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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-W0084 |

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| *Title:* | **HDR CE2:** **CE2.a-2, CE2.c, CE2.d and CE2.e-3** | | |
| *Status:* | Input Document to JCT-VC | | |
| *Purpose:* | Proposal | | |
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# Abstract

This proposal reports a combination of CE2 subtests: CE2.a-2 on luma forward reshaping improvement, CE2.c on chromaQPOffset, CE2.d on DeltaQP adjustment for luma, and CE2.e-3 on automatic selection of ETM parameters. The experiment is to test non-normative luma reshaping improvement as well as joint optimization of reshaper and encoder. The encoder optimization methods include chromaQPOffset, luma DeltaQP adjustment, and deblocking filter parameter selection. Subjective evaluation was conducted on both Pulsar and SIM2. It is asserted that compared to Anchor v3.2, the proposed joint optimization of reshaper and encoder provides visible subjective quality improvements for many of the test clips, primarily in the form of more texture details.

# Introduction

In this proposal, a combination of improved luma forward reshaper and encoder optimization based on CE2 subtest CE2.a-2, CE2.c, CE2.d and CE2.e-3 is investigated [1]. The improved luma forward reshaper includes two parts: an automatic reshaper update algorithm and a forward luma reshaping algorithm. The improved reshaper does not require any changes to the current ETM syntax. The piecewise polynomial (PWP) approximation source code is also improved compared to the first release of ETM software. The encoder optimization methods are based on three tools from CE1 test [2]: deblocking filter parameter selection and chromaQPOffset from [3] and DeltaQP adjustment for luma from [4]. These encoder-only methods are integrated into this proposal by taking signal change caused by reshaping into consideration. In the rest of this contribution, we will use CE2\_DI to refer to this combination of CE2 subtests.

# CE subtests algorithm description

## CE2.a-2: luma reshaper improvement

In this sub CE, two types of improvement have been made. The first improvement is on the update mechanism and the second is on the luma reshaping model.

### Improvement on reshaper metadata update

Instead of using scene information from external configuration file, we proposed a fully automated reshaping update algorithm. The reshaper parameters are derived and updated based on following conditions:

* There are a few conditions for which a change will be noted, as listed below:
  + It is the first frame to be processed. A change is noted. An update is enforced.
  + There is adequate range change. Range detection is based on difference of maximum Y from current picture and previous picture. If the difference is larger than a threshold, a change is noted.
  + There is adequate content characteristic change after a period of time. This check is performed every second (or intra period). Block based content analysis is employed for the “check point” image. If there are threshold-exceeding changes of block statistics compared to the previous block statistics stored when the most recent reshaper update happened, a change is noted.
* If a change is noted, a new luma reshaper metadata is derived based on the current image. It is possible that after piece-wise polynomial approximation, the new metadata turns out to be the same as before. Thus, a comparison is made between the new reshaper parameters with the previously stored ones. An actual metadata update will happen only if the new metadata is not identical to the metadata previously signaled.
* If an actual metadata update happens, the previous metadata storage will be updated to the new one and stored block statistics will be updated for next comparison.

The following table describes changes of metadata update mechanism in ETM r0, ETM r1 and CE2\_DI.

|  |  |  |  |
| --- | --- | --- | --- |
|  | ETM\_r0 (Dec.11 2015) | ETM\_r1(Jan.20 2016) | CE2\_DI |
| When to derive new metadata | POC info read from external cfg file | 1st frame, range change, every second (intra period) | 1st frame, range change, content characteristic change, every second (intra period) |
| When to update new metadata | update when a new metadata is derived | update when a new metadata is derived | update when a new metadata is derived and not identical to the previous one |

### Improvement on luma reshaping model

In ETM software, a heuristic method based on power function is proposed for luma forward reshaping [5]:

y = a \* (x + b)α + c

By changing α, we can shift codewords between dark area and bright area. One drawback of power function is that it adjusts codewords globally in a relatively coarse manner. The reshaping transfer function (mapping between input codewords and output codewords) always has to be a power curve. Once the alpha value is fixed, the curve shape is fixed. Since the ETM luma reshaper is based on a piecewise polynomial (PWP) model, we can have more freedom to adjust the reshaping transfer function with finer approximation.

