# TECHNICAL SPECIFICATION

# ISO/TS 22028-3

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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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International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

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 normative document:

— an ISO Publicly Available Specification (ISO/PAS) represents an agreement between technical experts in an ISO working group and is accepted for publication if it is approved by more than 50 % of the members of the parent committee casting a vote;

— an ISO Technical Specification (ISO/TS) represents an agreement between the members of a technical committee and is accepted for publication if it is approved by 2/3 of the members of the committee casting a vote.

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order to decide whether it will be confirmed for a further three years, revised to become an International Standard, or withdrawn.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again after a further three years, at which time it must either be transformed into an International Standard or be withdrawn.

ISO/TS 22028-3 was prepared by Technical Committee ISO/TC 42, *Photography*, in collaboration with Technical Committee ISO/TC 130, *Graphic technology*.

ISO 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)* [Technical Specification]

— *Part 3: Reference input medium metric RGB colour image encoding (RIMM RGB)* [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 colorimetry co-ordinates.

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) is also specified for use with high-dynamic range input sources. (E)RIMM RGB is intended to be a companion 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.

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

ISO/CIE 10527:1991, *CIE standard colorimetric observers*

CIE Publication 15, *Colorimetery*

## 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 colorimetric 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**
colorimetric 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**
**colorimetric colour space**
colour space having an exact and simple relationship to CIE colorimetric values

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

**3.4**
**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.

**3.5**
**colour encoding**
generic term for a quantized digital encoding of a colour space, encompassing both colour space encodings and colour image encodings

**3.6**
**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

**3.7**
**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 be not 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.

**3.8**
**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.

**3.9**
**colour space**
geometric representation of colours in space, usually of three dimensions

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

**3.10**
**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.)

**3.11**
**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.

**3.12**
**continuous colour space values**
real-valued, unbounded colour space values that have not been encoded using a digital encoding method

**3.13**
**digital imaging system**
system that records and/or produces images using digital data

**3.14**
**extended gamut**
colour gamut extending outside that of the standard sRGB CRT display as defined by IEC 61966-2-1

**3.15**
**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.

**3.16**
**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]

**3.17**
**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

**3.18**
**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 is image data in an output-referred image state.

NOTE 2 Output referred image data is 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 is frequently considered to be the starting point for the colour re-rendering performed by a printer designed to receive sRGB image data.

**3.19**
**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.

**3.20**
**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 is 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 colorimetry estimates. Absolute scene colorimetry 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 is 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.



 

**3.21**
**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]

**3.22**
**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.

**3.23**
**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.

# 4 Requirements

## 4.1 General

Reference input medium metric RGB (RIMM RGB) is an extended colour gamut RGB colour image encoding of the colorimetry of a scene-referred image. The scene-referred image has the intended colour appearance when viewed in a specified reference viewing environment. The image colorimetry is encoded in terms of an additive RGB colour space associated with a hypothetical additive colour device having a specified set of primaries, no cross-talk between the colour channels and a maximum luminance value corresponding to 200 % of a perfect diffuse reflector (i.e. an observer adaptive luminance factor of 2,0).

NOTE 1 Scene-referred image data can correspond to an actual view of the natural world, or a simulation of such a view. It can also correspond to a modified scene determined by applying modifications to an original scene. For example, such 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. Any such scene modifications need to leave the image in a scene-referred image state, and need to be done in the context of the expected colour rendering transform. For example, typical colour rendering transforms will include a boost in the chroma of the image. Any boost in colourfulness of the scene (e.g. making the grass greener) must be done with the knowledge that there will be an additional chroma boost during colour rendering. Consequently, the colour rendering transform must be included in any image preview path that is used to provide subjective feedback to a user during the scene-editing process.

NOTE 2 The image colorimetry 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, 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.

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. 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.

The image colorimetry shall be based on flareless (or flare corrected) colorimetric measurements as described in CIE Publication No. 15 using the CIE 1931 standard colorimetric observer defined in ISO/CIE 10527.

When digital images are interchanged in an open systems environment using the RIMM RGB or ERIMM RGB colour encodings, a default colour rendering function or a full resolution standard output-referred image should be associated with the RIMM RGB or ERIMM RGB image data in order to unambiguously define baseline colour rendering aims for the image, and allow the image to be used in applications which do not directly support the usage of scene-referred image data. Furthermore, in an open systems environment, the RIMM RGB or ERIMM RGB image data should be exchanged using a file format which requires the file reader to apply the default colour rendering function or use the standard output-referred image data as the image data to be conveyed, unless the RIMM RGB or ERIMM RGB image data is specifically requested by the application.

