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Photography and graphic technology — Extended colour encodings for digital image storage, manipulation and interchange —

Part 3: Reference input medium metric RGB colour image encoding (RIMM RGB)

Photographie et technologie graphique — Codages par couleurs étendues pour stockage, manipulation et échange d'image numérique —

Partie 3: Codage d'image en couleurs RVB par référence d'entrée par voie métrique

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Foreword

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The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

In other circumstances, particularly when there is an urgent market requirement for such documents, a technical committee may decide to publish other types of document:

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An ISO/PAS or ISO/TS is reviewed after three years in order to decide whether it will be confirmed for a further three years, revised to become an International Standard, or withdrawn. If the ISO/PAS or ISO/TS is confirmed, it is reviewed again after a further three years, at which time it must either be transformed into an International Standard or be withdrawn.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO/TS 22028-3 was prepared by Technical Committee ISO/TC 42, *Photography*.

This second edition cancels and replaces the first edition (ISO/TS 22028-3:2006), which has been technically revised.

ISO/TS 22028 consists of the following parts, under the general title *Photography and graphic technology — Extended colour encodings for digital image storage, manipulation and interchange*:

— *Part 1: Architecture and requirements*

— *Part 2: Reference output medium metric RGB colour image encoding (ROMM RGB)*

— *Part 3: Reference input medium metric RGB colour image encoding (RIMM RGB)* [Technical Specification]

The following parts are under preparation:

— *Part 4: European Colour Initiative RGB colour image encoding [eciRGB (2008)]* [Technical Specification]

Introduction

This part of ISO 22028 has been developed in order to meet the industry need for a complete, fully-documented, publicly-available definition of a wide-primary scene-referred extended colour gamut red-green-blue (RGB) colour image encoding. This encoding provides a way to represent scene-referred images that does not limit the colour gamut to those colours capable of being displayed on a CRT monitor, or require the use of negative RGB colourimetry coordinates.

A scene-referred extended colour gamut colour encoding is particularly desirable for professional photography applications. For example, colours captured by digital cameras, as well as conventional capture devices such as photographic film, can be outside those that can be represented within the colour gamut of a typical monitor or other types of output devices. Similarly, scene-referred images can have a larger luminance dynamic range than output-referred images since they have not been modified by a colour rendering process to fit the images to a specific output medium applying appropriate tone and colour reproduction aims. Retaining the unrendered scene-referred image data has the advantage that it preserves the option to make decisions about how a particular image is to be rendered. For example, a scene-referred image of a backlit scene can retain information about both the dark foreground region and the bright background region of the scene. This information can be used to make a properly exposed print of either the foreground region or the background region, or alternatively can be used to create an improved image by rendering the two regions differently.

By using a standard scene-referred extended colour gamut colour image encoding, images can be stored, interchanged and manipulated without restricting the image to a particular rendering intent or output device. The reference input medium metric RGB (RIMM RGB) colour encoding specified in this part of ISO 22028 meets the needs of these types of applications. An extended dynamic range version of this colour image encoding known as extended reference input medium metric RGB (ERIMM RGB), and a floating point version known as FP-RIMM RGB are also specified for use with high-dynamic range input sources. The scene-referred RIMM RGB colour image encoding is intended to be complementary to the output-referred ROMM RGB colour image encoding specified in ISO/TS 22028-2. Both colour encodings are based on the same “wide RGB” additive colour space to facilitate the development of image processing algorithms and simple colour rendering transformations to convert scene-referred RIMM RGB images to rendered output-referred ROMM RGB images.

The International Organization for Standardization (ISO) draws attention to the fact that it is claimed that compliance with this document may involve the use of patents concerning extended range colour encodings given in 4.4 and 4.5. ISO takes no position concerning the evidence, validity and scope of this patent right.

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Photography and graphic technology — Extended colour encodings for digital image storage, manipulation and interchange —

Part 3: Reference input medium metric RGB colour image encoding (RIMM RGB)

1 Scope

This part of ISO 22028 specifies a family of scene-referred extended colour gamut RGB colour image encodings designated as reference input medium metric RGB (RIMM RGB). Digital images encoded using RIMM RGB can be manipulated, stored, transmitted, displayed or printed by digital still picture imaging systems. Three precision levels are defined using 8-, 12- and 16-bits/channel.

An extended luminance dynamic range version of RIMM RGB is also defined, designated as extended reference input medium metric RGB (ERIMM RGB). Two precision levels of ERIMM RGB are defined using 12- and 16-bits/channel.

FP-RIMM RGB, a floating point version of RIMM RGB, defines the expression method of RIMM RGB in a floating point figure. Three precision levels of FP-RIMM RGB are defined using 16-, 32- and 64-bits/channel.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 12234-2, *Electronic still-picture imaging — Removable memory — Part 2: TIFF/EP image data format*

ISO 22028-1:2004, *Photography and graphic technology — Extended colour encodings for digital image storage, manipulation and interchange — Part 1:Architecture and requirements*

ISO 11664-1, *Colorimetry — Part 1: CIE standard colorimetric observers*[1)]

CIE Publication 15, *Colorimetery*

IEEE 754, *IEEE Standard for Floating-Point Arithmetic*

1) Replaces ISO/CIE 10527.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
adapted white
colour stimulus that an observer who is adapted to the viewing environment would judge to be perfectly achromatic and to have a luminance factor of unity; i.e. absolute colourimetric coordinates that an observer would consider to be a perfect white diffuser

NOTE The adapted white can vary within a scene.

3.2
additive RGB colour space
colourimetric colour space having three colour primaries (generally red, green and blue) such that CIE XYZ tristimulus values can be determined from the RGB colour space values by forming a weighted combination of the CIE XYZ tristimulus values for the individual colour primaries, where the weights are proportional to the radiometrically linear colour space values for the corresponding colour primaries

NOTE 1 A simple linear 3 × 3 matrix transformation can be used to transform between CIE XYZ tristimulus values and the radiometrically linear colour space values for an additive RGB colour space.

NOTE 2 Additive RGB colour spaces are defined by specifying the CIE chromaticity values for a set of additive RGB primaries and a colour space white point, together with a colour component transfer function.

