Automatic colour management for variable processes between original scene and reproduction using 16 colours of ISO/IEC 15775

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Abstract

Four ISO/IEC-test charts have been defined in ISO/IEC 15775 (1999) to specify image reproduction of colour copiers. Corresponding test charts have been defined in DIN 33866-1 to 5 (in print) to specify image reproduction of colour copiers, printers, scanners and monitors. All colours of all test charts are defined in CIELAB coordinates. In applications the devices including software are used for test chart input and output in the three different combinations „analog - analog“ (copiers), „digital - analog“ (printers, monitors) and „analog - digital“ (scanners, Photo-CD-systems).

This paper uses mainly ISO/IEC-test colours of a 16 step grey scale (defined by *olv**-coordinates according to the standard) in the original scene to calibrate the variable (photographic and Photo-CD) analog-digital process. The relative digital *olv**-input data and the digital *olv*'*-output data are used to get approximately the same digital output (image file) independent of exposure (e. g. between -1 stop under to +2 stop over exposure for slide or negative film) and other variables, e. g. the digitizing Photo-CD-process. This “direct” colour management method adds a new method compared to the ICC colour management method which fails to handle variable processes and can not manage the variable data of original scenes taken by the photographic process.

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 [1] 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. The new national standards DIN 33866-1 to 5 [1] (in print, drafts May to Nov. 1999) and the International Standard ISO/IEC 15775 are based on equivalent colour series. Both use approximately the same colour series both in **digital** and **analog** test charts and approximately the same layout. The creation of **digital** test charts and the production of **analog** test charts is described in a separate paper [7] of this conference.

Table 1: Realisation and application of ISO/IEC- and DIN-test charts for colour image devices

Input	**Output**	**Input and output media and applications**			**Standard**
		Input media	**Output media**	**Application**	
–	–	–	–	**Basis**	**DIN 33866−1**
analog	**analog**	ISO/IEC-test chart (hardcopy) DIN-test chart (hardcopy)	Hardcopy	**Copier**	**ISO/IEC 15775** **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**

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An overview of the different standards DIN 33866-X and their relationship to ISO/IEC 15775 is given in Table 1. The table describes the application and realisation of ISO/IEC- and DIN-test charts and the

methods for the specification of reproduction qualities of colour image devices “analog - analog” (copiers), analog - digital (scanners) and “digital - analog” (printers, monitors) and may therefore be used as basis for the comparison and choice of such devices.

English translations of the drafts of DIN 33866-X have been under the URL: http://www.achtech.com.br/sc28/15775.html since one year for international test. DIN decided recently to propose DIN 33866-X as a basis for an International Standard to be produced by ISO/IEC JTC1/SC28 for the larger field of colour image reproduction which includes printers, monitor, scanners, digital cameras, the photographic process and others. The discussion of this proposal is one main topic of the next ISO/IEC JTC1/SC28 plenary meeting during June 2000 in Berlin.

Remark: The standards of the series DIN 33866-X define requirements for the quality of the image reproduction and the standards of the series IEC 61966 define measurable transfer properties of homogeneous colour areas.

1. Scope of ISO/IEC 15775

The International Standard ISO/IEC 15775 is designed for the realisation and application of ISO/IEC-test charts for colour copiers. This International Standard allows to test the reproduction properties of colour copiers and is intended both to recognize the limits and to compare the different devices. To test the reproduction properties of a colour copier there are different possibilities:

Input of at least one achromatic digital test chart 1 or 3 and one chromatic digital test chart 2 or 4 according to ISO/IEC 15775 and production of an output.

Assessment of the output by comparison – subjective visual test and/or objective specification – with the corresponding analog test charts 1 to 4 according to ISO/IEC 15775

NOTE 1 Four ISO/IEC-test charts both in halftone (offset reproduction) and in continuous tone (photographic reproduction) have been produced by different manufacturers in test productions (DIN, JBMA and BAM). Information about where to obtain test chart layout and colorimetric *L*a*b** data to produce the charts may be found in Annex of ISO/IEC 15775.

