**INTERNATIONAL ORGANISATION FOR STANDARDISATION**

**ORGANISATION INTERNATIONALE DE NORMALISATION**

**ISO/IEC JTC1/SC29/WG11**

**CODING OF MOVING PICTURES AND AUDIO**

**ISO/IEC JTC1/SC29/WG11 N15795**

**October 2015, Geneva, Switzerland**

|  |  |
| --- | --- |
| **Source** | **Video Subgroup** |
| **Status** | **Approved** |
| **Title** | **HDR Core Experiment 2 on 4:2:0 YCbCr NCL fixed point for HDR Video Coding** |
| **Author** | D.Rusanovskyy (Qualcomm), E. Francois (Technicolor), L. Kerofsky (InterDigital), T. Lu (Dolby), K. Minoo (Arris) |

# Introduction

This document describes the core experiment 2 (CE2) on normative 4:2:0 YCbCr NCL fixed point for HDR Video Coding established at the 113th MPEG meeting.

CE2 report to be presented in January 2016, F2F meeting. Current CE2 description and test plan is subject of change by the resolution of January 2016, F2F meeting.

This document describes the core experiment on normative solutions for HDR video coding.

The CE2 Mandates:

1. Develop fully automated encoder/reshaper algorithm as a reference for CE2
2. Further investigate improvements over the reference code base (H2M)
3. Report results to interim F2F meeting, Jan.2016
4. Refine CE description if necessary by a resolution of F2F meeting of Jan.2016
5. Report results of CE to JCT meeting, Feb.2016

# List of participants

Table 1 List of participants:

|  |  |  |
| --- | --- | --- |
| Participants | Affiliation | Email |
| Z. Gu  K. Minoo | Arris | [Zhouye.Gu@arris.com](mailto:Zhouye.Gu@arris.com)  [Koohyar.Minoo@arris.com](mailto:Koohyar.Minoo@arris.com) |
| T. Lu  P. Yin | Dolby | [tlu@dolby.com](mailto:tlu@dolby.com)  [pyin@dolby.com](mailto:pyin@dolby.com) |
| J. Ström | Ericsson | [jacob.strom@ericsson.com](mailto:jacob.strom@ericsson.com) |
| Yi-Jen Chiu  Yi-Chu Wang | Intell | [yi-jen.chiu@intel.com](mailto:yi-jen.chiu@intel.com) [yi-chu.wang@intel.com](mailto:yi-chu.wang@intel.com) |
| Y. He  L. Kerofsky  Y. Ye | InterDigital | [Yuwen.he@interdigital.com](mailto:Yuwen.he@interdigital.com)  [Louis.kerofsky@interdigital.com](mailto:Louis.kerofsky@interdigital.com)  [Yan.ye@interdigital.com](mailto:Yan.ye@interdigital.com) |
| Jung Won Kang,  Jinho Lee | ETRI | [jungwon@etri.re.kr](mailto:jungwon@etri.re.kr)  [jinosoul@etri.re.kr](mailto:jinosoul@etri.re.kr) |
| R. Goris  R. Brondjik | Philips | [rocco.goris@philips.com](mailto:rocco.goris@philips.com)  [robert.brondijk@philips.com](mailto:robert.brondijk@philips.com) |
| Sungwon Lee  D. Rusanovskyy | Qualcomm | [lsungwon@qti.qualcomm.com](mailto:lsungwon@qti.qualcomm.com)  [dmytro.rusanovskyy@ieee.org](mailto:dmytro.rusanovskyy@ieee.org) |
| S. Lasserre  F. Le Leannec  E. Francois | Technicolor | [Sebastien.lasserre@technicolor.com](mailto:Sebastien.lasserre@technicolor.com)  [Fabrice.leleannec@technicolor.com](mailto:Fabrice.leleannec@technicolor.com)  [edouard.francois@technicolor.com](mailto:edouard.francois@technicolor.com) |
| Elena Alshina, Youngo Park | Samsung | [elena\_a.alshina@samsung.com](mailto:elena_a.alshina@samsung.com) [youngo.park@samsung.com](mailto:youngo.park@samsung.com) |
| Cheolkon Jung | Xidian University(China) | [zhengzk@xidian.edu.cn](mailto:zhengzk@xidian.edu.cn) |

# List of proposals

List of proposals, targeting Exploration Test Model (ETM) design and proposals to be studied in CE2 are listed below.

