IPTC

IPTC - NAA Digital Newsphoto Parameter Record Guideline 1

Comité International des Télécommunications de Presse

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BACKGROUND

When a photographic image is scanned [either a positive (print) or a negative] the output is achieved by measuring the amount of light being reflected from or transmitted through the image. The scanner normally does this in a mode or domain called linear transmittance (for a negative) or linear reflectance (for a print). The characteristics of Linear Transmittance/ Reflectance (Lin_{TR}) information are such that they are not suitable for accurate display or printing of the scanned image. If it is necessary to display or print the image conversions must be carried out into the domains that are normally used for display and printing devices. These are commonly known as TV Gamma (TV γ) and Linear Density respectively. The conversion from Lin_{TR} to TV γ and Linear Density is carried out by applying different mathematical formulae to the data. When a common range of values is used for the Lin_{TR} data then these changes can be expressed by means of simple look-up tables.

INTRODUCTION

The Digital Newsphoto Parameter Record (DNPR) provides a standard for the transmission of digitised newsphoto images together with essential information related to the generation of the image data file. One of the parameters included (DataSet 3:120) is the quantisation method. Most scanners create image data using linear reflectance/transmittance as the quantisation method, although some convert internally to the linear density domain.
More scanners are becoming available that operate in the TV Gamma domain specifically intended to provide images for display on monitors rather than for printing purposes.
Image files received into picture desk systems are often converted into the linear density mode prior to display, manipulation and storage. This conversion process depends upon the maximum density range of the system and the resultant data file values remain characterised by this initial linear density range. It is also possible to convert within the same domain for devices with different maximum density ranges. The following diagram shows these different conversion processes.

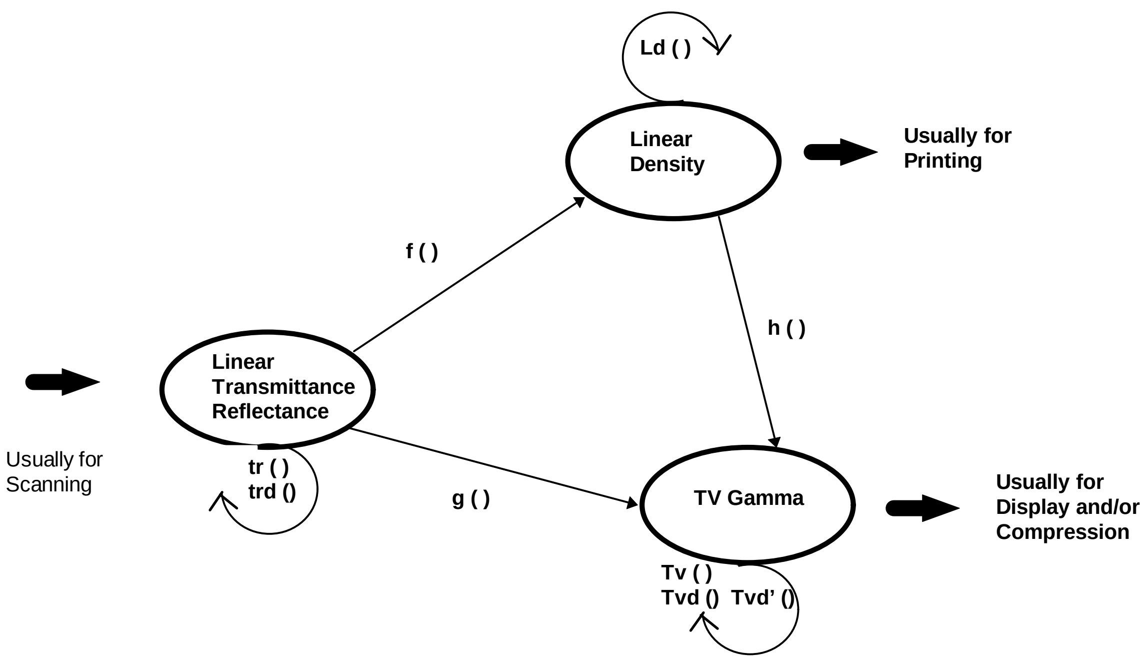


Figure 1: Domain Translation Possibilities

Although the DNPR can indicate that the image quantisation is changed to linear density it currently has no method of indicating the maximum density range applicable to the conversion process.
The maximum density range of any one system is not significant when images are stored and retrieved locally or are transferred to and from other systems with the same maximum density range. However if a printer is used with a different maximum density range or images are transferred between systems with different maximum density ranges (the general case between products from different vendors) then perceived image density suffers. Images can appear either excessively light or excessively dark and this is not acceptable to the end user. In order to solve this problem it is necessary to explore the nature of the conversions involved and then decide how to compensate for the different maximum density ranges of the various systems.

MAXIMUM DENSITY RANGE

Maximum density range is the difference between D_{max} and D_{min}. It is assumed that D_{min} is (or can be set to zero) and the term D_{max} is adopted to mean the maximum density range. It is the value of the maximum density at which the scanner is able to produce an output that is discernible above the sensor threshold. This information is normally published by the scanner manufacturer. Current scanners are able to detect maximum densities in the order of 2.5.

This parameter is significant since if the material to be scanned has a density range greater than the scanner the scanner limits the output at the D_{max} point. Scanning is always done to achieve the best result and so full advantage is taken of scanner output range of values when the material has a maximum density less than the scanner D_{max}. The scanner operator or the automatic driver software will adjust the operating conditions by exposure control or other mechanisms to ensure the output data covers the total scanner range irrespective of the actual material maximum density.