NOTE 3 The JPEG 2000 file format provides a mechanism for storing images in RIMM RGB or ERIMM RGB and specifying baseline colour rendering aims through the use of the Restricted ICC Profile method.

NOTE 4 In some cases, it can be desirable for a user or an application to override the provided baseline colour rendering aims in order to specify custom colour rendering aims for an image.

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

## 4.2 Reference viewing environment

The reference viewing environment shall be such that the adapted white has the chromaticity values of CIE Standard Illuminant $D_{50}$ ($x_0$ = 0,345 7, $y_0$ = 0,358 5).

The absolute luminance level of the adapted white in the reference viewing environment shall be 15 000 cd/m$^2$.

NOTE 1 This absolute luminance level is intended to be typical of bright outdoor viewing environments.

NOTE 2 The luminance of the adapting field can be assumed to be 20 % of the luminance of the adapted white.

The reference viewing environment shall be characterized by an average surround. This means that the area immediately surrounding the image border shall be assumed to be a uniform grey having the chromaticity values of CIE standard illuminant $D_{50}$ ($x_0$ = 0,345 7, $y_0$ = 0,358 5) and an observer adaptive luminance factor of 0,2 relative to the adapted white.

There is no viewing flare for the scene other than that already included in the scene colorimetric values.

NOTE 3 The reference viewing environment is intended to provide a context for interpreting the colour appearance of the encoded image colorimetry. It does not necessarily correspond to the original viewing environment for the scene-referred image data. In many cases, it can be desirable to interpret the actual relative colorimetry of the image in the context of the reference viewing environment, even when the image is captured in a different viewing environment. (A chromatic adaptation and/or white balance step is usually required to ensure that neutral image content is properly reproduced.) For example, if an image is captured in a dim viewing environment, it is often pleasing to define the desired colour appearance of the image relative to the brighter reference viewing environment resulting in higher perceived luminance and chrominance contrast for the image. In such cases, the actual white-balanced relative colorimetry of the image can be used without any further colour appearance transformation. For cases where the image colorimetry has the intended colour appearance in an actual viewing environment that differs significantly from the reference viewing environment specified here, appropriate transformations will possibly be necessary to determine the corresponding colorimetry that would produce the intended colour appearance in the reference viewing environment. However, for actual viewing environments similar to the reference viewing environment, it probably will not be necessary to make such adjustments. The reference viewing environment was selected to make such adjustments unnecessary for many practical applications.



 

### 4.3 Reference medium primaries and white point

The $x$-$y$ chromaticity values for the 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/CIE 10527. 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 colour image encoding

### 4.4.1 Encoding principles

RIMM RGB colour image encodings 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). The image tristimulus values shall be those that produce the intended colour appearance when viewed in the reference viewing environment.

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.

NOTE Images intended to be viewed in viewing environments other than the reference viewing environment can be encoded in RIMM RGB or ERIMM RGB by first determining the corresponding tristimulus values that would produce the intended colour appearance when viewed in the reference viewing environment. The corresponding tristimulus values can be determined by using an appropriate colour appearance transformation to account for the differences between the viewing conditions.

For some applications, it can be desirable to determine original absolute scene colorimetry from encoded (E)RIMM RGB colour image encoding values. In such cases, it is recommended that any information needed to relate the encoded image colorimetry back to the actual scene colorimetry needs to 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-balance and/or viewing environment transformations that have been applied.

Image colorimetry encoded as RIMM RGB or ERIMM RGB shall 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 perfect diffuse reflector in the reference viewing environment is 1,0.

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

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.

NOTE This normalization implies that the colour space white point luminance will be equal to the luminance level of the adapted white in the reference viewing environment, which was specified to be 15 000 cd/m$^2$.

### 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 $Z_N$):

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

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:

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

where

$C$ is either $R$, $G$, or $B$;

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

$E_{\mathrm{clip}} = 2{,}0$;

and

$$V_{\mathrm{clip}} = 1{,}099 E_{\mathrm{clip}}^{0{,}45} - 0{,}099 \approx 1{,}402 \tag{4}$$

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:

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

where $C$ is either $R$, $G$, or $B$; $C'_{\mathrm{RIMM}}$ is the nonlinear RIMM RGB colour space value; $C''_{\mathrm{RIMM}}$ 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:

$$C'_{\mathrm{ERIMM}} = \begin{cases} 0{,}0; & C_{\mathrm{RIMM}} \le 0 \\ \left(\dfrac{0{,}0789626}{E_{\mathrm{t}}}\right) C_{\mathrm{RIMM}}; & 0 < C_{\mathrm{RIMM}} \leqslant E_{\mathrm{t}} \\ \left(\dfrac{\lg C_{\mathrm{RIMM}} + 3{,}0}{5{,}5}\right); & E_{\mathrm{t}} < C_{\mathrm{RIMM}} \leqslant E_{\mathrm{clip}} \\ 1{,}0; & C_{\mathrm{RIMM}} > E_{\mathrm{clip}} \end{cases} , \qquad (6)$$

where

$C$ is either $R$, $G$, or $B$;

