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| *Title:* | **Description of HEVC Scalable Extensions Core Experiment SCE1: Color Gamut and Bit-Depth Scalability** | | |
| *Status:* | Output Document to JCT-VC | | |
| *Purpose:* | CE description | | |
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# Abstract

This document provides the description of Core Experiment 1 (SCE1) on Color Gamut and Bit-Depth Scalability in SHVC.

# Introduction

Color Gamut Scalability has been mentioned in the requirements of Scalable Coding Extension of HEVC. It allows addressing the cases the original Enhancement Layer uses a different color gamut than the Base Layer. This can be useful for instance in case of deployment of UHD services compatible with legacy HD devices: HD is using the Rec.709, while UHD is likely to use some of the parameters defined in the Rec.2020. Another realistic use case described in [4] considers UHDTV forward compatibility where color gamut is different between base and enhancement layers.

The general diagram of a scalable video encoder including a prediction tool for color differences between the base layer (BL) and enhancement layer (EL) is shown in Figure 1.



Figure : Color Space Scalable Encoder.

# Participants

P = Participants (Contribution),

C = Crosscheckers.

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# Test sequences

As decided at the 14th JCTVC meeting in Vienna, the color graded sequences provided in AHG14 [2] and described in SCE4 description [1][3] (Table 1) are used for this SCE.

The sequences with the associated license conditions are available at the Hannover FTP site: [ftp.tnt.uni-hannover.de/scalable/sequences/CGS](ftp://ftp.tnt.uni-hannover.de/scalable/sequences/CGS) with scalability use credentials.

An MD5 file per file is provided to verify that the locally down scaled version of the sequences are identical to the sequences on the FTP site.

Table 1: List of test sequences.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Test Sequences** | **size** | **fps** | **Frames** | **Bit-depth** |
| BT709\_Birthday\_1920x1080\_60\_zerophase\_0.9pi.yuv | 1920 x 1080 | 60 | 300 | 8 |
| BT709\_BirthdayFlashPart1\_1920x1080\_60\_zerophase\_0.9pi.yuv | 1920 x 1080 | 60 | 300 | 8 |
| BT709\_BirthdayFlashPart2\_1920x1080\_60\_zerophase\_0.9pi.yuv | 1920 x 1080 | 60 | 300 | 8 |
| BT709\_Parakeets\_1920x1080\_50\_zerophase\_0.9pi.yuv | 1920 x 1080 | 50 | 250 | 8 |
| BT709\_TableCar\_1920x1080\_60\_zerophase\_0.9pi.yuv | 1920 x 1080 | 60 | 300 | 8 |
| BT709\_Birthday\_1920x1080\_60\_10bit\_zerophase\_0.9pi.yuv | 1920 x 1080 | 60 | 300 | 10 |
| BT709\_BirthdayFlashPart1\_1920x1080\_60\_10bit\_zerophase\_0.9pi.yuv | 1920 x 1080 | 60 | 300 | 10 |
| BT709\_BirthdayFlashPart2\_1920x1080\_60\_10bit\_zerophase\_0.9pi.yuv | 1920 x 1080 | 60 | 300 | 10 |
| BT709\_Parakeets\_1920x1080\_50\_10bit\_zerophase\_0.9pi.yuv | 1920 x 1080 | 50 | 250 | 10 |
| BT709\_TableCar\_1920x1080\_60\_10bit\_zerophase\_0.9pi.yuv | 1920 x 1080 | 60 | 300 | 10 |
| BT2020\_Birthday\_1920x1080\_60\_10bit\_zerophase\_0.9pi.yuv | 1920 x 1080 | 60 | 300 | 10 |
| BT2020\_BirthdayFlashPart1\_1920x1080\_60\_10bit\_zerophase\_0.9pi.yuv | 1920 x 1080 | 60 | 300 | 10 |
| BT2020\_BirthdayFlashPart2\_1920x1080\_60\_10bit\_zerophase\_0.9pi.yuv | 1920 x 1080 | 60 | 300 | 10 |
| BT2020\_Parakeets\_1920x1080\_50\_10bit\_zerophase\_0.9pi.yuv | 1920 x 1080 | 50 | 250 | 10 |
| BT2020\_TableCar\_1920x1080\_60\_10bit\_zerophase\_0.9pi.yuv | 1920 x 1080 | 60 | 300 | 10 |
| BT2020\_Birthday\_3840x2160\_60\_10bit\_zerophase\_0.9pi.yuv | 3840 x 2160 | 60 | 300 | 10 |
| BT2020\_BirthdayFlashPart1\_3840x2160\_60\_10bit\_zerophase\_0.9pi.yuv | 3840 x 2160 | 60 | 300 | 10 |
| BT2020\_BirthdayFlashPart2\_3840x2160\_60\_10bit\_zerophase\_0.9pi.yuv | 3840 x 2160 | 60 | 300 | 10 |
| BT2020\_Parakeets\_3840x2160\_50\_10bit\_zerophase\_0.9pi.yuv | 3840 x 2160 | 50 | 250 | 10 |
| BT2020\_TableCar\_3840x2160\_60\_10bit\_zerophase\_0.9pi.yuv | 3840 x 2160 | 60 | 300 | 10 |

