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| **Joint Collaborative Team on Video Coding (JCT-VC)**  **of ITU-T SG 16 WP 3 and ISO/IEC JTC 1/SC 29/WG 11**  13th Meeting: Incheon, KR, 18–26 Apr. 2013 | Document: JCTVC-M0089 |

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| --- | --- | --- | --- |
| *Title:* | **Non SCE4: simplified design of cross-color inter-layer (test 4.2.4)** | | |
| *Status:* | Input Document | | |
| *Purpose:* | Proposal | | |
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# Abstract

In order to simplify samples processing and reduce the latency on decoder side 2 modifications are of very promising cross-color inter-layer filter tested in SCE4 are proposed in this contribution. Variable de-scaling shift in original design was replaced by fixed left shift. This modification simplifies samples processing and it is almost lossless: cross-color inter-layer filter provides 0,4% Luma and 7,3%(IntraBL)/7,8% (RefIdx) Chroma BD-rate gain in average. Instead up-sampled Luma signal we suggest to use reconstructed base-layer Luma for cross-color inter-layer filtering. In this case decoder doesn’t need to wait until Luma will be up-sampled and inter-layer prediction for Luma and Chroma are independent. This modification even improves the gain from cross-color inter-layer filter to 0,4% Luma 8,0% (RefIdx) and makes design implementation friendly.

# Introduction

Cross-color inter-layer filtering (proponents call it also “Chroma enhancement”) was proposed by Inter Digital in [JCTVC-L0059]. This tool was included into SCE4 and provided 0,4% (Luma) and 7,6% (Chroma) average BD-rate gain.

Tool works both for IntraBL and RefIdx frameworks and requires access to only reconstructed collocated base-layer picture (which is any-way needed for inter-layer texture prediction).

Cross-color inter-layer filtering is implemented as 2D no-separable 4x3 filter, which refers to up-sampled Luma signal in order to reduce the difference between up-sampled and original Chroma signal (as shown on Figure 1).

Separable filters are very friendly for SIMD implementation. 2D non-separable filter from Fig. 1 is equivalent to 3 times application of 1D 4 taps filter. So compare to 2D separable up-sampling filter in SHM1.0 (which is 4 taps) amount of operations will be ~1.5 times higher.

Variable filter coefficients are not friendly for implementation. But this tools was proposed as additional inter-layer filter (not up-sampling filter which is key part of SHVC design), which could be switched on and off in SPS. In this case variable coefficients are acceptable.

**Fig. 1**. Cross-color inter-layer filter: circles – Luma, stars –Chroma, red star – current Chroma sample, red dots surround Luma samples taken into account for current Chroma sample processing.

Proposed modification A.

The goal of this modification is sample processing and slice header simplification.

In original design of cross-color inter-layer filter sample processing is performed as follows:

. (1)

Values , and are signaled in slice-header for Cb and Cr (separately). Additionally tool can be switched On and Off Cb and Cr separately (with corresponding flag encoding in slice header).

Variable shift is not friendly for implementation. According to statistics collected using bit-streams from test 4.2.4 in SCE4 in majority of cases was chosen. We propose to fix this value equal to 16. This simplifies implementation and saves 10 bits in slice header (in original design was encoded using 5 bits fixed length code).

If slice level on/off flag for this tool is false then Chroma samples will not be modified. The same will happen if in (1) is equal to 0. In order to avoid duplicated functionality of syntax elements in a slice header we suggest modifying coding for:

* In original design
  + is encoded using 10-bits fixed length code; if this value is not zero the sign of was signaled (1 bit flag).
* In proposed design
  + is encoded using 11-bits fixed length code.

In terms of specification text proposed modification looks as follows shown in Tables 1-2. Highlighted in yellow lines (which include condition check) are removed.

