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| *Title:* | **CE on entropy coding for high bit depth and high bit rate coding** | | |
| *Status:* | Output document of JVET | | |
| *Purpose:* | Core Experiment description | | |
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# Abstract

The goal of this Core Experiment (CE) is to conduct a study of entropy coding for VVC which will consider Rice parameter derivation and transform coefficient clipping proposals submitted to the U meeting of JVET.

Participants in this activity are Kwai, Qualcomm, Sharp, Sony and KDDI.

The software basis for this CE is VTM-12. For the test sequences, configurations and test conditions, the High Bit-depth CTC described in JVET-U2018 is used, unless otherwise specified in the CE description.

# Participants

|  |  |  |  |
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# Test conditions and evaluation criteria

The proposals will be tested under the High Bit-Depth CTC specified in [1] in both lossy and lossless configurations.

Planned tests in the CE shall be implemented on, and compared with, VTM-12.0 with the modification described in JVET-U2018[1] to enable high bit depth processing. In addition, the software base (a.k.a. CE-base) and anchor of the CE will be augmented with the rice coding modifications described in CE-1.1 and CE-2.1 of the CE from the U meeting [2].

For CE-1 tests, CE-1.1 is replaced by the proposed test, and CE-2.1 is used for TSRC.

For CE-2 tests, CE-2.1 is replaced by the proposed test, and CE-1.1 is used for RRC.

The above “used” means that the macro and cfg should be enabled in testing.

For CE-3 tests, proposed test is implemented on CE-base (CE-1.1 and CE-2.1)

For 16 bit testing, extended precision processing will be enabled, and all results will be compared with an anchor with the same setting and code base. For 12 bit testing, extended precision will be disabled and the results will be compared with an anchor with extended precision disabled.

For CE-2, screen content testing using TGM 1080 and TGM 720 from the screen content CTC (with InternalBitDepth set to 12) is mandatory, for other CE tests it is optional.

Transform skip settings will follow CTC settings for all tests.

Proposals will be compared with respect to bit rate, objective quality and complexity. To provide an indication of complexity, comparative run-times for encoding and decoding, memory requirements, newly introduced dependencies and number of operations will be used. In addition, throughput issues should be considered, in particular any change to the bin to bit ratio.

If a proposal changes coding for 8 or 10 bit sources, additional VVC 10 bit CTC results shall be provided.

# Proposals descriptions

## Rice parameter selection for high bit depths (JVET-U0057 and CE-1.5/CE-2.3 of JVET-U0022)

The proposal JVET-U0057 describes a simplification of a modification previously reported in JVET-T0072 to the VVC Rice parameter derivation method for both regular residual coding (RRC) and transform skip residual coding (TSRC). The modification extends the existing VVC Rice parameter deriviation method by adding an adaption technique based on selecting one of a series of counters. These counters generate a prediction of the log2 size of each coefficients being coded once for each sub-TU coded. The counters are incremented whenever a coefficient on the leading diagonal of the TU is coded which is greater than predicted and decremented whenever a coefficient is less than predicted. When coding a coefficient, the log2 predicted size is then used to derive a suitable number of bits to shift right the computed value of *locSumAbs*. This size of this shift is then added to the rice value derived from the lookup table *g\_auiGoRiceParsCoeff*. TSRC is modified to use this log2 predicted size to update the Rice parameter directly as TSRC does not use the locSumAbs mechanism.

## Rice parameter derivation for high bit depths (JVET-U0050 and CE-1.3 of JVET-U0022)

The proposal of JVET-U0050/JVET-T0085 introduces a modification to the VVC Rice parameters derivation method for regular residual coding (RRC). It is proposed to use a formula instead of conventional look-up table. Specifically, the rice parameter value is predicted based on an adjusted value of the *locSumAbs* using linear prediction with log2 operation. The linear prediction calicurate floorLog2(a \* *locSumAbs* + b) + c. The linear prediction parameter (a, b and c) depend on syntax (i.e. abs\_reminder or dec\_abs\_level). An enablied flag for the proposed method is signalled in SPS. This flag doesn’t affect the process if bitdepth is equal or less than 10.

## Slice based Rice parameter selection for transform skip residual coding (JVET-U0075)

The proposal of JVET-U0075 introduces a modification to the VVC Rice parameters derivation method for transform skip residual coding (TSRC). It is proposed to explicitly signal the Rice parameter for each slice to indicate the Rice parameter for the binary codewords of abs\_remainder. In the proposed method, one control flag is signaled in sequence parameter set to indicate the Rice parameter used for the TSRC is allowed to be adjusted for each slice separately. When the flag is enabled, another syntax element is further signaled for each slice to indicate the Rice parameter used for the TSRC of that slice. Otherwise (the flag is disabled), no further syntax element is signaled at slice level and the default Rice parameter (e.g. 1) is used for all the slices.