# Reference software (Anchors)

The reference software will be *SHM5.0* including the bit-depth scalability feature and the option to set the weighted prediction restricted to inter-layer prediction, as adopted in JCTVC-O0194. A modification will be made on top of *SHM5.0* to support the insertion of regular Intra Random Access Point (IRAP) to emulate more realistic broadcast/broadband use case as proposed in [1][3]:

* Regular IRAP insertion: modificationto support insertion of regular SPS, PPS (every *N* frames)*.*

The modified software *SHM5.0\_irap* will be provided by Technicolor.

The anchor will not be using these modifications.

The random access period parameter *N* will be set to nx64 for 60Hz sequences, and to nx48 for 50Hz sequences. This corresponds to inserting the SPS and PPS roughly every n seconds, corresponding to realistic values encountered in broadcast or broadband applications. It is suggested to set n = 1.

The anchors will be based on *SHM5.0* with WP restricted to inter layer prediction (ILP) enabled in both cases.

# Complexity evaluation

Following complexity information shall be reported and crosschecked for each test in this core experiment.

* The number of multipliers and bit-depth of multiplier.
* The sizes of LUT in number of table entries on the LUT.
* The number of stages and a short summary of each stage, reporting how many passes of the data or pipeline stages.
* Whether re-sampling is used when reporting the number of multiplications.
* Whether cross color dependency is being used.
* Description of CGS information derivation at encoder side.

The datasheet template will be used from the BOG report [3]

Proposals should include descriptions of the encoder optimizations being use.

# Description of Experiments

2x and 1x scalability shall be tested with RA and AI configurations with the following contents:

Table : Test conditions

|  |  |  |
| --- | --- | --- |
|  | **Base layer** | **Enhancement layer** |
| Test cases | Base layer | Enhancement layer |
| 2x: RA and AI | 1080p 8-bit BT.709 QP\_BL={22, 26 ,30, 34} | 2160p 10-bit BT.2020 QP\_EL1={22, 26, 30, 34} QP\_EL2={24, 28, 32, 36} |
| 1x: RA and AI | 1080p 10-bit BT.709 QP\_BL={22, 26 ,30, 34} | 1080p 10-bit BT.2020 QP\_EL1={22, 26, 30, 34} QP\_EL2={18, 22, 26, 30} |

The common SHVC test conditions (QPs) will be used for AI and RA configurations, 2x.

For the 1x case we will use the same QPs for the base layer as on the SHVC test conditions and for the enhancement layer delta QPs are 0 and -4.

At the encoder side, the computation of the CGS information shall not utilize information other than current frame. Encoder may signal CGS information for each frame if necessary.

## JCTVC-P0124 (Nokia)

In order to improve coding efficiency for CoGS three modifications are proposed.

1. Region based mapping: Based on the observations in JCTVC-L0334 and JCTVC-M0197, dividing the YUV colorspace into regions and using different color space mapping function for each region improves the coding efficiency. This technique was also used in SCE1 responses and also included in our proposal, where the YUV region is divided into an NxNxN region and separate parameters are signaled separately for each region.

