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| *Title:* | **BoG report on chroma intra prediction** | | |
| *Status:* | Input Document to JCT-VC | | |
| *Purpose:* | Report | | |
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| *Source:* | BoG on chroma intra prediction | | |

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This contribution summarizes activities of the break out group (BoG) on review of non-CE chroma intra prediction proposals. Proponents confirmed that the HM anchor used for comparison is based on HM4 code with LM bug fix.

# Review of proposals

## Proposals overview

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| --- | --- | --- | --- |
| **Doc** | **Proposal description** | **Performance**  **(**xxx) = w/o SteamLo/Nebuta | **Complexity analysis**  Added complexity Complexity reduction |
|  | **Coding efficiency proposals** | **Y U V** |  |
| G119 | Modified left samples interpolation in LM mode ([1,3,3,1] instead of [1,1]) | 0.0 -0.2 -0.2  (0.0 -0.1 -0.1)  HM4.0 w/o LM fix | 5 times of the addition for left samples filtering |
| G173 | New V Prediction = Regular V prediction + (Reconstructed U Residue) /2 | -0.3 -1.0 -2.9  (-0.4 -1.2 -3.1) | Dependency between U and V channels  1 more addition and 1 more shift for each pixel |
| G244 | Identify all-cases in alpha value estimation and replaces wrong alpha by pre-computed values (signaled in slice header of APS) | 0.0 -3.5 -3.8  (0.0 -1.6 -1.3) | Up to 5 more comparisons per TU  1 static table of 16 elements stored on 5 bits per element  12 syntax elements (38 bits) in slice header or APS  16 less multiplications for 16x16, 4 less multiplications for 8x8  Border samples filtering equivalently simplified  6 bits for alpha derivation instead of 7 |
| G346 | Predict U, V from residue Y (linear model)  explicit signaling of linear model parameters | -0.1 -4.1 -4.7  (-0.1 -2.1 -2.1)  HM4.0 w/o LM fix | Complexity for partitions NxN is higher than LM mode for partitions 2Nx2N (luma residue computed twice)  Parsing dependency issue (when decoding the alpha)  Use same TU depth for chroma as used in G442 (TU specification) for RM.  There is some kind of question as to what extent G442 like TU depth increases the overall combined gain. |
| G358 | Add 2 LM modes with different neighboring samples | -0.1 -3.3 -3.4  (0.0 -1.9 -1.8) | Either add 2 more modes or replace vert/horiz modes by LM-like modes (added complexity compared to horiz/vertic modes especially for the encoder)  When 4 modes used, no dynamic interpretation of the mode at the decoder side |
|  | **Combinations of proposals** |  |  |
| G955 | Combines G173, G244, G246, G442  Cross check G995, G1030 (Late) | -0.4 -7.3 -9.3  (-0.5 -5.1 -6.6) |  |
| G1009 | Combines G173+G346  Cross checker (No cross check), Late | -0.4 -4.5 -6.5  (-0.5 -3.1 -4.7) |  |
| G1024 | Combines G173+G358 (method number 3)  No cross check, Late | -0.4 -3.9 -5.7  (-0.4 -2.6 -4.3) |  |
|  | **Design clean-up & Generalization proposals** |  |  |
| G419 | 1. Align HM software to WD regarding ref samples padding process  2. Use 1st left column reference instead of 2nd left reference column for left luma samples | 0.1 0.8 0.7 |  |
| G245 | Generalizes LM mode for any 4:2:0 chroma phased signal:  -Insert chroma phase information in SPS  -Modify luma filter for LM based on chroma phase |  |  |