3.3
adopted white
spectral radiance distribution as seen by an image capture or measurement device and converted to colour signals that are considered to be perfectly achromatic and to have an observer adaptive luminance factor of unity; i.e. colour signals that are considered to correspond to a perfect white diffuser

NOTE 1 The adopted white can vary within a scene, if such variation is supported by the imaging system.

NOTE 2 The adopted white is not required to be an estimate or approximation of the adapted white. For example, if a scene lit by tungsten illumination is captured using a DSC with the white balance set to D55 (daylight), the adopted white will be D55 but the adapted white will be closer to a tungsten illuminant (e.g. ISO 7589 Studio Tungsten or CIE Illuminant A).

NOTE 3 See 3.1.

3.4
colourimetric colour space
colour space having an exact and simple relationship to CIE colourimetric values

NOTE Colourimetric colour spaces include those defined by CIE (e.g. CIE XYZ, CIELAB, CIELUV), as well as colour spaces that are simple transformations of those colour spaces (e.g. additive RGB colour spaces).

3.5
colour component transfer function
single variable, monotonic mathematical function applied individually to one or more colour channels of a colour space

NOTE 1 Colour component transfer functions are frequently used to account for the nonlinear response of a reference device and/or to improve the visual uniformity of a colour space.

NOTE 2 Generally, colour component transfer functions will be nonlinear functions such as a power-law (i.e. "gamma") function or a logarithmic function. However, in some cases a linear colour component transfer function can be used.

3.6
colour encoding
generic term for a quantized digital encoding of a colour space, encompassing both colour space encodings and colour image encodings

3.7
colour gamut
solid in a colour space, consisting of all those colours that are either present in a specific scene, artwork, photograph, photomechanical, or other reproduction, or capable of being created using a particular output device and/or medium

3.8
colour image encoding
digital encoding of the colour values for a digital image, including the specification of a colour space encoding, together with any information necessary to properly interpret the colour values such as the image state, the intended image viewing environment and the reference medium

NOTE 1 In some cases, the intended image viewing environment will be explicitly defined for the colour image encoding. In other cases, the intended image viewing environment can be specified on an image-by-image basis using metadata associated with the digital image.

NOTE 2 Some colour image encodings will indicate particular reference medium characteristics, such as a reflection print with a specified density range. In other cases, the reference medium will not be applicable, such as with a scene-referred colour image encoding, or will be specified using image metadata.

NOTE 3 Colour image encodings are not limited to pictorial digital images that originate from an original scene, but are also applicable to digital images with content such as text, line art, vector graphics and other forms of original artwork.

3.9
colour rendering
mapping of image data representing the colour-space coordinates of the elements of a scene to output-referred image data representing the colour space coordinates of the elements of a reproduction

NOTE Colour rendering generally consists of one or more of the following:

- compensating for differences in the input and output viewing conditions;
- tone scale and gamut mapping to map the scene colours onto the dynamic range and colour gamut of the reproduction;
- applying preference adjustments.

3.10
colour space
geometric representation of colours in space, usually of three dimensions

[CIE Publication 17.4:1987, 845-03-25]

3.11
colour space encoding
digital encoding of a colour space, including the specification of a digital encoding method, and a colour space value range

NOTE Multiple colour space encodings can be defined based on a single colour space where the different colour space encodings have different digital encoding methods and/or colour space value ranges. (For example, 8-bit sRGB and 10-bit e-sRGB are different colour space encodings based on a particular RGB colour space.)

3.12
colour space white point
colour stimulus to which colour space values are normalized

NOTE It is not necessary that the colour space white point correspond to the assumed adapted white point and/or the reference medium white point for a colour image encoding.

3.13
image state
attribute of a colour image encoding indicating the rendering state of the image data

NOTE The primary image states defined in this document are the scene-referred image state, the original-referred image state and the output-referred image state.

3.14
luminance factor
ratio of the luminance of the surface element in the given direction to that of a perfect reflecting or transmitting diffuser identically illuminated

[CIE Publication 17.4:1987, 845-04-69]

3.15
observer adaptive luminance factor
ratio of the luminance of a stimulus to the luminance of a stimulus that an observer adapted to the viewing environment would interpret to be a perfect white diffuser

3.16
output-referred image state
image state associated with image data that represents the colour space coordinates of the elements of an image that has undergone colour rendering appropriate for a specified real or virtual output device and viewing conditions

NOTE 1 When the phrase “output-referred” is used as a qualifier to an object, it implies that the object is in an output-referred image state. For example, output-referred image data are image data in an output-referred image state.

NOTE 2 Output referred image data are referred to the specified output device and viewing conditions. A single scene can be colour rendered to a variety of output-referred representations depending on the anticipated output viewing conditions, media limitations and/or artistic intents.

NOTE 3 Output-referred image data can become the starting point for a subsequent reproduction process. For example, sRGB output-referred image data are frequently considered to be the starting point for the colour re-rendering performed by a printer designed to receive sRGB image data.

3.17
scene
spectral radiances of a view of the natural world as measured from a specified vantage point in space and at a specified time

NOTE A scene can correspond to an actual view of the natural world or to a computer-generated virtual scene simulating such a view.

3.18
scene-referred image state
image state associated with image data that represents estimates of the colour space coordinates of the elements of a scene

NOTE 1 When the phrase “scene-referred” is used as a qualifier to an object, it implies that the object is in a scene-referred image state. For example, scene-referred image data are image data in a scene-referred image state.

NOTE 2 Scene-referred image data can be determined from raw DSC image data before colour rendering is performed. Generally, DSCs do not write scene-referred image data in image files, but some do so in a special mode intended for this purpose. Typically, DSCs write standard output-referred image data where colour rendering has already been performed.

NOTE 3 Scene-referred image data typically represents relative scene colourimetry estimates. Absolute scene colourimetry estimates can be calculated using a scaling factor. The scaling factor can be derived from additional information such as the image OECF, FNumber or ApertureValue, and ExposureTime or ShutterSpeedValue tags.

NOTE 4 Scene-referred image data can contain inaccuracies due to the dynamic range limitations of the capture device, noise from various sources, quantization, optical blurring and flare that are not corrected for, and colour analysis errors due to capture device metamerism. In some cases, these sources of inaccuracy can be significant.

