SMPTE STANDARD

VC-5 Video Essence — Part 4: Subsampled Color Difference Components

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Foreword

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SMPTE ST 2073-4 was prepared by Technology Committee 10E.

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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.

The VC-5 Image Formats defined in SMPTE ST 2073-3 describe image formats with the same number of components per sample. This standard extends the image formats to include $Y'C'_1C'_2(A)$ images with subsampled color difference components. The repetitive structure of subsampled color difference components is modeled using pattern elements, which were introduced in SMPTE ST 2073-3 for the purpose of describing the arrangement of color components in CFA images.

The default color space for $Y'C'_1C'_2(A)$ images is defined in SMPTE ST 2073-3.

1 Scope

This standard extends the Y′C′$_1$C′$_2$(A) image format defined in SMPTE ST 2073-3 to include subsampled color difference components (including 4:2:2, 4:2:0, 4:1:1, and 4:1:0). An alpha channel is optional and can have the same resolution as the Y′ channel or the same resolution as the C′$_1$ and C′$_2$ channels.

This standard adds the **AlphaSampling** parameter to specify whether the alpha component is subsampled.

Operations that resample color difference components are out of scope.

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

SMPTE ST 2073-3:2015, VC-5 Video Essence — Part 3: Image Formats

4 Terms and Definitions

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

4.1 canonical component order

Ordering of components in a pattern element with all luma components in scan line order, followed by all C_1 components in scan line order, followed by all C_2 components in scan line order.

4.2 color difference component image (CDCI)

Sample array that contains both luma and color difference components.

4.3 color difference sample

Sample that contains a single color difference component.

4.4 luma component

Y′ color component.

4.5 luma sample

Sample that contains a single luma component.

4.6 luma sample row

Sample array row that contains one or more luma samples.

5 Notation

This document uses the notation defined in SMPTE ST 2073-1, VC-5 Elementary Bitstream and SMPTE ST 2073-3, Image Formats. No new notation is defined in this standard.

6 Overview (Informative)

Section 7 describes how the **PatternWidth** and **PatternHeight** parameters (defined in SMPTE ST 2073-3) are used to describe color difference component subsampling.

Section 8 specifies how a subsampled color difference component image is represented in a VC-5 bitstream.

Section 9 describes the $Y'C'_1C'_2(A)$ image format which was defined in SMPTE ST 2073-3.

Section 10 specifies constraints on the bitstream syntax.

Annex A defines the new **AlphaSubsampling** tag-value pair for alpha component subsampling.

Annex B describes how parameters that determine the image structure, such as **ComponentsPerSample** and **ChannelCount**, are affected by the changes introduced in this standard.

Annex C describes how common image formats with subsampled color difference components can be represented using the techniques described in Section 7.

Annex D and Annex E describe the steps to decode or encode, respectively, VC-5 bitstreams that represent images with subsampled color difference components.

7 Image Structure

7.1 Sample Arrays

An image with subsampled color difference components shall be modeled as a sample array.

Note: The model is not intended to describe how an image is stored in memory (SMPTE ST 2073-3, Section 7).

7.2 Pattern Elements

The values for the **PatternWidth** and **PatternHeight** parameters shall be as defined in one of the last four rows of Table 1.

Note: The first row in Table 1 with **PatternWidth** and **PatternHeight** both equal to 1 corresponds to the $Y'C'_1C'_2$(A) image format defined in SMPTE ST 2073-3.

Note: The **PatternWidth** and **PatternHeight** codec state parameters defined in SMPTE ST 2073-3 are used in this standard to specify the width and height, respectively, of the rectangular grid of Y' components values that correspond to each C'_1 and C'_2 pair in the subsampled image.

Table 1 – Color difference component sampling specified by PatternWidth and PatternHeight

PatternWidth	PatternHeight	Color Difference Component Sampling
1	1	4:4:4
2	1	4:2:2
2	2	4:2:0
4	1	4:1:1
4	4	4:1:0

Every sample in the pattern element shall contain one Y' component.