## Proposals review

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| **Contrib** | **Topics** | **Summary changes & comments** |
| Coding efficiency – single tools | | |
| G119 | LM prediction | Modified left samples interpolation in LM mode ([1,3,3,1] instead of [1,1])  2 other modifications not directly relates to chroma: removes three MPM remapping tables and takes planar mode as the remapped mode, The third modification enables total number of the remaining Intra modes to be expressed as powers of 2.  Complexity is 5 times number of additions with 0.2% gain.  This filter is applied to immediate left neighbor.  SteamLoco shows higher chroma gain 1.7 and V 2.3 and no loss in luma. |
| G173 | Pred V using resU | New V Prediction = Regular V prediction + (Reconstructed U Residue) /2  U/2 residue is added to V residue to create the V residue  U/2 addition is a new idea. It may complicate the pipeline because of dependency between U & V.  This approach is applied to all intra modes except LM mode. It was noted that the results are asymmetric with respect to U & V and it is conceivable that visual artificat may happen. It is also noted that the observed unbalance is based on bit rate reduction and looking at PSNR numbers reflects some level of unbalance as well it is however minor 0.04 vs. 0.09!  MediaTek JCTVC-G676 Cross Check.  JCTVC-G173 is used in combination with JCTVC-G1024 , JCTVC-G955 and JCTVC-G1009. The gain is additive.  Results for SteamLoco and Nebuta are not good. |
| G244 | LM prediction | In the OLS process to estimate alpha value in LM mode, a detection of ill-cases is performed. 4 types of ill-cases are considered. For each type, a pre-determined alpha value is used to replace the estimated ill-case alpha. The pre-determined fixed values are stored as static table of 16 possible values 5-bit long (the normal alpha value is kept 7 bits long). 4 index, corresponding to each one of the 4 ill-cases type, are coded for each component to indicate which alpha values among the 16 fixed table are to be used in place of the normal alpha value. A total of 38-bit index values (for each component, 2 thresholds of 2 and 3 bits, 4 values of 4-bits) could be sent either at PPS or APS.  The decision on which fixed values to choose is based on 5 comparisons at the TU level.  Decoder needs to perform similar operation as the encoder to obtain the index value for 7-bit alpha value. The proponents suggest that this added complexity can be further reduced by performing sub-sampling of the reference luma & chroma samples. In addition, the proponents are also providing a combined solution that limits the number of sub-sampled reference values to 8 regardless of the block size. The combined solution has decreased alpha bit-accuracy from 7-bit to 6-bit.  Number of compares per PU is increased however because of sub-sampling factor, number of computations for alpha is substantially decreased. Number of computations for 4x4 block size is not changed i.e., no sub-sampling. It was also noted that significant visual improvements in chroma are observed based on the results provided by proponents. Higher gains are observed in class A. The cross checker for the original proposal (G270) indicated that he could see visible visual chroma improvements in some sequences e.g., class A. Large gains are observed in SteamLoco (0.7 Y, -24.1 U, -31.8 V) and Nebuta (-0.4 Y, -17.2 U, -21.9 V).  Relevance to G129. |
| G346 | Chr pred using luma res (RM mode) | Predict U, V from residue Y (linear model)  explicit signaling of linear model parameters  New V Prediction = Regular V prediction + (av\*Yres )  New U Prediction = Regular U prediction + (au\*Yres )  This is a new intra prediction mode called rm for chroma . It is the last element in the Table? This method does DM first and if RM is chosen it adds the residue.  au & av values are 4-bit each and are transmitted to the decoder using truncated unary codes per PU. All TUs within PU share the same au & av values.  The encoder has to calculate the au & av values based on the current PU block and not the neighbor reference samples. Encoder complexity is increased but how to derive au & av values is non-normative!  Cross checker G069 and G911  StreamLoco shows 0.3 luma loss U 24% and V 35% gain, respectively. It was also noted that similarity exists to method 2 of G442 in terms of TU depth. The difference is that proponents apply this to RM mode, only. Syntax modification is needed and there exits parsing dependency.  Proponents request to have this approach included in CE6 for further study. |
| G358 | LM prediction | Add 2 LM modes with different neighboring samples  Alpha and Beta values are calculated separately for left and above reference samples named LMA, LMB.  Total number of samples are the same as normal Lm for the calculation of alpha and Beta. Above reference samples are extended to the right in LMA. For LML reference samples are extended to left bottom.  \In terms of mode coding three methods are proposed:   1. Current HM4 modes (6) + 2 new modes (LMA + LML)   DM, LM, LML, LMA, Planar, Ver, Hor, DC   1. DM, LM, LML, LMA, Ver, DC 2. DM, LM, LML, LMA   Cross-Checker: InterDigital G273  What is done when left and/or above not available? Regular padding use similar to normal chroma mode.  Method 3 has simpler table.  There was also a question whether results are available for DM, LM, LML, only? No results exist?  Excluding Nebuta and SteamLoco the average change in chroma 0.4 and no change in luma. |
| Coding efficiency – combinations testing | | |
| G955 | Combine G173, G244, G246, G442 | A request was made to proponents to provide additional results based on the combinations of G173 & G244. This helps to make a better comparison with G1009 & G1024 |
| G1009 | Combine G173+G346 |  |
| G1024 | Combines G173+G358 |  |
| Design clean-up / generalization | | |
| G419 | LM prediction | It is noted that discrepancy exists between the HM & WD in the description of padding process for the LM mode. Proponents provide a text to unify the two. In addition there are many Eq. 8.30s that appear after Eq. 8.45.  In addition, the proponents note that the padding process defined and they offer a solution based on using the 1st left column reference instead of 2nd left reference column. Losses are observed (put the results) but this approach helps to unify the padding process that includes LM, as well. The proponents were asked to show their results based on the HM4 bug fix anchor asap (Sony will do the cross-check). It was further clarified by the proponents that some ambiguity rather than “lack of the padding process for LM” exits. BoG asked Victor from Panasonic and Sato-san form Sony to clarify this issue with the proponents and report the results. |
| G245 | LM prediction | Generalize LM mode for any 4:2:0 chroma phased signal  This contribution provides a way to signal the phase of chroma at SPS for different chroma phases in 4:2:0. To know the phase relationship between luma and chroma is important for LM. BoG encouraged the proponents to work with Arturo (CISCO) in order to list applications where it is important to support different chroma phases. Added complexity due to support of different chroma phase filters was also noted.  In addition, the proponents also propose to remove the shifting process in the sub-sampling operation. As the result the internal bitdepth is increase by 1-bit with no gain in HW complexity! No change in terms of performance! |
| Information | | |
| G511 | LM prediction | Information document |