**Table 1.** Slice header specification text for original design.

|  |  |
| --- | --- |
| **cross\_color\_filter\_cb\_flag** | u(1) |
| if (cross\_color\_filter\_cb \_flag) { |  |
| **cb\_ cross\_color \_filter\_ mult\_abs** | u(10) |
| for( k = 0; k < 12; k++ ) |  |
| **cb\_ cross\_color \_filter\_coeff\_plus8[k]** | u(4) |
| if (cb\_ cross\_color \_filter\_ mult\_abs){ |  |
| **cb\_ cross\_color \_filter\_ mult\_sign** | u(1) |
| **cb\_ cross\_color \_filter\_ shift** | u(5) |
| } |  |
| } |  |
| **cross\_color\_filter\_cr\_flag** | u(1) |
| if (cross\_color\_filter\_cr \_flag) { |  |
| **cr\_ cross\_color \_filter\_ mult\_abs** | u(10) |
| for( k = 0; k < 12; k++ ) |  |
| **cr\_ cross\_color \_filter\_coeff\_plus8[k]** | u(4) |
| if (cr\_ cross\_color \_filter\_ mult\_abs){ |  |
| **cr\_ cross\_color \_filter\_ mult\_sign** | u(1) |
| **cr\_ cross\_color \_filter\_ shift** | u(5) |
| } |  |
| } |  |

**Table 2.** Slice header specification text for proposed design

|  |  |
| --- | --- |
| **cross\_color\_filter\_cb\_flag** | u(1) |
| if (cross\_color\_filter\_cb \_flag) { |  |
| **cb\_ cross\_color \_filter\_no\_zero\_mult** | u(11) |
| for( k = 0; k < 12; k++ ) |  |
| **cb\_ cross\_color \_filter\_coeff\_plus8[k]** | u(4) |
| } |  |
| **cross\_color\_filter\_cr \_flag** | u(1) |
| if (cross\_color\_filter\_cr flag) { |  |
| **cr\_ cross\_color \_filter\_no\_zero\_mult** | u(11) |
| for( k = 0; k < 12; k++ ) |  |
| **cr\_ cross\_color\_filter \_filter\_coeff\_plus8[k]** | u(4) |
| } |  |

Proposed modification B.

The goal of this modification is resolving the latency.

SHM1.0 uses inter-layer texture prediction which is independent for Luma and Chroma.

The block diagram for original design of cross-color inter-layer filter is shown Fig. 2. In order to start cross-color filtering of Chroma decoder shall wait until up-sampling for Luma component will be finished.

RecBL Y

RecBL Cr&Cb

Up-sampled Y

Up-sampled Cr&Cb

Cross-color filter

Inter Layer Texture

Prediction

\*\*\*Latency

**Fig. 2.** Original design

**Fig. 3.** Proposed design.

RecBL Y

RecBL Cr&Cb

Up-sampled Y

Up-sampled Cr&Cb

Cross-color filter

Inter Layer Texture

Prediction

We would suggest to use reconstructed Luma samples from base-layer (before up-sampling) instead up-sampled Luma signal. In this case Luma and Chroma inter-layer texture prediction can be done in parallel. And there is no need for decoder to wait until Luma up-sampling is finished during inter-layer Chroma texture prediction.

# Performance test results

All tests were performed following SCE4 description: all intra, random access and low-delay-P tests were performed for x2, x1,5 and SNR scalability tests. Tool was tested in both IntraBL and RefIdx frameworks. Optional low-delay –B test results are also provided, but excluded from average in order to simplify comparison with SCE output.

Brief summary of test results is shown in Table 3: “ALL” means average BD-rate counted across all mandatory tests; “AI” – “all intra” ; “MC” – random access and low-delay-P spatial scalability tests ; “SNR” – SNR scalability tests. Test 4.2.4 was released in 2 variants. Our implementation and tests are based on v1 (which was available earlier).

