



# JVET-P0335 AHG15: Chroma QP mapping table for HDR

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Dolby Laboratories, Inc.

# Overview

What problem are we trying to solve?

- improve the luma and chroma balance for HDR common test conditions (CTC).

What is causing the problem?

- The reversal in the order of chroma QP offset and mapping tables in VTM 6.0

What solution are we proposing?

- update the non-normative chroma QP mapping tables for HDR (PQ and HLG)
- no essential SW changes over VTM (only new cfg files).

# Outline

- Introduction
  - Examination of the chroma QP mapping change in VTM6.0
  - Chroma QP mapping for HDR CTC
    - PQ (class H1): HD
    - HLG (class H2): UHD
- Proposal
  - Encoder only modification to rebalance luma and chroma
  - New cfg files, no essential SW changes over VTM
- Conclusion

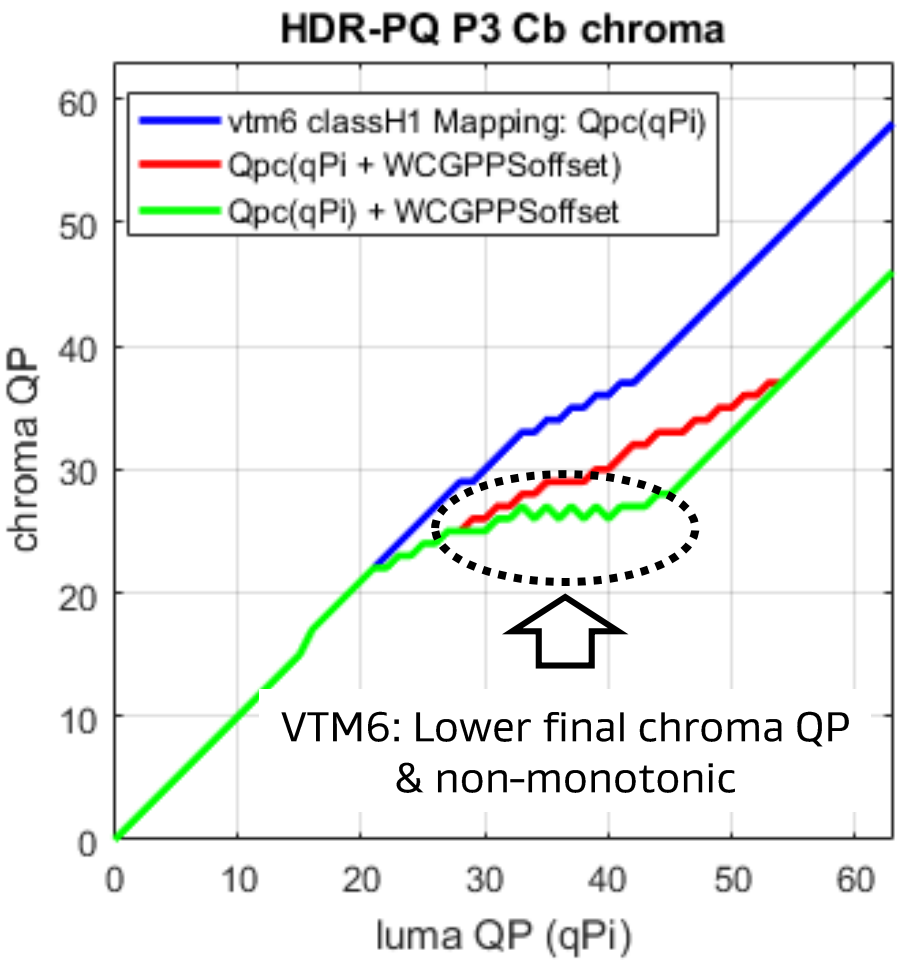


# Examination of chroma QP mapping change in VTM 6.0

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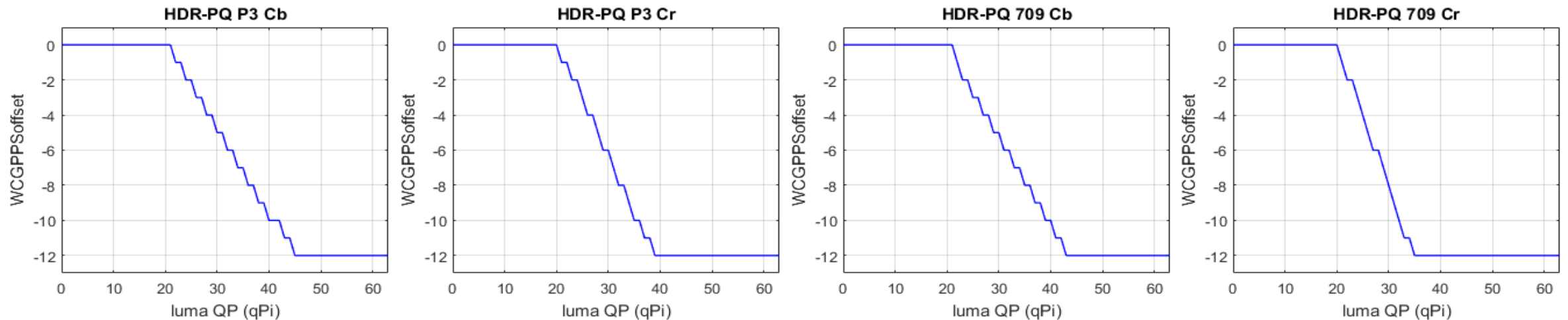