A pattern element shall contain one C'_1 color component and one C'_2 color component and both color components shall be in the sample in the first row and first column of the pattern element.

Note: The restriction, specified in SMPTE ST 2073-3, that each sample in a pattern element has the same number of components is removed for this standard.

The default co-siting shall be such that both C'_1 and C'_2 components are coincident with the Y' component in the first row and first column of the pattern element. Co-siting is described in Digital Video and HD (Figure 12.1).

7.3 Color Difference Component Subsampling (Informative)

The scheme for color difference component subsampling is implicitly defined by the width and height of the pattern elements. Since only one C'_1 and only one C'_2 color difference component can be present in a pattern element, the spacing between color difference components is equivalent to the pattern element dimensions.

If the **PatternWidth** is 2 and the **PatternHeight** is 1, then there is one pair of color difference components in every two consecutive columns of the sample array. This is known as 4:2:2 subsampling.

If the **PatternWidth** is 2 and the **PatternHeight** is 2, then there is one pair of color difference components for every two consecutive rows and columns in the sample array. This is known as 4:2:0 subsampling.

7.4 Image Dimensions

All luma sample rows in the sample array shall contain the same number of luma samples.

The value of the **ImageWidth** parameter shall be the number of luma samples in each luma sample row of the sample array. The value of the **ImageHeight** parameter shall be the number of luma sample rows in the sample array.

7.5 Alpha Channel

If the value of the **AlphaSampling** parameter is 1, then exactly one alpha component value shall be included in each sample that contains a luma component.

If the value of the **AlphaSampling** parameter is 2, then exactly one alpha component value shall be included in each sample that contains a color difference component and in no other sample in the pattern element.

Note: The presence of an alpha channel is signaled by **ChannelCount** equal to 4.

8 Bitstream Structure

8.1 Component Array Count

The number of channels in the bitstream shall be 3 or 4.

8.2 Component Array Dimensions

8.2.1 Luma Channel Dimensions

The value of **ChannelWidth** for the luma component array shall equal the value of **ImageWidth**.

The value of **ChannelHeight** for the luma component array shall equal the value of **ImageHeight**.

8.2.2 Color Difference Component Dimensions

The value of **ChannelWidth** for the color difference component arrays shall equal the value of **ImageWidth** divided by the value of **PatternWidth**.

The value of **ChannelHeight** for the color difference component arrays shall equal the value of **ImageHeight** divided by the value of **PatternHeight**.

8.2.3 Alpha Channel Dimensions

If **AlphaSampling** is 1, then the **ChannelWidth** and **ChannelHeight** shall equal the corresponding values for the luma component array (Section 8.2.1).

If **AlphaSampling** is 2, then the **ChannelWidth** and **ChannelHeight** shall equal the corresponding values for the color difference component arrays (Section 8.2.2).

8.3 Component Vector

A component vector shall comprise the Y′ values in a pattern element in raster-scan order, the C'_1 component value, the C'_2 component value in that order, and if **ChannelCount** is 4, the alpha component values in raster-scan order.

The Y′ component values in a component vector shall map one-to-one to the Y′ component values in a pattern element as follows:

$$i' = i\,w + j$$

where:

i is the index of the row of samples in the pattern element with $0 \le i < h$,

j is the index of the column of samples in the pattern element with $0 \le j < w$,

i' is the index of the Y′ component value in the component vector with $0 \le i' < n$,

h is the value of **PatternHeight**,

w is the value of **PatternWidth**,

and n is the product of **PatternHeight** and **PatternWidth**.

The C'_1 component value shall be at index n in the component vector and the C'_2 component value shall be at index $n + 1$ in the component vector.