**Table 3.** Performance test summary.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Tool | ALL Luma | ALL Chroma | AI Luma | AI Chroma | MC Luma | MC Chroma | SNR Luma | SNR Chroma |
| IntraBL framework | | | | | | | | |
| 4.2.4 v1 | **-0,38%** | **-7,57%** | -0,77% | -7,63% | -0,23% | -8,23% | -0,27% | -6,18% |
| Modification A | **-0,37%** | **-7,25%** | -0,74% | -7,19% | -0,23% | -7,80% | -0,27% | -6,21% |
| Modification A&B | **-0,30%** | **-6,12%** | -0,60% | -5,47% | -0,16% | -6,40% | -0,27% | -6,21% |
| RefIdx framework | | | | | | | | |
| 4.2.4 v1 | **-0,40%** | **-8,14%** | -0,79% | -8,31% | -0,25% | -8,73% | -0,28% | -6,79% |
| Modification A | **-0,39%** | **-7,80%** | -0,76% | -7,84% | -0,26% | -8,29% | -0,29% | -6,77% |
| ~~Modification A&B~~ | **~~-0,32%~~** | **~~-6,57%~~** | ~~-0,61%~~ | ~~-6,02%~~ | ~~-0,19%~~ | ~~-6,75%~~ | ~~-0,29%~~ | ~~-6,77%~~ |
| Modification A&B | -0,41% | -8,00% | -0,80% | -8,02% | -0,28% | -8,60% | -0,29% | -6,77% |

Details of these tests can be found in section 7 and excel spread-sheets attached to this contribution.

# Complexity assessment

Complexity assessment was done according to [2]. There are no changes compare to original design in the worst case. Average numbers for memory access and computations are also pretty similar to original design of test 4.2.4 v1 in SCE4. The goal of proposed modification is implementation simplification and resolving the latency (there is no memory access reduction).

Complexity assessment for IntraBL framework.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | All Intra tests | | | | Test scenarios with MC (RA, LD-P) | | | |
| tool | Pure | DDR-2 | DDR-3 | Mults | Pure | DDR-2 | DDR-3 | Mults |
| IntraBL framework | | | | | | | | |
| 4.2.4 v1 | 108% | 101% | 101% | 140% | 101% | 101% | 101% | 107% |
| Modification A | 108% | 101% | 101% | 140% | 101% | 101% | 101% | 107% |
| Modification A&B | 108% | 101% | 101% | 140% | 101% | 101% | 101% | 107% |
| RefIdx framework | | | | | | | | |
| 4.2.4 v1 | 107 % | 101% | 101% | 140% | 101% | 101% | 101% | 107% |
| Modification A | 107 % | 101% | 101% | 140% | 101% | 101% | 101% | 107% |
| Modification A&B | 107 % | 101% | 101% | 140% | 101% | 101% | 101% | 107% |

Authors would like to thank Jie Dong from Inter Digital for careful and comprehensive cross-check of presented materials.

# Conclusions

**Based on following summary:**

* **0,4% average Luma BD-rate gain**
* **8,0% (RefIdx) average Chroma BD-rate gain**
* **No latency on decoder side**
* **Inter-layer texture prediction can be done for Luma and Chroma in parallel**
* **Constant de-scaling shift**
* **Simplified compare to original version syntax in slice-header**

**Samsung suggests adoption of cross-color inter-layer filter to the next version for SHVC test model with proposed simplifications.**

# References

[1] *J. Dong, Y. He, Y. Ye,* **Chroma enhancement for ILR picture** JCTVC-L0059 document, January, 2013.

[2] *E. François, A. Tabatabai, E. Alshina***, BoG report: Methodology for evaluating complexity of combined and residual prediction methods in SHVC**, JCTVC-L0440 document, January, 2013.

