

SMPTE STANDARD

VC-5 Video Essence —
Part 3: Image Formats

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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 its Standards Operations Manual.

SMPTE ST 2073-3 was prepared by Technology Committee 10E.

Intellectual Property

SMPTE draws attention to the fact that it is claimed that compliance with this Standard may involve the use of one or more patents or other intellectual property rights (collectively, "IPR"). The Society takes no position concerning the evidence, validity, or scope of this IPR.

Each holder of claimed IPR has assured the Society that it is willing to License all IPR it owns, and any third party IPR it has the right to sublicense, that is essential to the implementation of this Standard to those (Members and non-Members alike) desiring to implement this Standard under reasonable terms and conditions, demonstrably free of discrimination. Each holder of claimed IPR has filed a statement to such effect with SMPTE. Information may be obtained from the Director, Standards & Engineering at SMPTE Headquarters.

Attention is also drawn to the possibility that elements of this Standard may be subject to IPR other than those identified above. The Society shall not be responsible for identifying any or all such IPR.

Introduction

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

The VC-5 Elementary Bitstream defined in SMPTE ST 2073-1 encodes arrays of components as independent channels and does not specify the type of components that are represented in the bitstream, but defines an extensible syntax for the elements that comprise a bitstream. This standard extends the bitstream syntax with new elements that describe the format of the image represented by a bitstream.

The image formats covered by this standard are images that can be modeled as a single rectilinear grid of samples, called a sample array, with a fixed number of components per sample, including image formats such as $R'G'B'(A)$ and $Y'C_1C_2(A)$ without sub-sampled color differences.

For the purposes of this standard, the C_1 and C_2 color difference components correspond to the blue color difference and red color difference, respectively.

A sample array can model any Color Filter Array (CFA) sensor, such as Bayer, that consists of a repetition of rectilinear pattern elements with the same structure.

1 Scope

This standard specifies extensions to the VC-5 Elementary Bitstream defined in SMPTE ST 2073-1 for representing R'G'B'(A) images, Y'C₁C₂(A) images without color difference component sub-sampling, and Color Filter Array (CFA) images including Bayer image formats. This standard specifies the default color space for R'G'B' and Y'C₁C₂ color values.

This standard extends SMPTE ST 2073-1 by adding new parameters and chunk elements:

The **ImageFormat** parameter specifies the type of image: R'G'B'(A), Y'C₁C₂(A), CFA, or Bayer;

The **PatternWidth**, **PatternHeight**, and **ComponentsPerSample** parameters specify the structure of CFA images, including Bayer images;

The **MaxBitsPerComponent** parameter specifies an upper bound on the number of bits needed to represent all values in the component arrays present in the bitstream;

The **VendorSpecificData** chunk element allows private data to be embedded in a VC-5 bitstream;

The **InverseTransform**, **InverseTransform16**, and **InversePermutation** chunk elements specify how to transform and reorder decoded component arrays into the same color space and order as originally presented to the encoder;

The **UniqueImageIdentifier** chunk element specifies the image sequence and position within the sequence of an image represented by a VC-5 bitstream.

This standard extends SMPTE ST 2073-1 by defining three stages for transforming decoded component arrays into images: inverse component transform, inverse component permutation, and image repacking process.

This standard extends SMPTE ST 2073-1 to specify levels of performance for decoder implementations.

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

SMPTE ST 330:2011, Unique Material Identifier (UMID)

SMPTE ST 2073-1:2014, VC-5 Video Essence — Part 1: Elementary Bitstream

IEEE 802-2001, Standard for Local and Metropolitan Area Networks: Overview and Architecture.

4 Terms and Definitions

For the purposes of this standard, the following definitions shall apply:

4.1 color difference component

Color component that represents the difference between two colors.

4.2 color difference component sub-sampling

Color difference components with less spatial resolution than the Y' components.

4.3 component vector

One-dimensional vector of scalar values.

4.4 Y' component

Weighted sum of R'G'B' color components that are optionally gamma-corrected.

4.5 pattern element

Two-dimensional array of samples used to tessellate the sample array.

Note: The pattern element normally contains just a few samples.

4.6 Sample

Element in an array of samples, each element comprising one or more component values.

4.7 sample array

Two-dimensional array of samples.

4.8 sample array dimensions

Width and height of the sample array in units of samples.

4.9 sample array height

Number of lines (rows) in a sample array.

4.10 sample array width

Number of samples per line (row) in a sample array.

4.11 signed integer

Two's complement integer that may be positive, negative, or zero.

4.12 unsigned integer

Integer that may be positive or zero.

4.13 VC-5 bitstream

Bitstream that is compliant with one or more parts of SMPTE ST 2073.

5 Notation

This document uses the notation defined in SMPTE ST 2073-1 VC-5 Elementary Bitstream.

The value of the operation $\text{clamp}(x, l, u)$ is l if x is less than l , u if x is greater than u , and otherwise equal to x .

6 Overview (Informative)

This standard extends the elementary bitstream with syntax elements that describe how common image formats are represented in VC-5 bitstreams.

Each of the image formats covered in this document is modeled as a single sample array with one or more components per sample. Sample arrays are described in Section 7.

Any image that can be modeled as a single sample array can be unpacked into component arrays with one component from each sample in each array (Section 8). This standard defines the inverse component transform for reversing the effect of color space transformation applied by the encoder to improve compression (Section 8.5) and defines the inverse component permutation for reordering the component values into the same order as originally presented to the encoder (Section 8.6).

Section 9 describes the image formats defined in this standard: R'G'B' images with an optional alpha channel (Section 9.1), Y'C₁C₂ images with an optional alpha channel, but no sub-sampling (Section 9.2), Color Filter Array (CFA) images (Section 9.3), and Bayer images (Section 9.4).