If **ChannelCount** is 4 and **AlphaSampling** is 1, then the alpha component values in a component vector shall map one-to-one to the alpha component values in a pattern element as follows:

$$k' = i\,w + j + \mathrm{n} + 2$$

where:

i is the index of the row of samples in the pattern element with $0 \le i < h$,

j is the index of the column of samples in the pattern element with $0 \le j < w$,

k' is the index of the alpha component value in the component vector with $0 \le k' < n$,

h is the value of **PatternHeight**,

w is the value of **PatternWidth**,

and n is the product of **PatternHeight** and **PatternWidth**.

If **ChannelCount** is 4 and **AlphaSampling** is 2, then the single alpha component value in the pattern element shall be at index $n + 2$ in the component vector.

If **ChannelCount** is not equal to 4, then the component vector shall not contain alpha component values.

8.4 Inverse Component Transform and Inverse Component Permutation

The inverse component transform shall be applied to every component vector in the decoded component arrays and the inverse component permutation shall be applied to every component vector output by the inverse component transform as specified in SMPTE ST 2073-3 Section 8.4 and Figure 3.

9 Image Formats

9.1 Image Format Parameter

The value of the **ImageFormat** parameter shall be 2.

Note: Subsampled $Y'C'_1C'_2$ is an extension of the **ImageFormat** for $Y'C'_1C'_2$(A) images with 4:4:4(:4) sampling defined in SMPTE ST 2073-3.

9.2 Channel Number Assignments (Informative)

The assignment of Y', C'_1, C'_2, and alpha component arrays to channel numbers is specified in SMPTE ST 2073-3 Table 4.

10 Bitstream Syntax

10.1 Bitstream Header

One **ImageWidth** tag-value pair shall be present in the bitstream header and one **ImageHeight** tag-value pair shall be present in the bitstream header.

One **PatternHeight** tag-value pair shall be present in the bitstream header and one **PatternWidth** tag-value pair shall be present in the bitstream header.

One **ImageFormat** tag-value pair shall be present in the bitstream header.

10.2 Bitstream Restrictions

The **ChannelWidth** and **ChannelHeight** tag-value pairs shall be ignored.

The **ComponentsPerSample** parameter shall be ignored.

Note: The **ChannelWidth** and **ChannelHeight** are derived parameters (Section 8.2) and the number of components is not the same for all samples in the pattern element as described in Annex B.

Annex A Codec State Parameters (Normative)

A.1 Bitstream Extensions

The codec state parameters defined in SMPTE ST 2073-1 Annex B.1 and SMPTE ST 2073-3 Annex A.2 shall be extended to include the codec state parameters defined in Annex A.2 of this standard.

The tag-value pairs defined in SMPTE ST 2073-1 Annex B.2 and SMPTE ST 2073-3 Annex A.3 shall be extended to include the tag-value pairs defined in Annex A.3 of this standard.

A.2 Parameter Descriptions

A.2.1 AlphaSampling

The **AlphaSampling** parameter specifies whether the width and height of the alpha component array are equal to one of the width and height of the luma component array or the width and height of either color difference component array.

The value of the **AlphaSampling** parameter shall be either 1 or 2 (Section 7.5).

A.3 Tag-Value Pairs

The tag-value pairs that represent the codec state parameters defined by this standard in a VC-5 bitstream shall be as listed in Table A.1, with the tag number and default value as listed in that table. The tag-value pairs defined by this standard shall be header parameters if so specified in Table A.1.

Table A.1 – Codec state parameters defined by this standard

Parameter Name	Tag Number	Default Value	Header Parameter?	Reference
AlphaSampling	109	1	Yes	A.2.1

Annex B Bitstream Structure (Informative)

B.1 Components Per Sample

The **ComponentsPerSample** parameter is not relevant for bitstreams defined by this standard because the number of components is not the same for all samples in a pattern element.

The number of component values c in a pattern element is:

$$c = h\,w + 2 + a$$

where:

h is **PatternHeight**,

w is **PatternWidth**,

a is the number of alpha component values in the pattern element.

The number of alpha component values in the pattern element is one of the values:

a = 1 if **ChannelCount** is 4 and **AlphaSampling** is 2,

a = $h\,w$ if **ChannelCount** is 4 and **AlphaSampling** is 1,

a = 0 otherwise.