# Patent rights declaration(s)

**Samsung Electronics, Ltd. may have current or pending patent rights relating to the technology described in this contribution and, conditioned on reciprocity, is prepared to grant licenses under reasonable and non-discriminatory terms as necessary for implementation of the resulting ITU-T Recommendation | ISO/IEC International Standard (per box 2 of the ITU-T/ITU-R/ISO/IEC patent statement and licensing declaration form).**

# Details of tests

**Table 4.** Performance test summary for modification A in IntraBL framework.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **AI HEVC 2x** | | | **AI HEVC 1.5x** | | |  |  |  |
|  | Y | U | V | Y | U | V |  |  |  |
| Class A | -0,9% | -7,3% | -5,7% |  |  |  |  |  |  |
| Class B | -0,8% | -6,1% | -8,0% | -0,7% | -7,4% | -9,3% |  |  |  |
| **Overall (Test vs Ref)** | -0,8% | -6,4% | -7,3% | -0,7% | -7,4% | -9,3% |  |  |  |
| **Overall (Test vs single layer)** | 11,5% | 6,6% | 5,6% | 9,5% | 2,4% | 0,4% |  |  |  |
| **EL only (Test vs Ref)** | -1,5% | -7,6% | -8,4% | -2,2% | -10,3% | -12,4% |  |  |  |
| Enc Time[%] | 102,1% | | | 101,7% | | |  |  |  |
| Dec Time[%] | 106,5% | | | 104,5% | | |  |  |  |
| Enc Mem[%] | 102,6% | | | 103,7% | | |  |  |  |
| BL Match | Matched | | | Matched | | |  |  |  |
|  |  |  |  |  |  |  |  |  |  |
|  | **RA HEVC 2x** | | | **RA HEVC 1.5x** | | | **RA HEVC SNR** | | |
|  | Y | U | V | Y | U | V | Y | U | V |
| Class A | -0,4% | -10,6% | -7,1% |  |  |  | -0,4% | -8,4% | -4,9% |
| Class B | -0,3% | -7,7% | -9,0% | -0,2% | -9,5% | -10,8% | -0,3% | -6,6% | -7,4% |
| **Overall (Test vs Ref)** | -0,3% | -8,5% | -8,5% | -0,2% | -9,5% | -10,8% | -0,3% | -7,1% | -6,7% |
| **Overall (Test vs single layer)** | 18,9% | 20,6% | 22,3% | 16,3% | 16,7% | 17,7% | 14,5% | 19,7% | 24,1% |
| **EL only (Test vs Ref)** | -0,6% | -9,2% | -9,0% | -0,7% | -10,9% | -12,1% | -0,6% | -8,0% | -7,4% |
| Enc Time[%] | 100,8% | | | 100,6% | | | 100,4% | | |
| Dec Time[%] | 108,7% | | | 107,8% | | | 108,7% | | |
| Enc Mem[%] | 103,2% | | | 104,2% | | | 112,2% | | |
| BL Match | Matched | | | Matched | | | Matched | | |
|  |  |  |  |  |  |  |  |  |  |
|  | **LD-P HEVC 2x** | | | **LD-P HEVC 1.5x** | | | **LD-P HEVC SNR** | | |
|  | Y | U | V | Y | U | V | Y | U | V |
| Class A | -0,2% | -9,1% | -5,2% |  |  |  | -0,3% | -7,1% | -4,3% |
| Class B | -0,2% | -4,7% | -5,9% | -0,1% | -7,4% | -9,6% | -0,2% | -4,8% | -5,9% |
| **Overall (Test vs Ref)** | -0,2% | -6,0% | -5,7% | -0,1% | -7,4% | -9,6% | -0,2% | -5,5% | -5,4% |
| **Overall (Test vs single layer)** | 25,8% | 28,0% | 30,5% | 22,4% | 23,6% | 23,5% | 22,1% | 26,9% | 31,6% |
| **EL only (Test vs Ref)** | -0,3% | -6,3% | -5,8% | -0,5% | -8,1% | -10,2% | -0,3% | -6,0% | -5,8% |
| Enc Time[%] | 100,7% | | | 100,4% | | | 100,2% | | |
| Dec Time[%] | 109,3% | | | 107,2% | | | 108,9% | | |
| Enc Mem[%] | 103,3% | | | 104,4% | | | 112,4% | | |
| BL Match | Matched | | | Matched | | | Matched | | |