NOTE 5 The transformation from raw DSC image data to scene-referred image data depends on the relative adopted whites selected for the scene and the colour space used to encode the image data. If the chosen scene adopted white is inappropriate, additional errors will be introduced into the scene-referred image data. These errors can be correctable if the transformation used to produce the scene-referred image data are known, and the colour encoding used for the incorrect scene-referred image data has adequate precision and dynamic range.

NOTE 6 The scene can correspond to an actual view of the natural world, or be a computer-generated virtual scene simulating such a view. It can also correspond to a modified scene determined by applying modifications to an original scene to produce some different desired scene. Any such scene modifications need to leave the image in a scene-referred image state and need to be done in the context of an expected colour rendering transform.

3.19
tristimulus value
amounts of the three reference colour stimuli, in a given trichromatic system, required to match the colour of the stimulus considered

[CIE Publication 17.4:1987, 845-03-22]

3.20
veiling glare
light, reflected from an imaging medium, that has not been modulated by the means used to produce the image

NOTE 1 Veiling glare lightens and reduces the contrast of the darker parts of an image.

NOTE 2 In CIE Publication 122, the veiling glare of a CRT display is referred to as ambient flare.

3.21
viewing flare
veiling glare that is observed in a viewing environment but not accounted for in radiometric measurements made using a prescribed measurement geometry

NOTE The viewing flare is expressed as a percentage of the luminance of adapted white.

3.22
working colour space
colour space encoding in which operations such as image edits, enhancements, or colour rendering are performed

NOTE 1 The image state in a working colour space can change as operations are performed.

NOTE 2 If operations performed in a working colour space are guided by viewing the image on a medium, that medium and the associated viewing conditions become the reference for the resulting image.

4 Requirements

4.1 General

Reference input medium metric RGB (RIMM RGB) and the ERIMM and FP-RIMM associated versions of RIMM RGB are extended colour gamut RGB colour image encodings of the colourimetry of a scene-referred image, white balanced to be relative to a specified adopted white. The image colourimetry is encoded in terms of an additive RGB colour space associated with a hypothetical additive colour device having a specified set of primaries and no cross-talk between the colour channels. The RIMM RGB colour image encoding has a maximum luminance value corresponding to 200 % of a perfect diffuse reflector (i.e. an observer adaptive luminance factor of 2,0). Extended reference input medium metric RGB (ERIMM RGB) is an extended luminance dynamic range version of RIMM RGB having a maximum observer adaptive luminance factor of about 316. The maximum luminance value of FP-RIMM RGB colour image encoding is limited only by the floating point encoding range. In RIMM RGB, ERIMM RGB and FP-RIMM RGB, the image colourimetry shall be based on flareless (or flare corrected) colourimetric measurements as described in CIE Publication No. 15 using the CIE 1931 standard colourimetric observer defined in ISO 11664-1.

Scene-referred image data may correspond to an actual view of the natural world, or a simulation of such a view. It may also correspond to a modified scene determined by applying modifications to an original scene. In order to be appropriate for encoding as RIMM RGB, ERIMM RGB or FP-RIMM RGB, any scene modifications shall leave the image in a scene-referred image state.

Scene-referred image data may have an associated pre-determined colour rendering transform. When an associated pre-determined colour rendering transform is present with scene-referred image data, such an intended colour rendering transform should be included in any image preview path that is used to provide subjective feedback to a user, unless:

— The user has selected direct viewing of the scene-referred image and intends that modifications are to be previewed in the scene-referred state.

— The scene-referred image data has been converted to an appropriate working colour space for manual editing and colour rendering. In this case the user may exercise the option to apply or not apply an associated pre-determined colour rendering transform, if present, when the scene-referred image data are converted to the working colour space.

EXAMPLES Scene modifications could include removing haze from the captured image, or allowing a user to manually adjust the exposure/white balance. It could also include more complex operations such as using a “dodge-and-burn” algorithm to correct over-exposed regions of a backlit scene. (This can be viewed as being analogous to “re-lighting” the scene.) Scene modifications could also include applying desired changes to the scene such as simulating a “night” scene, making grass greener to make it look healthier, or making the sky bluer to make it look clearer. However, typical colour rendering transforms will include a boost in the midtone contrast and chroma of the image. Consequently, any boost in colourfulness of the scene (e.g. making the grass greener) needs to be done with the knowledge that there may be an additional chroma boost during colour rendering.

NOTE 1 The image colourimetry of the scene-referred image can contain inaccuracies due to the dynamic range limitations of the capture device, noise from various sources, quantization, optical blurring and flare that are not corrected for, and colour analysis errors due to capture device metamerism. In some cases, these sources of inaccuracy can be significant.

Three different precision levels are defined for RIMM RGB, and shall be identified as RIMM8 RGB, RIMM12 RGB and RIMM16 RGB, for 8-, 12- and 16-bits/channel (24-, 36- and 48-bits/pixel) representations, respectively.

For extended reference input medium metric RGB (ERIMM RGB), two different precision levels are defined and shall be identified as ERIMM12 RGB and ERIMM16 RGB, for 12- and 16-bits/channel (36- and 48-bits/pixel) representations, respectively.

Floating point reference input medium metric RGB (FP-RIMM RGB) is a floating point encoded version of RIMM RGB with a linear colour component transfer function. Half-, single- or double-precision floating point numbers, as defined in IEEE 754:2008, may be used in TIFF/EP files as defined in ISO 12234-2, requiring 48-, 96- and 192-bits/pixel, respectively.

NOTE 2 RIMM RGB, ERIMM RGB or FP-RIMM RGB images are intended for use in system environments that support scene-referred images. However, they can be interchanged in environments that do not support scene-referred images if a default colour rendering transform or a full resolution standard output-referred image that is supported in the environment is associated with the scene-referred image. The TIFF/EP and JPEG 2000 file formats can use ICC profiles to support RIMM RGB, ERIMM RGB or FP-RIMM RGB images in system environments designed to support output-referred images.

