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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**  23rd Meeting: San Diego, USA, 19–26 February 2016 | Document: JCTVC-W0033r1 / m37691 |

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| *Title:* | **HDR CE2: report of experiment CE2.b-1 on SDR-backward compatible configuration (reshape setting 1)** | | |
| *Status:* | Input Document to JCT-VC | | |
| *Purpose:* | Proposal | | |
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# Abstract

This document reports the results of experiments HDR CE2.b-1. These experiments relate to SDR backward compatible configuration, and focus on reshape setting 1 that involves cross-plane color reshaping. The experiments only involve the reshaping algorithm, and does not require any change in the current ETM syntax and inverse reshaping process. The modified reshaper tuning algorithm for reshape setting 1 is proposed to be adopted in the ETM. It is reported that the proposed changes improves the reshaped SDR content quality (in terms of visual rendering of contrast and colors), while preserving the compression performance.

# Introduction

The current Exploratory Test Model (ETM\_RC\_r1, delivered on January 21, 2016) implements three configurations, controlled by reshaper setting parameter. Core experiment CE2.b-1 focuses on reshaper setting 1, relating to SDR backward compatibility feature, with the usage in the chroma reshaping of cross-plane mode.

CE2.b-1 only addresses the reshaping part, and aims at generating improved (in terms of visual rendering of contrast and colors) reshaped SDR content, while preserving the compression performance. No change to the current ETM syntax and inverse reshaping process is required.

In next section, the current ETM\_RC\_r1 reshaping process ofr rshapeSetting 1 configuration is summarized. Following section describes the different experiments made on top of this version.

# ETM\_RC\_r1 process overview for reshapeSetting 1 configuration

Reshaper setting 1 configuration applies cross-plane mode for chroma reshaping, using two piece-wise-linear (PWL) modelled look-up-tables (LUTs) to control the chroma components. The luma component is reshaped using an intra-plane piece-wise-polynomial (PWP) modelled LUT. In the current ETM settings, 8 pieces are used both for luma PWP and for chroma PWL models.

The reshaping process works in four main steps, as shown in Figure 1:

1. Conversion of input HDR signal into Y’CbCr 10b 4:2:0 with inverse ST.2084 (PQ) EOTF;
2. Reshaping of 10b luma PQ to get an SDR-like 10b luma;
3. Automatic generation of an intermediate SDR 4:2:0 Y’CbCr picture;
4. Derivation of cross-plane chroma PWL models parameters to fit as much as possible the chroma components of the intermediate 4:2:0 Y’CbCr SDR picture.

In the following sub-sections, short description of these processes is provided. More details on the reshaping algorithms in ETM\_RC\_r1 are provided in document JCTVC-W0031 [1].



Figure 1: simplified block diagram of ETM\_RC\_r1 process in reshapeSetting 1 configuration.

## Y reshaping

Y reshaping is achieved using the following function

F(L) = log( 1. + (L / Ba)g ) / log( 1. + (P / Ba)g )

controlled by two adaptive tuning parameters Ba, g, and by the peak luminance P. In ETM\_RC\_r1, g is set to 2.8, and Ba varies depending on the content. The resulting function is modeled by a PWP 8 pieces model. Y is then scaled to and quantized in Full or Standard Range signal.

## Intermediate SDR generation

To generate the intermediate SDR (YintermUintermVinterm), the following steps apply:

1. Generate HDR luminance Lhdr from input linear-light HDR R,G,B samples
2. Convert Yreshape to linear-light Lreshape as follows

Lreshape = ( (Yreshape – off) / scale ) (1 / 0.45)

where off and scale are the parameters for Full or Standard Range normalization of Yreshape

1. Scale linear-light HDR R,G,B samples by ratio w = Lreshape / Lhdr
2. Convert scaled R,G,B to SDR R’,G’,B’ as follows

R’ = 1023 \* (Rscaled)0.45 G’ = 1023 \* (Gscaled)0.45 B’ = 1023 \* (Bscaled)0.45

1. Convert SDR R’,G’,B’ to 10b Y’CbCr then downsample chroma to get 10b 4:2:0 signal YintermUintermVinterm

## Chroma LUTs fitting

The chroma LUTs fitting computes the two LUTs LUTcb and LUTcr in order to fit as much as possible the chroma components of the intermediate SDR picture. The LUTs are derived by least mean squares optimization, with minimization of the following functions:

with OC equal to 512 (29) for 10 bits content.

