

SMPTE RECOMMENDED PRACTICE

VC-3 Decoder and
Bitstream Conformance

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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 RP 2019-2 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.

1 Scope

This document specifies the testing procedures to be used to verify the conformance of SMPTE VC-3 video decoders and the conformance of VC-3 bitstreams. A description of the test data files is provided. Additionally, information regarding the VC-3 reference decoder is provided.

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.

3 Normative References

The following standards contain provisions which, 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 2019-1:2016, VC-3 Picture Compression and Data Stream Format

SMPTE VC-3 Test Materials — Reference Decoder Software and Bitstreams

ISO/IEC 23002-1:2006, Information Technology — MPEG Video Technologies — Part 1: Accuracy Requirements for Implementation of Integer-Output 8×8 Inverse Discrete Cosine Transform

4 Overview (Informative)

Figure 1 depicts the VC-3 decoder verification process diagram. There are two test sequences which the decoder will need to pass in order for a target decoder to successfully conform to SMPTE VC-3.

The first test sequence is called Decoder Front-End Conformance Testing and is detailed in Section 6.1.1.

The second test sequence is called the Inverse Discrete Cosine Transform Statistical Test. It is described in Section 6.1.2.

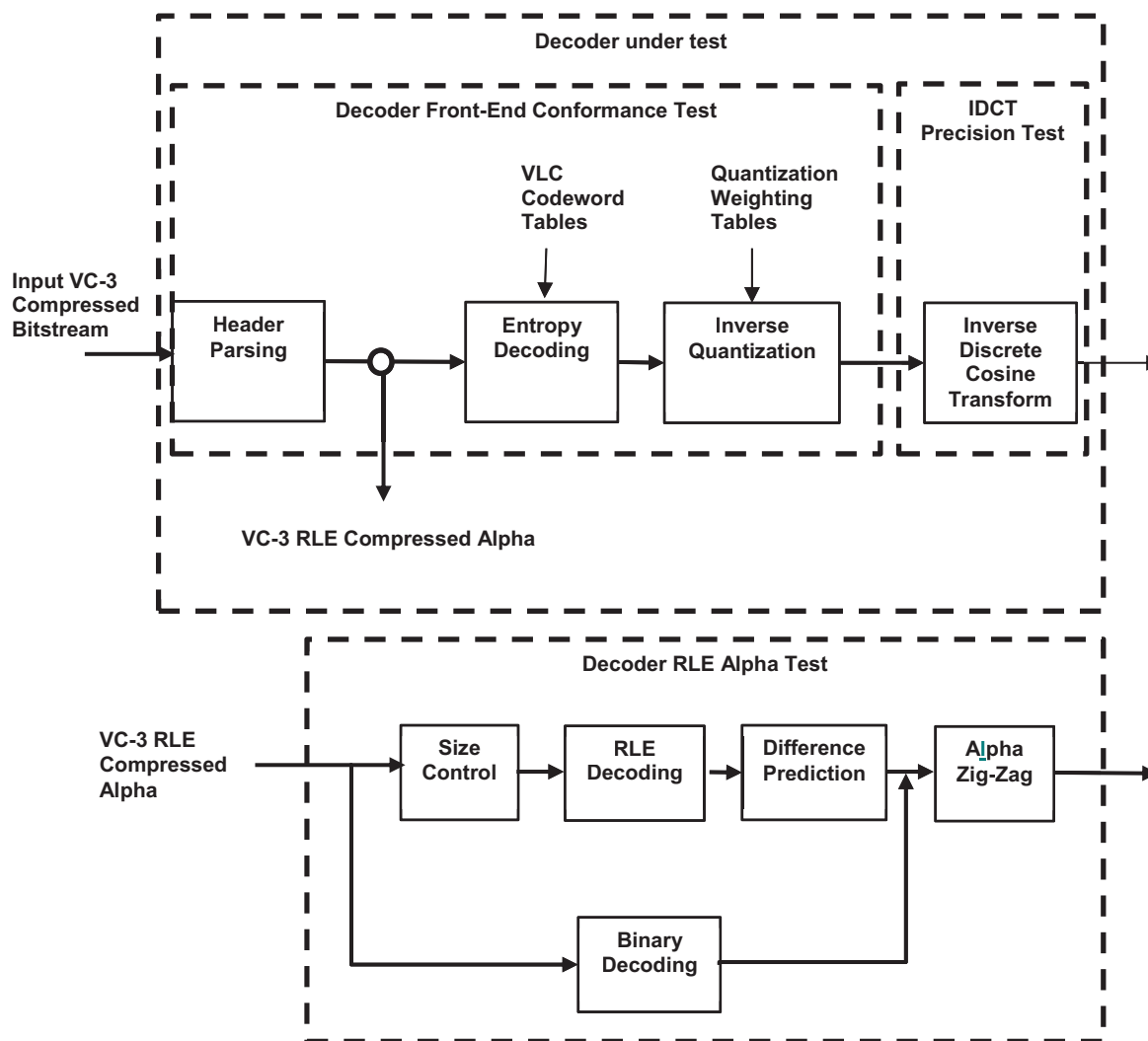


Figure 1 – Target Decoder Conformance Testing

The purpose of the first test (Decoder Front-End Conformance Test) is to test the front-end of the VC-3 decoding stages; i.e. the header parsing, entropy decoding, inverse quantization stages of the decoding process and decoding process of compressed alpha channel. This test compares the output of a reference decoder's diagnostic output against the output of the target decoder. The reference decoder and testing materials are described in Section 5. VC-3 test files and the software reference decoder are available at the

SMPTE Store at <http://smpte.org>. Navigate to the SMPTE Store, then to Test Materials, to locate the VC-3 materials and the corresponding license. The reference decoder conforms to the complete decoding process specified in SMPTE ST 2019-1. Since the Entropy Decoding, Inverse Quantization and RLE decoding stages are mathematically specified, a conforming decoder's output from this processing chain will match exactly with another conforming decoder's output. This enables the Decoder Front-End Conformance Test to be specified as a binary comparison between the reference decoder's output and the target decoder's output.