# Chroma QP mapping for VTM5 and VTM6

	VTM5 and earlier	VTM6
chroma QP tables	default	signalled
separate tables	no	Cb, Cr, and jointCbCr
chroma QP offset	applied before table $Qpc(qPi + offset)$	applied after table $Qpc(qPi) + offset$
SDR CTC table	default	based on O0186
HDR CTC table	default	same as VTM5
Below QP-16	No special handling	chroma QP = luma QP



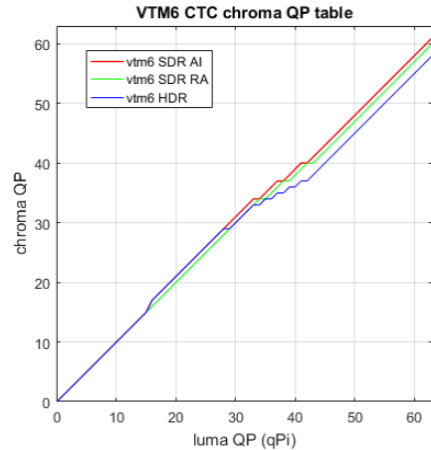
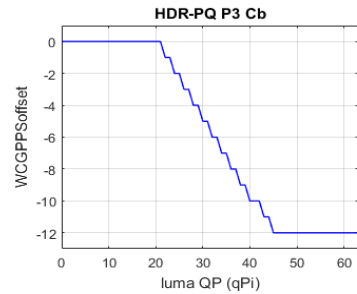
# Chroma QP Design for HDR PQ CTC in VTM5.0

- Chroma QP offset adjustment is applied at the encoder (WCGPPSEnable=1, for PQ CTC).
- Chroma QP offset (WCGPPSoffset) is computed using linear equations that have the following characteristics:
  - larger luma QP results in more **negative** chroma QP offset → to help mitigating chroma artefacts observed in low bitrate coding (high QP)
  - different equations are used for Cb and Cr, and for BT.709 and P3



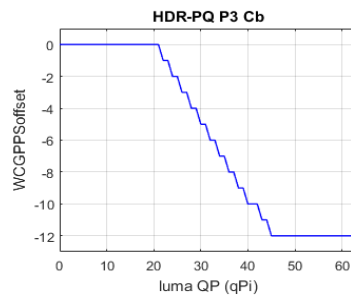
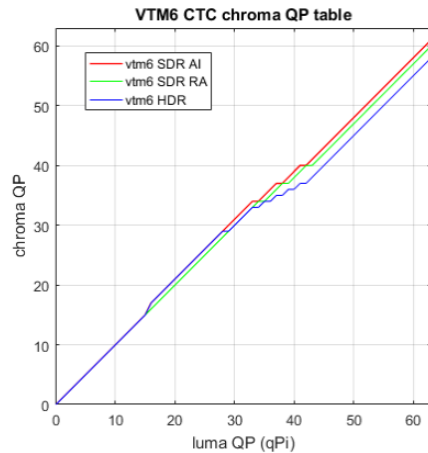
# Chroma QP mapping for HDR PQ CTC in VTM6.0