NOTE 2 For each **analog** ISO/IEC-test chart produced by a manufacturer according to the International Standard ISO/IEC 15775 there exists a corresponding **digital** ISO/IEC-test chart.

2. Test charts, copier output and assessment

The **analog** and **digital** test charts for the assessment of copier outputs are defined in ISO/IEC 15775.

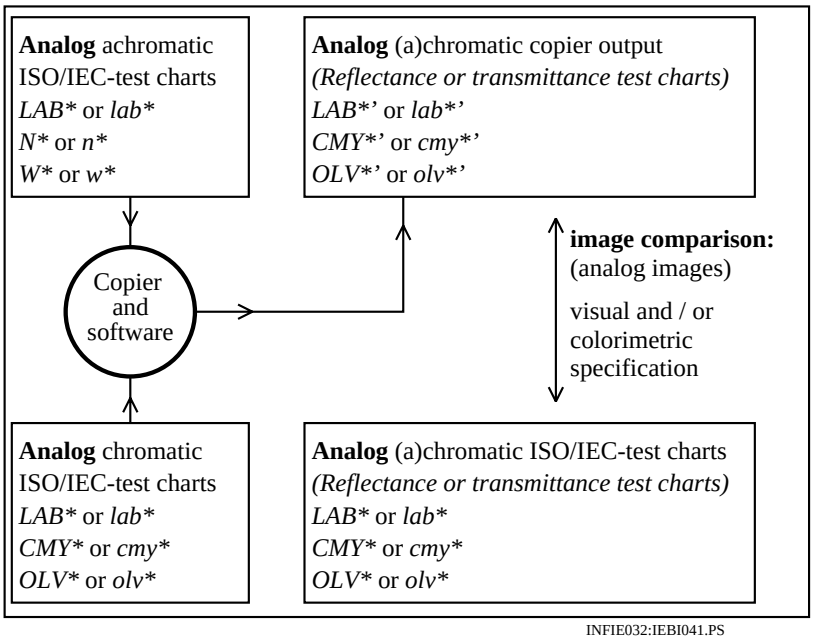

Figure 1: Specification of the image reproduction of copiers by comparison of output and

original

Fig. 1 shows the specification of image reproduction of the colour copier output by visual assessment and/or colorimetric measurement. All colours of the **analog** ISO/IEC-test charts are defined in *L*a*b**-CIELAB coordinates. either defined as absolute *(LAB*)* or relative *(lab*)* data. Actual productions may differ slightly compared to the intended CIELAB coordinates. The default colour spaces is defined by the six chromatic colours *CMYOLV* (*C*=Cyanblue, *M*=Magentared, Y=Yellow, *O*=Orangered, *L*=Leafgreen, *V*=Violetblue) and the two achromatic colours *NW* (N=black (french=Noir), *W*=White) of offset colour printing, defined in ISO 2846 [3]. The mean deviation of intended CIELAB parameters and produced **analog** test charts according to DIN 33866 is 2,5 CIELAB units, see [2].

One must have in mind that the following operating modes for copying influence the copier output:

– copier mode
– contrast mode
– copier driver
– paper used
– other supplies used (toner, inks, copier cassettes)

It is required to specify the operating modes for copying in the test reports

For the test according to the International Standard ISO/IEC 15775 at least two of four copier outputs are required which one must make together one after another with unchanged mode for the colour copier.

3. Automatic colour management for original scenes

The **analog** test charts according to ISO/IEC 15775 with equidistant 16 grey steps (in a *-image according to the CIELAB colour space) allow to correct the digital image files belonging to this **analog** reference.