## Recommendation

**JCTVC-G419**

* Recommend the adoption of the WD text for harmonization of WD and HM5.0 SW for LM.
* Clarify the padding process in LM and its unification with normal intra prediction padding process. However WD text does not say anything for padding process for LM mode

**JCTVC-G173**

* Basis of the combined solution for JCTVC-G995, G1009, G1024.
* Support for adoption by non-proponent

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|  | HM4.0 |  |  |  | G173 |  |  |  |  |  |  |
|  | Avg. Y | Avg. U | Avg. V | V-U | Avg. Y | Avg. U | Avg. V | V-U | Avg. Increase | Max Increase | Min. Increase |
| A-E | 38.02 | 41.61 | 42.2 | 0.59 | 38.02 | 41.63 | 42.28 | 0.65 | 0.06 | 0.17 | -0.02 |

**JCTVC-G245**

Knowledge of chroma phase is necessary for LM intra prediction mode for applications requiring support for different chroma phase format than the current HEVC chroma format specification. As examples, the two following applications request support of various chroma formats:

* **Headend encoders** : ingested video content are often pre-processed by encoders. It is common to combine chroma subsampling with this pre-processing stage. Chroma subsampling schemes tend to differ to a greater extent, resulting in diverse chroma shift content.

* **Transcoding**: support of generic chroma formats is also required in applications such as network video distribution, potentially involving cascaded transcoding processes. Degradation of chroma components at each transcoding operation must be as much as possible controlled.

## Proposals abstract

### Coding efficiency

[JCTVC-G119](http://phenix.it-sudparis.eu/jct/doc_end_user/current_document.php?id=3370) Modifications to Intra-frame coding [Y. Lin, H. Yang, L. Liu, J. Zheng, H. Yu (Huawei)]

This contribution presents three modifications to intra frame coding: (1) down-sampling filter for left reference luma samples in LM mode is changed from 2-tap to 4-tap, (2) removal of the remapping tables used in MPM prediction, (3) simplification of Intra mode coding by using FLC instead of VLC. As a result, it is reported that BD-rate results for the first modification is: AI-HE: Y: 0.0, U: -0.2, V: -0.2, and AI-LC: Y: 0.0, U: -0.2, V: -0.2. The second modification removes three MPM remapping tables and takes planar mode as the remapped mode. BD-Rate results for this modification are reported to be: AI-HE: Y: 0.0, U: 0.1, V: 0.0, and AI-LC: Y: 0.0, U: 0.0, V: 0.1. The third modification enables total number of the remaining Intra modes to be expressed as powers of 2. Meanwhile Intra mode coding method in Intra LC configuration is changed from VLC to FLC, which unifies binarization for Intra mode coding in both HE and LC Intra configurations. BD-Rate results for this harmonization are reported to be: AI-HE: Y: -0.1, U: 0.0, V: 0.0, and AI-LC: Y: 0.1, U: 0.1, V: 0.1.