The value of D_{max} will be used in the formulae derived for domain translation and should be available with the image data as part of the output from a scanning process. If the image data is subsequently re-processed in another system such that the value of D_{max} is changed then this new value must be used to update the D_{max} (DataSet 3:140). D_{max} is relevant no matter which colour space is used. For some colour spaces the end points are relevant (DataSet 3:125) and in these cases if the NCPS values are not used the actual end point values can be mapped to the receiving system internal values that represent minimum and maximum density.

The formulae covering the conversion between systems of different D_{max} allow the retention of the smaller density range i.e. when converting to a higher range system values beyond the D_{max} of the lower do not appear as coded values. Similarly, from a higher range system the values above the D_{max} of the lower are all set to the D_{max} of the lower range system. This approach was adopted following practical tests and is considered to be satisfactory for news industry purposes.

IMAGE HANDLING - TRANSFER BETWEEN SYSTEMS

The formulae in this guideline are intended to be used on monochrome or primary colour image separations only. The following terms are used throughout: Lin_{tr} = the Linear Transmittance/Reflectance value, Lin_d = the linear density value, TV_γ = is the TV gamma value. Ntr, Nd and Nγ are the bit resolutions of the digitised signals in the Lin_{tr}, Lin_d and TV_γ domains respectively. It should be noted that the theory assumes that the whitest point corresponds to zero density. In the computer domain it is normal that a data value of zero produces the blackest output. It is necessary to convert density values to their 2^N -1 complement where N is the number of bits used for coding. The formulae reflect this conversion and the term $Clin_d$ applies to the converted values. $Clin_d = (2^N - 1) - Lin_d$.

1. CONVERSION BETWEEN LINEAR REFLECTANCE/TRANSMITTANCE AND LINEAR DENSITY

As shown in Appendix A in a practical system with a real D_{max}:

$$Clin_d = (2^{N_d} - 1) + \frac{2^{Nd} - 1}{D_{max}} \log_{10}\left(\frac{Lin_{tr}}{2^{Ntr} - 1}\left(1 - 10^{-D_{max}}\right) + 10^{-D_{max}}\right)$$

With $0 \le Lin_{tr} \le 2^{Ntr}-1$

$0 \le Clin_d \le 2^{Nd}-1$

[A table of values derived for an 8 bit system with a D_{max} of 1.6 is given at Appendix C]

Transfer function f () : conversion from linear reflectance / transmittance to density

From this formula it is possible to calculate Lin_{tr} from $Clin_d$:

$$Lin_{tr} = (2^{Ntr} - 1)\,\frac{10^{\frac{Clin_d - (2^{Nd}-1)}{2^{Nd}-1} D_{max}} - 10^{-D_{max}}}{1 - 10^{-D_{max}}}$$

With $0 \le Lin_{tr} \le 2^{Ntr} -1$

$0 \le Clin_d \le 2^{Nd}-1$

Transfer function f () $^{-1}$: conversion from density to linear reflectance / transmittance

2. CONVERSION BETWEEN LINEAR REFLECTANCE/TRANSMITTANCE AND TV GAMMA

- Let Lin_{tr} be the digitized linear reflectance/transmittance signal coded with 2^{Ntr} levels between 0 and $2^{Ntr} - 1$ within a maximum density range of D_{max}.

- Let TV_γ be the digitized TV gamma signal coded with $2^{N\gamma}$ levels between 0 and $2^{N\gamma} -1$

The relation between Lin_{tr} and TV_γ is given by :

$$\frac{TV_{\gamma}}{2^{N\gamma}-1} = \left(\frac{\mathrm{Lin}_{tr}}{2^{Ntr}-1}\right)^{1/\gamma}$$

$0 \leq TV_{\gamma} \leq 2^{N\gamma}-1$

$0 \leq Lin_{tr} \leq 2^{Ntr}-1$

$\gamma = 2.22$ for NTSC

<u>Transfer function g () : conversion from linear reflectance/transmittance to TV Gamma</u>

The inverse relation is given by :

$$\frac{Lin_{tr}}{2^{N_{tr}}-1} = \left(\frac{TV_{\gamma}}{2^{N_{\gamma}}-1}\right)^{\gamma}$$

$0 \leq Lin_{tr} \leq 2^{Ntr} - 1$

$0 \leq TV_{\gamma} \leq 2^{N\gamma} - 1$

$\gamma = 2.22$ for NTSC

<u>Transfer function g () $^{-1}$: conversion from TV Gamma to linear reflectance/transmittance</u>

3. <u>CONVERSION BETWEEN DENSITY AND TV GAMMA</u>

If we combine functions f () $^{-1}$ and g () it comes to :

$$\frac{TV_{\gamma}}{2^{N_{\gamma}}-1} = \left(\frac{10^{\frac{\mathrm{Clin}_d-(2^{\mathrm{Nd}}-1)}{2^{\mathrm{N_d}}-1}\mathrm{D_{max}}} - 10^{-\mathrm{D_{max}}}}{1-10^{-\mathrm{D_{max}}}}\right)^{1/\gamma}$$