The colour image encoding defined in this part of ISO 22028 conforms to the requirements defined in Clause 5 of ISO 22028-1:2004.

4.2 Adopted white

The adopted white shall have the chromaticity values of CIE Standard Illuminant D_{50} (x_0 = 0,345 7, y_0 = 0,358 5).

In the absence of image file metadata that provides image-specific values, the absolute luminance level of the adopted white should be assumed to be 15 000 cd/m^2, the surround should be assumed to be average, and the luminance of the adapting field should be assumed to be 20 % of the luminance of the adopted white. There is no viewing flare assumed for the scene other than that already included in the scene colourimetric values.

NOTE These default values are intended to be typical of bright outdoor viewing environments.

4.3 Reference medium primaries and white point

The *x*-*y* chromaticity values for the RIMM RGB, ERIMM RGB, and FP-RIMM RGB primaries shall be as given in Table 1. All chromaticity values specified in this document shall be based on the CIE 1931 two-degree standard observer defined in ISO 11664-1. Rationale for the choice of these primaries is given in Annex A.

The colour space white point, corresponding to equal amounts of the three RGB primaries, shall have the *x*-*y* chromaticity values of CIE Standard Illuminant D_{50} given as given in Table 1.

Table 1 — CIE chromaticities for reference medium primaries and white point

Reference medium primaries and white point	CIE chromaticities			
	x	*y*	*u'* [a]	*v'* [a]
Red	0,734 7	0,265 3	0,623 4	0,506 5
Green	0,159 6	0,840 4	0,050 0	0,592 5
Blue	0,036 6	0,000 1	0,050 0	0,000 3
White point	0,345 7	0,358 5	0,209 2	0,488 1

[a] The *u'*-*v'* chromaticity values for the RGB primaries and colour space white point given in this table can be derived from the *x*-*y* chromaticity values and are provided for information purposes.

4.4 RIMM RGB, ERIMM RGB, FP-RIMM RGB colour image encoding

4.4.1 Encoding principles

RIMM RGB colour image encoding values shall be determined from the tristimulus values of a scene-referred image using a matrix transformation (see 4.4.3) followed by a colour component transfer function (see 4.4.4) and a digital encoding function for one of three different bit-depths (see 4.4.5).

ERIMM RGB colour image encoding values shall be determined in an identical manner to those for RIMM RGB, except that a different colour component transfer function (see 4.4.6) and a different digital encoding function (see 4.4.7) shall be used instead of those given in 4.4.4 and 4.4.5.

FP-RIMM RGB colour image encoding values shall be determined in an identical manner to those for RIMM RGB, except the results of applying the matrix transformation specified in 4.4.3 shall be encoded directly as floating point numbers, instead of applying the colour component transfer function and digital encoding function specified in 4.4.4 and 4.4.5.

For some applications, it can be desirable to determine original absolute scene colourimetry from encoded RIMM, ERIMM or FP-RIMM RGB colour image encoding values. In such cases, any information needed to relate the encoded image colourimetry back to the actual scene colourimetry should be associated with the image (for example, as metadata tags in the image file). Examples of useful information would include parameters such as *F*/#, exposure time, and brightness value for the original capture, as well as information describing any white balancing and/or scene analysis transformations that have been applied.

Image colourimetry encoded as RIMM RGB, ERIMM RGB or FP-RIMM RGB should not contain colours outside the spectrum locus.

4.4.2 Tristimulus value normalization

The image tristimulus values shall be normalized such that the normalized Y tristimulus value of the adopted white is 1,0.

$$X_N = \frac{X}{Y_{PDR}} \quad Y_N = \frac{Y}{Y_{PDR}} \quad Z_N = \frac{Z}{Y_{PDR}} \tag{1}$$

where

X, Y and Z	are the scene-referred image tristimulus values, after having been white balanced to produce tristimulus values relative to the RIMM RGB adopted white;
X_N, Y_N and Z_N	are the normalized image tristimulus values;
Y_{PDR}	is the Y tristimulus value of the scene adopted white after white balancing to the RIMM RGB adopted white chromaticity.

4.4.3 RIMM RGB conversion matrix

The following matrix shall be used to compute linear RIMM RGB colour space values (R_{RIMM}, G_{RIMM} and B_{RIMM}) from the normalized image tristimulus values (X_N, Y_N and Z_N):

$$\begin{bmatrix} R_{RIMM} \\ G_{RIMM} \\ B_{RIMM} \end{bmatrix} = \begin{bmatrix} 1{,}3460 & -0{,}2556 & -0{,}0511 \\ -0{,}5446 & 1{,}5082 & 0{,}0205 \\ 0{,}0000 & 0{,}0000 & 1{,}2123 \end{bmatrix} \begin{bmatrix} X_N \\ Y_N \\ Z_N \end{bmatrix} \tag{2}$$

This matrix can be derived from the chromaticities given in Table 1, which shall be considered to be the normative defining quantities.

NOTE This matrix will map normalized image tristimulus values with the chromaticity of D_{50} to equal linear RIMM RGB colour space values. A neutral with a Y_N value of 1,0 will map to linear RIMM RGB colour space values of 1,0. A neutral with a Y_N value of 0,0 will map to linear RIMM RGB colour space values of 0,0.

4.4.4 RIMM RGB colour component transfer function

The functional form of the RIMM RGB colour component transfer function shall be:

$$C'_{RIMM} = \begin{cases} 0{,}0; & C_{RIMM} < 0{,}0 \\ \left(\frac{1}{V_{clip}}\right) 4{,}5\, C_{RIMM}; & 0{,}0 \le C_{RIMM} < 0{,}018 \\ \left(\frac{1}{V_{clip}}\right)\left(1{,}099\, C_{RIMM}^{0{,}45} - 0{,}099\right); & 0{,}018 \le C_{RIMM} < E_{clip} \\ 1{,}0; & C_{RIMM} \ge E_{clip} \end{cases} \tag{3}$$

where

C is either R, G, or B;

C_{RIMM} and C'_{RIMM} are the radiometrically linear and nonlinear RIMM RGB colour space values, respectively;

$E_{clip} = 2{,}0$

and

$$V_{clip} = 1{,}099 E_{clip}^{0{,}45} - 0{,}099 \approx 1{,}402 \qquad (4)$$

NOTE This colour component transfer function is based on that specified in ITU-R BT.709-3.