Annex C Common Image Formats (Informative)

This annex describes how to represent common color difference component images using the scheme described in this standard. Color difference component images are described in SMPTE ST 377-1.

A Y′C′$_1$C′$_2$ image with 4:2:2 subsampled color difference components is modeled as a single sample array with pattern elements that are one row high by two columns wide (Figure C.1). Half of the samples comprise Y′, C′$_1$ and C′$_2$ components, the other half of the samples are only Y′ components.

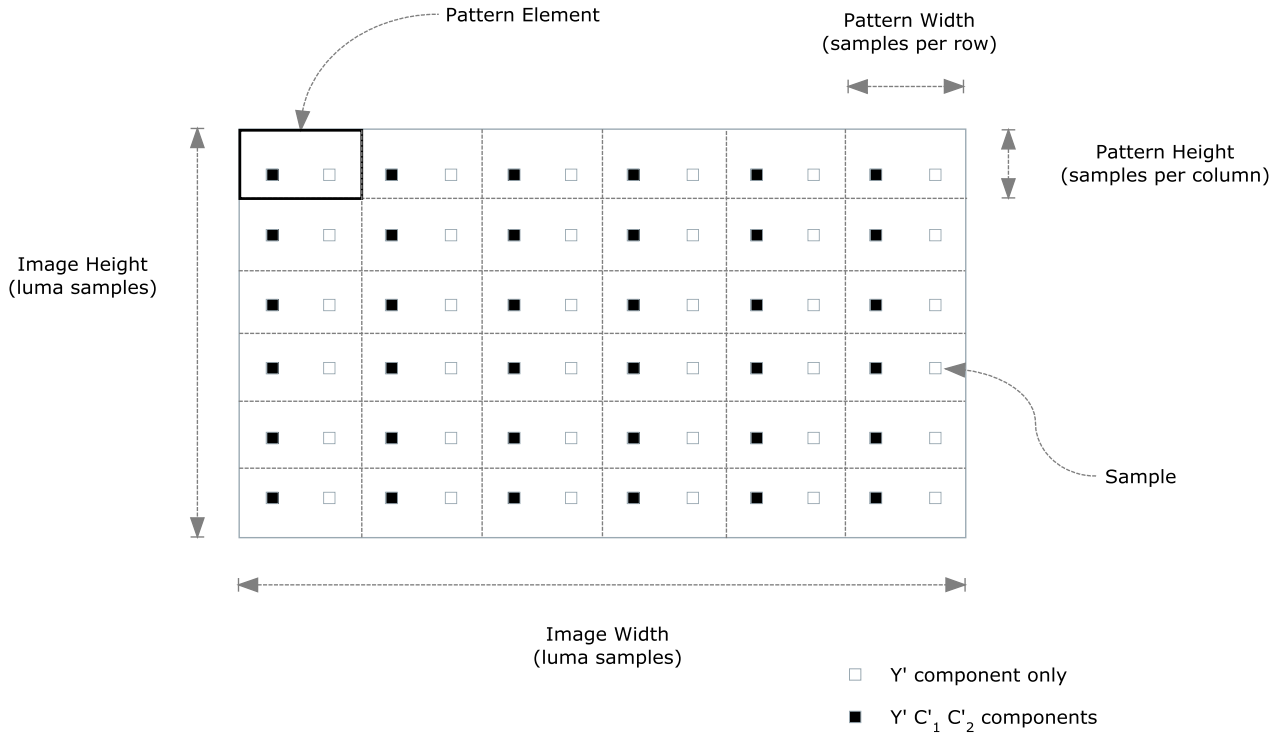

Figure C.1 – Sample array with 4:2:2 color difference component sub-sampling

A Y′C′$_1$C′$_2$ image with 4:2:0 subsampled color difference components is modeled as a single sample array with pattern elements that are two rows high by two columns wide (Figure C.2).