|  |  |  |
| --- | --- | --- |
| MPEG number | Title | Source |
| m37269 | Candidate Test Model for HDR extension of HEVC | Dolby, InterDigital |
| m37285 | Proposed initial Test Model for HEVC HDR extension | Philips, Qualcomm, Technicolor |
| m37332 | Test model draft for HDR reshaping and adaptation | ARRIS |
| m37400 | Test model draft for SDR backward compatibility from CE2.2.a proposal | Technicolor |
| m37427 | Candidate HDR test model proposal from CE2.1.3 test | Qualcomm |
| m37479 | Draft Test Model for HDR extension of HEVC | Arris, Dolby, InterDigital, Philips, Qualcomm, Technicolor |
| m37091 | CE2.1.2b: HDR coding in Y'CbCr color space based on BT.2020 and ST 2084 transfer functions | Arris |
| m37092 | On single layer HDR coding with SDR backward compatibility | Arris |
| m37245 | CE2-related: Report of LumaATF with LCS | Qualcomm |
| m37267 | Comments on Reshaping for HDR/WCG compression | Dolby |

Proposal m37479 is a harmonized designed supported by all proponents. Solution proposed in m37479 is used as a code base for further development.

# Exploration Test Model

The Exploration Test Model (ETM) design is described in output document N15792, bellow is provided a short summary which is related to the integration plan.

For luma, reshaper is modeled using a piecewise 2nd order polynomial or piecewise linear model. The maximum number of pieces is 8. The use of 8 segments allows approximation of most “reasonable” curves, i.e., continuous, and bounded derivative. The 2nd order polynomial model is used to approximate complex, non-linear smooth curves efficiently without the need to use a large number of segments. For less complex curves, the piecewise linear model with up to 8 pieces provides sufficient performance with reduced complexity. For a specific implementation, the piecewise polynomial and linear models can be implemented using a LUT or computation depending on its trade-off consideration between memory access and computation. The segment locations are part of the reshaper parameters. The segment locations are derived at the decoder side from segment lengths, which are signaled for each segment. The freedom to select the segment locations allows adaptation to the particular signal being modelled.

For chroma, reshaper is based on piecewise linear model reshaper functions with up to 32 pieces. The piecewise linear model is constructed from parameters which include number of utilized segments, a length of each segment and a scale value applied for each segment, and a global offset value. Chroma reshaper operates in two possible modes.

* In mode 0, reshaper is performed as Dynamical Range Adjustment (DRA), which is applied independently to each chroma component using piece-wise linear functions.
* In mode 1, reshaper is performed as Cross-Component Scaling (CCS), with a scaling factor applied to each chroma sample and being a function of the co-located luma sample. This scaling factor function is also modeled as a piece-wise linear function

In some implementation, reshaper piece-wise linear functions can be implemented through a LUT.

Parameters of the luma and chroma reshaper models are signaled in the PPS syntax.

# Software

A code base software will include modified HDRTools [2] for pre-post processing and modified HM [1] for signalling of metadata and conducting HDR reconstruction in YCbCr 4:2:0 fixed point implementation. The software will be produced according to the integration plan specified in Section 5.2 and will be made available from the following MPEG FTP site [3], using the usual MPEG credentials.

Planned software release will include the following elements:

* Default setting for each configuration to be provided at the software release date.
* Encoder side algorithms are expected to be fully automated. Metadata provided to encoder to be limited to actual color gamut ID of the content (which may differ from the gamut ID of the container) and frame id of the scene cuts when relevant.

## Integration methodology

The following integration methodology to be utilized:

Each integrator releases by the specified deadline produced source code and objective results, including md5 checksums to all participants of the integration plan. The next integrator in the chain conducts the cross-check of the previous release and conduct own integration. Configuration to be simulated at each integration stage will be defined during the integration process.

## Integration Plan

HM16.7 [1] to be used as a code base for integrations of the normative post-processing and signaling. Updated HDRTools SW [2] of the CE1 anchor to be used as a code-base for pre-processing. The following integration plan was agreed:

1. **Chroma Processing of m37427 (Qualcomm): 2 week**

Introducing to the HDRTools code base an encoding algorithm (pre-processing) for coding of HDR video signal. Introducing to the HM-based ETM normative post-processing (reshaper) of chroma components of decoder video signal and signalling of parameters of post-processing in the SPS/PPS headers. Reshaper on chroma samples is modelled with a piece-wise linear function introduced in m37427 and performed as Dynamical Range Adjustment (DRA). DRA is applied independently to each chroma component using piece-wise linear functions. Parameters of chroma reshaper to be automatically derived from color gamut information of the input HDR video signal, which is provided to the encoder as an input parameter.