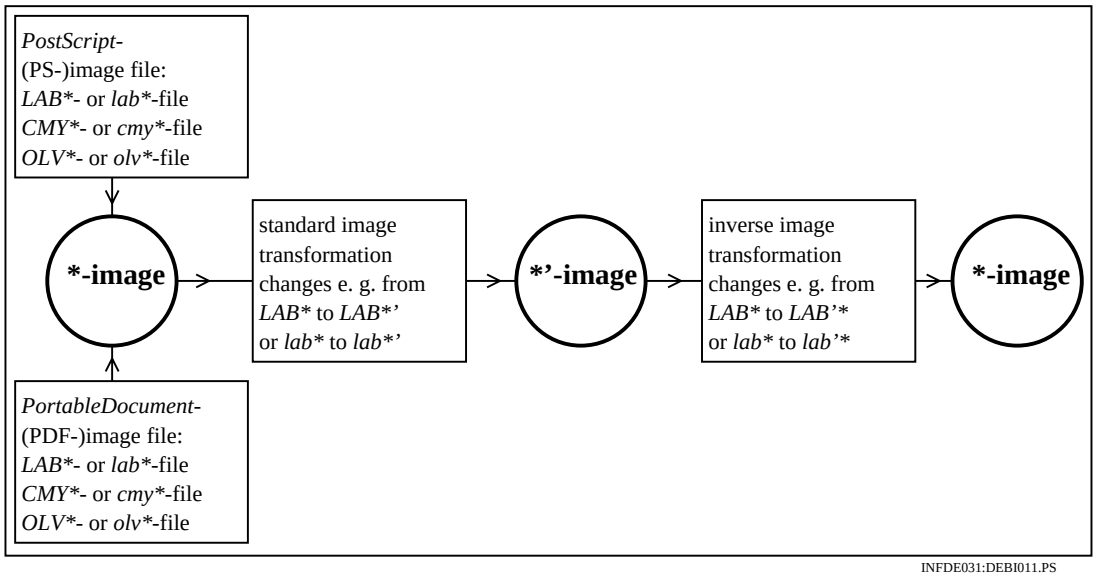

Figure 2: Standard and inverse image transformation

Fig. 2 shows that the standard image transformation changes a *-image („star-image“) into a *'-image („star-dash-image“) and that the inverse image transformation changes a *'-image („star-dash-image“) into a *-image („star-image“)

If one takes a picture with 16 equidistant grey steps as „reference“, e. g. as the first picture on slide or negative film, then the digital values of this grey series behave different, dependent on the film material, the taking illuminant, the exposure, the film development and the digitizing process (e. g. the Photo-CD system). In image files the digital values vary normally in an 8 bit range (0 to 255) and the digital values should be spaced in 16 equal steps: 0, 17, 34, 51, ..., 221, 238, 255.

We have taken „original scenes“ with the 16 equally spaced grey steps and 14 CIE-test colours defined in ISO/IEC 15775 (and DIN 33866). Table 2 shows a complete PostScript program including the digital values of the reproduced colours *olv*‘* which correspond to the 16 equally spaced grey steps in the original scene, defined as colours *olv**.