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

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

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

and

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

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:

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

where

$C$ is either $R$, $G$, or $B$;

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

$C''_{\mathrm{ERIMM}}$ 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 RIMM16 RGB**

| $Y_N$ | lg $Y_N$ | 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 |

## 4.5 Inverse RIMM RGB transformation

### 4.5.1 General

The conversion of RIMM RGB colour space encoding values back to scene-referred image tristimulus values is accomplished by inverting the digital encoding function given in Equation (5) and the colour component transfer function given in Equation (3), and then applying the inverse of the matrix given in Equation (2), and the inverse of the normalizationfunction given in Equation (1). Similarly, ERIMM RGB colour space 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 Equation (8) and the colour component transfer function given in Equation (6) is used in place of the corresponding RIMM RGB functions.

### 4.5.2 Inverse RIMM RGB digital encoding function

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

$$C'_{\text{RIMM}} = \frac{C''_{\text{RIMM}}}{I_{\text{max}}} \qquad (9)$$

where

$C$ is either $R$, $G$, or $B$;

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

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

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

The inverse digital encoding given in Equation (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 Equation (10):

$$C_{\text{RIMM}} = \begin{cases} \dfrac{V_{\text{clip}} C'_{\text{RIMM}}}{4{,}5}; & 0 \leqslant C'_{\text{RIMM}} < \dfrac{0{,}081}{V_{\text{clip}}} \\ \left( \dfrac{V_{\text{clip}} C'_{\text{RIMM}} + 0{,}099}{1{,}099} \right)^{1/0{,}45}; & \dfrac{0{,}081}{V_{\text{clip}}} \leqslant C'_{\text{RIMM}} < 1 \end{cases} \qquad (10)$$

where

$C$ is either $R$, $G$ or $B$;

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

$V_{\text{clip}}$ is given in Equation (4).

The inverse colour component transfer function given in Equation (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:

$$C'_{\text{ERIMM}} = \frac{C''_{\text{ERIMM}}}{I_{\max}} \qquad (11)$$

where

$C$ is either $R$, $G$, or $B$;

$C''_{\text{ERIMM}}$ is the digital ERIMM RGB colour space encoding;

$C'_{\text{ERIMM}}$ 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 Equation (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 Equation (10):

$$C_{\mathrm{RIMM}} = \begin{cases} \left( \dfrac{C'_{\mathrm{ERIMM}} E_{\mathrm{t}}}{0{,}078\,962\,6} \right); & 0 < C'_{\mathrm{ERIMM}} \leqslant 0{,}078\,962\,6 \\ \mathrm{antilg}\left[ 5{,}5\, C'_{\mathrm{ERIMM}} - 3{,}0 \right]; & 0{,}078\,962\,6 < C'_{\mathrm{ERIMM}} \leqslant 1 \end{cases}, \quad (12)$$

where

$C$ is either $R$, $G$ or $B$;

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

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

$E_{\mathrm{t}}$ is given in Equation (7).

The inverse colour component transfer function given in Equation (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 ($R_{\mathrm{RIMM}}$, $G_{\mathrm{RIMM}}$ and $B_{\mathrm{RIMM}}$) to the corresponding normalized scene-referred image tristimulus values ($X_{\mathrm{N}}$, $Y_{\mathrm{N}}$ and $Z_{\mathrm{N}}$) shall be given by:

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

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:

$$\begin{aligned} X &= X_{\mathrm{N}} Y_{\mathrm{PDR}} \\ Y &= Y_{\mathrm{N}} Y_{\mathrm{PDR}} \\ Z &= Z_{\mathrm{N}} Y_{\mathrm{PDR}} \end{aligned} \quad (14)$$

where

$X$, $Y$ and $Z$ are the scene-referred image tristimulus values;

$X_{\mathrm{N}}$, $Y_{\mathrm{N}}$ and $Z_{\mathrm{N}}$ are the normalized image tristimulus values;

$Y_{\mathrm{PDR}}$ is the $Y$ tristimulus value of a perfect diffuse reflector.

# 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 colorimetry of a pleasing colour rendered image generally does not match the colorimetry 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 Annex A of ANSI/I3A IT10.7666.) 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 an (E)RIMM RGB colour encoding represents a mechanism for the unambiguous specification of the colour appearance 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 used for digital image interchange in an open systems environment, it is



 