## On Rice Parameter Derivation with Content Adaptation (JVET-U0062)

The proposal of JVET-U0062 introduces a rice parameter selection method of regular residual coding. It is proposed for high bit depth coding to decomposes the locSumAbs value into shift parameter and index parameter of the pre-defined look-up table in VVC version 1. When the internal bit-depth is greater than 10 bit, the proposed selection is always applied. No slice level signalling is required to adjust the shift parameter.

## Transform coefficients range extension for high bit-depth coding (JVET-U0052)

The proposal of JVET-U0052 intoduces an extended coefficient precision for high bit-depth coding for VVC. This proposal provides two methods as follow:

Method 1:

ExtendedPrecisionFlag = extended\_precision\_processing\_flag && bitDepth > 10

Log2TransformRange = ExtendedPrecisionFlag ? Max( 15, Min(20, BitDepthY + 6) ) : 15

bdShift1 = BitDepthY + rectNonTsFlag + ( ( Log2 ( nTbW ) + Log2 ( nTbH ) ) / 2 ) + 10 − Log2TransformRange+ sh\_dep\_quant\_used\_flag

bdShift2 = ( nTbH > 1  &&  nTbW > 1 ) ? 5 + Log2TransformRange – BitDepth : 6 + Log2TransformRange – BitDepth

truncSuffixLen = Log2TransformRange

maxPreExtLen = 26 – Log2TransformRange

Method 2:

Log2TransformRange = Max( 15, Min(20, BitDepthY + 5 ) )

bdShift1 = BitDepthY + rectNonTsFlag + ( ( Log2 ( nTbW ) + Log2 ( nTbH ) ) / 2 ) + 10 − Log2TransformRange+ sh\_dep\_quant\_used\_flag

bdShift2 = ( nTbH > 1  &&  nTbW > 1 ) ? 5 + Log2TransformRange – BitDepth : 6 + Log2TransformRange – BitDepth

truncSuffixLen = Log2TransformRange

maxPreExtLen = 26 – Log2TransformRange

For method 1 an enabled flag is signaled in SPS extension. For method 2 derives without ExtendedPrecisionFlag. Both methods use clipping 20 for the coefficient range and do not change 8 to 10 bit case.

## RRC rice derivation methods CE1.1 and CE1.2.a of JVET-U0064

Two method of RRC rice derivation process were proposed in JVET-U0064 with globally and locally derived adjusment for rice parameter derivation. In the first method (earlier tested as CE1.1 in JVET-U0064), to extend the range of the Rice parameters, it is proposed to normalize values locSumAbs with a shift derived parameter, if locSumAbs exceed certain threshold, such that scaled value would fit in the allowed range of the Table 128 of the VVC specficiation without clipping. Following this, an output of the Table 128 is being adjusted by incrementing with shift derived parameter value if scaling process was taken a place for a given locSumAbs value.In the second method, (earlier tested as CE1.2.a in JVET-U0064),locally adaptive adjusment for Rice parameter derivation is being evaluated. Similarly to the the first method, to extend the range of the Rice parameters, it is proposed to normalized values *locSumAbs* with a shift, if *locSumAbs* exceed certain threshold, such that scaled value would fit in the allowed range of the Table 128 of the VVC specficiation without clipping. Following this, an output of the Table 128 is being adjusted by incrementing with shift value if scaling process was taken a place for a given locSumAbs value.

## RRC rice derivation methods of 3.6 with history utilization (Methods of CE1.2.b of JVET-U0064 and CE3.5 of JVET-U0066)

Two methods of history utilization for improving performance of the RRC rice derivation were proposed in JVET-U0064 and JVET-U0066. The first method of history utilization was earlier tested in CE1.2.b of JVET-U0064). In this method, a history update was conducted in a TU and its history result was utilized in the following TU to replace template based Rice parameter derivation for certain transform coeffitients. The second method of history utilization was earlier tested in CE3.5 of JVET-U0066). In this method, a history update process was identical to method 1, with history result utilization being integrated to the template-based Rice derivation process.

# Planned tests

## Tests on proposed regular residual coding.

|  |  |  |
| --- | --- | --- |
| **Test** | **Proponent(s)** | **Cross-checker(s)** |
| *CE-1.1* | Qualcomm | Alibaba |
| *CE-1.2* | Qualcomm | Sharp |
| *CE-1.3* | Qualcomm | Sony |
| *CE-1.4* | Qualcomm | Sony |
| *CE-1.5* | Sony | Qualcomm |
| *CE-1.6* | Sony | Qualcomm |
| *CE-1.7* | Sharp | Qualcomm |
| *CE-1.8* | KDDI | Sharp |

## CE-1.1: Method of CE-1.1 from JVET-U0064

In this test, improvements to the first method described in section 3.6 and tested in CE-1.1 of JVET-U0064 to be tested.