4.4.5 RIMM RGB digital encoding function

The digital encoding function for the RIMM RGB colour space encoding is given by:

$$C''_{RIMM} = Round\left(C'_{RIMM} \times I_{max}\right) \qquad (5)$$

where C is either R, G, or B; C'_{RIMM} is the nonlinear RIMM RGB colour space value; C''_{RIMM} is the digital RIMM RGB colour space encoding; I_{max} is the maximum integer value used for the digital encoding; and the *Round*( ) function returns the nearest integer value.

For RIMM8 RGB, I_{max} shall be 255.

For RIMM12 RGB, I_{max} shall be 4095.

For RIMM16 RGB, I_{max} shall be 65535.

NOTE The digital encoding function maps a nonlinear colour space value range of 0,0 to 1,0 (corresponding to a linear colour space value range of 0,0 to 2,0) onto a digital code value range of 0 to I_{max}.

4.4.6 ERIMM RGB colour component transfer function

The functional form of the ERIMM RGB colour component transfer function shall be:

$$C'_{ERIMM} = \begin{cases} 0{,}0\,; & C_{RIMM} \le 0{,}0 \\ \left(\dfrac{0{,}0789626}{E_t}\right) C_{RIMM}\,; & 0{,}0 < C_{RIMM} \le E_t \\ \left(\dfrac{\log_{10} C_{RIMM} + 3{,}0}{5{,}5}\right); & E_t < C_{RIMM} \le E_{clip} \\ 1{,}0\,; & C_{RIMM} > E_{clip} \end{cases} \qquad (6)$$

where

C is either R, G, or B;

C_{RIMM} is the linear RIMM RGB colour space value;

C'_{ERIMM} is the nonlinear ERIMM RGB colour space value;

$E_{clip} = 10^{2{,}5}$ approximately 316,23 is the upper exposure limit;

and

$$E_t = e/1\,000 \approx 0{,}00271828 \qquad (7)$$

is the breakpoint between the linear and logarithmic segments, e being the base of the natural logarithm.

4.4.7 ERIMM RGB digital encoding function

The digital encoding function for the ERIMM RGB colour space encoding is given by:

$$C''_{ERIMM} = Round\left(C'_{ERIMM} \times I_{max}\right) \quad (8)$$

where

- C is either R, G, or B;
- C'_{ERIMM} is the nonlinear ERIMM RGB colour space value;
- C''_{ERIMM} is the digital ERIMM RGB colour space encoding;
- I_{max} is the maximum integer value used for the digital encoding;
- $Round(\ )$ is the function that returns the nearest integer value.

For ERIMM12 RGB, I_{max} shall be 4095.

For ERIMM16 RGB, I_{max} shall be 65535.

NOTE 1 The digital encoding function maps a nonlinear colour space value range of 0,0 to 1,0 (corresponding to a linear colour space value range of 0,0 to 316,23) onto a digital code value range of 0 to I_{max}.

NOTE 2 The following table shows sample neutral patch encodings for RIMM8 RGB, RIMM12 RGB and ERIMM12 RGB.

Table 2 — Neutral patch encodings for RIMM8 RGB, RIMM12 RGB and ERIMM12 RGB

Y_N	$\log_{10} Y_N$	**RIMM8 RGB**	**RIMM12 RGB**	**ERIMM12 RGB**
0,001	−3,00	1	13	119
0,01	−2,00	8	131	745
0,10	−1,00	53	849	1489
0,18	−0,75	74	1194	1679
1,00	0,00	182	2920	2234
2,00	0,30	255	4095	2458
8,00	0,90	N/A	N/A	2906
32,00	1,50	N/A	N/A	3354
316,23	2,50	N/A	N/A	4095

4.4.8 FP-RIMM RGB colour component transfer function

The functional form of the FP-RIMM RGB colour component transfer function shall be:

$$C_{FP\text{-}RIMM} = C_{RIMM}$$

where

- C_{RIMM} is the linear RIMM RGB colour space value;
- $C_{FP\text{-}RIMM}$ is the FP-RIMM RGB colour space value in a floating point figure based on IEEE 754:2008.

Negative values for $C_{FP\text{-}RIMM}$ are allowed as far as their equivalent chromaticity coordinates are within the spectral locus.

4.5 Inverse RIMM RGB transformation

4.5.1 General

The conversion of RIMM RGB colour encoding values back to scene-referred image tristimulus values is accomplished by inverting the digital encoding function given in Formula (5) and the colour component transfer function given in Formula (3), and then applying the inverse of the matrix given in Formula (2), and the inverse of the normalization function given in Formula (1). Similarly, ERIMM RGB colour encoding values are converted back to scene-referred image tristimulus values using the same procedure, except that the inverse of the digital encoding function given in Formula (8) and the colour component transfer function given in Formula (6) is used in place of the corresponding RIMM RGB functions. Likewise, FP-RIMM RGB colour encoding values are converted back to scene-referred image tristimulus values using the same procedure, except there is no need to invert either the digital encoding function or the colour component transfer function.

4.5.2 Inverse RIMM RGB digital encoding function

The inverse digital encoding function for the RIMM RGB colour space encoding is given by:

$$C'_{\mathrm{RIMM}} = \frac{C''_{\mathrm{RIMM}}}{I_{\max}} \tag{9}$$

where

C is either R, G, or B;

C''_{RIMM} is the digital RIMM RGB colour space encoding;

C'_{RIMM} is the nonlinear RIMM RGB colour space value;

$I_{\max}$ is the maximum integer value used for the digital encoding.

The inverse digital encoding given in Formula (9) can be determined by inverting the digital encoding function specified in 4.4.5, which shall be considered to be the normative definition.