In the CE test, the content adaptive luma reshaping algorithm is further refined. The ST. 2084 luminance range is divided into a number of pieces and codewords are allocated into each piece based on image statistics computed on the fly. The allocation of codewords for each piece is based on following criteria:

* For pieces with sample values not found in the input video content (e.g., most content does not contain samples from range of 4000nits to 10000nits), allocate few or no codewords.
* For other pieces with sample values found in the input video content, choose among four categories based on image statistics (block based sample statistics such as sum of dark) to pre-assign a number of codewords {CW\_PQ/2, CW\_PQ, mean(CW\_PQ,CW\_POW), max(CW\_PQ, CW\_POW)}, where CW\_PQ is the number of codewords based on original PQ transfer function (no reshaping), CW\_POW is the number of codewords based on power reshaping function in the luma reshaping model in ETM. For example (10bit output), for a piece with luminance range [L1, L2), CW\_PQ = (PQTF(L2) – PQTF(L1))\*1024; CW\_POW = ((PQTF(L2))α – (PQTF(L1))α)\*1024. PQTF is the transfer function to convert ST. 2084 luminance to normalized PQ value.
* If there is unused codewords, allocate them to the pieces with high luminance.

A target forward reshaping LUT can be computed based on accumulating codewords assignment for each piece. A target inverse reshaping LUT can be deduced from target forward reshaping LUT and then approximated by the PWP model. The actual inverse and forward reshaping LUTs are constructed with the derived PWP parameters to avoid mismatch caused by polynomial approximation discrepancies.

It is noted that the reshaper is design by taking encoder optimization especially DeltaQP for luma into consideration. For example, for bright clips, we allocate a bit more codewords than those needed for dark area to provide encoder with more freedom to move bits around in order to boost subjective performance.

All proposed algorithms are for luma forward reshaping and does not change the current ETM syntax.

