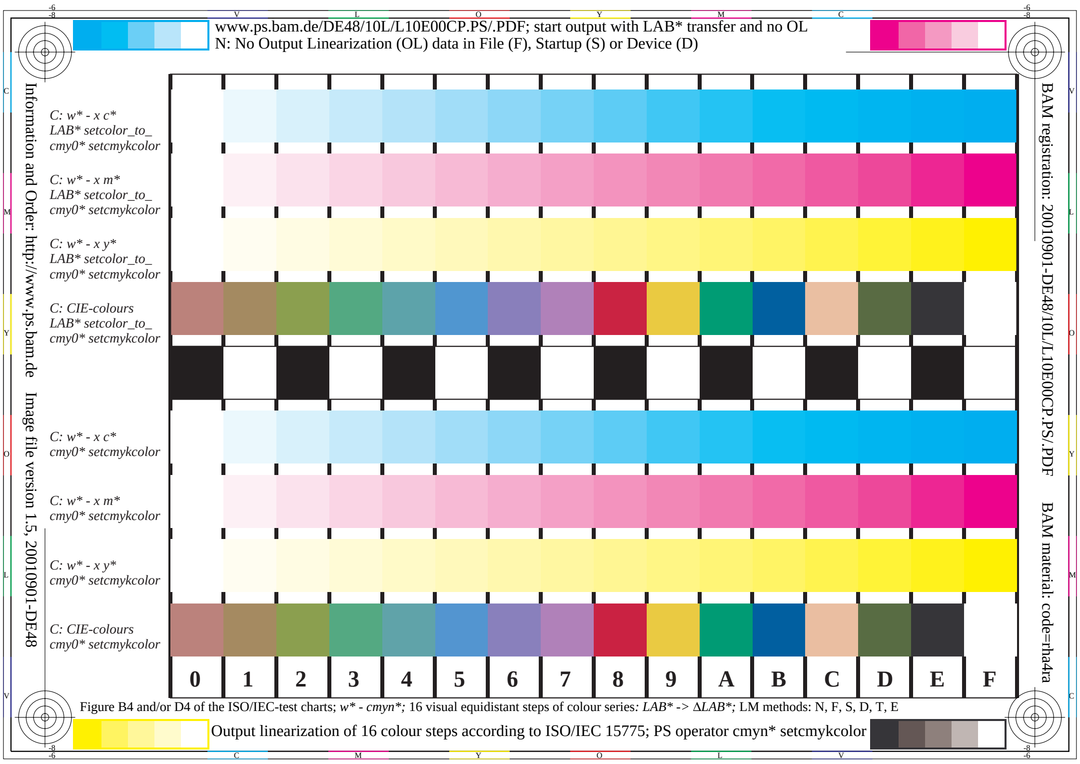


Figure 16: Use of LAB*_to_cmy0* setcmykcolor and cmy0* setcmykcolor for the 48 cmy* standard colours and the 16 CIE-test colours of the ISO/IEC-test chart no. 2.

Fig. 15 and 16 include 16 step colour series defined by LAB* coordinates. Three 16 step series with 48 cmy* standard colours and the CIE-test colours are shown. In Fig. 15 the upper series is produced using the PS code

```
LAB* setcolor
```

and the bottom figure is produced using the PS codes

```
cmy0* setcmykcolor
```

The output of the two colour series is different. The present software produces different output depending on the colour space used.The file with the letter L (=linear) indicates that the linearly spaced LAB* data are used in the MTL code. In the Fig. 15 within the file the PS codes

```
LAB* setcolor
```

at the top are replaced by

```
LAB*  LAB*_to_cmy*  setcmykcolor
```

and the bottom figure is again produced using the above PS code for cmy*.

Fig. 16 shows two identical colour series at the top and the bottom. But LAB* data are used for the series at the top and cmy* data for the series at the bottom. It was intended to get the same output independent of the colour space used and this step is reached here in Fig. 16.