**Table 5.** Performance test summary for modification A in RefIdx framework.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **AI HEVC 2x** | | | **AI HEVC 1.5x** | | |  |  |  |
|  | Y | U | V | Y | U | V |  |  |  |
| Class A | -0,8% | -6,9% | -5,5% |  |  |  |  |  |  |
| Class B | -0,8% | -5,7% | -7,5% | -0,7% | -8,1% | -10,2% |  |  |  |
| **Overall (Test vs Ref)** | -0,8% | -6,1% | -6,9% | -0,7% | -8,1% | -10,2% |  |  |  |
| **Overall (Test vs single layer)** | 12,0% | 8,2% | 7,1% | 9,7% | 1,2% | -0,8% |  |  |  |
| **EL only (Test vs Ref)** | -1,4% | -7,1% | -8,0% | -2,2% | -11,2% | -13,5% |  |  |  |
| Enc Time[%] | 104,3% | | | 104,1% | | |  |  |  |
| Dec Time[%] | 104,8% | | | 105,0% | | |  |  |  |
| Enc Mem[%] | 104,4% | | | 105,8% | | |  |  |  |
| BL Match | Matched | | | Matched | | |  |  |  |
|  |  |  |  |  |  |  |  |  |  |
|  | **RA HEVC 2x** | | | **RA HEVC 1.5x** | | | **RA HEVC SNR** | | |
|  | Y | U | V | Y | U | V | Y | U | V |
| Class A | -0,4% | -9,9% | -6,6% |  |  |  | -0,4% | -9,0% | -5,4% |
| Class B | -0,3% | -7,2% | -8,7% | -0,3% | -10,5% | -12,0% | -0,3% | -7,7% | -8,5% |
| **Overall (Test vs Ref)** | -0,3% | -8,0% | -8,1% | -0,3% | -10,5% | -12,0% | -0,3% | -8,1% | -7,6% |
| **Overall (Test vs single layer)** | 19,7% | 22,2% | 23,6% | 17,0% | 14,9% | 15,8% | 15,4% | 19,4% | 24,7% |
| **EL only (Test vs Ref)** | -0,6% | -8,6% | -8,6% | -0,8% | -11,9% | -13,3% | -0,6% | -8,9% | -8,4% |
| Enc Time[%] | 101,4% | | | 101,2% | | | 100,9% | | |
| Dec Time[%] | 108,7% | | | 108,3% | | | 107,5% | | |
| Enc Mem[%] | 103,5% | | | 104,4% | | | 112,2% | | |
| BL Match | Matched | | | Matched | | | Matched | | |
|  |  |  |  |  |  |  |  |  |  |
|  | **LD-P HEVC 2x** | | | **LD-P HEVC 1.5x** | | | **LD-P HEVC SNR** | | |
|  | Y | U | V | Y | U | V | Y | U | V |
| Class A | -0,2% | -8,1% | -4,4% |  |  |  | -0,3% | -7,3% | -4,3% |
| Class B | -0,2% | -4,1% | -5,3% | -0,2% | -7,5% | -10,0% | -0,2% | -5,2% | -6,1% |
| **Overall (Test vs Ref)** | -0,2% | -5,2% | -5,1% | -0,2% | -7,5% | -10,0% | -0,3% | -5,8% | -5,6% |
| **Overall (Test vs single layer)** | 26,4% | 30,1% | 32,1% | 22,6% | 23,1% | 22,5% | 23,1% | 26,6% | 31,6% |
| **EL only (Test vs Ref)** | -0,3% | -5,5% | -5,2% | -0,6% | -8,3% | -10,8% | -0,4% | -6,3% | -6,0% |
| Enc Time[%] | 101,4% | | | 101,1% | | | 100,9% | | |
| Dec Time[%] | 109,8% | | | 108,9% | | | 108,1% | | |
| Enc Mem[%] | 103,7% | | | 104,8% | | | 112,3% | | |
| BL Match | Matched | | | Matched | | | Matched | | |

