

SMPTE RECOMMENDED PRACTICE

Full-Range Image Mapping



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Foreword

SMPTE (the Society of Motion Picture and Television Engineers) is an internationally-recognized standards developing organization. Headquartered and incorporated in the United States of America, SMPTE has members in over 80 countries on six continents. SMPTE's Engineering Documents, including Standards, Recommended Practices, and Engineering Guidelines, are prepared by SMPTE's Technology Committees. Participation in these Committees is open to all with a bona fide interest in their work. SMPTE cooperates closely with other standards-developing organizations, including ISO, IEC and ITU.

SMPTE Engineering Documents are drafted in accordance with the rules given in Part XIII of its Operations Manual.

SMPTE RP 2077 was prepared by Technology Committee 10E.

Intellectual Property

At the time of publication no notice had been received by SMPTE claiming patent rights essential to the implementation of this Engineering Document. However, attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. SMPTE shall not be held responsible for identifying any or all such patent rights.

Introduction

This section is entirely informative and does not form an integral part of this Engineering Document.

Each pixel in a digital image is commonly encoded as a triplet of n-bit binary words — see, for instance, SMPTE ST 125, SMPTE ST 274 and ST SMPTE 296 for the process by which such encoding is generated.

In a full-range digital image, the code values of the reference black and white triplets are the minimum and maximum values that can be encoded by an n-bit unsigned binary integer, $(0, 0, 0)$ and $(2^n - 1, 2^n - 1, 2^n - 1)$ respectively, i.e. the "full range" of code values.

This specification defines mappings allowing source full-range images to be carried by (i) digital interfaces that rely upon protected values, e.g. for synchronization, and (ii) narrow-range digital image formats where the full-range of code values is not utilized for the range between reference black and white¹. These mappings can be used to devise methods to interoperate with analog workflows, but those methods are outside the scope of this document.

On digital interfaces that rely upon protected values, a small number of code values are prohibited from appearing in triplets. For instance, the 10-bit interface defined in SMPTE ST 292-1 protects code values outside the range [4,1019].

¹ The terms "reference black" and "reference white" have the same meanings herein as in SMPTE ST 125, SMPTE ST 274 and SMPTE ST 296, which state "picture information shall be linearly represented by red, green and blue tristimulus values (RGB), lying in the range 0 (reference black) to 1 (reference white)".

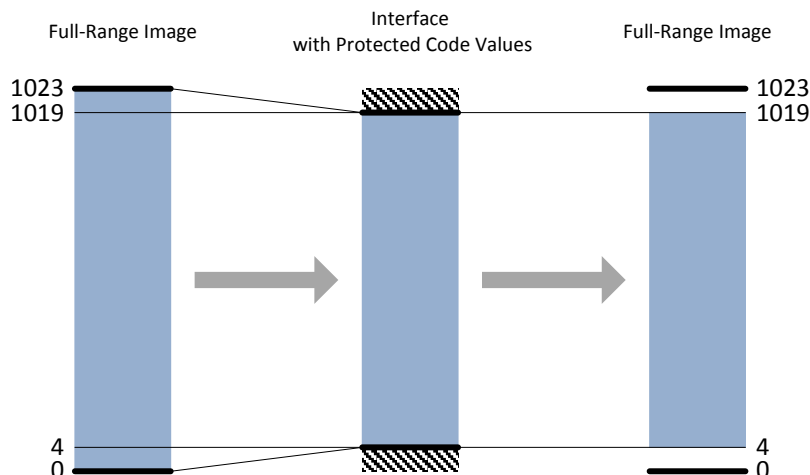


Figure 1 – Full-Range Image Mapping over an Interface that Rely upon Protected Code Values

In this first scenario, Section 4.1 specifies that, given a full-range image as input, code values falling within the protected range are clipped to the closest permitted value without any scaling. As illustrated in Figure 1, no additional processing is required if the resulting narrow-range image is mapped back to full-range at a later time, but the resulting full-range image will be missing any code value clipped by the initial mapping to the digital interface.