The next intended step is output linearisation for the 128 standard colours of in Fig. 17 and 18 (next page). In a former paper [7.7] the output linearisation has been described for the 16 step series between white and the six chromatic colour at the **surface of the colour solid**. Now we have here CIE-test colours located **inside the colour solid.** For the CIE-test colours defined by LAB* data some cmy* data become negative and some greater than one. This is not a real problem as the PS operator setcmykcolor will skip the data automatically to 0 and 1 in both cases.

7. Output Linearisation (OL) of 128 standard colours with LAB* data

The general linearisation of all the colours **on the surface and inside the colour solid** is more complex. One may look at the colour triangle in Fig. 8 (right). In a model we assume a linear spacing for the series W – O and a square spacing for the series W – N. Then there must be a smooth transition. We use the eigencolour value e*w (compare Fig. 9) which is 1 for the series W – O and zero for the series W – N. So a series in the middle (e*w=0.5) must be described by half of the (linear) spacing W – O and half of the (square) spacing W – N. For a give colour on the middle line (e*w=0.5) we need an appropriate value on both the W – O and the W – N line. The value is deteremined by the whiteness w* which increases parallel to the line N – O from cero to the value 1 which is reached for white W.

Similar there must be a smooth transition between two neighbouring hues, e. g. Orange red O and Yellow Y. The series W – O may have a linear spacing and the series W – Y may have a square spacing in the start output. So a series in the middle (xp=0,5) may be described by half of the linear scaling W – O and half of the square scaling W – Y. For a given colour defined by a hue in the middle (xp=0,5) we need an appropriate value on both the W – O and the W – Y line. The value is again the whiteness w*w which increases parallel to the line O – Y from this line to white W.

Based on these ideas we have developed two methods for Output Linearisation (OL). For all colours inside and outside the colour solid we distinguish two methods for Output Linearisation (OL):

1. The **analytical method** based on the Ostwald colour triangle equation. The Ostwald colour triangle equation is c* + n* + w* = 1 (chromaticness + blackness + whiteness = 1).

2. The **geometrical method** based on lines in a CIELAB hue plane. In CIELAB space the lines connect in a hue plane both the black point N, the colour F and the peripheral colour Pw on the whitish surface of the colour solid, and then the white point W, the colour F and the peripheral blackish colour Pn.

The **analytical method** for Output Linearisation (OL) is shown for the colour series W – CMY and the CIE-test colours by the URL: http://www.ps.bam.de/DE48/DE48.HTM and for the colour series W – OLVN(=CMY) by the URL: http://www.ps.bam.de/DE49/DE49.HTM

The **geometrical method** for Output Linearisation (OL) is applied for the colour series W – CMY and the CIE-test colours by the URL: http://www.ps.bam.de/DE38/DE38.HTM and for the colour series W – OLVN(=CMY) by the URL: http://www.ps.bam.de/DE39/DE39.HTM