PSL1-program: Horizontal rectangle-grey elements (16 steps) with *("star") and *'("star-dash")-coordinates

```
%!PS-Adobe-3.0 EPSF-3.0  MMTA034:MMTA031.EPS 29.04.2000
%%BoundingBox:70 80 234 160
/FS {findfont exch scalefont setfont} bind def
%%EndProlog
gsave
/picstr 48 string def  %for 16x3 olv*-data

6 /Times-Roman FS
472 83 moveto
     (INFMM034:MMTA041.EPS) show
 72 90 translate

/olv*-data [%olv* (dec); %i,j:128x192; k,l: 016x007; hex
  1    0.0    0.0    0.0 %i,j:121   6; k,l: 002 001; 00
  2   17.0   17.0   17.0 %i,j:121  18; k,l: 002 002; 11
  3   34.0   34.0   34.0 %i,j:121  30; k,l: 002 003; 22
  4   51.0   51.0   51.0 %i,j:121  42; k,l: 002 004; 33
  5   68.0   68.0   68.0 %i,j:121  54; k,l: 002 005; 44
  6   85.0   85.0   85.0 %i,j:121  66; k,l: 002 006; 55
  7  102.0  102.0  102.0 %i,j:121  78; k,l: 002 007; 66
  8  118.0  118.0  119.0 %i,j:121  90; k,l: 002 008; 77
  9  135.0  135.0  136.0 %i,j:121 102; k,l: 002 009; 88
 10  152.0  152.0  153.0 %i,j:121 114; k,l: 002 010; AA
 11  169.0  169.0  170.0 %i,j:121 126; k,l: 002 011; BB
 12  186.0  186.0  187.0 %i,j:121 138; k,l: 002 012; CC
 13  203.0  203.0  204.0 %i,j:121 150; k,l: 002 013; DD
 14  220.0  220.0  221.0 %i,j:121 162; k,l: 002 014; EE
 15  237.0  237.0  238.0 %i,j:121 174; k,l: 002 015; DD
 16  255.0  255.0  255.0 %i,j:121 186; k,l: 002 016; FF
] def %End olv*-data

/olv*'-data [%olv*'(dec);%i,j:128x192;i-variation: 6pixel j-variation: 6 pixel
  1   15.8    8.4   11.0 %i,j:121   6 i  2  2  1  3  0  1 j  0  0  0  0  0  0
  2   17.2    8.8   11.0 %i,j:121  18 i  0  1  2  2  2  1 j  4  1  1  0  0  0
  3   35.0   22.4   29.0 %i,j:121  30 i  0  0  3  2  1  2 j  1  1  0  1  1  0
  4   48.2   40.4   41.0 %i,j:121  42 i  1  1  1  0  0  0 j  2  3  3  2  2  1
  5   62.0   56.8   56.4 %i,j:121  54 i  1  1  1  4  4  4 j  1  1  1  1  2  1
  6   73.6   68.6   68.2 %i,j:121  66 i  0  0  0  1  1  2 j  0  0  0  1  1  2
  7   87.2   82.4   81.6 %i,j:121  78 i  1  2  1  1  3  1 j  1  2  1  0  0  0
  8  100.0   95.4   97.2 %i,j:121  90 i  2  1  0  0  0  0 j  2  1  1  0  0  0
  9  113.8  108.4  110.4 %i,j:121 102 i  1  2  2  0  0  0 j  0  0  0  0  0  0
 10  126.2  123.0  126.4 %i,j:121 114 i  1  2  1  1  2  1 j  1  2  1  2  1  1
 11  139.4  136.4  140.4 %i,j:121 126 i  1  1  1  0  0  0 j  1  1  1  0  0  0
 12  153.4  149.4  155.8 %i,j:121 138 i  0  0  0  1  1  2 j  1  1  2  0  0  0
 13  166.8  163.4  167.4 %i,j:121 150 i  2  1  1  2  1  1 j  0  0  0  2  1  1
 14  179.4  175.2  179.2 %i,j:121 162 i  0  0  0  1  2  1 j  0  0  0  1  1  0
 15  196.4  191.0  195.2 %i,j:121 174 i  1  2  2  2  2  1 j  0  0  0  0  0  0
 16  207.0  204.2  207.6 %i,j:121 186 i  0  1  2  4  4  4 j  0  0  0  1  1  1
] def %End olv*'-data

016 3600 div 72 mul 40 mul 12 mul dup 16 div 5 mul scale
                                               %olv*-data (upper row), olv*'-data (bottom row)
016 005 8 [016 0 0 005 neg 0 005]
{currentfile picstr readhexstring pop}
false 3
colorimage
7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F
000000111111222222333333444444555555666666777777888888999999AAAAAABBBBBBCCCCCCDDDDDDEEEEEEFFFFFF
7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F
0F080B11080B23161D3028293E3838494444575251645F61716C6E7E7B7E8B888C99959BA6A3A7B3AFB3C4BFC3CFCCCF
7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F7F
%%EndData
grestore
showpage
%%Trailer
```