In narrow-range digital image formats, the reference black and white triplets, $(R_{BLACK}, R_{BLACK}, R_{BLACK})$ and $(R_{WHITE}, R_{WHITE}, R_{WHITE})$ respectively, are specified with $R_{BLACK} > 0$ and $R_{WHITE} < 2^n - 1$. For instance, as illustrated in Figure, the reference black and white triplets of a 8-bit R'G'B' image encoded as specified in SMPTE ST 125, SMPTE ST 274 and SMPTE ST 296 are equal to (16, 16, 16) and (235, 235, 235), respectively. In other words, while reference black and reference white are the same color in both narrow-range and full-range images, their respective encoded values are different.

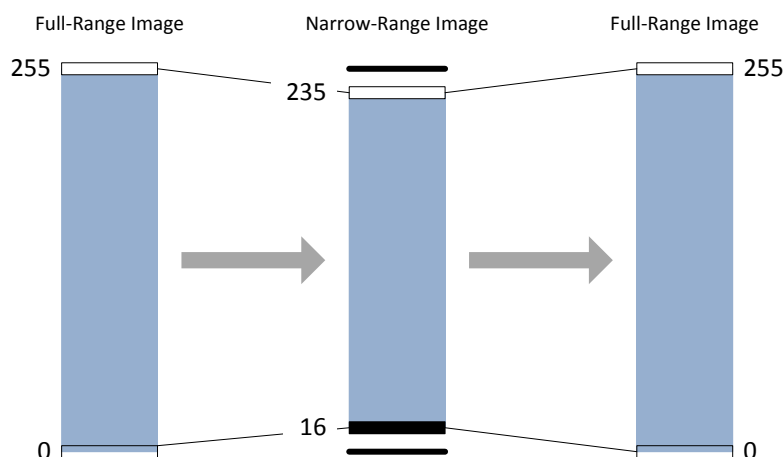


Figure 2 – Mapping a Full-range Image to and from a Narrow-Range Image

In this second scenario, Section 6 specifies that the full-range image code values be scaled to the reference black to white range of the narrow-range image format. If a full-range image mapped to narrow-range needs to be mapped back to full-range, the specification defines a second mapping such that, once a full-range

value has been mapped to a narrow-range value (and quantization information lost), no further information is lost if the mapping is repeated.

This second mapping is not generally applicable to mapping from narrow-range images to full-range images since code values outside the range from reference black to white are simply clipped. For instance, any code value larger than 235 in an 8-bit studio range image is clipped to 235. This can result, for instance, in a change in the hue of pixels containing such code values. If a narrow-range image contains code values outside the range from reference black to white and such behavior is not desired, then another mapping, outside the scope of this specification, can be applied. The separate practices of using full-range image versus narrow-range image originate from the worlds of computer graphics and video, respectively. In the process of converging the practices and mapping between them, users are cautioned to be aware of the compromises that can result.

Narrow-range, as defined herein, encompass a number of commonly used terms such broadcast range, SMPTE range, nominal range, reduced range, head range, video range, standard range, etc.

1 Scope

This Recommended Practice defines mappings of full-range digital images to and from (i) digital image formats and interfaces that rely upon protected values, e.g. for synchronization, and (ii) narrow-range digital image formats and interfaces where the full-range of code values is not utilized for the range between reference black and white. These mappings are not generally applicable to mapping of source narrow-range images, e.g. studio range images, to full-range images.

2 Conformance Notation

Normative text is text that describes elements of the design that are indispensable or contains the conformance language keywords: "shall", "should", or "may". Informative text is text that is potentially helpful to the user, but not indispensable, and can be removed, changed, or added editorially without affecting interoperability. Informative text does not contain any conformance keywords.

All text in this document is, by default, normative, except: the Introduction, any section explicitly labeled as "Informative" or individual paragraphs that start with "Note:"

The keywords "shall" and "shall not" indicate requirements strictly to be followed in order to conform to the document and from which no deviation is permitted.