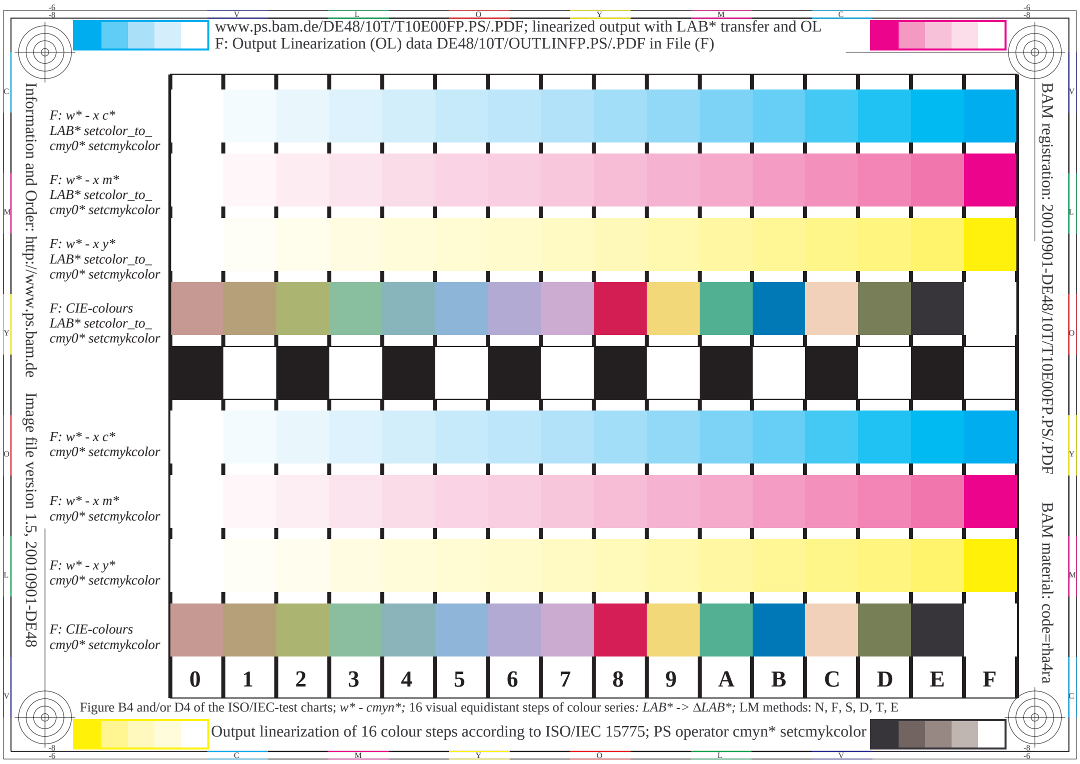


Figure 17: Use of LAB*_to_cmy0* setcmykcolor (top) and cmy0* setcmykcolor (bottom) for the 48 cmy* standard colours and the 16 CIE-test colours

Fig. 17 includes **both the LAB* to cmy* transfer and the Output Linearisation (OL)** for the colour series W – CMY on the **surface of the colour solid** and the CIE-test colours **inside the colour solid**.