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Table 2: Digital *- and *‘-coordinates in an image file

The PostScript parameter „colorimage“ show the *olv**-hexadecimal values of the original image (second line) and the *olv*‘*-hexadecimal values of the image file (fourth line) produced by a Photo-CD process. A so called PostScript „transfer“ functions in front of the PostScript parameter „colorimage“ can transform the irregular spacing, between decimal15.8 and 207.0 (hexadecimal 0F to CF) of the first column, to a regular decimal spacing 0.0, 17.0, ..., 238, 255 (hexadecimal 00, 11, ..., FF) and similar for the two other columns. As long as the digital output values are monotone for all three columns the corrected data in the image file are equally spaced in all three values. One can expect this property as long as the film is not over- or underexposed to much.

Figure 3: Fig. B1 of test chart according to ISO/IEC 15775 for slide film (0.5 stop overexposure)

Figure 4: Fig. D1 of test chart according to ISO/IEC 15775 for negative film (1.0 stop overexposure)

For slide films the limits are reached for 1 stop under- and to stops overexposure and for negative film the limits are reached for 2 stops under- and 4 stops overexposure. The illumination reaching the film plane can vary by a factor 64 (1 stop is twice the light reaching the film plan) and still we can get the digital values within the image file equally spaced. The image reproduction of the original scene becomes by this method also approximately independent of many other parameters used, e. g. film material, taking illuminant, film development, digitizing process.

Examples of the flower motive used in Fig. 3 and 4 are on the following web site:

www.ps.bam.de/INFBE04/INFBE04.HTM

A slide film has been used for different exposures between -1.5 stop underexposure and 1.5 stop overexposure in steps of 0.5 stops. A negative film has been used for different exposures between -2.0 stops underexposure and 4.0 stops overexposure in steps of 0.5 stops. Comparison of uncorrected and optimized output is possible. The *olv**-data were taken from the pixel images ot 128 x 192 pixels and 5 pixels are used to calculate the decimal (and hexadecimal) values shown in Table 2.

In the programming language *PostScript* it is possible to define the correction method within the *PostScript* image file by a general transfer function *(olv*'->olv*)* which use the two tables *(olv*'* and *olv*)* in front of the image data. Not every PostScript interpreter can do this data transformation within the image file. For general use it is necessary to calculate the transformation separately. A software may read the PostScript file with the *olv*'*-data in the image file, change the data to *olv** and produce a corrected image file including equally spaced *olv**-data.

The following two figures have been produced by this method using slide film and negative film and the Photo-CD process. It is hard to see a difference between the two film materials.

The technical variations using different productions and film developments of the same film material correspond to one stop exposure variation. This leads for instance to a visual change from „very good“ to „good“ on a 5 step image quality scale. It is easy to eliminate these variation and to produce a „reproducible image reproduction“ if one takes a „reference“ picture (e. g. as a first picture of a film) which defines the data for correction.

4. Future developments

A default colour space *cmyolvnw** is used in ISO/IEC 15775. The * (star) indicates that ther is a unique relationship to the CIELAB colour space and the CIELAB coordinates *L*a*b**. The eight colours *cmyolvnw** are defined in ISO/IEC 15775 in *L*a*b**-coordinates.

The three offset colours (*O*=orangered, *L*=leafgreen, *V*=violetblue) in reflectance mode are very different compared to the television colours *(RGB)* in transmittance (luminous) mode. The mean difference for the six chromatic colours is 31 CIELAB units. The CIELAB difference between Violetblue *V* of offset printing and Blue *B* of television is 74 CIELAB units. This is the same difference as between the two colours White *W* and Black *N* (french=noir) of offset printing. Therefore new coordinates *olv** instead of *rgb** are used. The terms *r, g, b, j* (J=yellow, french: jeaunne) are reserved for the unique hues, e.g. Red as neither yellowish nor blueish (compare [2] and the paper of K. Richter [7] of the CIS 2000 conference)