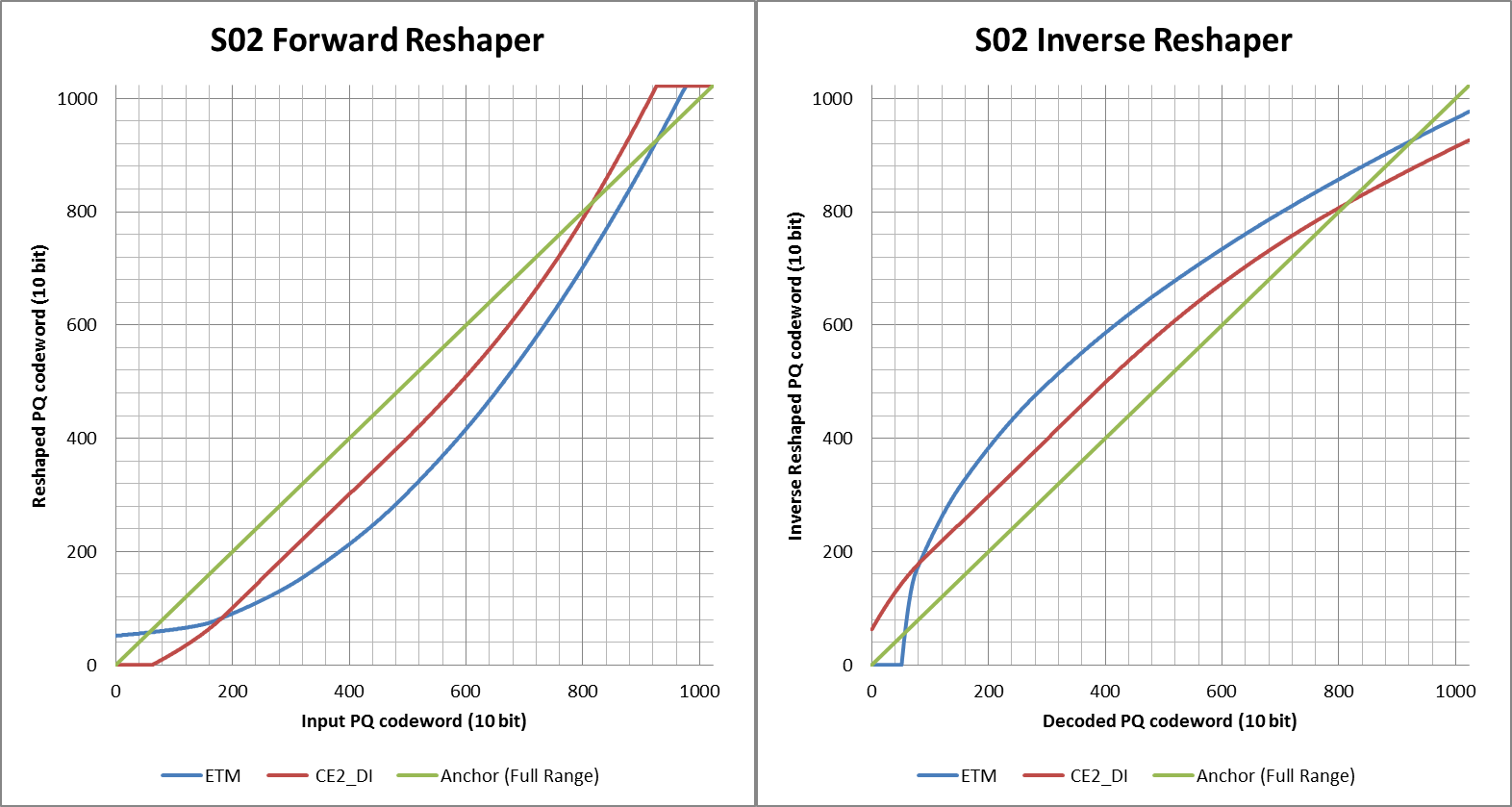


Figure . Comparison of luma reshaping curves for clip Market

An example of the actual luma reshaping curve of the Market sequence is shown in Figure 1. The left figure shows the forward reshaping curve and right figure shows the inverse reshaping curve. It is clearly shown that the CE2\_DI reshaping curve has a more flexible shape than the power curve in ETM.

## CE2.e-3: automatic selection of ETM parameters for luma reshaping

Elements planned for investigation under CE-2.e-3 relating to automatic parameter and model selection were incorporated in the interim ETM software released on January 20, 2016. As part of this SW release, the encoder enforces bitstream dynamic range limits on the PWP model parameters as described in the ETM description document JCTVC-W0031 [5]. Additionally the decoder software was made robust against extreme ranges of parameter setting. These improvements in automation and robustness are included in all CE2 tests built on the interim ETM\_r1 software. These changes do not result in MD5sum changes of the processed YUV and the encoded bitstreams (verified during ETM interim software update).

## Joint optimization of reshaper and encoder

In [6], we have shown that there are two types of quantization in the full system: one is sample quantization in baseband signal and one is transform quantization in codec. Reshaping is located in-between. Current reshaping specification can only allow sample value mapping based on the luminance level, without consideration of any spatial information. In HEVC codec, transform quantization (for luma) is applied within a spatial block and can be adjusted spatially. It is our belief that joint optimization of both can bring more compression improvement. In this CE experiment, we adapted encoder algorithms in CE1 for reshaping.

### CE2.c: Chroma quantization parameter adjustment

In HEVC Main/Main-10 profile, the chroma quantization parameters can be adjusted at the sequence level and slice level. The sequence level chroma QP offsets for each chroma component, relative to the luma QP, are signaled at Picture Parameter Set (PPS), which will apply to all slices that refer to this PPS. The QP offsets signaled at PPS will also affect the QP calculation used for chroma deblocking. The slice level chroma QP offsets are signaled in the slice header, and are only applied to that specific slice. The slice QP offsets can provide fine granularity adjustment, but it will not affect the QP calculation for chroma deblocking. The proposed chroma QP adjustment is to adjust the chroma QP by considering the temporal level and chroma reshaping: allocating more bits to pictures at lower temporal level than to those at higher temporal level.

The chroma QP adjustment in HDR/WCG anchor [2] is computed as follows:

QPc\_offset = S2\*(S1\*QP + O)

where QP is sequence level luma QP, and QPc\_offset is chroma QP offset. S2/S1 and O are the scaling factor and offset applied in HDR/WCG anchor.

We add an additional QPc\_adj based on TL\_Idx, the temporal level index, and subtract the QP impact dQPc\_reshape caused by chroma reshaping:

QPc\_offset = S2\*(S1\*QP + O) + QPc\_adj(TL\_Idx) – dQPc\_reshape

dQPc\_reshape is calculated as:

dQPc\_reshape = Clip(-12, 6, 6\*log2(slope(inv\_reshape(DCc))))

where slope(inv\_reshape(DCc)) is the slope of inverse reshaping function at DCc, which is the DC value of the corresponding chroma component in the current picture.

The final chroma QP QPc is calculated as:

QPc = QP + Clip(-12, 0, QPc\_offset)

The chroma QP adjustment QPc\_adj(TL\_Idx) for Cb and Cr components used in the simulation is shown in Figure 2.