[JCTVC-G173](http://phenix.it-sudparis.eu/jct/doc_end_user/current_document.php?id=3426) Cross-channel intra chroma residual prediction [Y. Chiu, Y. Han, L. Xu, W. Zhang, H. Jiang (Intel)]

This contribution reports the cross-channel residual prediction technique to improve the intra chroma prediction of HM 4.0. The cross-channel residual prediction technique linearly estimates the residuals of Cr pixel from the reconstructed Cb residuals. Compared to the HM4.0 anchor, the proposed cross-channel intra chroma residual prediction technique achieves an average BD bitrate improvement of -0.4% on Y, -1.1% on Cb, -2.8% on Cr for the common test condition of AI\_HE cases, and of -0.3% on Y, -0.8% on Cb, -3.3% on Cr for the common test condition of AI\_LC cases without significant impact on the CPU run time (1% increase in Enc time, 0% increase in Dec time for AI\_HE cases, 0% increase in both Enc/Dec time for AI\_LC cases). Additonal data of the combined G172 & G173 is reported to demonstrate an average BD bitrate reductions of -0.57% on Y, -1.62% on U, -2.98% on V for AI\_HE case and an average -0.48% on Y, -1.58% on U, -3.87% on V for AI\_LC case.

[JCTVC-G244](http://phenix.it-sudparis.eu/jct/doc_end_user/current_document.php?id=3497) Luma-based chroma prediction - Model correction [C. Gisquet, E. François (Canon)]

This contribution presents a modification to the luma-based chroma intra prediction mode, where the alpha parameter values are checked and replaced by constant values, depending on statistics used to compute the alpha values. It is reported that this method obtains 4.2% to 4.5% average coding BD-rate gain for U and V components, with a negligible impact on encoder and decoder runtime. Additionally, simplifications to the OLS computation and reduction in the number of bits needed for the chroma prediction samples computation are evaluated, with reportedly around 3.9% chroma BD-rate gain (i.e. around a 0.3% decrease of the former chroma gain, which is below what is measured for equivalent simplifications in HM4.0).

[JCTVC-G346](http://phenix.it-sudparis.eu/jct/doc_end_user/current_document.php?id=3603) Chroma intra prediction based on residual luma samples [K. Kawamura, T. Yoshino, H. Kato, S. Naito (KDDI)]

This contribution presents additional chroma intra mode. HM4.0 employs LM (linear model) mode which was reported in JCTVC-E266 as chroma intra prediction. The LM mode predicts chroma samples based on reconstructed luma with linear model. Parameter of the linear model is derived from adjacent blocks with linear least square solution. However, LM mode is insufficient to predict texture where the correlation among adjacent blocks is low. Inter-channel prediction of chroma intra residuals is thus introduced. Chroma intra direction is derived from luma intra direction. Parameter of inter-channel correlation model is derived and coded on the encoder side. Compared to the HM4.0, the average BD-bitrate gain is 0.1%, 4.1%, 4.7% for all intra HE configuration respectively for Y, U and V components.

[JCTVC-G358](http://phenix.it-sudparis.eu/jct/doc_end_user/current_document.php?id=3615) New modes for chroma intra prediction [X. Zhang, O. C. Au, J. Dai, F. Zou, C. Pang, X. Wen (HKUST)]

This document proposes two new intra modes LML and LMA for predicting chroma from luma. The prediction process is almost the same as LM mode except the neighborhoods used for training the parameters in the linear model are different. In LML mode, left and down left neighborhoods form the training set. In LMA mode, above and above right neighborhoods form the training set. Moreover, by introducing LML and LMA, the chroma intra prediction mode list can be shortened without losing coding gain. Compared with the bug-fixed HM4.0, the average BD-rate gain is 0.1%, 3.6%, 3.6% under intra configuration for Y, Cb and Cr components respectively without Class F, while 4% encoding time is saved at the same time.