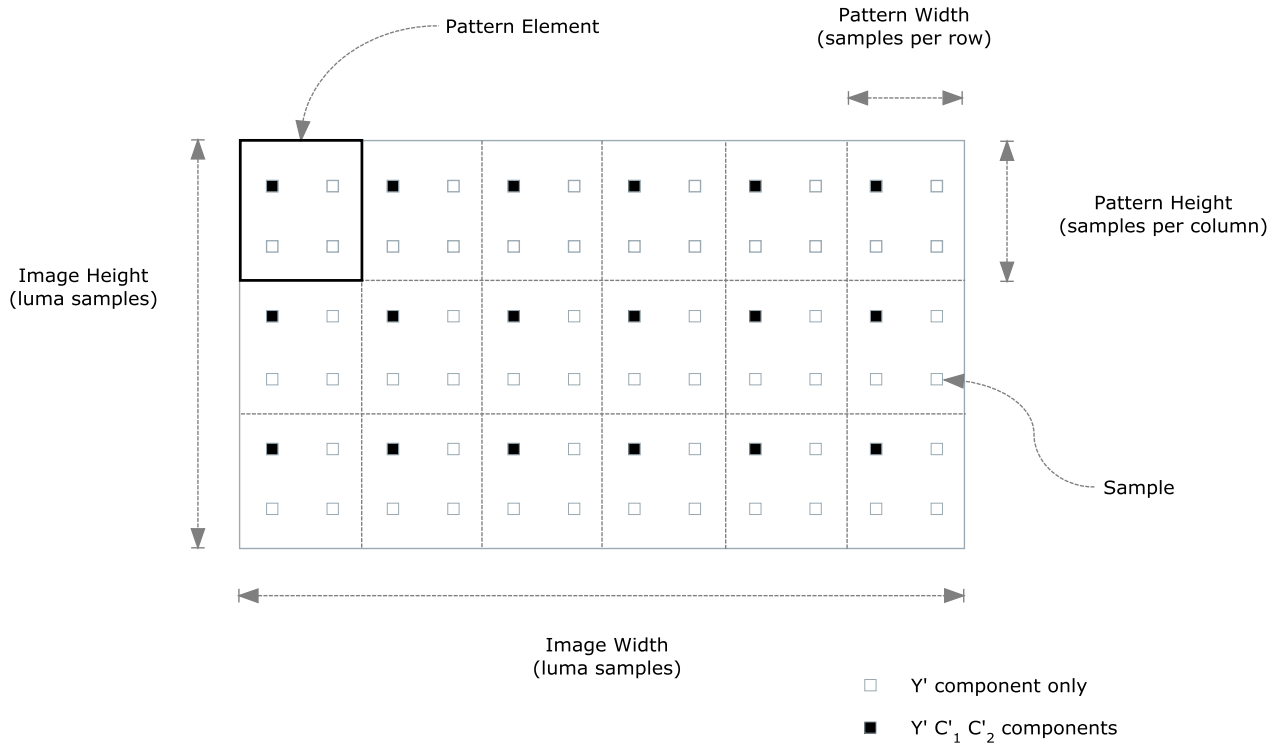

Figure C.2 – Sample array with 4:2:0 color difference component sub-sampling

A $Y'C'_1C'_2$ image with 4:1:1 subsampled color difference components is modeled as a single sample array with pattern elements that are one row high by four columns wide (Figure C.3).