With $0 \leq Clin_{d} \leq 2^{Nd} - 1$

$0 \leq TV_{\gamma} \leq 2^{N\gamma} - 1$

$\gamma = 2.22$ for NTSC

Transfer function h () : conversion from density to TV Gamma

If we combine functions f () and g () $^{-1}$ then :

$$\mathrm{Clin}_d = (2^{Nd} - 1) + \frac{2^{Nd} - 1}{D_{max}} \log_{10}\left(\left(\frac{TV_\gamma}{2^{N\gamma} - 1}\right)^{\gamma} (1 - 10^{-D_{max}}) + 10^{-D_{max}}\right)$$

$$o \leq \mathrm{Clin}_d \leq 2^{Nd} - 1$$

$$0 \leq TV_\gamma \leq 2^{N\gamma} - 1$$

$$\gamma = 2.22 \text{ for NTSC}$$

Transfer function h () $^{-1}$: conversion from TV Gamma to density

4. CONVERSION FROM DENSITY TO DENSITY WITH DIFFERENT D_{max}

- let Clin_{dA} be a digitized density signal coded with a density range of D_{maxA} between 0 and $2^{NdA} - 1$ for system A.
- let Clin_{dB} be a digitized density signal coded with a density range of D_{maxB} between 0 and $2^{NdB} - 1$ for system B.

As can be seen in Appendix B :

$$(2^{NdB} - 1) - \mathrm{ClindB} = \left(\frac{2^{NdB} - 1}{2^{NdA} - 1}\right)\left(\frac{D_{maxA}}{D_{maxB}}\right)\left((2^{NdA} - 1) - \mathrm{ClindA}\right) + (2^{NdB} - 1)\left(\frac{D_{maxB} - D_{maxA}}{D_{maxB}}\right)$$

$$0 \leq \mathrm{Clin}_{dA} \leq 2^{NdA} - 1$$

$$0 \leq \mathrm{Clin}_{dB} \leq 2^{NdB} - 1$$

Transfer function Ld () : conversion from density to density with different D_{max}

5. CONVERSION FROM LINEAR REFLECTANCE/TRANSMITTANCE TO LINEAR REFLECTANCE/TRANSMITTANCE WITH DIFFERENT D_{MAX}

- let Lin_{trA} be a digitized reflectance/transmittance signal coded with a density range of D_{maxA} between 0 and 2^{NdA} - 1 for system A.
- let Lin_{trB} be a digitized reflectance/transmittance signal coded with a density range of D_{maxB} between 0 and 2^{NdB} - 1 for system B.

We have established in Appendix B that :

$$\mathrm{Lin}_{\mathrm{trB}} = \mathrm{Lin}_{\mathrm{trA}} \frac{\left(2^{\mathrm{NdB}} - 1\right)\left(1-10^{-\mathrm{D}_{\mathrm{maxA}}}\right)}{\left(2^{\mathrm{NdA}} - 1\right)\left(1-10^{-\mathrm{D}_{\mathrm{maxB}}}\right)} + \left(2^{\mathrm{NdB}} - 1\right)\left(\frac{10^{-\mathrm{D}_{\mathrm{maxA}}} - 10^{-\mathrm{D}_{\mathrm{maxB}}}}{1-10^{-\mathrm{D}_{\mathrm{maxB}}}}\right)$$

$$0 \le Lin_{trA} \le 2^{NdA} - 1$$

$$0 \le Lin_{trB} \le 2^{NdB} - 1$$

Transfer function trd() : conversion between two linear reflectance/transmittance signal with different D_{max}

6. CONVERSION FROM TV GAMMA DOMAIN TO TV GAMMA DOMAIN WITH DIFFERENT D_{MAX}

- let $TV_{\gamma A}$ be a digitized TV gamma signal coded with a density range of D_{maxA} between 0 and $2^{N\gamma A}$ - 1 with a gamma value of γ for system A.

let $TV_{\gamma B}$ be a digitized TV gamma signal coded with a density range of D_{maxB} between 0 and $2^{N\gamma B}$ - 1 with the same gamma value of γ for system B.

Combining functions g $()^{-1}$, trd (), g ():

$$\frac{TV_{\gamma B}}{2^{N\gamma B} - 1} = \left(\left(\frac{TV_{\gamma A}}{2^{N\gamma A} - 1}\right)^{\gamma} \frac{1-10^{-\mathrm{D}_{\mathrm{maxA}}}}{1-10^{-\mathrm{D}_{\mathrm{maxB}}}} + \frac{10^{-\mathrm{D}_{\mathrm{maxA}}} - 10^{-\mathrm{D}_{\mathrm{maxB}}}}{1-10^{-\mathrm{D}_{\mathrm{maxB}}}}\right)^{1/\gamma}$$

$$0 \le TV_{\gamma B} \le 2^{N\gamma B} - 1$$

$$0 \le TV_{\gamma A} \le 2^{N\gamma A} - 1$$

$$\gamma = 2.22 \text{ for NTSC}$$

Transfer function Tvd() : conversion between two TV gamma signals with different D_{max}

7. CONVERSION FROM TV GAMMA DOMAIN TO TV GAMMA DOMAIN WITH DIFFERENT GAMMA

- let $TV_{\gamma A}$ be a digitized TV gamma signal coded with a density range of D_{max} between 0 and $2^{N\gamma A}$ - 1 with a gamma value of γ_A for system A.

- let $TV_{\gamma B}$ be a digitized TV gamma signal coded with a density range of D_{max} between 0 and $2^{N\gamma B}$ - 1 with the same gamma value of γ_B for system B.