More details on the cross-plane LUT optimization for reshape setting 1 are provided in document JCTVC-W0031 [1].

# Proposed modifications

## Core changes

The main changes considered in CE2.b-1 are shown in shown in Figure 2. First modification is the addition of a fitting process for the luma component, in order to fit as much as possible the intermediate SDR luma. This re-tuning of luma aims at improving the perceived saturation of the output SDR version resulting from the reshaping.



Figure 2: simplified block diagram of CE2.b-1 reshaping algorithm.

The luma LUT is derived as follows:

with a weighting function defined as

The function intends to favour or not the low luma levels from the reshaping. When A is small (we use 0.01 by default), the weight will favour low luma values (and therefore more intense colors).

In addition, the following changes have been made:

* In the Y reshaping block, to get more contrasted pictures, the parameter g is set to 2.4 instead of 2.8.
* In the Intermediate SDR generation block, a smooth clipping applies once the R,G,B samples are scaled (after step 3 in process described in section 2.2).
* In the PWL modelling of chroma LUTs, 32 pieces are used instead of 8. This allows finer matching to the intermediate SDR colors and results in a noticeable impact on the SDR rendering.

## Objective metrics

Objective metrics using common test conditions are reported inTable 2.

Table 2. Objective metrics.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | X | Y | Z | XYZ | tOSNR-XYZ | DE100 | MD100 | PSNRL100 |
| FireEaterClip4000r1 | 29.3% | 18.1% | 70.9% | 35.6% | 77.9% | 46.6% | -43.9% | 15.2% |
| Market3Clip4000r2 | 10.1% | 5.2% | 12.5% | 9.5% | 8.7% | 34.8% | -94.7% | -3.4% |
| SunRise | 13.5% | 10.7% | 10.8% | 11.7% | 9.5% | 44.0% | -44.2% | -1.2% |
| BikeSparklers cut 1 | 3.8% | 1.3% | 10.3% | 5.3% | 8.7% | 22.6% | -29.0% | 5.8% |
| BikeSparklers cut 2 | 4.9% | 3.1% | 8.6% | 5.5% | 9.9% | 21.4% | -47.6% | 8.0% |
| GarageExit | 8.5% | 4.5% | 9.3% | 7.2% | 8.1% | 29.3% | -56.5% | 2.5% |
| ShowGirl2Teaser | 24.5% | 18.3% | 45.7% | 29.8% | 71.5% | 17.2% | -82.1% | 8.6% |
| StEM\_MagicHour cut 1 | -1.0% | 1.7% | 5.9% | 3.0% | 2.3% | -12.1% | -40.8% | -0.9% |
| StEM\_MagicHour cut 2 | 4.5% | 4.5% | 9.1% | 6.7% | 6.4% | -5.4% | -29.8% | 2.0% |
| StEM\_MagicHour cut 3 | 8.0% | 5.7% | 25.7% | 16.5% | 17.4% | 11.4% | -7.1% | 0.6% |
| StEM\_WarmNight cut 1 | 2.4% | 3.3% | 1.4% | 2.1% | 3.3% | -13.3% | -19.8% | -1.0% |
| StEM\_WarmNight cut 2 | 9.3% | 4.8% | 11.7% | 9.2% | 17.9% | -3.8% | -74.6% | -2.3% |
| BalloonFestival | 11.0% | 8.5% | 16.8% | 13.0% | 17.7% | 39.5% | -64.2% | -6.2% |
| EBU\_04\_Hurdles | 7.1% | -1.7% | -0.8% | 0.8% | -1.2% | 22.7% | 27.9% | -8.1% |
| EBU\_06\_Start | 14.1% | -1.8% | 14.5% | 8.9% | 8.5% | 56.2% | -8.3% | -10.2% |
| **Overall** | 10.0% | 5.7% | 16.8% | 11.0% | 17.8% | 20.7% | -41.0% | 0.6% |