2. Matrix based mapping: The WP process in HEVC does not utilize any cross-component correlation. In other words, the luminance of prediction pixel utilizes a linear gain-offset model that takes luminance of reference pixel (and not chrominance values) as input. As analyzed in JCTVC-L0334, utilizing a matrix based mapping more accurately reflects the BT.2020 to BT.709 mapping:



Gain(Y, Cb, Cr) is a 3x3 matrix and Offset(Y, Cb, Cr) is a 1x3 matrix. Encoder uses simple linear regression to derive the parameters of the matrices (using more complicated algorithms could further improve coding efficiency)

3. Polynomial mapping: In order to better capture the non-linear relationship between two color spaces, a second order polynomial equation is used as follows:

 (2)

Similar to Equation 1, Gain1(Y, Cb, Cr) and Gain2(Y, Cb, Cr) are 3x3 matrices and Offset(Y, Cb, Cr) is a 1x3 matrix. (Y0, Cb0, Cr0) is the central point of the corresponding region. For example, when there are 8x8x8 regions and BL data are 10bit, Y0 =((Y709>>7)<<7)+64. This is to reduce the dynamic range of polynomial part of Equation 2. The benefit of using polynomial equations is that one could reduce the number of regions as non-linear characteristics can already be captureds with the polynomial equation.

Four configurations are tested:

Configuration 1: N=8, linear matrix mapping (YUV colorspace is divided into 8x8x8 regions)  
Configuration 2: N=1, linear matrix mapping (Region based WP is disabled and only difference to HEVC WP is linear matrix based equations)  
Configuration 3: N=8, no matrix based WP (Matrix based WP is disabled and only difference to HEVC WP is signaling different WP parameters for different regions)  
Configuration 4: N=1, polynomial matrix mapping enabled (Region based WP is disabled and only difference to HEVC WP is polynomial matrix based equations)

## Combination of JCTVC-P0128 and JCTVC-P0197 (Technicolor, InterDigital, and Qualcomm)

The basic design of JCTVC-P0197 is the same as JCTVC-P0063. Two changes are made:

1. Color gamut conversion with asymmetric 3D LUT is moved to before upsampling. For the 8-bit BL and 10-bit EL test case, bit-depth and color gamut are converted with 3D LUT at the same stage, and “O0194\_JOINT\_US\_BITSHIFT” is disabled. For 2x case, computational complexity is reduced since the conversion process is applied on ¼ of the pixels.
2. Additionally phase alignment filter is added to luma/chroma samples before color gamut conversion. Specifically, for luma L4, L5, L8, L9 in , the input chroma components are derived with simple resampling filters as follows:

C(L4) = (C0\*3 + C2 + 2)>>2

C(L5) = ((C0+C1)\*3 + (C2+C3) + 4)>>3

C(L8) = (C0 + C2\*3 + 2)>>2

C(L9) = ((C0+C1) + (C2+C5)\*3 + 4)>>3



Figure . Default phase shift between luma and chroma samples for YUV420 chroma format: squares are luma samples, circles are chroma samples

On top of this, the table coding method from JCTVC-P0128 is implemented.

Two configurations are to be tested:

Configuration 1, the phase alignment filter is enabled.

Configuration 2, the phase alignment filter is disabled.

# Cross-checks

|  |  |  |  |
| --- | --- | --- | --- |
| **Test** | **Proponent** | **Use case** | **Cross-Checker** |
| 1.1 | Nokia | 1x |  |
| 2x |  |
| 1.2 | Nokia | 1x |  |
| 2x |  |
| 1.3 | Nokia | 1x | Sony |
| 2x | Sony |
| 1.4 | Nokia | 1x |  |
| 2x |  |
| 2.1 | Technicolor, InterDigital, and Qualcomm | 1x |  |
| 2x |  |
| 2.2 | Technicolor, InterDigital, and Qualcomm | 1x |  |
| 2x |  |

# Time-line and Responsibilities

**T0:** Reference software *SHM5.0* release date with WP (restricted to ILP) available.

**January 31st 2014:** Finalization of the CE description.

**T0 + 1 week:** Reference software *SHM5.0\_ irap* distributed to participants by Technicolor.

**T0 + 1 week:** Create anchor results.

**T0 + 4 weeks:** Cross-verification begins: proponents provide software, draft contribution text and results to cross-verifiers(s) and CE coordinators.

**March 14th 2014** Cross-verifiers report results to CE participants.

# References

1. [P. Bordes](mailto:philippe.bordes@technicolor.com), [E. Alshina](mailto:elena_a.alshina@samsung.com), [A. Duenas](mailto:alberto@ngcodec.com), [Y. He](mailto:yan.ye@interdigital.com), [X. Li](mailto:lxiang@qti.qualcomm.com), [S.E. Kim](mailto:kimse@sharplabs.com), “Description of Core Experiment SCE4: Color Gamut and Bit-Depth Scalability,” JCTVC-O1101, October 2013, Geneva, CH.
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