Combining functions g () and g () $^{-1}$:

$$\frac{TV_{\gamma B}}{2^{N\gamma A}-1} = \left(\frac{TV_{\gamma A}}{2^{N\gamma A}-1}\right)^{\frac{\gamma_A}{\gamma_B}}$$

$0 \leq TV_{\gamma A} \leq 2^{N\gamma A} - 1$

$0 \leq TV_{\gamma B} \leq 2^{N\gamma B} - 1$

γ_A and γ_B as γ values

Transfer function Tv() : Conversion between two TV gamma signals with different gamma

8. CONVERSION FROM TV GAMMA DOMAIN TO TV GAMMA DOMAIN WITH DIFFERENT GAMMA AND DIFFERENT D_{MAX}

- let $TV_{\gamma A}$ be a digitized TV gamma signal coded with a density range of D_{maxA} between 0 and $2^{N\gamma A}$ - 1 with a gamma value of γ_A for system A.

- let $TV_{\gamma B}$ be a digitized TV gamma signal coded with a density range of D_{maxB} between 0 and $2^{N\gamma B}$ - 1 with a gamma value of γ_B for system B.

Combining functions g () $^{-1}$,trd (), g ():

$$\frac{TV_{\gamma B}}{2^{N\gamma B}-1} = \left(\left(\frac{TV_{\gamma A}}{2^{N\gamma A}-1}\right)^{\gamma_A} \frac{1-10^{-\mathrm{D}_{\mathrm{maxA}}}}{1-10^{-\mathrm{D}_{\mathrm{maxB}}}} + \frac{10^{-\mathrm{D}_{\mathrm{maxA}}}-10^{-\mathrm{D}_{\mathrm{maxB}}}}{1-10^{-\mathrm{D}_{\mathrm{maxB}}}}\right)^{1/\gamma_B}$$

$0 \leq TV_{\gamma A} \leq 2^{N\gamma A} - 1$

$0 \leq TV_{\gamma B} \leq 2^{N\gamma B} - 1$

γ_A and γ_B as gamma values

Transfer function Tvd'() : conversion between two TV gamma signals with different gamma and different D_{max}

PRACTICAL RESULTS

IPTC and NAA have carried out test using these relationships for the transfer of images between different systems available in the market. The results confirmed that the theory is satisfactory for uncompressed image files. However, in order to be universally applicable it is necessary to append the D_{max} value of the source system to an image file. It is proposed to achieve this by extending the use of the DNPR DataSet 3:140 so that it is valid for all quantisation methods. The contents of DataSet 3:140 will be the value of D_{max} x 100.

To allow for systems not yet able to implement this feature users are advised that an assumed default value of 160 applies. Information Providers will need to ensure that their customers are notified by other means if the value of D_{max} applicable to their images is other than the default of 1.6. Once the change to DataSet 3:140 is implemented then separate notification will be unnecessary.

DISPLAY ADJUSTMENT

The correction of an image quantisation values to allow for the different maximum density range of the originating and receiving systems will not always result in a perfect screen display. It may be necessary to apply a gamma correction to allow for the response of the screen phosphors. Appendix D provides a table for correction to the density values when a gamma of 2.2 occurs. (This is the normal CCIR TV monitor value).

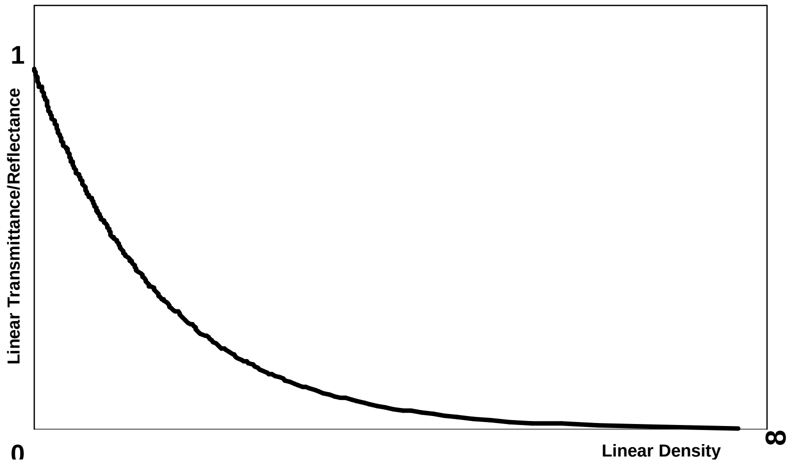
APPENDIX A

Derivation of Linear Density LInear Reflectance/Transmittance Relationship for a System with a Finite Maximum Density Range (D_{max})

The general relationship for an infinite density range is given by:

$$Lin_{tr} = \left(Lin_{tr\,\max}\right)10^{-d}$$

This can be plotted as shown below. The density values are unbounded at the high end.



Where a maximum density value is given (the practical case) the equation must be modified as follows:

$$Lin_{tr} = A\left(Lin_{tr\,\max}\right)10^{-d} \;+\; B$$

Where the following boundary conditions apply

When $Lin_{tr} = 0$ then $d = D_{max}$
and $Lin_{tr} = Lin_{trmax}$ for $d = 0$

Hence

$$0 \;=\; A\left(Lin_{tr\,\max}\right)10^{-d} \;+\; B$$

$$-A\left(Lin_{tr\,\max}\right)10^{-d} \;=\; B$$

By substitution

$$Lin_{tr} = A\left(Lin_{tr\,\max}\right)10^{-d} \;-\; A\left(Lin_{tr\,\max}\right)10^{-D_{\max}}$$

$$A \;=\; \frac{1}{1 \;-\; 10^{-D_{\max}}}$$

Hence

$$B \;=\; \frac{-\left(Lin_{tr\,\max}\right)10^{-D_{\max}}}{1 \;-\; 10^{-D_{\max}}}$$