## Comments on using 32 pieces instead of 8 pieces for chroma reshaping

The chroma LUT estimation described in section 2.3 is based on a least mean squares estimation. The input samples in the estimation are the reshaped luma samples Yreshape. To have more stability, the LUT is sparsely estimated. Instead of estimating the LUT value for each Yreshape sample value, the estimation is achieved on ranges of Yreshape values. This generates a sparse LUT that is subsequently modelled by the PWL.

The sparsity is directly linked to the number of pieces used in the PWL. For 8 pieces, 1 point in the LUT represents 128 luma values. For 32 pieces, 1 point in the LUT represents 32 luma values. This is illustrated in Figure 3, that shows the LUTs for BalloonFestival (1st picture) when using 8 or 32 pieces. The blue points correspond to the sparse LUT estimation, and the orange line corresponds to the LUT resulting from the PWL model.

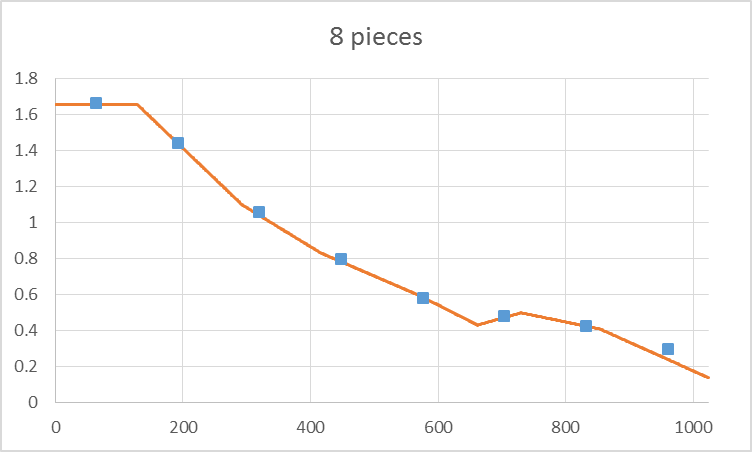
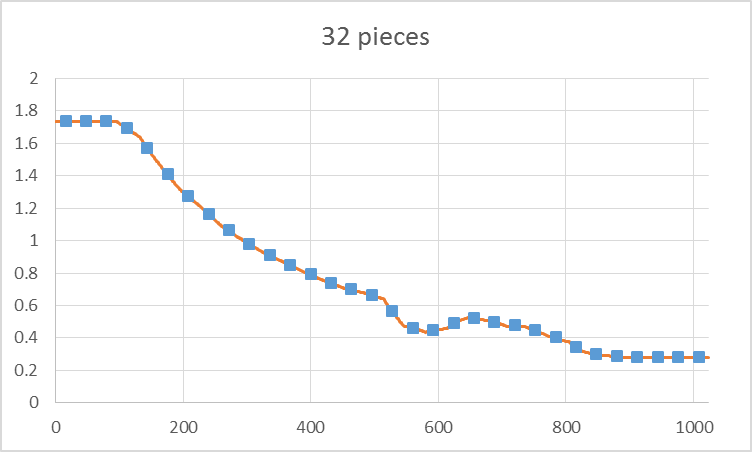
 

Figure 3. Illustration of PWL-modeled LUTs in case of 8 or 32 pieces.

An illustration of the potential differences in the resulting SDR is shown in Figure 4 and Figure 5. Using 32 pieces instead of 8 leads to more colored pictures.

Figure 4. 1st reshaped picture of ShowGirl with 8 (left) or 32 (right) pieces.

Figure 5. 1st reshaped picture of MagicHours with 8 (left) or 32 (right) pieces.