There is a unique relationship between the default colour space *cmyolvnw** used in ISO/IEC 15775 and the CIELAB colour space in both directions. The maximum *(max)* and minimum *(min)* of the three coordinates *olv** define the relative blackness *n** = 1 - *max (olv*)* and relative whiteness *w*= min (olv*)*. The hue and relative chromaticness are defined by the two larger of the three *olv**-coordinates. One may define *d*=maximum value of (olv*)* and *e*=intermediate value of (olv*)*. All the coordinates of the default colour space *cmyolvnw** can be calculated from *denw** including the CIELAB data of any *olv**- or *cmy**-combination and vice versa. This is shown for the colour space plane *onw** in the next figure.

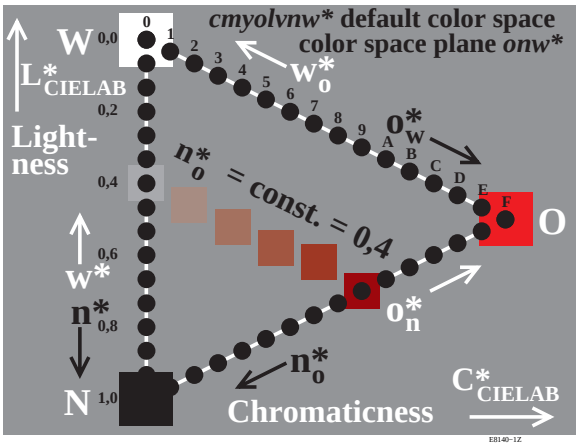

Figure 5: Relation between colour spaces *cmyolvnv and CIELAB in the *onw** colour plane.**
Figure 5 shows 16 colour steps between the 3 colours *O* (Orangered), *N* (Black) and *W* (White) either defined by hexadecimal values (range 0 to F) or digital values (range 0 to 1). For example a colour of relative blackness *n**=0,4 is mixed by 60% of the colour *O* and 40% of the colour *N*. The CIELAB data of these two colours are defined and therfore the mixture colour can be calculated. Similar for any colour defined by CIELAB data the colours of the default colour space *cmyolvnw** can be calculated.

It is intended to use the default colour space *cmyolvnw** for either an **update** of existing colour management methods (e. g. with ICC profiles) or for a **direct** colour management method. For input (analog - digital process) the **direct** colour management method of this paper lead to a high quality of the digital image file for original scenes using photographic material and the Photo-CD system. For output (digital - analog process) of this digital file , e. g. on a printer, a corresponding **direct** colour management method is useful. The *olv**-output data (calculated from measured CIELAB-data of a printer output) for equally spaced *olv**-data of the **digital** input file define a transfer function. This transfer function allows to produce an inverse digital image file with *olv'**-data (dash-star-data).

The output of the inverse image file with the *olv'**-data (dash-star-data) produces the intended output with *olv**-data (star-data). The accuracy can be proofed by measuring the CIELAB-data of the output and by comparison with the intended CIELAB-data.

This idea has been described and used in a draft DIN 33872 [5] to specify the yield of consumables (toner/ink) for copiers, printers, fax equipment and their combinations. *PostScript* files [6] are used for this method. It is intended to produce the same equally spaced 16-step grey scale on every printer. The offset grey scale of ISO/IEC 15775 is the reference.

This reference output is reached by measuring the CIELAB *L**-data of a first output. It is required to include the measured *L**-data in a second *PostScript* file which produces the intended output with the 16-step grey scale for any hardware-software combination. For the test of copiers it is required to change the analog test chart input and this leads to the same analog grey scale on every copier. This method allows to compare the yield of consumables (toner/ink) on the same basis for all devices independent of hardware and software (e. g. the printer driver).