VTM5 order: offset  $\rightarrow$  table  $\rightarrow$  final chroma QP



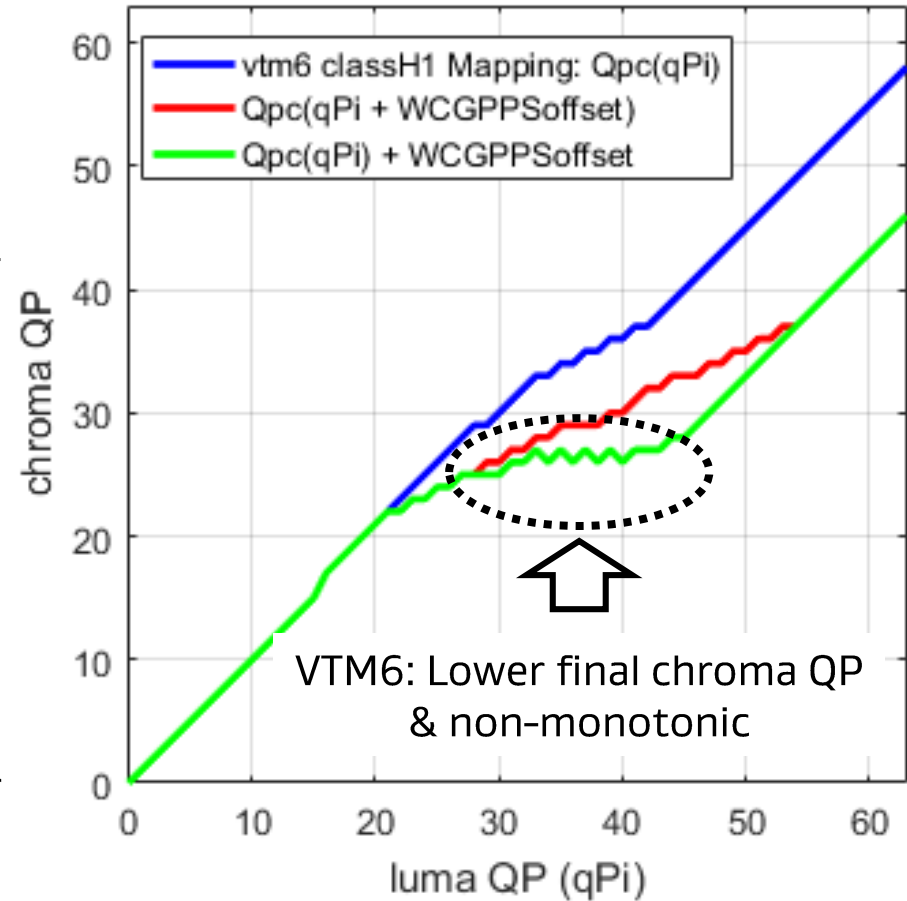
VTM5 order

VTM6 order: table  $\rightarrow$  offset  $\rightarrow$  final chroma QP



VTM6 order

HDR-PQ P3 Cb chroma



VTM6: Lower final chroma QP & non-monotonic

# HDR PQ CTC Performance in VTM6.0

- Compared with VTM5.0
  - Overall coding performance: **1% loss in luma** and large gain in chroma for AI and RA
  - Subjectively, no chroma difference between VTM5.0 and VTM6.0 was observed

AI					RA				
DE100	PSNRL100	wPsnrY	wPsnrU	wPsnrV	DE100	PSNRL100	wPsnrY	wPsnrU	wPsnrV
-9.90%	1.15%	1.19%	-13.94%	-28.44%	-8.65%	1.17%	1.11%	-18.02%	-32.70%

- Comparing with HM16.18
  - Chroma gain is found to be much larger than the luma gain for both AI and RA.
  - For RA, for example, the overall chroma gain is 44% compared to luma gain of 28%.

AI					RA				
DE100	PSNRL100	wPsnrY	wPsnrU	wPsnrV	DE100	PSNRL100	wPsnrY	wPsnrU	wPsnrV
-46.38%	-23.60%	-23.40%	-58.05%	-49.74%	-43.94%	-28.23%	-28.04%	-59.64%	-68.05%

- Suggest: better luma and chroma balance might be achieved for VTM 6.0 PQ CTC.



# Chroma QP mapping for HDR HLG CTC

- For HLG, The QP mapping remain same as that in VTM5.0. no additional WCGPPSoffset is applied.
  - Change in the order of applying a chroma QP offset does not impact HLG
- Performance compared to HM16.18 suggest better luma and chroma balance might be achieved for VTM 6.0 HLG CTC.