## CE-1.2: Method of CE-1.2.a from JVET-U0064

In this test, improvements to the second method described in section 3.6 and tested in CE-1.2 of JVET-U0064 to be tested.

## CE-1.3: History utilization method of JVET-U0064

In this test, improvements to the first history based method described in section 3.7 and earlier studied as CE1.2.b in JVET-U0064 is being tested.

## CE-1.4: Method of CE-1.2.a from JVET-U0064

In this test, improvements to the second history based method described in section 3.7 and earlier studied as CE3.5 in JVET-U0066 is being tested.

After T5 deadline, proponent of the CE1.4 tests identified an encoder issue and proposed a software update to address it. Proposed change is not-normative, encoder only and limited to RRC history update during the RDO process. Updated SW and results were made available in the CE1.4 branch on 03/23/2021. After discussion with the cross-checker and CE participants, it was agreed to include updated SW and results for CE1.4 evaluation.

## CE-1.5: Method of CE-1.5 from JVET-U0057 with parameter set update once per sub-TU

In this test, the method proposed in CE-1.5 of JVET-U0057 is augmented by an SPS level flag which enables / disables the the method.

## CE-1.6: Method of CE-1.5 from JVET-U0057 with parameter set update once per TU

In this test, the method proposed in CE-1.5 of JVET-U0057 is modified to update the parameter set once per TU. In addition the method is augmented by an SPS level flag which enables / disables the the method.

## CE-1.7: Method of CE-1.3 from JVET-U0050.

For this experiment, the method proposed in CE-1.3 in JVET-U0050, it is proposed to use a formula instead of conventional look-up table for RRC, is evaluated.

## CE-1.8: Method of JVET-U0062

For this experiment, method proposed in JVET-U0062, it is proposed to decompose locSumAbs value into shift parameter and index parameter of the conventioan look-up table for RRC, is evaluated.

## Tests on proposed transform skip residual coding.

|  |  |  |
| --- | --- | --- |
| **Test** | **Proponent(s)** | **Cross-checker(s)** |
| CE-2.1 | Kwai | Qualcomm |
| CE-2.2 | Sony | Kwai |
| CE-2.3 | Sony | Kwai |

## CE-2.1: Method of JVET-U0075

Method proposed in JVET-U0075, it is proposed to explicitly signal the Rice parameter for each slice to indicate the Rice parameter for the binary codewords of abs\_remainder. In the proposed method, one control flag is signaled in sequence parameter set to indicate the Rice parameter used for the TSRC is allowed to be adjusted for each slice separately. When the flag is enabled, another syntax element is further signaled for each slice to indicate the Rice parameter used for the TSRC of that slice. Otherwise (the flag is disabled), no further syntax element is signaled at slice level and the default Rice parameter (e.g. 1) is used for all the slices.

After T5 deadline, proponent of the CE2.1 tests identified an encoder issue and proposed a software update to address it. Proposed change is non-normative and it does not affect results under HBD CTC (LowQP/ stdQP). It is an encoder side fix to deside Rice parameter for TGM sequences. Updated SW and results were made available in the CE2.1 branch on 03/24/2021. After discussion with the cross-checker and CE participants, it was agreed to include updated SW and results for CE2.1 evaluation.

## CE-2.2: Method of CE-2.3 from JVET-U0057 with parameter set update once per sub-TU

In this test, the method proposed in CE-2.3 of JVET-U0057 is augmented by an SPS level flag which enables / disables the the method.

## CE-2.3: Method of CE-2.3 from JVET-U0057 with parameter set update once per TU

In this test, the method proposed in CE-2.3 of JVET-U0057 is modified to update the parameter set once per TU. In addition the method is augmented by an SPS level flag which enables / disables the the method.

## Tests on proposed transform coefficient clipping

|  |  |  |
| --- | --- | --- |
| **Test** | **Proponent(s)** | **Cross-checker(s)** |
| CE-3.1 | Sharp | Sony |
| CE-3.2 | Sharp | Sony, Qualcomm |

## CE-3.1: Method 1 of JVET-U0052

In this test, Method 1 proposed in JVET-U0052, transform coefficients range extension for high bit-depth coding, is tested.

ExtendedPrecisionFlag = extended\_precision\_processing\_flag && bitDepth > 10

Log2TransformRange = ExtendedPrecisionFlag ? Max( 15, Min(20, BitDepthY + 6) ) : 15

In this test, the software base will follow the completion of the initial ce base, that CE-1.1 is used for RRC and CE-2.1 is used for TSRC.

## CE-3.2: Method 2 of JVET-U0052

In this test, Method 2 proposed in JVET-U0052, transform coefficients range extension for high bit-depth coding, is tested.