The purpose of the second test (Inverse Discrete Cosine Transform Statistical Test) is to measure the statistical properties of an Inverse Discrete Cosine Transform (IDCT) implementation. Since the implementation of the IDCT is not completely specified in SMPTE ST 2019-1, there can be small variations depending upon a decoder's implementation. That is why the statistical measures listed in Section 6.1.2 are applied — the precision and accuracy of a decoder's IDCT are measured to verify that it meets the required statistical tolerance.

The purpose of the third test is to ensure the lossless Alpha decoding works according to specification and that the decoder will return a result which can be used for binary comparison of the overall decoding results.

The International Standards Organization (ISO/IEC) has written a document (ISO/IEC 23002-1) describing accuracy requirements for IDCT operations in video compression systems. This Recommended Practice refers to the ISO/IEC documents when detailing the requirements of the Inverse Discrete Cosine Transform Statistical Tests.

Note: The use of "YCbCr" terminology in this document is consistent with its use in ST 2019-1

Finally, Section 6.2 describes the bitstream conformance testing procedure.

5 Description of Testing Materials

5.1 Reference Decoder Software

The reference decoder which implements the complete decoding process specified in SMPTE ST 2019-1 shall be used for testing bitstream conformance. This sub-section describes the operation of the reference decoder.

The reference decoder, in the form of C++ source code and associated documentation, provides decoding functionality for VC-3 conformant bitstreams. It compiles under common "Windows, Linux and Mac OS X" operating systems. The source code will compile to a library, using a generic make file.

The reference decoder supports two modes of operation: "Diagnostic Output" and "Reference Channel Output". These are described further in following sub-sections.

5.1.1 Diagnostic Mode Output

The diagnostic mode output of the reference decoder shall be utilized to verify a candidate decoder's conformance to the VC-3 standard as described in Section 6.1.1. When operating in this mode, the reference decoder will perform the header parsing, the entropy decoding, and the inverse quantization processing steps as shown in Figure 2.