Giving

$$10^{-d} = \frac{Lin_{tr}}{Lin_{trmax}}(1 - 10^{-D_{\max}}) + 10^{-D_{\max}}$$

or

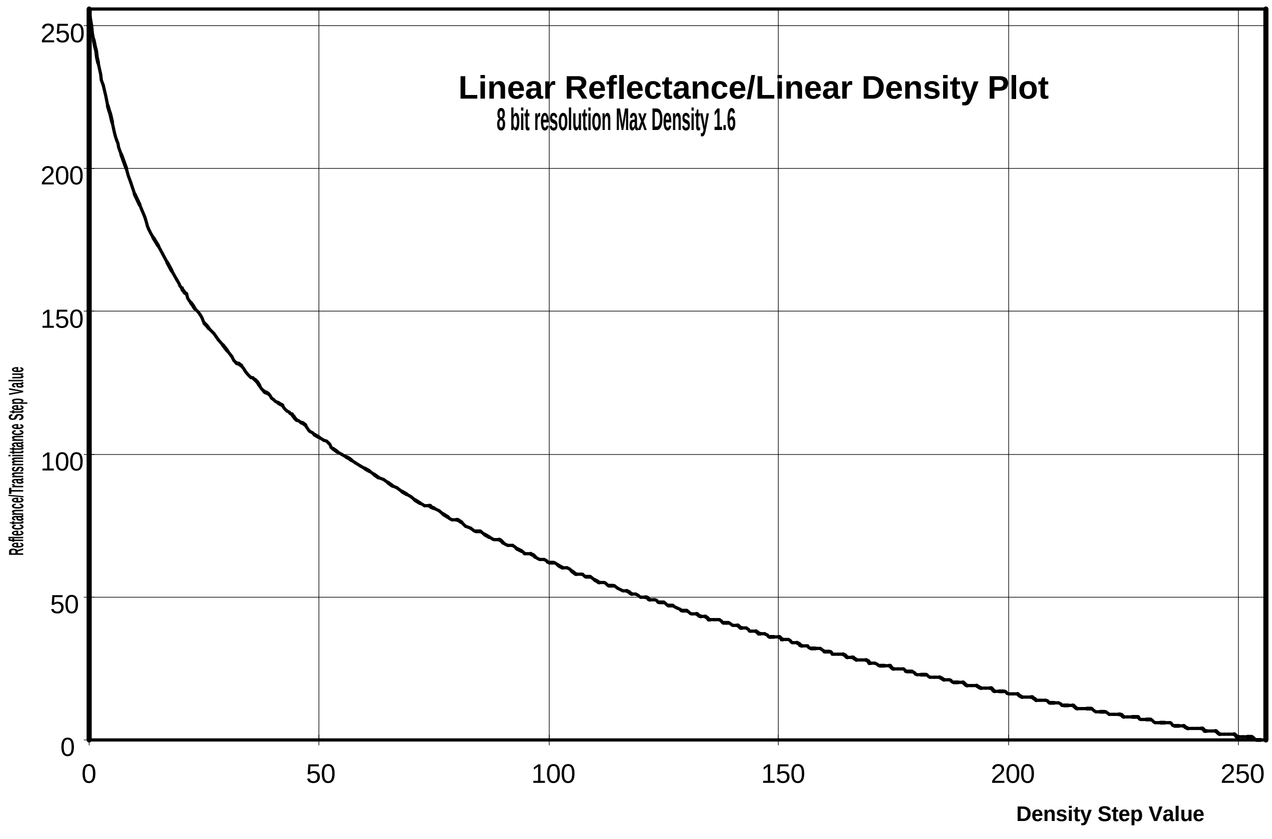
$$d = -\log_{10}(\frac{Lin_{tr}}{Lin_{trmax}}(1 - 10^{-D_{\max}}) + 10^{-D_{\max}})$$

For 8 bit systems (n = 8) Lin_{trmax} will be normalised to $2^n - 1$ (= 255) and the normalised form for density values is:

$$d = -(\frac{2^n - 1}{D_{\max}})\log_{10}(\frac{Lin_{tr}}{2^n - 1}(1 - 10^{-D_{\max}}) + 10^{-D_{\max}})$$

where 0 <= d <= 255 and is a discrete presentation of the DENSITY which varies between 0 and 1.6.

A plot of the resultant curve is shown below with D_{max} constrained to a value of 1.6. The values used are shown in the table at Appendix C.



A further relationship may be derived between the linear reflectance values represented within 2 systems using a different maximum density range. In general the relationship between the reflectance/transmittance output of a system and the density value observed is given by:

$$v = v_0 * 10^{-d}$$

or

$$v = \alpha\, 10^{-d} - \beta$$

with conditions such that

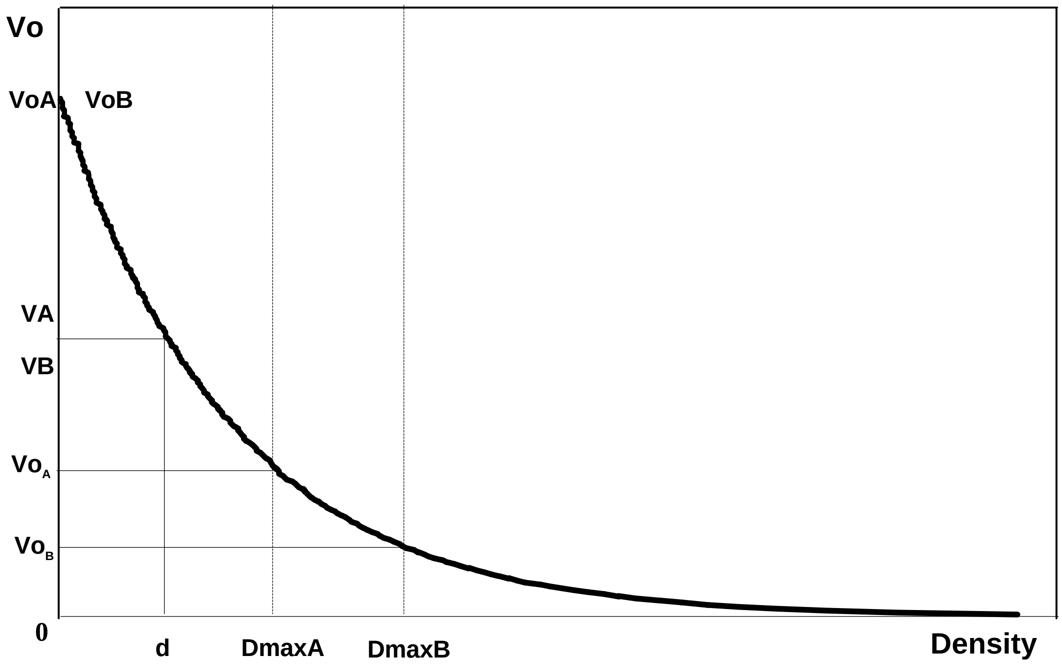
$$\text{when} \quad d = 0 \quad v = v_0$$
$$d = D_{\max} \quad v = 0$$

leads to

$$\alpha = v_0 \frac{1}{1 - 10^{-D_{\max}}}$$

and

$$\beta = v_0 \frac{10^{-D_{\max}}}{1 - 10^{-D_{\max}}}$$



A composite plot of reflectance against density for 2 systems with different maximum density ranges is shown above. Equations for both system A and system B can be solved for the values of v_A and v_B at a density value of d using the above result. This leads an expression for v_B in terms of v_A:

$$v_B = \frac{1 - 10^{-D_{\max A}}}{1 - 10^{-D_{\max B}}} v_A + v_0 \left(\frac{10^{-D_{\max A}} - 10^{-D_{\max B}}}{1 - 10^{-D_{\max B}}} \right)$$

or more generally

$$v_B = a v_A + b$$

This allows the linear transformation of information from one system to another providing the D_{max} for each system is known in advance.

Determination of D_{max} when manufacturer's information is not available.

By re-arranging the general equation given at the start of this Guideline and assuming that the value of reflectance for a known density can be measured or obtained by other means then:

$$D_{\max} = -\log_{10} \left(\frac{Lin_{tr} - (2^n - 1)10^{-d}}{Lin_{tr} - (2^n - 1)} \right)$$

providing that for 8 bit systems

$255 \geq Lin_{tr} \geq 0$ and $0 \leq d \leq D_{max}$ (maximum reflectance/transmittance ≡ minimum density ie the WHITE value)

This allows a value of D_{max} to be obtained for use in any domain translation required by the user.

APPENDIX B

Derivation of function Ld ()

The general relationship between linear reflectance/transmittance and linear density is given by $v=v_o10^{-d}$ (see Appendix A). This may be re-arranged as:-

$$d = -\log_{10}\left(\frac{v}{v_o}\right)$$

$$d = -\left(\log_{10} v - \log_{10} v_o\right)$$

$$d = \log_{10} v_0 - \log_{10} v$$

or

$$d = D_{\max} - \left(\frac{Lin_d}{2^{Nd} - 1}\right)D_{\max}$$

for $0 \leq Lin_d \leq 2^{Nd} -1$

$D_{max} \geq d \geq 0$

This can be re-written as:

$$d = D_{\max A} - \left(\frac{Lin_{dA}}{2^{NdA} - 1}\right)D_{\max A}$$ where d is the value for system A

and

$$d = D_{\max B} - \left(\frac{Lin_{dB}}{2^{NdB} - 1}\right)D_{\max B}$$ where d is the value for system B

when the value of d is the same for both systems then

$$D_{\max B}\left(2^{NdB} - 1\right) - Lin_{dB}D_{\max B} = D_{\max A}\left(2^{NdB} - 1\right) - D_{\max A}\left(\frac{2^{NdB} - 1}{2^{NdA} - 1}\right)Lin_{dA}$$

$$Lin_{dB} = \left(\frac{D_{\max B}\left(2^{NdB} - 1\right) + D_{\max A}\left(\frac{2^{NdB} - 1}{2^{NdA} - 1}\right)Lin_{dA} - D_{\max A}\left(2^{NdB} - 1\right)}{D_{\max B}}\right)$$

or

$$Lin_{dB} = \left(\frac{2^{NdB}-1}{2^{NdA}-1}\right)\frac{D_{\max A}}{D_{\max B}} Lin_{dA} + \left(2^{NdB}-1\right)\frac{D_{\max B}-D_{\max A}}{D_{\max B}}$$

and by substitution of $Clin_d = (2^{Nd} - 1) - Lin_d$

$$(2^{NdB} - 1) - ClindB = \left(\frac{2^{NdB} - 1}{2^{NdA} - 1}\right)\left(\frac{D_{maxA}}{D_{maxB}}\right)\left((2^{NdA} - 1) - ClindA\right) + (2^{NdB} - 1)\left(\frac{D_{maxB} - D_{maxA}}{D_{maxB}}\right)$$