4.5.3 Inverse RIMM RGB colour component transfer function

The nonlinear RIMM RGB colour space values shall be converted to linear RIMM RGB colour space values using Formula (10):

$$C_{\mathrm{RIMM}} = \begin{cases} \dfrac{V_{\mathrm{clip}} C'_{\mathrm{RIMM}}}{4{,}5}, & 0 \le C'_{\mathrm{RIMM}} < \dfrac{0{,}081}{V_{\mathrm{clip}}} \\[2ex] \left(\dfrac{V_{\mathrm{clip}} C'_{\mathrm{RIMM}} + 0{,}099}{1{,}099} \right)^{1/0.45}, & \dfrac{0{,}081}{V_{\mathrm{clip}}} \le C'_{\mathrm{RIMM}} \le 1 \end{cases} \tag{10}$$

where

C is either R, G or B;

C_{RIMM} and C'_{RIMM} are the linear and nonlinear RIMM RGB colour space values, respectively;

V_{clip} is given in Formula (4).

The inverse colour component transfer function given in Formula (10) can be determined by inverting the colour component transfer function specified in 4.4.4, which shall be considered to be the normative definition.

4.5.4 Inverse ERIMM RGB digital encoding function

The inverse digital encoding function for the ERIMM RGB colour space encoding is given by:

$$C'_{\mathrm{ERIMM}} = \frac{C''_{\mathrm{ERIMM}}}{I_{\max}} \tag{11}$$

where

C	is either R, G, or B;
C''_{ERIMM}	is the digital ERIMM RGB colour space encoding;
C'_{ERIMM}	is the nonlinear ERIMM RGB colour space value;
$I_{\max}$	is the maximum integer value used for the digital encoding.

The inverse digital encoding given in Formula (11) can be determined by inverting the digital encoding function specified in 4.4.7, which shall be considered to be the normative definition.

4.5.5 Inverse ERIMM RGB colour component transfer function

The nonlinear ERIMM RGB colour space values shall be converted to linear RIMM RGB colour space values using Formula (10):

$$C_{\mathrm{RIMM}} = \begin{cases} \left(\dfrac{C'_{\mathrm{ERIMM}} E_{\mathrm{t}}}{0{,}0789626}\right), & 0 \le C'_{\mathrm{ERIMM}} \le 0{,}0789626 \\ 10^{\left(5{,}5\, C'_{\mathrm{ERIMM}} - 3{,}0\right)}, & 0{,}00789626 < C'_{\mathrm{ERIMM}} \le 1 \end{cases} \tag{12}$$

where

C	is either R, G or B;
C'_{ERIMM}	is the nonlinear ERIMM RGB colour space value;
C_{RIMM}	is the linear RIMM RGB colour space value;
E_{t}	is given in Formula (7).

The inverse colour component transfer function given in Formula (12) can be determined by inverting the colour component transfer function specified in 4.4.6, which shall be considered to be the normative definition.

4.5.6 Inverse RIMM RGB conversion matrix

The conversion from linear RIMM RGB colour space values (R_{RIMM}, G_{RIMM} and B_{RIMM}) to the corresponding normalized scene-referred image tristimulus values (X_{N}, Y_{N} and Z_{N}) shall be given by:

$$\begin{bmatrix} X_{\mathrm{N}} \\ Y_{\mathrm{N}} \\ Z_{\mathrm{N}} \end{bmatrix} = \begin{bmatrix} 0{,}7977 & 0{,}1352 & 0{,}0313 \\ 0{,}2880 & 0{,}7119 & 0{,}0001 \\ 0{,}0000 & 0{,}0000 & 0{,}8249 \end{bmatrix} \begin{bmatrix} R_{\mathrm{RIMM}} \\ G_{\mathrm{RIMM}} \\ B_{\mathrm{RIMM}} \end{bmatrix} \tag{13}$$

This matrix can be derived from the chromaticities given in Table 1, which shall be considered to be the normative defining quantities.

NOTE When this matrix is applied to linear RIMM RGB colour space values that are equal, normalized image tristimulus values with the chromaticity of D_{50} are obtained.

4.5.7 Inverse tristimulus value normalization

The conversion from normalized image tristimulus values to the corresponding image tristimulus values shall be given by:

$$X = X_N Y_{PDR}$$
$$Y = Y_N Y_{PDR} \quad (14)$$
$$Z = Z_N Y_{PDR}$$

where

X, Y and Z	are the scene-referred image tristimulus values;
X_N, Y_N and Z_N	are the normalized image tristimulus values;
Y_{PDR}	is the Y tristimulus value of a perfect diffuse reflector.

4.5.8 Inverse FP-RIMM RGB colour component transfer function

The FP-RIMM RGB colour space values shall be converted to the linear RIMM RGB colour space by:

$$C_{RIMM} = C_{FP\text{-}RIMM}$$

where

C_{RIMM}	is the linear RIMM RGB colour space value;
$C_{FP\text{-}RIMM}$	is the FP-RIMM RGB colour space value in a floating point figure based on IEEE 754:2008.

Annex A
(informative)

Example colour rendering transform from RIMM RGB to ROMM RGB

The RIMM RGB colour encoding is intended to be an encoding of the colour of an original scene-referred image. On the other hand, the ROMM RGB colour encoding is intended to be an encoding of the colour of a colour rendered output-referred image. It is well known that the colourimetry of a pleasing colour-rendered image generally does not match the colourimetry of the corresponding scene. Therefore, transformation from RIMM RGB to ROMM RGB should include a colour rendering transform having appropriate tone/colour reproduction characteristics.

Among other things, the tone/colour reproduction process that renders the colours of a scene to the desired colours of the rendered image should compensate for differences between the scene and rendered image viewing conditions. For example, rendered images generally are viewed at luminance levels much lower than those of typical outdoor scenes. As a consequence, an increase in the overall contrast of the rendered image usually is required in order to compensate for perceived losses in reproduced luminance and chrominance. Further contrast increases in the shadow regions of the image also are needed to compensate for viewing flare associated with rendered-image viewing conditions.

In addition, psychological factors such as colour memory and colour preference should be considered in colour rendering. For example, observers generally remember colours as being of higher purity than they really were, and they typically prefer skies and grass to be more colourful than they were in the original scene. The tone/colour reproduction aims of well-designed imaging systems will account for such factors.

Finally, the tone/colour reproduction process also should account for the fact that the dynamic range of a rendered image may be substantially less than that of an original scene, especially scenes with specular highlights. It may therefore be necessary to discard and/or compress some of the highlight and shadow information of the scene to fit within the dynamic range of the rendered image.