Extensions to the bitstream syntax that are defined by this standard are described in Sections 10 and 11.

The default colorimetry for images with R'G'B' or Y'C₁C₂ color components is defined in Annex C.

Two new stages in the decoding process for applying the inverse component transform and reordering the components using the inverse component permutation are described in Annex D. The inverse transform and permutation followed by the image repacking process (also described in Annex D) allows the component arrays output by the decoding process as defined in SMPTE ST 2073-1 (VC-5 Elementary Bitstream) to be repacked into an image.

7 Image Structure

7.1 Sample Arrays (Informative)

Images that do not have color difference component sub-sampling can be modeled as a single sample array. A sample consists of one or more components at the same location in the sample array. All samples contain the same number and type of components in the same order. Components may be color components or other data such as alpha values for compositing or disparity values. Sometimes, in other documents, the use of the term pixel corresponds to the use of the term sample in this document.

The dimensions of a sample array are in units of samples.

Sample arrays have W samples per row and H rows of samples for a total of M samples:

$$M = W \times H$$

Each sample has C components per sample for a total of N components per sample array:

$$N = M \times C$$

Multiple image formats can map to the same set of component arrays input to the encoder. The image repacking process cannot output the original image format input to the image unpacking process without additional information provided to the decoder by the application.

7.2 Pattern Elements (Informative)

The sample array can be partitioned into a repeating pattern of samples as shown in Figure 1. The repeating pattern of samples is called a pattern element. The sample order is the same in every pattern element.

Each pattern element has w samples per row and h samples per column for a total of m samples per pattern element:

$$m = w \times h$$

Each sample has C components per sample for a total of n components per pattern element:

$$n = m \times C$$

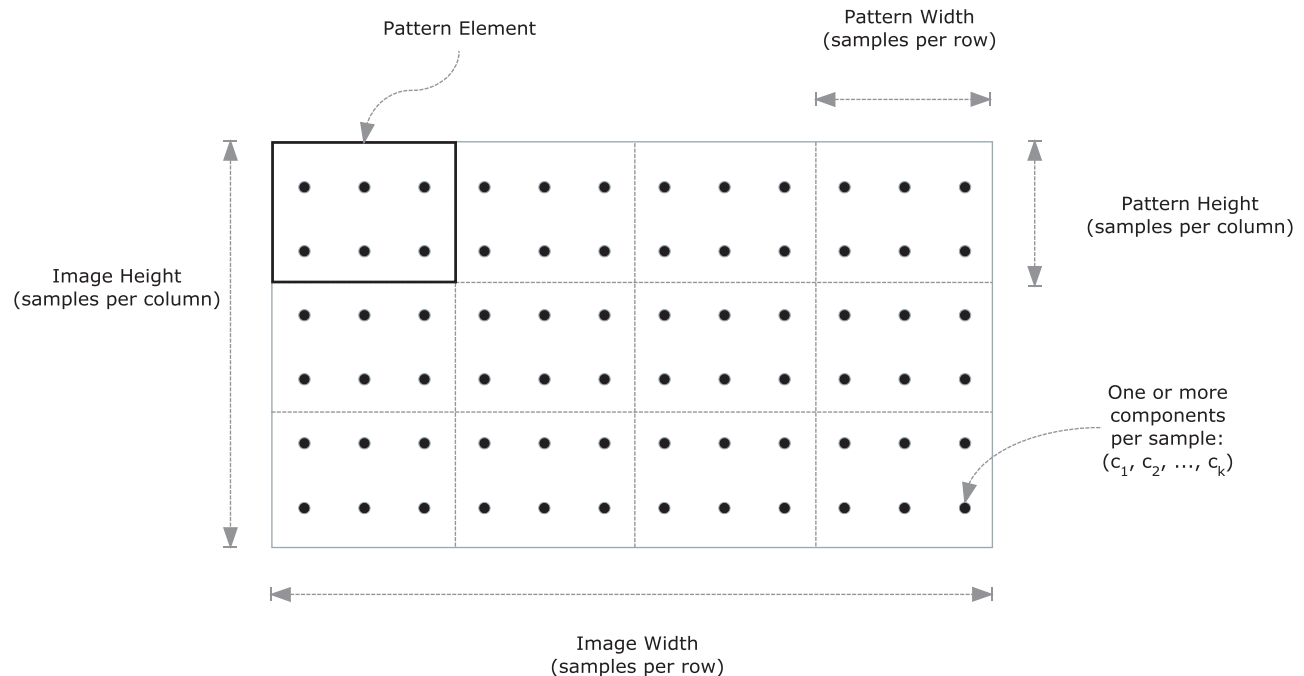


Figure 1 – A sample array consists of a repeating pattern of samples (pattern elements)

7.3 Pattern Element Dimensions

A sample array shall be partitioned into a repeating pattern of rectangular regions called pattern elements. (See the example in Figure 1.)

Each pattern element in the sample array shall be the same width and height and shall consist of the same component types in the same order.

The number of samples in each row of a pattern element shall be **PatternWidth**. The number of sample rows in each pattern element shall be **PatternHeight**. The number of components per sample shall be **ComponentsPerSample**.

The order of the components in each sample shall be the same.

Note: A pattern element is a three-dimensional array of component values (sample row, column within each row, and index to each component value in a sample).

7.4 Image Dimensions

The **ImageWidth** shall equal the number of samples in each row and **ImageHeight** shall equal the number of samples in each column of the sample array regardless of the dimensions of the pattern elements (Figure 1).

The value of **ImageWidth** shall be an integer multiple of **PatternWidth** and the value of **ImageHeight** shall be an integer multiple of **PatternHeight**.