Derivation of function trd ()

From function f () $^{-1}$

$$Lin_{trA} = \left(\frac{2^{NtrA}-1}{1-10^{-D\max A}}\right)10^{-dA} - \left(\frac{2^{NtrA}-1}{1-10^{-D\max A}}\right)10^{-D_{\max A}}$$

$$10^{-dA} = \frac{Lin_{trA}\left(1-10^{-D_{\max A}}\right)+\left(2^{NtrA}-1\right)10^{-D_{\max A}}}{2^{NtrA}-1}$$

and

$$10^{-dB} = \frac{Lin_{trB}\left(1-10^{-D_{\max B}}\right)+\left(2^{NtrB}-1\right)10^{-D_{\max B}}}{2^{NtrB}-1}$$

When dA = dB then

$$\begin{aligned} &Lin_{trA}\left(1-10^{-D_{\max A}}\right)\left(2^{NtrB}-1\right)+\left(2^{NtrA}-1\right)\left(2^{NtrB}-1\right)10^{-D_{\max A}} \\ &= Lin_{trB}\left(1-10^{-D_{\max B}}\right)\left(2^{NtrA}-1\right)+\left(2^{NtrB}-1\right)\left(2^{NtrA}-1\right)10^{-D_{\max B}} \end{aligned}$$

Leading to

$$Lin_{trB} = Lin_{trA}\left(\frac{1-10^{-D_{\max A}}}{1-10^{-D_{\max B}}}\right)\left(\frac{2^{NtrB}-1}{2^{NtrA}-1}\right) + \left(2^{NtrB}-1\right)\left(\frac{10^{-D_{\max A}}-10^{-D_{\max B}}}{1-10^{-D_{\max B}}}\right)$$

Appendix C. **Coded Values ofLinear Transmittance Reflectance, Corresponding Linear Density for 8 Bit System and Absolute Density. D_{max} = 1.6.**

Encoded Lin_{tr}	Encoded Density	Absolute Density	Encoded Lin_{tr}	Encoded Density	Absolute Density	Encoded Lin_{tr}	Encoded Density	Encoded Density
255	255	0.00	209	242	0.08	163	225	0.19
254	255	0.00	208	241	0.09	162	225	0.19
253	254	0.01	207	241	0.09	161	224	0.19
252	254	0.01	206	241	0.09	160	224	0.19
251	254	0.01	205	240	0.09	159	223	0.20
250	254	0.01	204	240	0.09	158	223	0.20
249	253	0.01	203	240	0.09	157	223	0.20
248	253	0.01	202	239	0.10	156	222	0.21
247	253	0.01	201	239	0.10	155	222	0.21
246	253	0.01	200	239	0.10	154	221	0.21
245	252	0.02	199	238	0.11	153	221	0.21
244	252	0.02	198	238	0.11	152	220	0.22
243	252	0.02	197	238	0.11	151	220	0.22
242	251	0.03	196	237	0.11	150	219	0.23
241	251	0.03	195	237	0.11	149	219	0.23
240	251	0.03	194	237	0.11	148	219	0.23
239	251	0.03	193	236	0.12	147	218	0.23
238	250	0.03	192	236	0.12	146	218	0.23
237	250	0.03	191	236	0.12	145	217	0.24
236	250	0.03	190	235	0.13	144	217	0.24
235	249	0.04	189	235	0.13	143	216	0.24
234	249	0.04	188	235	0.13	142	216	0.24
233	249	0.04	187	234	0.13	141	215	0.25
232	249	0.04	186	234	0.13	140	215	0.25
231	248	0.04	185	233	0.14	139	214	0.26
230	248	0.04	184	233	0.14	138	214	0.26
229	248	0.04	183	233	0.14	137	213	0.26
228	247	0.05	182	232	0.14	136	213	0.26
227	247	0.05	181	232	0.14	135	213	0.26
226	247	0.05	180	232	0.14	134	212	0.27
225	247	0.05	179	231	0.15	133	212	0.27
224	246	0.06	178	231	0.15	132	211	0.28
223	246	0.06	177	230	0.16	131	211	0.28
222	246	0.06	176	230	0.16	130	210	0.28
221	245	0.06	175	230	0.16	129	210	0.28
220	245	0.06	174	229	0.16	128	209	0.29
219	245	0.06	173	229	0.16	127	208	0.29
218	244	0.07	172	229	0.16	126	208	0.29
217	244	0.07	171	228	0.17	125	207	0.30
216	244	0.07	170	228	0.17	124	207	0.30
215	244	0.07	169	227	0.18	123	206	0.31
214	243	0.08	168	227	0.18	122	206	0.31
213	243	0.08	167	227	0.18	121	205	0.31
212	243	0.08	166	226	0.18	120	205	0.31
211	242	0.08	165	226	0.18	119	204	0.32
210	242	0.08	164	225	0.19	118	204	0.32

Appendix C. **Coded Values ofLinear Transmittance Reflectance, Corresponding Linear Density for 8 Bit System and Absolute Density. D_{max} = 1.6.**