There is no single “correct” set of colour rendering aims for mapping scene-referred RIMM RGB images to form output-referred ROMM RGB images. Optimal colour rendering aims may be application-dependent, or even image-dependent in some cases. For example, portraiture photographers may prefer lower-contrast, lower-colourfulness colour rendering aims, while advertising photographers may prefer higher-contrast, higher-colourfulness colour rendering aims. Similarly, the colour rendering aims that are optimal for “low-key” scenes may not be optimal for “high-key” scenes.

In general, it may be necessary to use three-dimensional look-up tables (LUTs), or other types of complex transformations, to implement a detailed set of colour rendering aims. However, the set of wide-RGB primaries specified for the RIMM RGB and ROMM RGB colour encodings were selected such that colour rendering aims having generally desirable characteristics can be implemented using simple channel-independent tone scale transformations. (For more information regarding this design criteria, see ANSI/I3A IT10.7666, Annex A.) Therefore, a simple colour rendering transformation for converting a RIMM RGB image to a corresponding ROMM RGB image can be accomplished by applying a one-dimensional LUT to each channel of the image. An example RIMM RGB-to-ROMM RGB tone scale LUT that will produce good results for well-exposed, normal dynamic range scenes in many consumer applications is given in Table A.1 and Figure A.1. However, depending on the application, different tone scale LUTs, or other more complex colour rendering transformations, may be appropriate to produce the desired colour rendering aims. An example tone scale LUT that implements similar colour rendering aims for ERIMM12 RGB images is given in Table A.2 and Figure A.2.

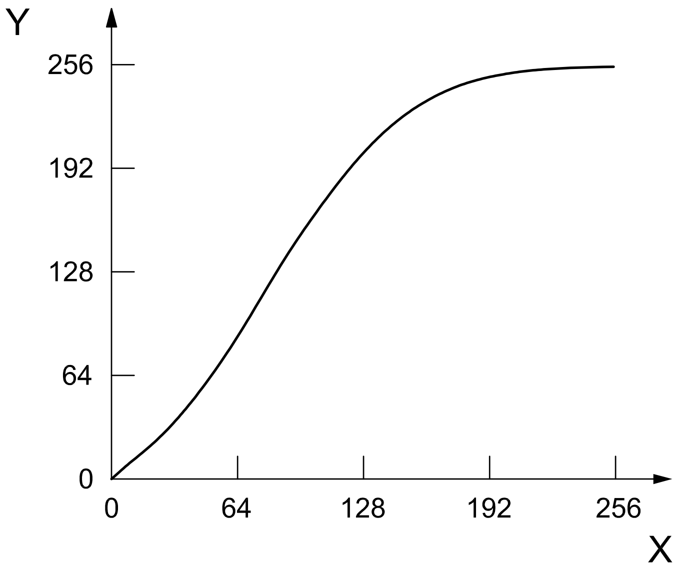
It should be noted that while the storage and/or interchange of images in a RIMM RGB colour encoding represents a mechanism for the unambiguous specification of the estimated colourimetry of a scene-referred image, it does not uniquely specify the colour appearance of a corresponding output-referred image. This is because a scene-referred image can be colour rendered using a variety of colour rendering aims as was discussed above. Therefore, when it is desired to provide an output-referred interpretation, it is necessary for a RIMM RGB image to be associated with a colour rendering transform to provide a mechanism for specifying a preferred output-referred image. For example, some file formats provide a means for tagging an image with an ICC profile. Since the reference medium associated with the ICC perceptual rendering intent is output medium, ICC profiles will necessarily include colour rendering aims for the image. The user could then apply the provided profile, or alternatively could choose to specify other colour rendering aims. This approach provides a means for effectively specifying an output-referred image, while maintaining the additional flexibility associated with a scene-referred image.

Table A.1 — Example tone scale LUT for colour rendering scene-referred RIMM8 RGB colour space encoding values to output-referred ROMM8 RGB colour space encoding values

RIMM8 RGB	ROMM8 RGB	RIMM8 RGB	ROMM8 RGB	RIMM8 RGB	ROMM8 RGB	RIMM8 RGB	ROMM8 RGB	RIMM8 RGB	ROMM8 RGB
0	0	52	66	104	164	156	231	208	252
1	0	53	68	105	166	157	231	209	252
2	0	54	69	106	168	158	232	210	252
3	1	55	71	107	170	159	233	211	252
4	2	56	73	108	171	160	234	212	252
5	4	57	75	109	173	161	234	213	252
6	5	58	77	110	175	162	235	214	252
7	7	59	78	111	176	163	236	215	253
8	9	60	80	112	178	164	236	216	253
9	10	61	82	113	179	165	237	217	253
10	11	62	84	114	181	166	237	218	253
11	12	63	86	115	183	167	238	219	253
12	13	64	88	116	184	168	239	220	253
13	14	65	90	117	186	169	239	221	253
14	15	66	92	118	187	170	240	222	253
15	16	67	94	119	189	171	240	223	253
16	17	68	96	120	190	172	241	224	253
17	18	69	98	121	192	173	241	225	253
18	19	70	100	122	193	174	242	226	254
19	20	71	102	123	195	175	242	227	254
20	21	72	104	124	196	176	243	228	254
21	22	73	106	125	197	177	243	229	254
22	23	74	108	126	199	178	244	230	254
23	24	75	110	127	200	179	244	231	254
24	25	76	112	128	201	180	244	232	254
25	26	77	114	129	203	181	245	233	254
26	28	78	116	130	204	182	245	234	254
27	29	79	119	131	205	183	245	235	254
28	30	80	121	132	207	184	246	236	254
29	31	81	123	133	208	185	246	237	254
30	33	82	125	134	209	186	247	238	254
31	34	83	127	135	210	187	247	239	254
32	35	84	129	136	211	188	247	240	254
33	37	85	130	137	213	189	247	241	254
34	38	86	132	138	214	190	248	242	254
35	39	87	134	139	215	191	248	243	254
36	41	88	136	140	216	192	248	244	254
37	42	89	138	141	217	193	249	245	254
38	44	90	140	142	218	194	249	246	254
39	45	91	141	143	219	195	249	247	254
40	47	92	143	144	220	196	249	248	255
41	48	93	145	145	221	197	250	249	255
42	50	94	147	146	222	198	250	250	255
43	51	95	149	147	223	199	250	251	255
44	53	96	150	148	224	200	250	252	255
45	54	97	152	149	225	201	250	253	255
46	56	98	154	150	226	202	251	254	255
47	58	99	156	151	227	203	251	255	255
48	59	100	158	152	227	204	251		
49	61	101	159	153	228	205	251		
50	63	102	161	154	229	206	251		
51	64	103	163	155	230	207	251		