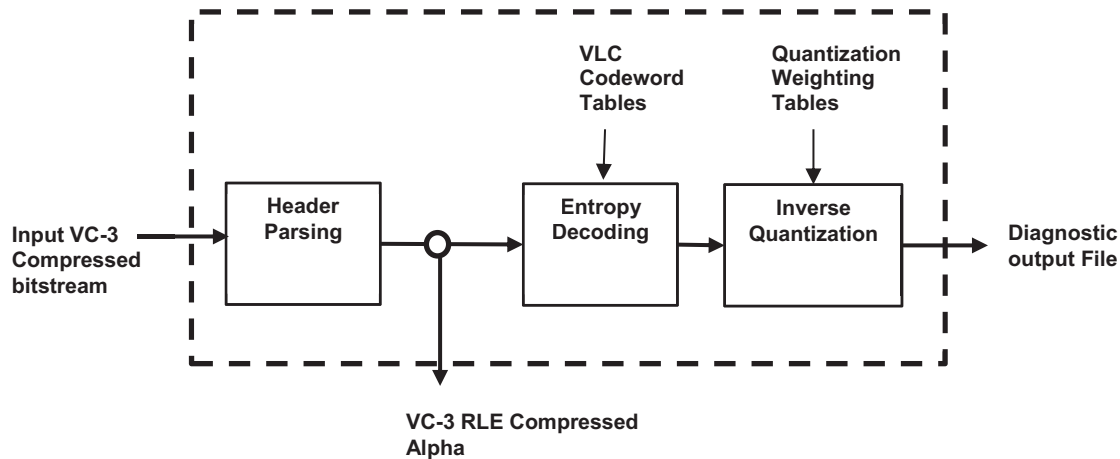


Figure 2 – Reference Decoder in Diagnostic Mode

When the reference decoder is in the diagnostic mode, it will generate diagnostic output files containing RLE Compressed Alpha if present in the bitstream and the 2-D Discrete Cosine Transform (DCT) coefficients $X_k^l(u,v)$, prior to the IDCT.¹ The variable, l , indicates the macroblock index. The variable, k , indicates the DCT block index. The variables u and v represent the horizontal and vertical indices, respectively.

The ordering of the output data shall follow the raster subdivision into macroblocks (see Figure 2 to Figure 8 as appropriate in SMPTE ST 2019-1). That is, $l = 0, 1, \dots, N_T$, where N_T is the number of macroblocks in a frame or field. Within a macroblock, the ordering shall be according to the DCT order as per Figure 9 to Figure 11 and Figure 15 in SMPTE ST 2019-1. In other words, $k = 0, 1, \dots, 3$, $k = 0, 1, \dots, 5$, $k = 0, 1, \dots, 7$ or $k = 0, 1, \dots, 11$.

Within a DCT block, the ordering of the DCT coefficients shall be from top to bottom, left to right as a raster scan would display the image. That is the first coefficient is $X_k^l(0,0)$, followed by $X_k^l(1,0)$. The last coefficient within a DCT block is $X_k^l(7,7)$.

The DCT coefficient data within the diagnostic output files shall be represented by two's complement, 16-bit values (i.e. short) in little endian format. A set of VC-3 compressed bitstreams and the corresponding diagnostic output files are provided with the SMPTE VC-3 test materials.

5.1.2 Reference Channel Output

When operating in the "Reference Channel Output" mode, the reference decoder will perform the entire decoding process described by SMPTE ST 2019-1. This mode shall be used to verify bitstream conformance as detailed in Section 6.2. The "Reference Channel Output" mode will verify the contents of the VC-3 header, compressed payload, and EOF area. If a non-conforming element is found in these regions, the reference decoder will output a diagnostic error message and terminate operation.

¹ The 2-D DCT coefficients should not be confused with the Cosine Basis Function values that are part of the IDCT. These coefficients are the 2-D, 8x8 block DCT transform representation of the encoded video raster.

When operating in the “Reference Channel Output” mode, the reference decoder will utilize a floating point implementation of the IDCT to avoid any problems associated with numerical precision such as arithmetic underflow or overflow.

Conforming decoder implementations need not use a floating point IDCT implementation. Suitable integer IDCT formulations exist.

The output file format for the reference decoder in this mode will depend on the Compression ID. For Compression ID other than 1256 and 1270, format will be header-less binary $YC_B C_R(A)$ 4:2:2(:4), with components written in order as per Figure 3 and Figure 4. The samples will be presented in an interleaved order $C_B, Y, (A), C_R, Y, (A)$ or planar order $\text{Plane1}(Y), \text{Plane2}(C_B), \text{Plane3}(C_R), (\text{Plane4}(A))$. For interlaced video, full-height frames will be produced as field one followed by field two. For compressions ID 1256 and 1270, the output file format will be header-less binary interleaved order $C_B, Y, C_R, (A)$ 4:4:4(:4) or $RGB(A)$ with components written in order as per Figure 5 and Figure 6. Note that alpha-components (shown in {...} and (...)) are optional and will be skipped (not 0 padded) if not present.

The output samples of the reference decoder will be arranged from left to right, top to bottom. The first sample will be the leftmost sample of the top row. This is the same order as a raster scan would display an image.

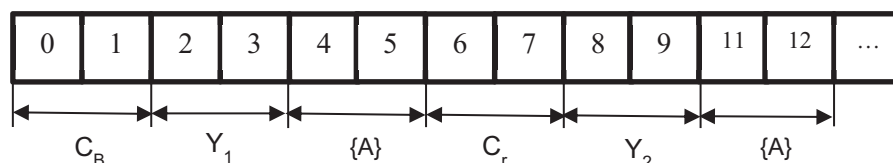


Figure 3 – Decoder output sequence ($YC_B C_R(A)$ 4:2:2(:4))

