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| *Title:* | **Description of the Exploratory Test Model (ETM) for HDR/WCG extension of HEVC** | | |
| *Status:* | Input Document to JCT-VC | | |
| *Purpose:* | Proposal | | |
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# Abstract

This document presents the Exploratory Test Model for HDR/WCG video compression. The document also comprises in attachment the current ETM syntax, the software implementation and resulting metrics compared to the HDR anchors.

# Introduction

This document describes the Exploratory Test Model (ETM) for the HDR and WCG extension of HEVC, as delivered to the xyz reflector on January 21, 2016. The ETM describes proposed normative process changes to the HEVC specification. The process is out of loop and does not involve changes in the normative decoding process. The corresponding syntax and semantics of the main block of the HDR reconstruction process, called reshaper, included in an SPS/PPS extension, is provided.

Section 2 provides an overview of the ETM framework. Section 3 describes the HDR video analysis and processing (also called reshaper) that applies prior to the HEVC encoding. Section 4 describes the HDR reconstruction process (inverse reshaper) that applies after HEVC decoding.

A description of the reshaper parameters derivation process on the encoder side is provided in document JCTVC-W0031 [1]. The document also comprises the ETM specification text, the reference software (ETM\_RC\_r1) and the corresponding simulation results, compared to the current HDR anchors (known as CE1 v3.2 anchors).

# ETM framework overview

A functional diagram of the ETM is shown in Figure 4. The system uses HEVC Main 10 profile for the bitstream generation and bitstream decoding, and uses meta-data provided by the decoder to control decoder side processing used to reconstruct an HDR and WCG representation. The input HDR signal is pre-processed to produce a modified HDR signal that is provided to the HEVC main 10 encoder. The HEVC main 10 decoder output is used to reconstruct the HDR signal. The pre-processing and post-processing steps primarily aim at improving the coding efficiency of HDR content, and at providing support of SDR backward compatibility. Efficient delivery of HDR and WCG content is achieved with the reshaper tool.

The only normative tool in the HDR reconstruction process proposed in this TM is inverse reshaper. In the sections below, more details on this tool are described. Non-normative technologies including SEI and VUI changes are not presented in this TM.



Figure . ETM system diagram.

# HDR video analysis and reshaping

HDR analysis and reshaping applies prior to the HEVC encoding. It maps the input HDR signal to a format adapted to the HEVC Main 10 profile (cf Figure 2).



Figure . Encoding diagram.

The normative encoding process utilizes the adaptive reshaper module after the HDR signal is converted from 4:4:4 to 4:2:0.

In a first functional setting, the purpose of reshaper is to change the signal characteristics of YCbCr to improve the coding efficiency of the existing HEVC Main 10 codec. The motivation has three aspects:

* PQ is designed to cover the full range of HDR signal from 0 to 10,000 nits. However, due to the display limitation and director's intent, the video range might be smaller than the full range.
* For HDR and WCG signal, we are dealing with a much larger color volume than SDR which includes both color and intensity.
* In case of SDR-backward compatibility, reshaper performs dynamic range reduction with control of color shift resulting from this dynamic range reduction.

Reshaper is designed to simultaneously improve texture sharpness and improve color performance. It can additionally enable SDR backward-compatible support. A parametric reshaper model is used to implement the following two features:

* Adaptive codeword re-distribution.
* Re-quantization of luma and chroma signal components.

In the other functional setting, the reshaper is aimed at providing SDR backward compatibility. The reshaped signal from the input HDR signal is compatible with SDR rendering devices and can therefore, after compression and decompression, be rendered on legacy SDR devices.

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 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 (intra-plane reshaping), reshaper is applied independently to each chroma component using piece-wise linear functions.
* In mode 1 (cross-plane reshaping), reshaper is performed as cross-component scaling, 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.

Parameters of the luma and chroma reshaper models are signaled in the PPS syntax and usually updated when there is a scene change or IRAP.

# HDR reconstruction process

Figure 3 provides an illustration of the HDR signal reconstruction process from the YCbCr 4:2:0 decoded samples.



Figure : overall architecture of the HDR reconstruction process.

The inverse reshaper for luma is based on a piece-wise polynomial (PWP) model, with 8 pieces. At the decoder side, a reconstructed luma sample Yinvr is derived using the following equation from the decoded luma sample Ydec:

Yinvr = a0j + a1j . Ydec + a2j . Ydec2 ( 1 )

where j is the index of the piece-wise segment to which Ydec belongs, and aij is the ith-order polynomial coefficient for the j-th segment.

For chroma, the inverse reshaper is based on a piece-wise linear (PWL) model, with up to 32 pieces. Two methods are supported for inverse chroma reshaping.

* For mode 0 (intra-plane chroma reshaping), input sample value Cdec is mapped to an output sample value Cinvr as following:

Cinvr = Cdec \* Scale[ i ] + Offset[ i ] ( 2 )

with i being the index of the piece-wise segment where Cdec belongs to, Scale[i] and Offset[i] being the linear model parameters of the i-th segment.

* For mode 1 (cross-plane chroma reshaping), input chroma sample Cdec is mapped to an output sample value Cinvr as following. A scaling factor sc dependent on the co-located luma sample Ydn is derived as follows:

sc = Ydn\* Scale[ i ] + Offset[ i ] ( 3 )

with i being the index of the piece-wise segment where Ydn belongs to, Scale[i] and Offset[i] being the linear model parameters of the i-th segment. Then Cinvr is obtained by scaling Cdec using the scaling factor sc:

Cinvr = offset1 + sc \* ( Cdec – offset2 ) ( 4 )

Ydn for a color sample (Cb or Cr) at location (i, j) is derived from Luma samples Y as follows:

Ydn = (Y(2\*i, 2\*j) + Y(2\*i+1, 2\*j) + Y(2\*i, 2\*j+1) + Y(2\*i+1, 2\*j+1) + 2)>>2 ( 5 )

# References

1. “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.

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