Table A.2 — Example tone scale LUT for colour rendering scene-referred ERIMM12 RGB colour space encoding values to output-referred ROMM8 RGB colour space encoding values

ERIMM12 RGB	ROMM8 RGB	ERIMM12 RGB	ROMM8 RGB	ERIMM12 RGB	ROMM8 RGB	ERIMM12 RGB	ROMM8 RGB	ERIMM12 RGB	ROMM8 RGB
0	0	825	11	1650	101	2475	255	3300	255
15	0	840	12	1665	105	2490	255	3315	255
30	0	855	12	1680	109	2505	255	3330	255
45	0	870	13	1695	113	2520	255	3345	255
60	0	885	13	1710	117	2535	255	3360	255
75	0	900	14	1725	122	2550	255	3375	255
90	0	915	14	1740	126	2565	255	3390	255
105	0	930	15	1755	130	2580	255	3405	255
120	0	945	16	1770	134	2595	255	3420	255
135	0	960	16	1785	138	2610	255	3435	255
150	0	975	17	1800	142	2625	255	3450	255
165	0	990	18	1815	146	2640	255	3465	255
180	0	1005	19	1830	150	2655	255	3480	255
195	0	1020	20	1845	155	2670	255	3495	255
210	0	1035	20	1860	159	2685	255	3510	255
225	0	1050	21	1875	163	2700	255	3525	255
240	0	1065	22	1890	168	2715	255	3540	255
255	0	1080	23	1905	172	2730	255	3555	255
270	0	1095	24	1920	176	2745	255	3570	255
285	0	1110	25	1935	181	2760	255	3585	255
300	1	1125	26	1950	185	2775	255	3600	255
315	1	1140	27	1965	189	2790	255	3615	255
330	1	1155	28	1980	194	2805	255	3630	255
345	1	1170	29	1995	198	2820	255	3645	255
360	1	1185	31	2010	202	2835	255	3660	255
375	1	1200	32	2025	206	2850	255	3675	255
390	1	1215	33	2040	210	2865	255	3690	255
405	1	1230	35	2055	214	2880	255	3705	255
420	1	1245	36	2070	217	2895	255	3720	255
435	1	1260	37	2085	221	2910	255	3735	255
450	2	1275	39	2100	224	2925	255	3750	255
465	2	1290	40	2115	227	2940	255	3765	255
480	2	1305	42	2130	230	2955	255	3780	255
495	2	1320	44	2145	233	2970	255	3795	255
510	2	1335	45	2160	235	2985	255	3810	255
525	3	1350	47	2175	238	3000	255	3825	255
540	3	1365	49	2190	240	3015	255	3840	255
555	3	1380	51	2205	242	3030	255	3855	255
570	3	1395	53	2220	244	3045	255	3870	255
585	4	1410	55	2235	245	3060	255	3885	255
600	4	1425	57	2250	247	3075	255	3900	255
615	4	1440	60	2265	248	3090	255	3915	255
630	5	1455	62	2280	249	3105	255	3930	255
645	5	1470	64	2295	250	3120	255	3945	255
660	6	1485	67	2310	251	3135	255	3960	255
675	6	1500	69	2325	252	3150	255	3975	255
690	7	1515	72	2340	252	3165	255	3990	255
705	7	1530	75	2355	253	3180	255	4005	255
720	8	1545	78	2370	253	3195	255	4020	255
735	8	1560	81	2385	254	3210	255	4035	255
750	9	1575	84	2400	254	3225	255	4050	255
765	9	1590	87	2415	254	3240	255	4065	255
780	10	1605	90	2430	254	3255	255	4080	255
795	10	1620	94	2445	255	3270	255	4095	255
810	11	1635	97	2460	255	3285	255		

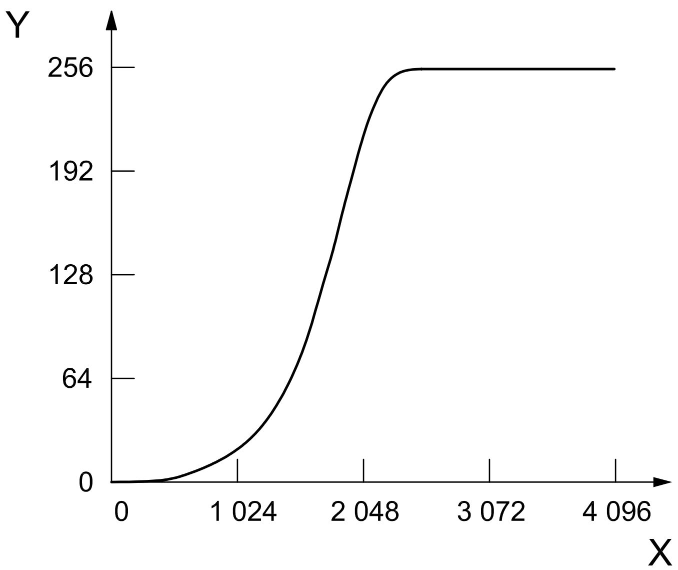


Key

X RIMM RGB

Y ROMM RGB

Figure A.1 — Example tone scale LUT for colour rendering scene-referred RIMM8 RGB colour space encoding values to output-referred ROMM8 RGB colour space encoding value



Key

X ERIMM RGB

Y ROMM RGB

Figure A.2 — Example tone scale LUT for colour rendering scene-referred ERIMM12 RGB colour space encoding values to output-referred ROMM8 RGB colour space encoding value

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