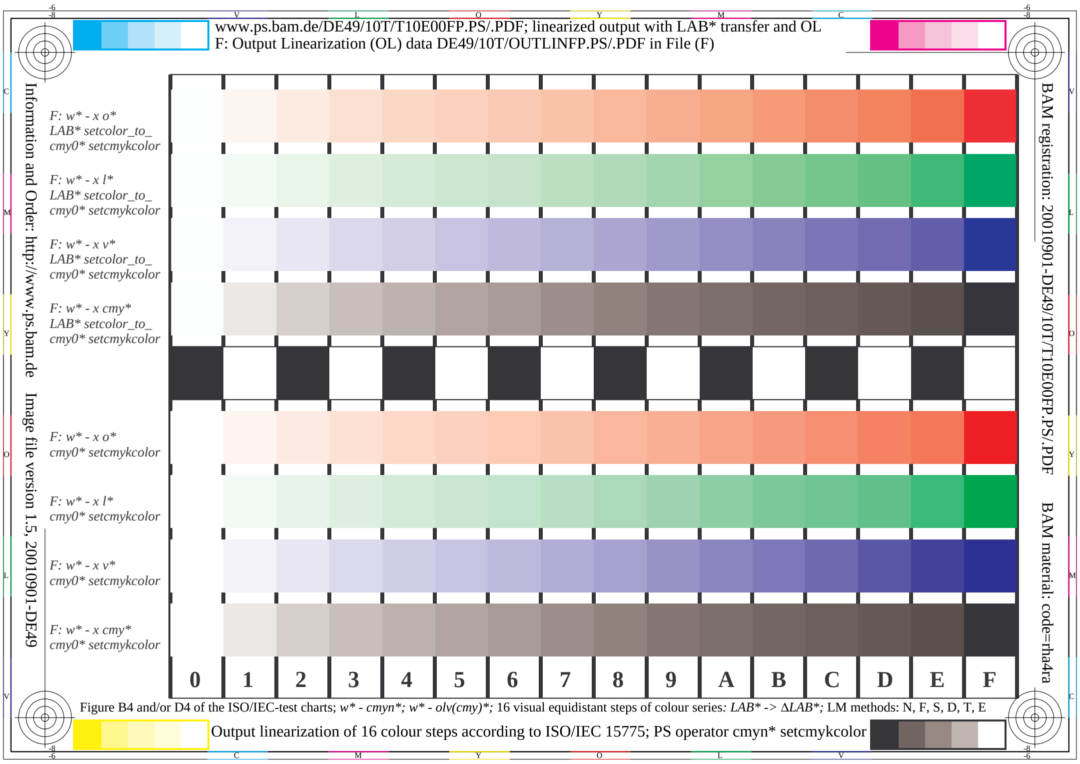


Figure 18: Use of LAB*_to_cmy0* setcmykcolor (top) and cmy0* setcmykcolor (bottom) for the 64 olvn* standard colours of the ISO/IEC-test chart no. 4.

Fig. 18 includes **the LAB*_to_cmy* transfer and the Output Linearisation (OL)** for the colour series

W – OLVN(=CMY) on the **surface of the colour solid.**

The top and the bottom colours in Fig. 17 and 18 must look equal and a real device must show the 16 step outputs which are equally spaced in CIELAB for all the colour series.

For the CIE-test colours the first experimental results show that the absolute CIELAB colour difference reduces from about 25 CIELAB units to about 12 CIELAB units for one real device. One must have in mind that both the DIN production and the JBMA production of the CIE-test colours in ISO/IEC-test charts gives an accuracy of about 10 CIELAB units. So this device result reaches nearly the accuracy of the test chart productions and a similar accuracy may be reached for images.

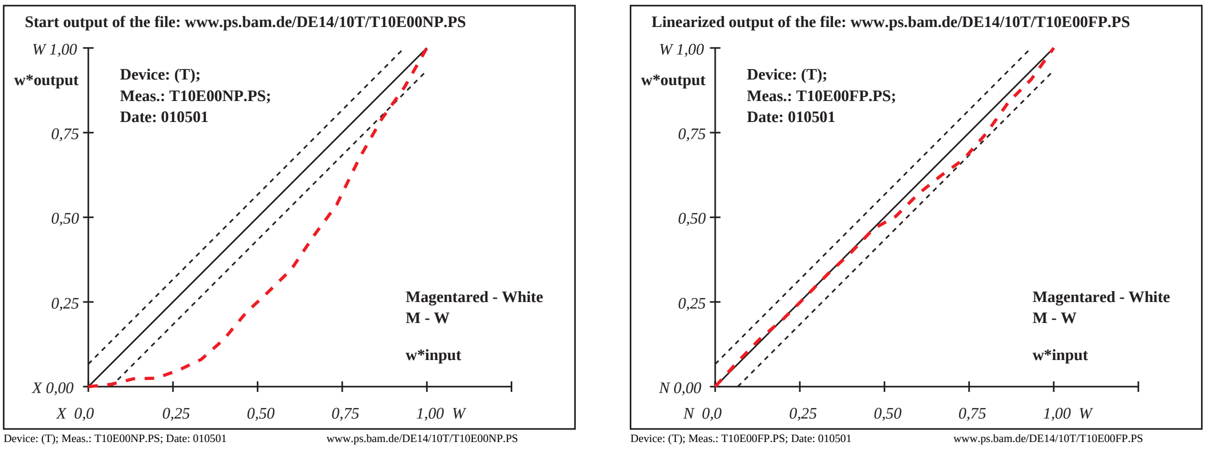


Figure 19: Input - Output relationship of the start output and the linearized output

Fig. 19 shows an example for the relationship between the input and output data for the start and linearized output of the former paper [7.7]. The measurement data of a start output one can find within the MTL code at the beginning of the files belonging to Fig. 17 and 18. The URL is given at the top.