Encoded Lin$_{tr}$	Encoded Density	Absolute Density	Encoded Lin$_{tr}$	Encoded Density	Absolute Density	Encoded Lin$_{tr}$	Encoded Density	Absolute Density
117	203	0.33	71	171	0.53	25	109	0.92
116	203	0.33	70	170	0.53	24	106	0.93
115	202	0.33	69	169	0.54	23	104	0.95
114	201	0.34	68	168	0.55	22	102	0.96
113	201	0.34	67	167	0.55	21	99	0.98
112	200	0.35	66	166	0.56	20	97	0.99
111	200	0.35	65	165	0.56	19	94	1.01
110	199	0.35	64	164	0.57	18	91	1.03
109	198	0.36	63	163	0.58	17	88	1.05
108	198	0.36	62	162	0.58	16	85	1.07
107	197	0.36	61	161	0.59	15	82	1.09
106	197	0.36	60	160	0.60	14	79	1.10
105	196	0.37	59	159	0.60	13	76	1.12
104	195	0.38	58	158	0.61	12	72	1.15
103	195	0.38	57	157	0.61	11	68	1.17
102	194	0.38	56	156	0.62	10	64	1.20
101	193	0.39	55	155	0.63	9	60	1.22
100	193	0.39	54	154	0.63	8	55	1.25
99	192	0.40	53	153	0.64	7	50	1.29
98	192	0.40	52	151	0.65	6	45	1.32
97	191	0.40	51	150	0.66	5	39	1.36
96	190	0.41	50	149	0.67	4	33	1.39
95	190	0.41	49	148	0.67	3	26	1.44
94	189	0.41	48	147	0.68	2	18	1.49
93	188	0.42	47	145	0.69	1	10	1.54
92	187	0.43	46	144	0.70	0	0	1.60
91	187	0.43	45	143	0.70			
90	186	0.43	44	141	0.72			
89	185	0.44	43	140	0.72			
88	185	0.44	42	138	0.73			
87	184	0.45	41	137	0.74			
86	183	0.45	40	136	0.75			
85	182	0.46	39	134	0.76			
84	182	0.46	38	133	0.77			
83	181	0.46	37	131	0.78			
82	180	0.47	36	129	0.79			
81	179	0.48	35	128	0.80			
80	178	0.48	34	126	0.81			
79	178	0.48	33	124	0.82			
78	177	0.49	32	123	0.83			
77	176	0.50	31	121	0.84			
76	175	0.50	30	119	0.85			
75	174	0.51	29	117	0.87			
74	173	0.51	28	115	0.88			
73	173	0.51	27	113	0.89			
72	172	0.52	26	111	0.90			

Appendix D.**Normalised Linear Transmittance Reflectance and Gamma Corrected Values (γCV) for 8 Bit System. γ = 2.22**

LinTR	γCV	LinTR	γCV	LinTR	γCV
0	0	64	137	128	187
1	21	65	138	129	188
2	29	66	139	130	188
3	35	67	140	131	189
4	39	68	141	132	190
5	43	69	142	133	190
6	47	70	143	134	191
7	51	71	143	135	192
8	54	72	144	136	192
9	57	73	145	137	193
10	59	74	146	138	193
11	62	75	147	139	194
12	64	76	148	140	195
13	67	77	149	141	195
14	69	78	150	142	196
15	71	79	150	143	197
16	73	80	151	144	197
17	75	81	152	145	198
18	77	82	153	146	198
19	79	83	154	147	199
20	81	84	155	148	200
21	83	85	156	149	200
22	85	86	156	150	201
23	86	87	157	151	201
24	88	88	158	152	202
25	90	89	159	153	203
26	91	90	160	154	203
27	93	91	160	155	204
28	94	92	161	156	204
29	96	93	162	157	205
30	97	94	163	158	206
31	99	95	164	159	206
32	100	96	164	160	207
33	102	97	165	161	207
34	103	98	166	162	208
35	104	99	167	163	208
36	106	100	167	164	209
37	107	101	168	165	210
38	108	102	169	166	210
39	110	103	170	167	211
40	111	104	170	168	211
41	112	105	171	169	212
42	113	106	172	170	212
43	114	107	173	171	213
44	116	108	173	172	214
45	117	109	174	173	214
46	118	110	175	174	215
47	119	111	175	175	215
48	120	112	176	176	216
49	121	113	177	177	216
50	122	114	178	178	217
51	124	115	178	179	217
52	125	116	179	180	218
53	126	117	180	181	219
54	127	118	180	182	219
55	128	119	181	183	220
56	129	120	182	184	220
57	130	121	182	185	221
58	131	122	183	186	221
59	132	123	184	187	222
60	133	124	184	188	222
61	134	125	185	189	223
62	135	126	186	190	223
63	136	127	186	191	224

Appendix D.**Normalised Linear Transmittance Reflectance and Gamma Corrected Values (γCV) for 8 Bit System. γ = 2.22**

LinTR	γCV
192	224
193	225
194	225
195	226
196	227
197	227
198	228
199	228
200	229
201	229
202	230
203	230
204	231
205	231
206	232
207	232
208	233
209	233
210	234
211	234
212	235
213	235
214	236
215	236
216	237
217	237
218	238
219	238
220	239
221	239
222	240
223	240
224	241
225	241
226	242
227	242
228	242
229	243
230	243
231	244
232	244
233	245
234	245
235	246
236	246
237	247
238	247
239	248
240	248
241	249
242	249
243	250
244	250
245	250
246	251
247	251
248	252
249	252
250	253
251	253
252	254
253	254
254	255
255	255