**Table 6.** Performance test summary for modifications A&B in IntraBL framework.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **AI HEVC 2x** | | | | **AI HEVC 1.5x** | | |  |  |  |
|  | Y | U | V | | Y | U | V |  |  |  |
| Class A | -1,1% | -9,0% | -6,4% | |  |  |  |  |  |  |
| Class B | -0,3% | -1,4% | -2,6% | | -0,7% | -6,6% | -8,1% |  |  |  |
| **Overall (Test vs Ref)** | -0,5% | -3,5% | -3,6% | | -0,7% | -6,6% | -8,1% |  |  |  |
| **Overall (Test vs single layer)** | 11,8% | 9,9% | 9,5% | | 9,6% | 3,3% | 1,6% |  |  |  |
| **EL only (Test vs Ref)** | -1,0% | -4,3% | -4,3% | | -2,1% | -9,2% | -10,8% |  |  |  |
| Enc Time[%] | 102,2% | | | | 101,7% | | |  |  |  |
| Dec Time[%] | 108,0% | | | | 106,4% | | |  |  |  |
| Enc Mem[%] | 104,0% | | | | 103,9% | | |  |  |  |
| BL Match | Matched | | | | Matched | | |  |  |  |
|  |  |  |  | |  |  |  |  |  |  |
|  | **RA HEVC 2x** | | | | **RA HEVC 1.5x** | | | **RA HEVC SNR** | | |
|  | Y | U | | V | Y | U | V | Y | U | V |
| Class A | -0,5% | -13,1% | | -7,8% |  |  |  | -0,4% | -8,4% | -4,9% |
| Class B | 0,0% | -2,0% | | -3,4% | -0,2% | -8,6% | -9,7% | -0,3% | -6,7% | -7,4% |
| **Overall (Test vs Ref)** | -0,2% | -5,2% | | -4,7% | -0,2% | -8,6% | -9,7% | -0,3% | -7,2% | -6,7% |
| **Overall (Test vs single layer)** | 19,1% | 24,8% | | 27,0% | 16,3% | 17,8% | 19,0% | 14,4% | 19,6% | 24,1% |
| **EL only (Test vs Ref)** | -0,3% | -5,5% | | -5,0% | -0,6% | -9,9% | -10,8% | -0,6% | -8,0% | -7,4% |
| Enc Time[%] | 101,0% | | | | 100,7% | | | 100,7% | | |
| Dec Time[%] | 110,3% | | | | 109,1% | | | 109,9% | | |
| Enc Mem[%] | 103,2% | | | | 104,3% | | | 112,2% | | |
| BL Match | Matched | | | | Matched | | | Matched | | |
|  |  |  |  | |  |  |  |  |  |  |
|  | **LD-P HEVC 2x** | | | | **LD-P HEVC 1.5x** | | | **LD-P HEVC SNR** | | |
|  | Y | U | | V | Y | U | V | Y | U | V |
| Class A | -0,3% | -11,2% | | -5,9% |  |  |  | -0,3% | -7,2% | -4,2% |
| Class B | -0,1% | -1,4% | | -2,3% | -0,1% | -6,8% | -8,7% | -0,2% | -4,8% | -6,0% |
| **Overall (Test vs Ref)** | -0,1% | -4,2% | | -3,3% | -0,1% | -6,8% | -8,7% | -0,2% | -5,5% | -5,5% |
| **Overall (Test vs single layer)** | 25,9% | 30,1% | | 33,6% | 22,4% | 24,3% | 24,7% | 22,1% | 26,9% | 31,5% |
| **EL only (Test vs Ref)** | -0,2% | -4,5% | | -3,5% | -0,4% | -7,5% | -9,3% | -0,4% | -6,0% | -5,9% |
| Enc Time[%] | 100,9% | | | | 100,5% | | | 100,5% | | |
| Dec Time[%] | 110,6% | | | | 109,9% | | | 109,6% | | |
| Enc Mem[%] | 103,3% | | | | 104,2% | | | 112,3% | | |
| BL Match | Matched | | | | Matched | | | Matched | | |