1. **Luma Processing of m37269 (Dolby and Interdigital) 2 weeks**

Introducing to the HDRTools code base an encoding algorithm (pre-processing) for coding of HDR video signal. Introducing to HM based ETM normative post-processing (reshaper) of luma components of decoder video signal and signalling of parameters of post-processing in the SPS/PPS headers. Reshaper on luma samples to be modeled using a piecewise 2nd order polynomial introduced in m37269. Parameters of luma reshaper to be automatically derived from scene cut information which is provided to the encoder as scene cut frame id.

1. **Chroma Processing of m37285 (Technicolor) 1week**

Introducing to the HDRTools code base an encoding algorithm (pre-processing) for coding of HDR video signal. Introducing to HM based ETM normative post-processing (reshaper) of chroma components of decoder video signal in SDR-compatible configuration and signalling of parameters of post-processing in the SPS/PPS headers. Reshaper is modelled with a piece-wise linear function, as introduced in m37285, and performed as Cross-Component Scaling (CCS), with a scaling factor applied to each chroma sample and being a function of the co-located luma sample. Parameters of reshaper to be automatically derived from color gamut and scene cut information of the input HDR video. This information to be provided to the encoder as input parameters.

1. **Signalling elements of m37332 (Arris) 1 weeks**

Introducing to ETM syntax elements extending functionality of the syntax, namely signalling of reshaping offsets and reuse of one reshaping function for both chroma data. Introducing to the HDRTools code base an encoding algorithm (pre-processing) for coding of HDR video signal by optimizing luma reshaping and cross-component reshaping parameters to achieve two objectives of increased coding efficiency and generation of SDR-affinity of YCbCr signal which takes into consideration the SDR display EOTF, color-space and black-level-lift (m37092).

## Integration timeline:

11/08/2015 Qualcomm

11/22/2015 Dolby + Interdigital

11/29/2015 Technicolor

12/06/2015 Arris

# Planned experiment

The following potential sub-tests were identified at the 113rd MPEG meeting.

1. CE2.a: performance improvement
2. CE2.b: Improve performance of SDR-capable configuration
3. CE2.c: chromaQP Offset
4. CE2.d: delta-QP adjustment for Luma
5. CE2.e: Enhancement of the current ETM:

Exact list of sub-tests and their description to be finalized by 20th of November, 2015.

## Test description

This section provides detailed on planned sub-tests.

### CE2.a performance improvement

This sub-test targets generic improvement on all component of HDR signal (Luma, Chroma). The following techniques proposed to 113rd MPEG meeting will be studied:

**CE2.a-1**

**m37245:** “CE2-related: Report of LumaATF with LCS”

Technique proposed in m37245 adopting luma based ATF and luma-driven chroma scaling (LCS), which scales chroma components with the coefficients derived by a given LCS function with the input of luma value of the corresponding pixel. The test results of m37245 report visual quality improvements over the independent chroma-components processing. Techniques of m37245 and improvement to be studied in **CE2.a-1** sub-test.

**CE2.a-2**

**m37267:** “Comments on Reshaping for HDR/WCG compression”

The automatic reshaping parameter generation process described in m37267 is to be incorporated in CE2 software to support automatic metadata-generation for the reshaper. The performance and improvement are to be studied in **CE2.a-2** sub-test.

**CE2.a-3**

**m37091**: “CE2.1.2b: HDR coding in Y'CbCr color space based on BT.2020 and ST 2084 TFs”

In this experiment the coding efficiency of different YCbCr color spaces, based on the color space transfer function (aka OETF) will be compared. Also the encoder optimization techniques based on perceptual-reshaping functions (namely Weber-law and Stevens-law, introduced in m37092) will be compared vs. data driven models.

### CE2.b Improve performance of SDR-capable configuration

This sub-test explores efficient coding of HDR content while keeping the coded YCbCr to be viewable on an SDR display. Following experiments will be explored.

**CE2.b-1**

**m37088** and **m37285**: Cross-channel modulation is proposed in m37088 and m37285 to control the color shift produced by luma reshaping in the SDR backward compatible mode. At inverse reshaper side, the cross-channel modulation applies to chroma samples using co-located luma sample as follows (for x being equal to “b” and “r”):

Cx\_reshape = ( Cx\_dec – offset1 ) \* Scale[ Ydec\_coloc ] + offset2

The technique will be further investigated to control the colors in order to match the colors of the original HDR content. Adaptation of Y reshaping will also be investigated to improve the HDR compression performance.

**CE2.b-2**

**m37092**: “On single layer HDR coding with SDR backward compatibility”

A mathematical model was proposed in m37092 for reshaping of chroma components based on: luma reshaping function and a target SDR display attributions such as EOTF, color space and black-level-lift. In this experiment, the impact of the above parameters on the coding efficiency of the HDR will be studied. In this test the quality of the SDR-affine signal will be visually inspected and compare to the HDR signal.