Compared to VTM5.0

AI			RA		
PsnrY	PsnrU	PsnrV	PsnrY	PsnrU	PsnrV
-0.40%	1.30%	0.05%	-1.69%	-2.59%	-2.17%

Compared to HM16.18

AI			RA		
PsnrY	PsnrU	PsnrV	PsnrY	PsnrU	PsnrV
-21.15%	-37.56%	-39.83%	-28.23%	-45.86%	-49.57%



# Proposal

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# Our proposal

- Modify chroma QP mapping tables at encoder to achieve better luma and chroma balance for both PQ and HLG CTC
- HDR PQ:
  - Absorb WCGPPSoffset into derived QP mapping table
  - Rely on subjective evaluation on a 4000-nit Pulsar display (reference display for PQ signal) to choose chroma QP table
  - Suggest to use separate P3 table
- HDR HLG:
  - Propose 2 candidate chroma QP tables for selection.
  - Subjective confirmation on professional display is recommended.

# HDR PQ Chroma QP Table Derivation

- We tested candidate functions to derive the following chroma QP tables:
  - A single chroma QP table for Cb, Cr, and jointCbCr; and
  - Separate chroma QP tables for each of Cb, Cr, and jointCbCr.
- Separate chroma QP tables are preferable to a shared table
  - Separate BT.709 (709) tables,
  - Separate P3 tables,
  - Separate mixed 709 and P3 tables (709 content uses 709 table, P3 content uses P3 table).
- JointCbCr was computed as of the average of the Cb and Cr tables.

# Candidate Chroma QP Table Evaluation for PQ signal

VTM6.0 anchor with WCGPPSEnable=0 was used as the baseline reference against which candidate chroma QP tables were compared.

- Objectively, “VTM6.0 anchor with WCGPPSEnable=0” has the worst chroma coding performance.
- Subjectively, “VTM6.0 anchor with WCGPPSEnable=0” results in significant chroma artifacts at low bitrate.
- It was observed that if BDRate of DE100 gain is close to or greater than 30% compared to “VTM6.0 anchor with WCGPPSEnable=0”, no significant chroma artifacts are seen during subjective viewing.