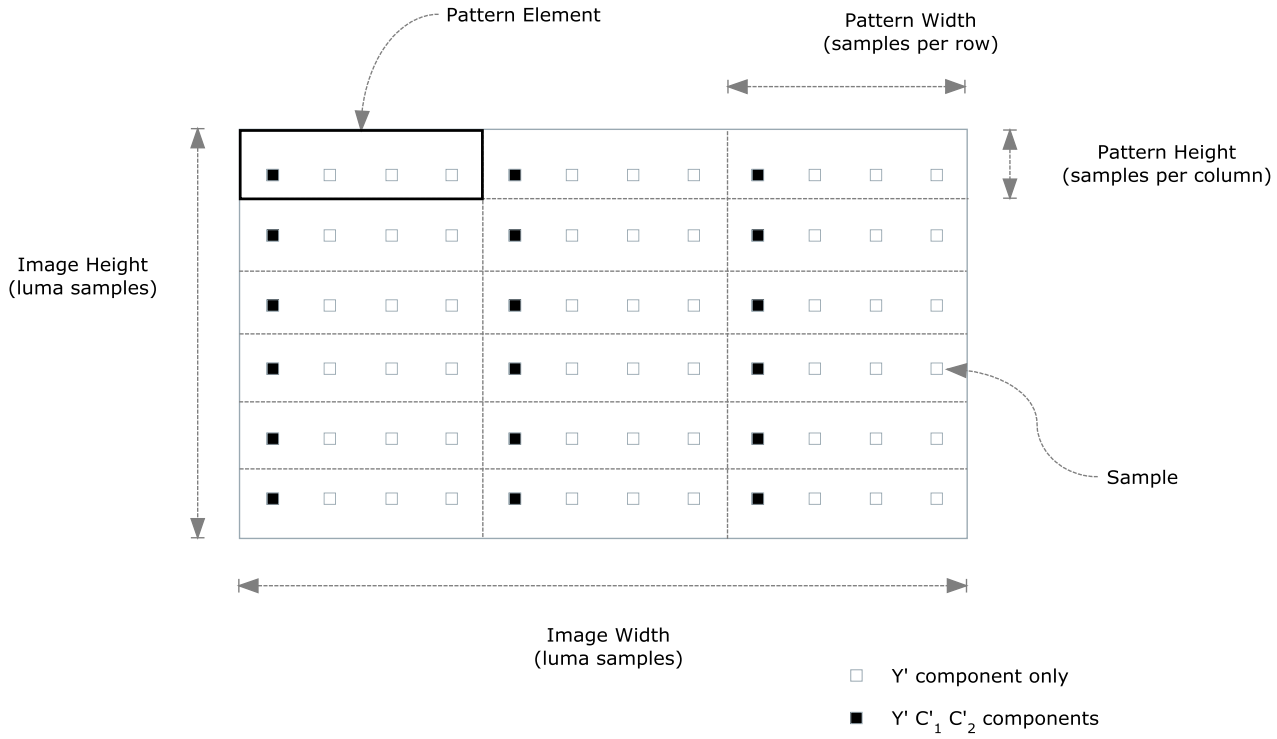

Figure C.3 – Sample array with 4:1:1 color difference component sub-sampling

A Y′C′$_1$C′$_2$ image with 4:1:0 subsampled color difference components is modeled as a single sample array with pattern elements that are four rows high by four columns wide (Figure C.4).