8. Chromatic ISO/IEC-test charts and Output Linearisation (OL)

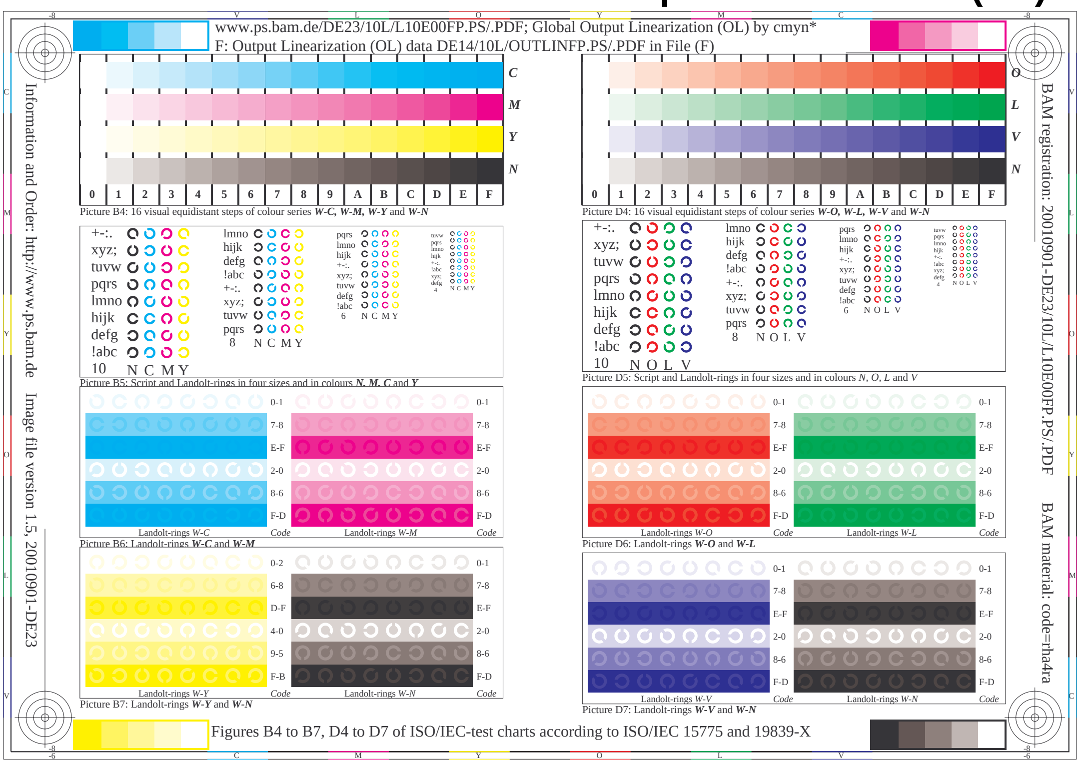


Figure 20: Start output of Fig. B4 to B7 and D4 to D7 of ISO/IEC-test charts no. 2 and 4.

Fig. 20 shows the start output of many figures of the ISO/IEC-test charts no. 2 and 4. It is hard to demonstrate the improvement by Output Linearisation (OL) by this papaer output. The result depends on the real start output of the device. Here we produce a linear output and square root model output to show the effect. One of the two outputs (Fig. 20 and 21) either on a printer or a monitor may give a much better spacing and illustrate the possibilities included in the methods developed here.