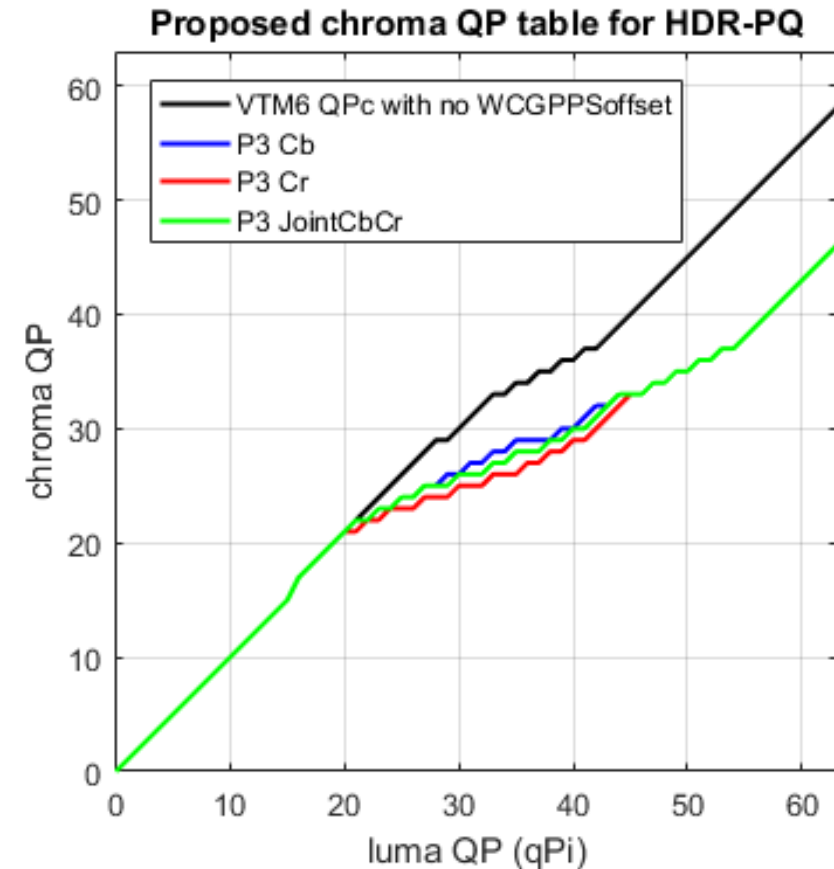
# Summary test results for HDR-PQ

	HDR PQ Q <sub>pC</sub> with WCGPPSEnable=0 versus HM16.18									
	AI					RA				
Test Case	DE100	PSNRL100	wPsnrY	wPsnrU	wPsnrV	DE100	PSNRL100	wPsnrY	wPsnrU	wPsnrV
VTM 6.0 official (WCGPPSEnable=1)	-46.38%	-23.60%	-23.40%	-58.05%	-49.74%	-43.94%	-28.23%	-28.04%	-59.64%	-68.05%
VTM 6.0 (WCGPPSEnable=0) QPc sep 709	-41.47%	-24.85%	-24.62%	-54.90%	-55.09%	-29.84%	-29.64%	-29.52%	-45.48%	-22.93%
VTM 6.0 (WCGPPSEnable=0) QPc sep P3	-33.78%	-25.90%	-25.78%	-49.73%	-32.22%	-24.39%	-30.35%	-30.27%	-38.16%	-3.68%
VTM 6.0 (WCGPPSEnable=0) sep mix 709/P3	-40.00%	-25.10%	-24.90%	-54.39%	-52.69%	-28.79%	-29.79%	-29.66%	-44.15%	-19.27%

	HDR PQ Q <sub>pC</sub> vs. VTM6.0 HDR PQ Anchor with WCGPPSEnable=0									
	AI					RA				
Test Case	DE100	PSNRL100	wPsnrY	wPsnrU	wPsnrV	DE100	PSNRL100	wPsnrY	wPsnrU	wPsnrV
VTM 6.0 official (WCGPPSEnable=1)	-42.54%	7.22%	8.07%	-44.77%	-65.14%	-44.69%	6.02%	6.71%	-53.98%	-74.48%
VTM 6.0 (WCGPPSEnable=0) QPc sep 709	-40.94%	5.58%	6.44%	-47.25%	-64.91%	-34.43%	4.09%	4.66%	-46.68%	-57.91%
VTM 6.0 (WCGPPSEnable=0) QPc sep P3	-33.89%	4.13%	4.84%	-40.96%	-50.24%	-30.59%	3.04%	3.55%	-41.16%	-51.54%
VTM 6.0 (WCGPPSEnable=0) sep mix 709/P3	-39.26%	5.25%	6.08%	-45.63%	-60.97%	-33.43%	3.89%	4.47%	-45.13%	-55.86%