**Table 7.** Performance test summary for modifications A&B in RefIdx framework.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **AI HEVC 2x** | | | | **AI HEVC 1.5x** | | |  |  |  |
|  | Y | U | V | | Y | U | V |  |  |  |
| Class A | -1,1% | -9,5% | -6,9% | |  |  |  |  |  |  |
| Class B | -0,3% | -1,5% | -2,8% | | -0,7% | -7,3% | -9,0% |  |  |  |
| **Overall (Test vs Ref)** | -0,5% | -3,8% | -3,9% | | -0,7% | -7,3% | -9,0% |  |  |  |
| **Overall (Test vs single layer)** | 12,2% | 10,9% | 10,5% | | 9,8% | 2,1% | 0,4% |  |  |  |
| **EL only (Test vs Ref)** | -1,0% | -4,6% | -4,6% | | -2,1% | -10,1% | -11,9% |  |  |  |
| Enc Time[%] | 103,9% | | | | 103,6% | | |  |  |  |
| Dec Time[%] | 105,7% | | | | 105,7% | | |  |  |  |
| Enc Mem[%] | 103,7% | | | | 105,4% | | |  |  |  |
| BL Match | Matched | | | | Matched | | |  |  |  |
|  |  |  |  | |  |  |  |  |  |  |
|  | **RA HEVC 2x** | | | | **RA HEVC 1.5x** | | | **RA HEVC SNR** | | |
|  | Y | U | | V | Y | U | V | Y | U | V |
| Class A | -0,6% | -13,7% | | -8,4% |  |  |  | -0,4% | -9,0% | -5,4% |
| Class B | 0,0% | -2,0% | | -3,6% | -0,2% | -9,5% | -10,7% | -0,3% | -7,7% | -8,5% |
| **Overall (Test vs Ref)** | -0,2% | -5,4% | | -5,0% | -0,2% | -9,5% | -10,7% | -0,3% | -8,1% | -7,6% |
| **Overall (Test vs single layer)** | 19,9% | 25,5% | | 27,7% | 17,1% | 16,1% | 17,3% | 15,4% | 19,4% | 24,7% |
| **EL only (Test vs Ref)** | -0,4% | -5,7% | | -5,3% | -0,7% | -10,8% | -11,9% | -0,6% | -8,9% | -8,4% |
| Enc Time[%] | 101,2% | | | | 100,9% | | | 100,7% | | |
| Dec Time[%] | 111,5% | | | | 110,4% | | | 109,7% | | |
| Enc Mem[%] | 103,5% | | | | 104,6% | | | 112,2% | | |
| BL Match | Matched | | | | Matched | | | Matched | | |
|  |  |  |  | |  |  |  |  |  |  |
|  | **LD-P HEVC 2x** | | | | **LD-P HEVC 1.5x** | | | **LD-P HEVC SNR** | | |
|  | Y | U | V | | Y | U | V | Y | U | V |
| Class A | -0,3% | -11,3% | -5,9% | |  |  |  | -0,3% | -7,3% | -4,3% |
| Class B | 0,0% | -1,4% | -2,0% | | -0,2% | -7,0% | -9,1% | -0,2% | -5,2% | -6,1% |
| **Overall (Test vs Ref)** | -0,1% | -4,3% | -3,1% | | -0,2% | -7,0% | -9,1% | -0,3% | -5,8% | -5,6% |
| **Overall (Test vs single layer)** | 26,5% | 31,3% | 34,8% | | 22,7% | 23,7% | 23,8% | 23,1% | 26,6% | 31,6% |
| **EL only (Test vs Ref)** | -0,2% | -4,5% | -3,2% | | -0,5% | -7,7% | -9,7% | -0,4% | -6,3% | -6,0% |
| Enc Time[%] | 101,3% | | | | 101,0% | | | 100,8% | | |
| Dec Time[%] | 110,9% | | | | 110,4% | | | 110,8% | | |
| Enc Mem[%] | 103,7% | | | | 104,7% | | | 112,4% | | |
| BL Match | Matched | | | | Matched | | | Matched | | |