Log2TransformRange = Max( 15, Min(20, BitDepthY + 5 ) )

In this test, the software base will follow the completion of the initial ce base, that CE-1.1 is used for RRC and CE-2.1 is used for TSRC.

## Combined tests (Description of combined tested and cross-checker’s assignment is to be completed by T4.)

|  |  |  |
| --- | --- | --- |
| **Test** | **Tester(s)** | **Cross-checker(s)** |
| CE-4.1 | Sharp | Kwai |
| CE-4.2 | Sharp | Qualcomm |
| CE-4.3 | Sony | Qualcomm |
| CE-4.4 | Sony | Kwai |
| CE-4.5 | Qualcomm | Sony |
| CE-4.6 | Qualcomm | Sharp |
| CE-4.7 | Qualcomm | Sony |

## CE-4.1: Combination test of CE-1.5, CE-2.1 and method 1 in JVET-U0052

In this test, state base rice paramter method and transform coefficient clipping is tested as follow:

The combination of CE-1.5 for RRC, CE-2.1 for TSRC and the method 1 describes JVET-U0052 will be tested.

This is a additional test to compare with the CE-3.1 which tested method 1 in JVET-U0052 on CE base (CE-1.1 and CE-2.1).

## CE-4.2: Combination test of CE-1.5, CE-2.1 and method 2 in JVET-U0052

In this test, state base rice paramter method and transform coefficient clipping is tested as follow:

The combination of CE-1.5 for RRC, CE-2.1 for TSRC and the method 2 describes JVET-U0052 will be tested.

This is a additional test to compare with the CE-3.2 which tested method 2 in JVET-U0052 on CE base (CE-1.1 and CE-2.1).

## CE-4.3: Combination test of CE-1.6 and CE-3.2

This test combines the RRC Rice coding modifications of CE-1.6 with the transform coefficient range extension modification of CE-3.2. For this test the TSRC method will be CE-2.1 in line with the CE anchor.

## CE-4.4: Combination test of CE-2.3 and CE-3.2

This test combines the TSRC Rice coding modifications of CE-2.3 with the transform coefficient range extension modification of CE-3.2. For this test the RRC method will be CE-1.1 in line with the CE anchor.

## CE-4.5: Combination test of CE-1.1, CE-2.1 and method 1 in JVET-U0052

In this test, state base rice paramter method and transform coefficient clipping is tested as follow:

The optimized integration of CE-1.1 for RRC, CE-2.1 for TSRC and transform coefficient range extension modification of CE-3.2.

## CE-4.6: Combination test of CE-1.2, CE-2.1 and method 1 in JVET-U0052

In this test, state base rice paramter method and transform coefficient clipping is tested as follow:

The optimized integration of CE-1.2 for RRC, CE-2.1 for TSRC and transform coefficient range extension modification of CE-3.2.

## CE-4.7: Combination test of CE-1.4, CE-2.1 and method 1 in JVET-U0052

In this test, state base rice paramter method and transform coefficient clipping is tested as follow:

The optimized integration of CE-1.4 for RRC, CE-2.1 for TSRC and transform coefficient range extension modification of CE-3.2.

# Time-line and Responsibilities

T1: 2021-January-29: Version of CE description with final descriptions for tests CE-1, CE-2 and CE-3 uploaded. Any changes of planned tests after this time need to be announced and discussed on the JVET reflector. Initially assigned description numbers shall not be changed later. If a test is skipped, it is to marked as "withdrawn".

T2: 2021-February-24 (VTM 12.0 = Feb. 17 + 1 week):

Integration of CE-1.1 and CE-2.1 into a separate CE branch of the VTM (CE anchor) is completed

T3: 2021-February-26 (VTM 12.0 + 2 week (not later than February 26)) :

Integration of all CE-1/CE-2/CE-3 tools into a separate CE branch of the VTM is completed and initial study by cross-checkers begins.

T4: 2021-March-12 (T3 + 2 weeks): Final description of combined tests is provided.

T5: 2021-March-12 (T3 + 2 weeks): Final version of CE-1/CE-2/CE-3 software and full results are provided, final cross-check begins.

T6: 2021-March-26 (T3 + 4 weeks): Final version of combination software and full results are provided, final cross-check of combination begins.

T7: 2021-April-09: CE contribution documents including specification text and complete test results are uploaded to the JVET document repository.

# References

[1] A. Browne, T. Ikai, D.  Rusanovskyy, X. Xiu, “Common test conditions for high bit depth and high bit rate video coding”, JVET-U2018, JVET, 21th Meeting: by teleconference, 6-15 Jan. 2021

[2] A.Browne, T. Hashimoto, H.-J. Jhu, D. Rusanovskyy, “CE: Summary Report on Entropy Coding for High Bit Depth and High Bit Rate Coding”, JVET-U0022, JVET, 21st Meeting by teleconference, 6-15 Jan. 2021