5. Information on web sites (compare ISO/IEC 15775)

Organisations with web addresses for additional informations:
ISO: International Organization for Standardization, 1 Rue de Varambé, CH–1211 Geneva, Switzerland
www.iso.ch

ISO/IEC JTC1 SC28: Information technology – Office systems
BNT/CB-21 – Associação Brasileira de Normas Técnicas, Av. 13 de Maio, 13/2007, Rio de Janeiro. RJ 20031-900, Brazil
www.actech.com.br/sc28

DIN: Deutsches Institut für Normung e.V., Burggrafenstrasse 6, D–10787 Berlin, Germany
www.din.de

DIN NI-28: Information technology – Office systems

www.din.de/33866 (digital DIN-test charts according to DIN 33866)

NOTE 1 Four **digital** DIN-test charts are available as *PostScript-(PS)* and *PDF*-files with text in English and German language and in different resolutions

NOTE 2 Four **analog** DIN-test charts are available as test patterns.

BAM: Federal Institute for Materials Research and Testing (BAM), Unter den Eichen 87, D–12200 Berlin, Germany

www.bam.de

BAM VIII–P13: Visual methods and image reproduction for NDT

www.ps.bam.de or http: //o2.ps.bam.de

NOTE 1 Four **digital** ISO-test charts are available as *PostScript-(PS)* and *PDF*-files with text in English and German language and in different resolutions

NOTE 2 Four **analog** ISO-test charts are available as test patterns by different manufacturers

NOTE The *PostScript*-Code of many figures used for analog and digital ISO- and DIN-test charts were taken from a book and a CD-ROM: Klaus Richter, Computergrafik und Farbmetrik, VDE-Verlag GMBH, Berlin, 1996,
ISBN 3–8007–1775–1 by agreement of the publisher.

PostScript and the *Portable Document Format* are Trademarks of *Adobe Systems Incorporated*.
For definition see:
Adobe Systems Incorporated, *PostScript* Language Reference Manual, Second edition, Addison-Wesley, 1990, ISBN 0–201–10174–2 and *Adobe Systems Incorporated*, *Portable Document Format*, Reference Manual, Addison-Wesley, 1993, ISBN 0–201–62628–4.

6. References

[1] DIN 33866 „Information technology – Office machines – Machines for colour image reproduction“ ;

Part 1: *Method of specifying image reproduction by **digital** and **analog** DIN-test charts – Classification and principles, draft May 1999, standard DIN 33866-1 in print.*

Part 2: *Method of specifying image reproduction of colour copying machines by **analog** test charts – Realisation and application. (May 1998, revised standard DIN 33866-2 in print)*

Part 3: *Method of specifying image reproduction with **digital** input and **analog** output as **hardcopy** of colour image devices: **“digital** – **analog”** (printers) – Realisation and application, draft May 1999, standard DIN 33866-3 in print.*

Part 4: *Method of specifying image reproduction with **analog** input and **digital** output of colour image devices: **“analog** – **digital”** (scanners) – Realisation and application, draft Nov. 1999, standard DIN 33866-4 in print.*

Part 5: *Method of specifying image reproduction with **digital** input and **analog** output as **softcopy** of colour image devices: **“digital** – **analog”** (monitors) – Realisation and application, draft Nov. 1999, standard DIN 33866-5 in print.*

[2] 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*“, 1999-12-01

[3] ISO 2846–1:1997, *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.709–2:1995, *Parameter Values for the HDTV Standards for Production and International Programme Exchange.*

[5] Draft DIN 33872; Oct. 1999; Determination of yield of consumables (toner/ink, black) for copiers, printers, fax equipment and their combinations.

[6] Klaus Richter, Computergrafik und Farbmetrik, VDE-Verlag GMBH, Berlin, 1996, including CD-ROM with 500 colour figures in PS- and PDF-format for educational purposes, ISBN 3–8007–1775–1, Colour figures also in different languages in Internet, see URL: www.ps.bam.de

[7] Klaus Richter, Analog and digital ISO/IEC-test charts according to ISO/IEC 15775, Colour Image Science Conference, Derby, 2000