The keywords, "should" and "should not" indicate that, among several possibilities, one is recommended as particularly suitable, without mentioning or excluding others; or that a certain course of action is preferred but not necessarily required; or that (in the negative form) a certain possibility or course of action is deprecated but not prohibited.

The keywords "may" and "need not" indicate courses of action permissible within the limits of the document.

The keyword "reserved" indicates a provision that is not defined at this time, shall not be used, and may be defined in the future. The keyword "forbidden" indicates "reserved" and in addition indicates that the provision will never be defined in the future.

A conformant implementation according to this document is one that includes all mandatory provisions ("shall") and, if implemented, all recommended provisions ("should") as described. A conformant implementation need not implement optional provisions ("may") and need not implement them as described.

Unless otherwise specified, the order of precedence of the types of normative information in this document shall be as follows: Normative prose shall be the authoritative definition; Tables shall be next; followed by formal languages; then figures; and then any other language forms.

3 Normative References

The following standards contain provisions which, through reference in this text, constitute provisions of this recommended practice. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this recommended practice are encouraged to investigate the possibility of applying the most recent edition of the standards indicated below.

There are no normative references.

4 Terms and Definitions

4.1 Full-Range Image

A full-range image consists of a collection of pixels, each being quantized using a triplet of n -bit unsigned integer words, where the triplets (0,0,0) and ($2^n - 1$, $2^n - 1$, $2^n - 1$) correspond to reference black and reference white, respectively. Table 1 lists reference black and white triplets for example bit depths.

Table 1 – Reference black and white triplets for example bit depths (Informative)

<i>Bit Depth</i>	<i>Reference Black</i>	<i>Reference White</i>
8	(0,0,0)	(255, 255, 255)
10	(0,0,0)	(1023, 1023, 1023)
12	(0,0,0)	(4095, 4095, 4095)

Note: Images for which not all pixels consist of triplets of words, e.g. images that use 4:2:2 sampling as defined in SMPTE ST 274, are not full-range images.

4.2 Narrow-Range Image

A narrow-range image consists of a collection of pixels, each being quantized using a triplet of n -bit integer words, where the black and white reference triplets are, respectively, (R_{BLACK} , R_{BLACK} , R_{BLACK}) and (R_{WHITE} , R_{WHITE} , R_{WHITE}), respectively, where $0 < R_{BLACK} < R_{WHITE} < 2^n - 1$.

5 Mapping to Interfaces and Formats that Rely upon Protected Code Values

The following shall apply when mapping a full-range image to a format or interface that (i) uses triplets of the same bit length, (ii) uses the same black and white reference triplets and (iii) defines protected code values that cannot be used so that only code values in the range $[CV_{LOW}, CV_{HIGH}]$ are permitted.

The function $M_{full \rightarrow permitted}$ ("map from full-range to permitted range") shall map a code value CV_{FULL} from a full-range image to a code value CV_P on the interface or format according to

$$M_{full \rightarrow permitted} : CV_{FULL} \rightarrow CV_P = \text{clamp}(CV_{LOW}, CV_{HIGH}, CV_{FULL}), \quad (1)$$

where

$$\text{clamp}(a, b, x) = \begin{cases} x, & \text{if } x \in [a, b] \\ a & \text{if } x < a \\ b & \text{if } x > b \end{cases}$$

The function $M_{permitted \rightarrow full}$ ("map from permitted range to full-range") shall map a code value CV_P on the interface or format to a code value CV_{FULL} for the full-range image according to

$$M_{permitted \rightarrow full} : CV_P \rightarrow CV_{FULL} = CV_P \quad (2)$$

Note: Any information in a full-range image encoded using code values outside the range $[CV_{LOW}, CV_{HIGH}]$ is lost in this mapping. Equivalently, full-range images sourced from an interface or format with protected code values will not contain code values outside the range $[CV_{LOW}, CV_{HIGH}]$.

Annex B contains an illustrative mapping to and from a 10-bit interface with $CV_{LOW} = 4$ and $CV_{HIGH} = 1019$.