Figure . The chroma QP offset adjustment used in the simulation

### CE 2.d: DeltaQP adjustment for luma

DeltaQP adjustment for luma is based on the same algorithm in CE1. The changes are the adaptation for luma reshaping. The default luma range table is designed based on average luma PQ value without reshaping. During encoding, the luma range table will be updated based on the active reshaping metadata. The default dQP mapping table is jointly optimized with the new reshaper.

### Deblocking filter parameter selection

A fast deblocking parameters searching algorithm is proposed. Two HEVC deblocking filter parameters, β and tc, are adaptively adjusted to optimize picture quality. If the reconstructed picture has low quality because the QP values applied to code the picture are high, then we can increase β and tc to make deblocking filter stronger to remove more blocking artifacts. Otherwise, if the reconstructed picture quality is sufficient, then we can decrease the β and tc values to make deblocking filter weaker. The encoder can select β and tc to minimize the distortion between deblocked picture and original picture. Denote BO and TO as β and tc, respectively.

(BO, TO)Opt = (1)

Where rec is the reconstructed picture before deblocking; orgYCbCr is the original picture; DB(rec, BO, TO) is the deblocked picture generated by deblocking the reconstructed picture rec with BO and TO parameters. The distortion between the two pictures is the weighted sum of individual distortion of each color component. Instead of applying parameter search in a brute force manner for each possible (BO, TO) pair, early termination is applied to accelerate the parameter searching process. If the distortion increases with one parameter BO (or TO), then further search of that parameter will be early terminated.

In order to avoid temporal flickering that may be caused by varying deblocking filter parameters between neighboring pictures, the hierarchical coding structure is considered. For those pictures at the same temporal layer coded with same QP, their deblocking parameters are kept similar.

# Software delivery

The software was delivered to all CE2 participants on Feb 1st and results are delivered on Feb 4th, as planned in CE2 timeline.

# Simulation results and analysis

## Improvement of reshaper update scheme

As described in section 2.1, in this CE, the reshaper metadata update logic is improved, leading to less frequent reshaper metadata update compared with ETM\_r1 (ETM\_r0 is read from external cfg). In Table 1, luma reshaper update frequency is reported. It is clear that the update frequency is reduced compared to ETM\_r1 which employs an automatic update scheme. Given the fact that most sequences only derive and update reshaper metadata once, and the analysis (content characteristic change detection) only happens in an infrequent way (once per second), the overall complexity increase of the preprocessor compared to Anchor is marginal for YUV generation. Also, the update scheme is a real-time on-the-fly process that only relies on current and previous information rather than using look-ahead or multi-pass based methods.

Consequently, due to less frequent update of the metadata, the bitrate of reshaper syntax carried in the PPS of HEVC bitstream is reduced from 0.484kbps to 0.339kbps (about 30%) on average compared with ETM\_r1, as shown in Table 2. The reshaper syntax counts both bits used to signal luma reshaper metadata and chroma reshaper metadata (chroma reshaping is kept unchanged compare to ETM\_r1). It should be noted that the reshaper syntax bitrate (0.339kbps in average) is almost negligible compared with the overall bitrate for all the compressed bitstreams. Even compared with the lowest compression bitrate R4, the reshaper syntax bitrate is only 0.06% of the rate of R4 on average.

Table . Luma reshaper update frequency

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  | **Number Luma Reshaper Updates** | | |
|  |  | **ETM\_r0** | **ETM\_r1** | **CE2\_DI** |
| class A | FireEaterClip4000r1 | 1 | 9 | 1 |
|  | Market3Clip4000r2 | 1 | 9 | 1 |
|  | SunRise | 1 | 9 | 1 |
| class B | BikeSparklers cut 1 | 1 | 5 | 1 |
|  | BikeSparklers cut 2 | 1 | 6 | 1 |
|  | GarageExit | 2 | 12 | 2 |
| class C | ShowGirl2Teaser | 43 | 31 | 12 |
| class D | StEM\_MagicHour cut 1 | 1 | 4 | 1 |
|  | StEM\_MagicHour cut 2 | 1 | 9 | 1 |
|  | StEM\_MagicHour cut 3 | 1 | 5 | 1 |
|  | StEM\_WarmNight cut 1 | 1 | 9 | 1 |
|  | StEM\_WarmNight cut 2 | 1 | 7 | 1 |
| class G | BalloonFestival | 1 | 10 | 1 |
| class H | EBU\_04\_Hurdles | 1 | 11 | 1 |
|  | EBU\_06\_Start | 1 | 11 | 1 |