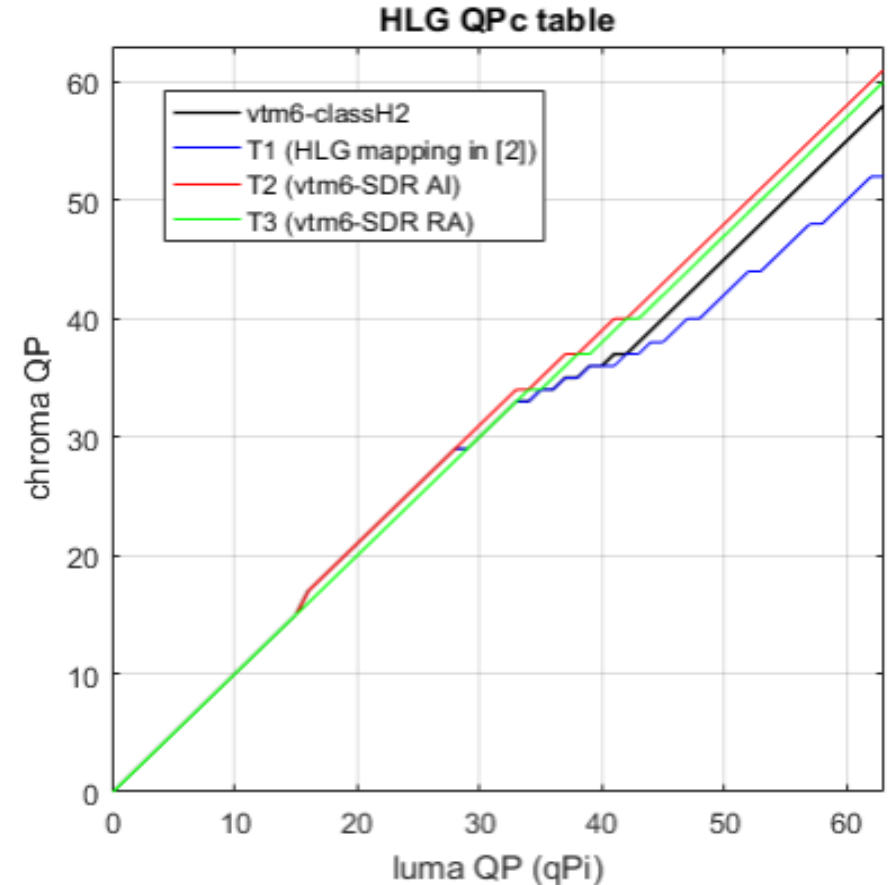
# Proposed QPc mapping for HDR-PQ

- Recommend to use the P3 separate tables
  - Subjective difference in color between proposal and HDR CTC Anchor was observed to be very minor even at low bitrate:  $Qp_c$  is an acceptable alternative for encoder optimization.
  - Provides best luma performance and balance between luma and chroma
  - Most HDR PQ content will be created in P3 colour space
  - Total signaling overhead is 226 bits for the separate Cb, Cr, and jointCbCr chroma QP tables.



# HLG Candidate Chroma QP Tables

- 3 candidate tables are tested:
  - T1: HLG chroma QP table originally proposed in JVET-00433[2], introducing a mild WCGCQPoffset for HLG
    - smallest chroma QP values for the higher range luma QP ( $q_{Pi} > 32$ ), provide best subjective chroma quality at low bitrate.
  - T2: SDR CTC AI table used in VTM6.0
    - highest chroma QP values for all QP thus it is expected to have worst chroma quality both subjectively (at low bitrate) and objectively in terms of BDRate.
  - T3: SDR CTC RA table used in VTM6.0
    - lowest chroma QP in middle range (luma  $q_{Pi}$  between 16 to 32) but has larger chroma QP than T1 and smaller chroma QP than T2 in high QP range.
    - expected to have slightly worse chroma quality than T1 and slightly better chroma quality than T2 at low bitrate (e.g. QP37), when chroma artifacts are subjectively visible.





# Summary test results for HDR-HLG

Compared to HM16.18

Test Case	AI			RA		
	PsnrY	PsnrU	PsnrV	PsnrY	PsnrU	PsnrV
VTM 6.0 official	-21.15%	-37.56%	-39.83%	-28.23%	-45.86%	-49.57%
T1: HLG table in [2]	-21.14%	-37.56%	-39.83%	-28.18%	-45.88%	-49.43%
T2: VTM6.0 SDR AI	-21.58%	-33.52%	-34.98%	-28.71%	-39.55%	-44.10%
T3: VTM6.0 SDR RA	-20.87%	-40.01%	-41.89%	-28.29%	-46.60%	-50.74%

Compared to VTM6.0

Test Case	AI			RA		
	PsnrY	PsnrU	PsnrV	PsnrY	PsnrU	PsnrV
T1: HLG table in [2]	0.00%	0.00%	0.00%	0.07%	-0.75%	-0.53%
T2: VTM6.0 SDR AI	-0.52%	6.24%	6.67%	-0.62%	13.18%	12.27%
T3: VTM6.0 SDR RA	0.40%	-3.85%	-3.81%	-0.02%	-1.16%	-2.80%

- T3 exhibits slight better BDRate improvements in U/V PSNRs than T1 although subjectively it should be the opposite.
- This is mainly because the BDRate is calculated with mid-range QPs (22-37) that T3 has lower chroma QP and therefore not aligned very well with subjective quality.

# HLG Subjective Evaluation

Subjective test is performed on a high-quality consumer display in HLG mode (LG C8 OLED display)

- Visually lossless HEVC bitstreams (x265 10b visually lossless mode with HLG signalling and bit rate set at 40Mbps).
- Compared to the VTM6.0 anchor, the visual difference between T1 and the VTM6.0 anchor is much less than what observed previously when comparing to the VTM5.0 anchor.
  - Suggest we may no longer need to reduce chroma QP aggressively for HLG when luma QP is large.
  - For HLG CTC, we recommend subjective evaluation be done using a professional BVM display to choose one of the tables from the T1 and T2 HLG chroma QP tables proposed.

# Conclusion

- Proposes to update non-normative chroma QP mapping tables for HDR to improve the luma and chroma balance in VTM 6.0 for HDR common test conditions (CTC).
- For HDR PQ (class H1), separate P3 tables are recommended to adopt in VTM software for Cb, Cr, and jointCbCr.
- For HDR HLG (class H2), 2 (T1 and T2) candidates are recommended and subjective evaluation be done using a professional BVM display.

# Acknowledgement

- We would like to thank InterDigital for the crosscheck JVET-P0623 for HDR PQ.



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