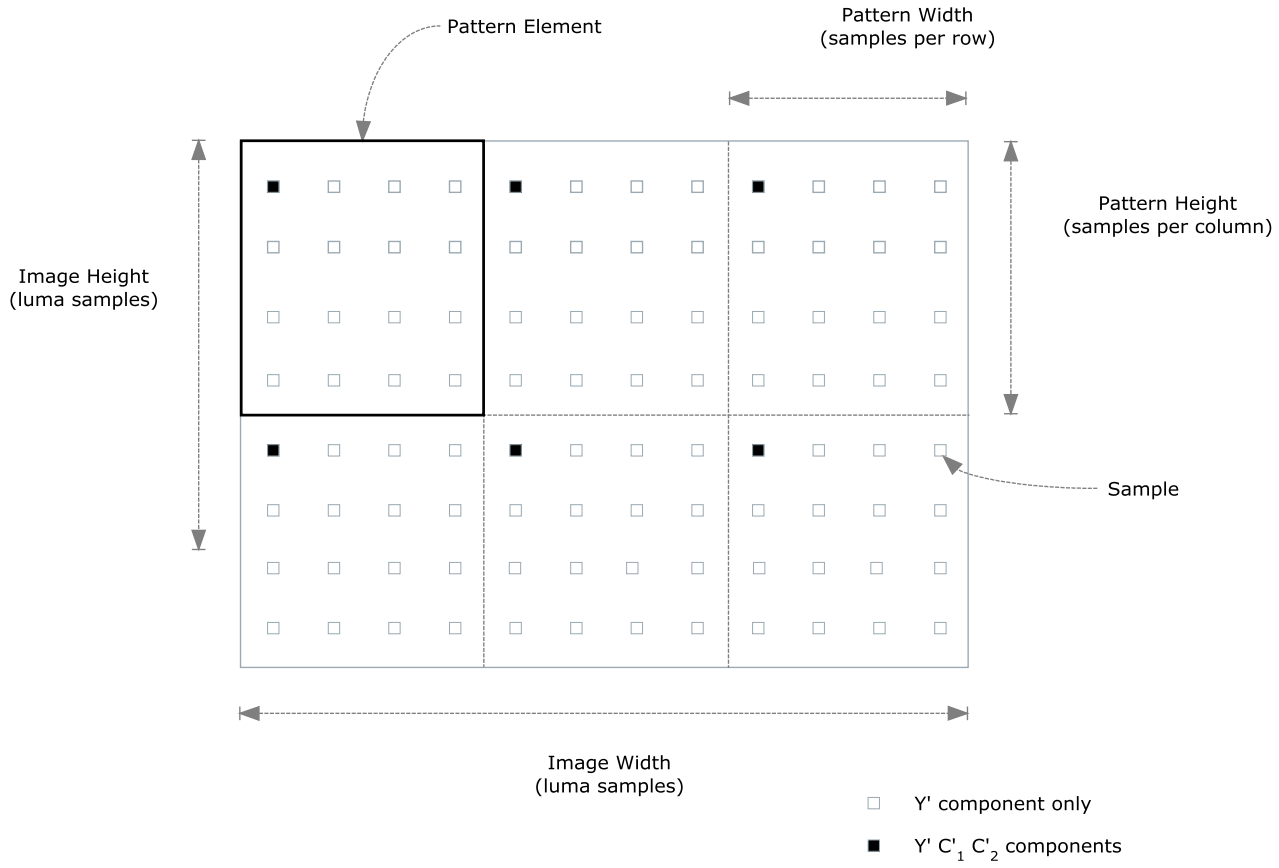

Figure C.4 – Sample array with 4:1:0 color difference component sub-sampling

Annex D Decoding Process (Informative)

D.1 Alpha Channel Sampling

The **AlphaSampling** parameter specifies the alpha component subsampling. The alpha component array can have the same dimensions as the luma component array or can have the same dimensions as either color difference component array.

D.2 Canonical Component Order

After decoding the component arrays in a VC-5 Part 4 bitstream and prior to applying the inverse component transform (SMPTE ST 2073-3 Figure 3), the component vectors formed from the decoded component arrays are in canonical component order.

D.3 Inverse Component Permutation

The inverse component permutation reorders the decoded components into the original order in the component vector output by the image unpacking process.

D.4 Image Repacking Process

The image repacking process packs the reordered component vectors output by the inverse component permutation into an output image. The storage format for the output image can be determined by external data provided to the decoder.

Annex E Encoding Process (Informative)

E.1 Image Unpacking Process

The image unpacking process converts an image from its storage format into an ordered set of Y′, C'_1, and C'_2 component arrays.

E.2 Forward Component Permutation

The encoder applies a forward component permutation to each component vector output by the image unpacking process to reorder the components into canonical component order.

Annex F Bibliography (Informative)

SMPTE ST 377-1:2011, Material Exchange Format (MXF) — File Format Specification

Amendment 1:2012 to SMPTE ST 377-1:2011

Amendment 2:2012 to SMPTE ST 377-1:2011

Charles Poynton, Digital Video and HD: Algorithms and Interfaces (Second Edition), Morgan Kaufmann, 2012