Table . Bitrate statistics

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | **Overall sequence bitrate (kbps)** | | | | **Reshaper bitrate (kbps)** | | **Percentage of CE2\_DI Reshaper bitrate over R4** |
|  |  | **R1** | **R2** | **R3** | **R4** | **ETM\_r1** | **CE2\_DI** |
| class A | FireEaterClip4000r1 | 2010 | 1229 | 807 | 524 | 0.320 | 0.322 | 0.06% |
|  | Market3Clip4000r2 | 7884 | 2695 | 1725 | 1268 | 0.645 | 0.369 | 0.03% |
|  | SunRise | 1803 | 1026 | 557 | 319 | 0.639 | 0.371 | 0.12% |
| class B | BikeSparklers cut 1 | 5346 | 4057 | 2091 | 1194 | 0.302 | 0.326 | 0.03% |
|  | BikeSparklers cut 2 | 5015 | 3845 | 2021 | 1157 | 0.314 | 0.376 | 0.03% |
|  | GarageExit | 2367 | 1402 | 747 | 460 | 0.581 | 0.320 | 0.07% |
| class C | ShowGirl2Teaser | 3444 | 1681 | 1004 | 602 | 0.739 | 0.424 | 0.07% |
| class D | StEM\_MagicHour cut 1 | 2062 | 1173 | 631 | 393 | 0.304 | 0.333 | 0.08% |
|  | StEM\_MagicHour cut 2 | 5515 | 3246 | 1679 | 1003 | 0.313 | 0.283 | 0.03% |
|  | StEM\_MagicHour cut 3 | 3641 | 2129 | 1111 | 683 | 0.339 | 0.325 | 0.05% |
|  | StEM\_WarmNight cut 1 | 3199 | 1524 | 884 | 520 | 0.300 | 0.308 | 0.06% |
|  | StEM\_WarmNight cut 2 | 1827 | 928 | 577 | 364 | 0.588 | 0.304 | 0.08% |
| class G | BalloonFestival | 3820 | 2266 | 1569 | 1237 | 0.577 | 0.330 | 0.03% |
| class H | EBU\_04\_Hurdles | 6540 | 3671 | 1858 | 1147 | 0.650 | 0.334 | 0.03% |
|  | EBU\_06\_Start | 2675 | 1623 | 835 | 522 | 0.642 | 0.363 | 0.07% |
|  | **Average** |  |  |  |  | **0.484** | **0.339** | **0.06%** |

## Improvement of HDR compression efficiency

The simulation results (bit rate statistics and objective metrics with md5sum check values) are provided in the attachment. Since objective metrics are found not well aligned with subjective evaluation, we judged the performance mainly based on subjective quality on HDR display. We conducted subjective viewing on both Pulsar and SIM2 displays in real-time playback mode. It was observed that many clips show visible improvements on texture appearance over Anchor v3.2, which relies on HEVC encoder optimization only. The color performance is found to be quite similar to that of the Anchor, even though this proposal is not focused on color performance improvements. Subjective viewing of the results would be made available during this meeting.

# Conclusion

In this proposal, the combination of luma reshaping and encoder optimization is investigated. It shows evidence that additional compression efficiency over the Anchor could be expected with joint optimization of luma reshaping and encoding.

# Acknowledgement

We would like to thank Qualcomm and Technicolor for helping to crosscheck this proposal.

# References

1. D.Rusanovskyy, E. Francois, L. Kerofsky, T. Lu, and K. Minoo, "HDR CE2: on 4:2:0 YCbCr NCL fixed point for HDR Video Coding ", N15795, Geneva, CH, Oct. 2015
2. J. Strom, J. Sole, Y. He, “HDR CE1: Optimization without HEVC Specification Change”, m37501, Geneva, CH, Oct. 2015.
3. Y. He, Y. Ye, L. Kerofsky, A. Vosoughi, “Encoder optimization for HDR/WCG coding”, m37223, Geneva, CH, Oct. 2015.
4. A. Segall, J. Zhao, J. Strom, K. Andersson, M. Pettersson, “AHG on HDR and WCG: Average Luma Controlled Adaptive dQP”, JCTVC-W0054, San Diego, US, Feb. 2016
5. K. Minoo, T. Lu, P. Yin, L. Kerofsky, D. Rusanovskyy, E. Francois, “Description of the reshaper parameters derivation process in ETM reference software”, JCTVC-W0031, San Diego, US, Feb. 2016
6. F. Pu, T. Lu, P. Yin, T. Chen, W. Husak, “Comments on Reshaping for HDR/WCG compression”, Doc. m37267, October 2015, Geneva, Switzerland.

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