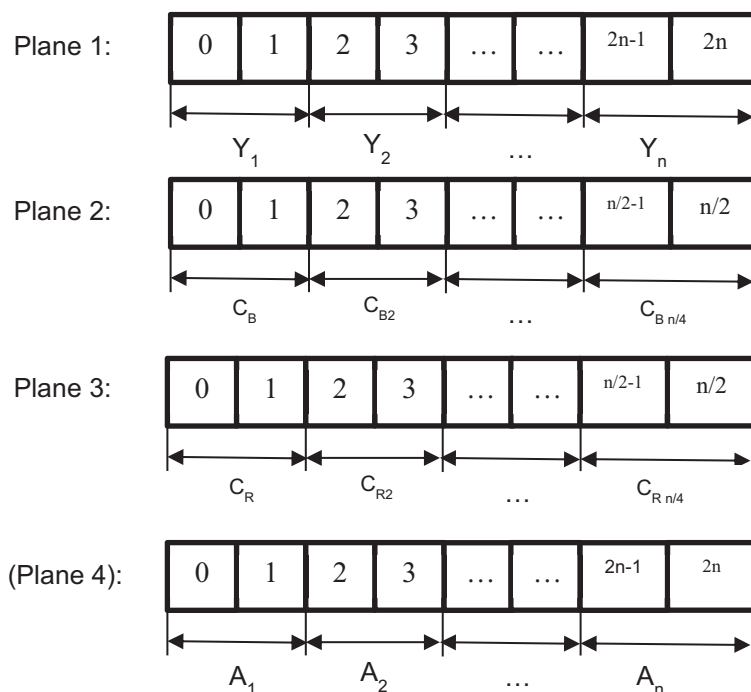


Figure 4 – Decoder output sequence ($YC_B C_R(A)$ 4:2:0(:4))

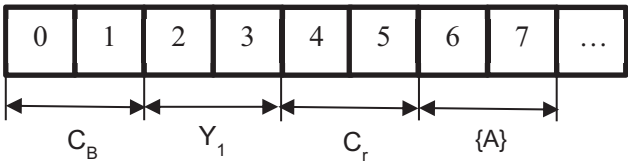


Figure 5 – Decoder output sequence (YCbCr(A) 4:4:4(4))

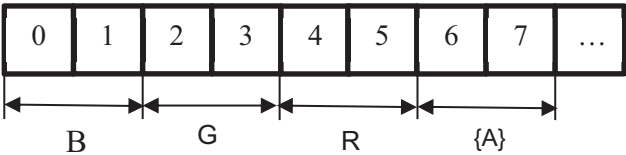


Figure 6 – Decoder output sequence (RGB(A))

For 10-bit or 12-bit components, each will be represented by 2 bytes in "big endian" order according to Figure 7 and Figure 8; within the 16-bit field, the most significant 10 bits or 12 bit will be valid and the other six or four lower bits will be ignored. Ignored bits will have a value of 0. The most significant 8 bits of a component will be mapped into the first byte (byte 0) and the lower 2/4 bits will be mapped into top 2/4 bits of the second byte (byte 1).

The VC-3 reference decoder will support 8-bit,10-bit and 12-bit decoding modes. The exact decoding mode will be determined by the SBD flag (see ST 2019-1, Figure 20 for more information on the Sample Bit Depth flag). For either bit length, the output of the decoder will be one of described above formats with the lower 8 bits (byte 1) of 16 bits being zero for the 8-bit mode.

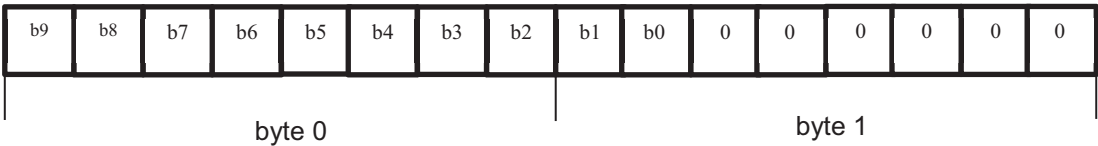


Figure 7 – Layout of the 10-bit data within the 16-bit data field

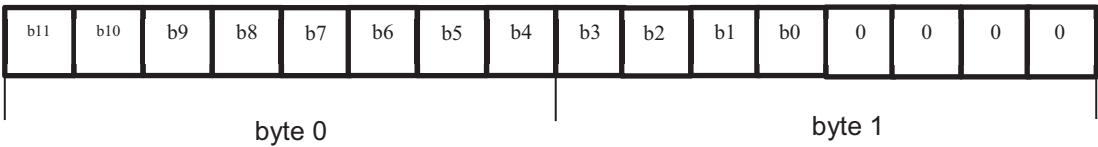


Figure 8 – Layout of the 12-bit data within the 16-bit data field