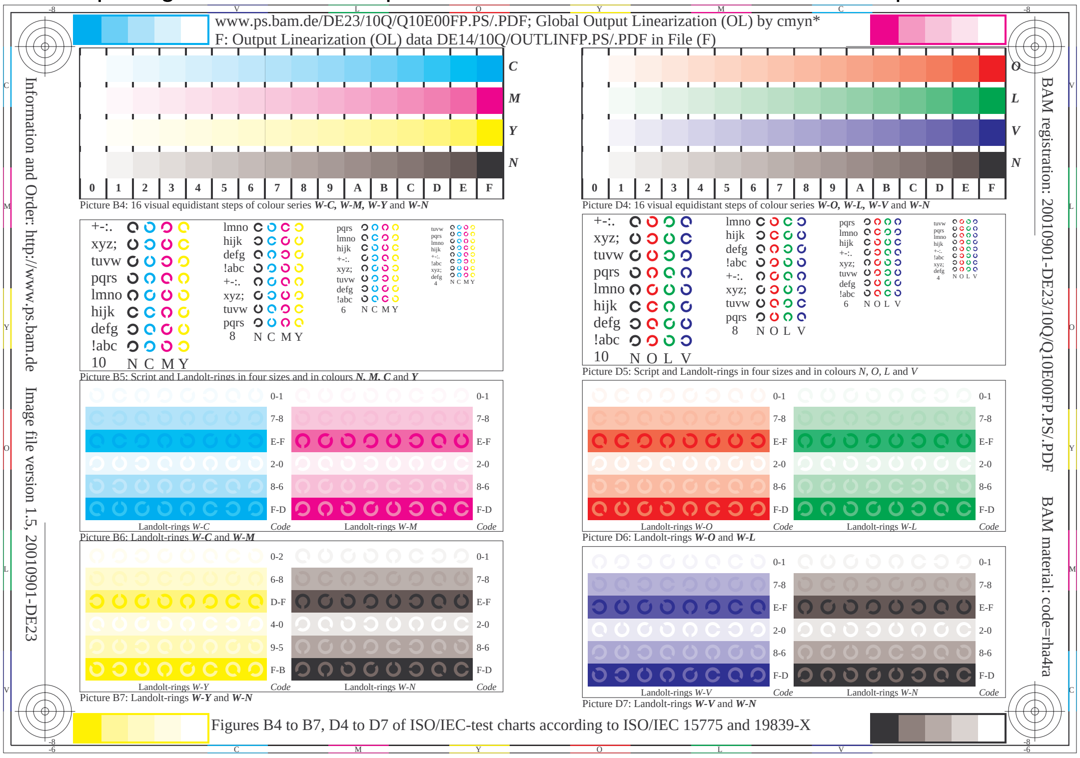


Figure 21: Model square output of Fig. B4 to B7 and D4 to D7 of ISO/IEC-test charts no. 2 and 4. Fig. 21 shows the model square output of many figures of the ISO/IEC-test charts no. 2 and 4. This output may demonstrate the changes and the possible improvement by Output Linearisation (OL). The result depends on the real start output of the device. There will be an improvement of this paper output if the start output (Fig. 20) shows many equal colour steps near the dark colours (C, M, Y, O, L, V and N) which is often the case by Adobe Acrobat Reader. The BAM is able to send real examples of the start and linearized output on request, see the email address at the beginning.

9. Summary

The BAM was the leader for the development of the **analog and digital DIN- and ISO/IEC-test charts** to be used for the different colour office devices.

The colours of the ISO/IEC-test charts are defined in the file by **LAB* (CIELAB) data** which are transferred to **cmy* data** within the file.

Linear equations between **LAB* and cmy*** allow to describe the colours on the surface and inside the colour solid for the different office devices.

Output Linearisation (OL) produces linear scales in both LAB* and cmy* space for the colours in the ISO/IEC-test charts.

The **CIE-test colours** defined by **LAB* data** are reproduced with a good accuracy by the cmy* data calculated within the file.

The **reproduction property** of the intended colours is in many cases for **linearized** devices within the intended accuracy and a colour management method is then often not necessary.

10. References

[1a] **DIN 33866-X**: Information technology – Office machines – Machines for colour image reproduction:
DIN 33866-1, Edition:2000-07; Part 1: Method for specifying image reproduction of colour devices by digital and analog test charts, Classification and principles; This standard includes analog DIN-test charts no. 1 to 4
DIN 33866-2, Edition:2000-10; Part 2: Method for specifying image reproduction of colour devices by

analog input and analog output for colour image reproduction devices: analog - analog (copiers) - Realisation and application
DIN 33866-3, Edition:2000-07; Part 3: Method for specifying image reproduction of colour devices by digital input and analog output as hardcopy for colour image reproduction devices: digital - analog (printers) - Realisation and application
DIN 33866-4, Edition:2000-10; Part 4: Method for specifying image reproduction of colour devices by analog input and digital output for colour image reproduction devices: analog - digital (scanners) - Realisation and application
DIN 33866-5, Edition:2000-10; Part 5: Method for specifying image reproduction of colour devices by digital input and analog output as softcopy for colour image reproduction devices: digital - analog (monitors) - Realisation and application