### CE2.c Chroma QP Offset

At the 113rd MPEG meeting, the chroma QP offset technique was studied in [m37179](http://wg11.sc29.org/doc_end_user/current_document.php?id=53443&id_meeting=165) and adopted in the HDR/WCG anchor. This sub-test target evaluation of the chroma QP offset impact on the performance of HDR/WCG ETM, and potential for cumulative gain from applying jointly chroma QP offset and specified in ETM chroma processing.

### CE2.d delta-QP adjustment for Luma

Additional tests in this category can be identified up to availability of software being produced in CE1.a development.

### CE2.e Enhancement of the current ETM

**CE2.e-1**

This sub-test will study various configurations of the current ETM for purposes of design optimization and performance improvement. More specifically, the following elements of the ETM will be studied:

1. Order of function for piece-wise modeling

Evaluating complexity of transfer functions utilized in ETF and optimizing order of polynomial utilized for piece-wise modeling

1. Number of partitions (pieces of the model)

Evaluating complexity of transfer functions utilized in ETF and optimizing number of partitions (pieces) of the piece-wise modeling

1. Efficient signaling of parameters

Defining a scope of required parameters and study methods of their efficient signaling

1. Combination of independent and cross-component processing

Studying implementation and performance of independent and cross-component processing in ETP and their harmonization.

**CE2.e-2**

**m37332**: “Test model draft for HDR reshaping and adaptation”

In this experiment the harmonization of luma and chroma reshaping models which allows for re-use of the same reshaping function for different color components will be studied. Also the varying degree of the piece-wise polynomial model with different orders of continuity (based on m37332) will be explored to measure the impact of reshaping model on the coding efficiency.

**CE2.e-3**

This sub-test will study enhancements to the automatic selection of parameters of the current ETM reshaping model. The focus will be on automatic selection of parameters for the luma reshaping model. More specifically, the following elements of the ETM will be studied:

1. Automatic selection of number and location of ranges
2. Automatic determination of model order
3. Automatic derivation of model parameters given ranges

Table 1. Planned CE2 sub-tests (List to be finalized by end of integration timeline)

|  |  |  |
| --- | --- | --- |
| **Planed sub-test** | **Proponents** | **Cross-checker** |
| CE2.a-1 luma ATF with LCS (m37245) | Qualcomm | TBD |
| CE2.a-2 reshaping (m37267) | Dolby | TBD |
| CE2.a-3 adaptive transfer function (m37091) | Arris | TBD |
| CE2.b-1 Cross-channel modulation (m37088 and m37285) | Technicolor | TBD |
| CE2.b-2 SDR backward compatibility study (m37092) | Arris | TBD |
| CE2.c Chroma QP offset (m37179) | Qualcomm | TBD |
| CE2.d DeltaQP adjustment for Luma | TBD | TBD |
| CE2.e-1 Enhancement of ETM | Qualcomm | TBD |
| CE2.e-2 harmonization of luma and chroma reshaping (m37332) | Arris | TBD |
| CE2.e-3 automatic selection of ETM parameters | Interdigital | TBD |

# Test conditions

AhG CTC specified in N15793 to be used.

ETM-specific parameters to be finalized and released by the end of the integration cycle.

# Anchors

The current at the experiment time anchors will be used for this test.

# Results reporting

Results will be reported in the two spreadsheets provided by the Common Test Condition document, document number is N15793.

# Time line

10/23/2015 Meeting ends

10/30/2015 Integration plan to be finalized and distributed over reflector

11/27/2015 Refine test plan and tests description and distributed over reflector

12/06/2015 Reference code base to be finalized and distributed among CE2 participants

01/12/2016 Description of the encoder

01/12/2016 Results for reference code base to be presented

02/01/2016 Software solutions for CE2 tests to be provided to CE2 participants

02/04/2016 CE2 test simulation results to be provided to CE2 participants

02/09/2016 CE2 test results and text description of the experiment to be reported

02/19/2016 CE2 test cross-check results to be reported

# Reference:

[1] HM16.7 Reference HEVC software (revision 4618), available online:

svn://hevc.kw.bbc.co.uk/svn/jctvc-hm/tags/HM-16.7

[2] HDRTools Reference software (revision 759), available online:

<http://wg11.sc29.org/svn/repos/Explorations/XYZ/HDRTools/tags/0.10>

[3] HDR/WCG Exploration Test Model, software available online: <http://wg11.sc29.org/content>, in directory: /Explorations/HDR/CEs\_Software\_113