## Bitrates of reshaper metadata

We depict in Table 2 the total average cost of reshaping metadata per sequence and for bitrates R1 and R4. The figures are derived with 32 pieces used for the chroma PWL models. The metadata bitrates varies from 0.03% to 1.03% maximum for FireEater. This shows that even with 32 pieces for PWL, the cost of reshaping metadata is small compared to the total bitrate, even at low bitrates.

Note that the algorithm for refreshing the reshaping metadata is based on the analysis of the average luminance temporal variations in the sequence. When the relative variation from previous frame where the metadata were signaled, exceeds a given threshold, new metadata are signaled. In current version, there is a light temporal smoothing of the estimated average luminance, and the threshold is set to 15%. Making the temporal smoothing stronger will lead to a lower metadata signaling frequency and then even lower cost for the reshaping metadata.

Table 2. Average bitrate of reshaping metadata (kbps) per sequence.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | QP Slice | total bitrate | metadata bitrate | % |
| FireEaterClip4000r1 | 20 | 1941.7 | 5.2 | 0.27% |
|  | 29.33 | 508.9 | 5.2 | 1.03% |
| Market3Clip4000r2 | 22.33 | 7760.8 | 2.2 | 0.03% |
|  | 34 | 1259.0 | 2.2 | 0.18% |
| SunRise | 18.66 | 1704.3 | 1.8 | 0.10% |
|  | 29.33 | 311.0 | 1.8 | 0.57% |
| BikeSparklers cut 1 | 23.33 | 5308.3 | 3.3 | 0.06% |
|  | 34 | 1177.3 | 3.3 | 0.28% |
| BikeSparklers cut 2 | 23.66 | 4833.4 | 2.2 | 0.04% |
|  | 34.33 | 1124.0 | 2.2 | 0.19% |
| GarageExit | 22 | 2346.7 | 3.1 | 0.13% |
|  | 34.66 | 445.8 | 3.1 | 0.70% |
| ShowGirl2Teaser | 20.66 | 3304.2 | 4.8 | 0.15% |
|  | 33.33 | 593.4 | 4.8 | 0.81% |
| StEM\_MagicHour cut 1 | 20.33 | 2082.9 | 1.9 | 0.09% |
|  | 33 | 389.2 | 1.9 | 0.48% |
| StEM\_MagicHour cut 2 | 21 | 5339.2 | 2.2 | 0.04% |
|  | 33 | 1002.6 | 2.2 | 0.22% |
| StEM\_MagicHour cut 3 | 20.66 | 3519.9 | 1.8 | 0.05% |
|  | 33 | 666.3 | 1.8 | 0.27% |
| StEM\_WarmNight cut 1 | 20.33 | 3230.2 | 1.7 | 0.05% |
|  | 33.33 | 508.3 | 1.7 | 0.34% |
| StEM\_WarmNight cut 2 | 20.66 | 1782.1 | 1.7 | 0.10% |
|  | 33 | 358.3 | 1.7 | 0.48% |
| BalloonFestival | 22.33 | 3760.4 | 1.5 | 0.04% |
|  | 31 | 1199.1 | 1.5 | 0.13% |
| EBU\_04\_Hurdles | 24 | 6271.5 | 1.8 | 0.03% |
|  | 35.66 | 1183.9 | 1.8 | 0.15% |
| EBU\_06\_Start | 22.66 | 2624.9 | 2.0 | 0.08% |
|  | 35.66 | 511.8 | 2.0 | 0.40% |

# References

1. “Proposed initial Test Model for HEVC HDR extension,” R. Brondijk, R. Goris, R. van der Vleuten, L. van de Kerkhof, D. Rusanovskyy, A. Ramasubramonian, D. Bugdayci, S. Lee, J. Sole, M. Karczewicz, F. Galpin, S. Lasserre, F. Le Leannec, T. Poirier, E. François, MPEG document M37285, Geneva, Switzerland, Oct. 2015.
2. “Description of the reshaper parameters derivation process in ETM reference software,” K. Minoo, T. Lu, P. Yin, L. Kerofsky, D. Rusanovskyy, E. François, JCTVC-W0031/MPEG M37536, San Diego, USA, Feb. 2016.

# Patent rights declaration(s)

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