[1b] **DIS ISO/IEC 19839-X**; Information technology - Office machines - Colour image reproduction equipment
DIS ISO/IEC 19839-1, Edition: 2000-04-Part 1: Method for specifying image reproduction of colour devices by digital and analog test charts, Classification and principles, 40 pages
DIS ISO/IEC 19839-2, Edition: 2000-04; Part 2: Method for specifying image reproduction of colour devices by digital input and analog output as hardcopy for colour image reproduction devices: digital - analog (printers) - Realisation and application, 10 pages
DIS ISO/IEC 19839-3, Edition: 2000-04; Part 3: Method for specifying image reproduction of colour devices by analog input and digital output for colour image reproduction devices: analog -digital (scanners) - Realisation and application, 16 pages
DIS ISO/IEC 19839-4, Edition: 2000-04; Part 4: Method for specifying image reproduction of colour devices by digital input and analog output as softcopy for colour image reproduction devices: digital - analog (monitors) - Realisation and application, 10 pages

[2] **ISO/IEC 15775**, Edition 1999-12; Information technology – Office machines – Machines for colour image reproduction - Method of specifying image reproduction of colour copying machines by analog test charts – Realisation and application

[3] **ISO 2846–1**, Edition 1997, Graphic technology – Colour and transparency of ink sets for four-colour-printing – Part 1: Sheetfed and heat-set web offset lithographic printing.

[4] **ITU-R BT.709–2**, Edition 1995, Parameter Values for the HDTV Standards for Production and International Programme Exchange.

[5] Richter, Klaus; Computergrafik und Farbmetrik, VDE-Verlag, Berlin, 1996, with 500 colour figures in PS and PDF on CD-ROM, ISBN 3-8007-1775-12

[6] Adobe, PostScript Language Reference Manual, Addison-Wesley, 1990

[7] Richter, Klaus: Date, Titel and Size of papers on web site, see http://www.ps.bam.de/INFXY91.HTM

[7.1] 010105: Comparison of properties of the International Standard series ISO/IEC 15775 or DIS ISO/IEC 19839-1 to -4 and IEC 61966-X in the field of Image Technology, CIE2A1.PDF (50 kByte, 4 pages)
[7.2] 010105: Definition of extended print colour space cmyolvnw* according to ISO/IEC 15775 or DIS ISO/IEC 19839-1 to 4 and comparison with sRGB and scRGB colour spaces according to IEC 61966-X., CIE2B1.PDF (355 kByte, 8 pages)
[7.3] 000922: Standard and Wide Gamut colour code (SGcode and WGcode) compatible with CIELAB, ISO/IEC 15775 and DIS ISO/IEC 19839-1 to 4 for colorimetric colour management and communication, CISO08.PDF (752 kByte)
[7.4] 000715: Applications of digital and analog ISO/IEC-test charts for specifying image reproduction of copiers, printers, scanners and monitors according to ISO/IEC 15775 and ISO/IEC DIS 19839-1 to 4, CGIP15.PDF (135 kByte)
[7.5] 000401: Automatic colour management for variable processes between original scene and reproduction using 16 colours of ISO/IEC 15775, CISV06.PDF (839 kByte), compare CIS2000 proceedings, Uni Derby, England, p. 197-204, 321-328
[7.6] 000401: Analog and digital ISO/IEC-test charts according to ISO/IEC 15775, CISP06.PDF (781 kByte)
[7.7] 010616: Development of analog and digital ISO/IEC- and DIN-standards for specifying image reproduction and for colour management, DFZBAM.PDF (1500 kByte)

[8] Saunders, David, Accurate Colour Images, AIC Color 01, Rochester, June 2001, p. 368.