[JCTVC-G955](http://phenix.it-sudparis.eu/jct/doc_end_user/current_document.php?id=4233) Joint contribution on the integration of several chroma coding tools [Gisquet Christophe (Canon), Chiu Yi-Jen (Intel), Minezawa Akira (Mitsubishi), Ichigaya Atsuro (NHK)] [late]

This joint contribution presents the results of combining several coding tools impacting chroma together. Namely those tools are “Cross-channel Intra chroma residual prediction” (JCTVC-G173, Intel), “Luma-based chroma prediction - Model correction” (JCTVC-G244, Canon), “On additional SAO Band Offset classifications” (JCTVC-G246, Canon) and “Improvement to chroma TU specification” (JCTVC-G442, Mitsubishi Electric and NHK). Compared to the individual tools, it is reported that their combinations are showing near-additive results, with BD rate equal to -0.4%, -7.7% and -9.7% for respectively Y, U and V components for AIHE configuration and -0.5%, -8.2% and -9.9% for AILC configuration. For these Intra configurations AIHE and AILC, the encoding and decoding time variations are respectively 100% and 100%, compared to HM4.0 without bugfix on alpha bits.

[JCTVC-G1009](http://phenix.it-sudparis.eu/jct/doc_end_user/current_document.php?id=4298) A joint contribution on the coding tools of residual prediction for intra chroma prediction [Y. Chiu, Y. Han, L. Xu, W. Zhang, H. Jiang (Intel), K. Kawamura, T. Yoshino, H. Kato, S. Naito (KDDI)] [late]

This joint contribution presents the results of combining two coding tools on the techniques of residual prediction for intra chroma prediction. Namely the tools are “Cross-channel Intra chroma residual prediction” (JCTVC-G173, Intel), “Chroma intra prediction based on residual luma samples” (JCTVC-G346, KDDI). Compared to the individual tools, it is reported that, comparing to HM4.0, the combination of the tools is showing near-additive results, with BD rate equal to -0.4%, -4.8% and -6.9% for respectively Y, U and V components with average run time 101% for encoding and 101% for decoding for AIHE configuration, and -0.4%, -4.0% and -6.8% with average run time 100% for encoding and 102% for decoding for AILC configuration.

### Design clean-up / generalization

[JCTVC-G419](http://phenix.it-sudparis.eu/jct/doc_end_user/current_document.php?id=3676) Inconsistency of intra LM mode between HM and WD [J. Lee, S.-C. Lim, H. Y. Kim, J. S. Choi (ETRI)]

This contribution reports inconsistency of intra LM mode between HM and WD. In the reference sample substitution process of WD 4.0, one neighboring row and one neighboring column are padded by available samples. Intra LM mode uses one row and 2nd left column of reconstructed luma blocks. Therefore, if left block is unavailable, LM mode cannot use 2nd left column. Currently, WD4.0 has no description for that case, and HM4.0 uses 1st left column instead of 2nd left column in LM mode. In this contribution, revised WD text is proposed to get rid of the inconsistency between HM and WD. In addition, a simplified LM mode is proposed to keep consistency of padding process. It is reported that the average BD-rate loss of the proposed method is 0.1%, 0.8%, and 0.7% for Y, U, and V in AI-HE, respectively.

[JCTVC-G245](http://phenix.it-sudparis.eu/jct/doc_end_user/current_document.php?id=3498) Non-CE6a: Use of chroma phase in LM mode [E. François, C. Gisquet, S. Pautet (Canon)]

This contribution relates to the luma-based chroma prediction mode (LM mode) and consists of two proposals.

The first proposal generalizes the LM mode to handle generic chroma phase configurations. It consists of signaling in the SPS chroma phase information and to use this information in the luma interpolation process. The approach has been tested using new generated test sequences, corresponding to different chroma phase configurations. For the most favorable chroma phase configuration, average BD-rate gains of 0.5% AV\* (0.1% Y, 1.6% U, 1.7 % V) AIHE and 0.4% AV\* (0.1% Y, 1.5% U, 1.5% V) AILC are reported. For the least favorable chroma phase configuration, average gains of 0.2% AV\* (0% Y, 0.6% U, 0.7% V) AIHE and 0.2% AV\* (0% Y, 0.4% U, 0.4% V AILC) are reported. RA configuration benefits are also reported to be in same range. Gains up to 1.1% AV\* (0.3% luma, 5.6% chroma) are reported on high resolution sequence classes.

The second proposal intends to reduce the number of operations involved in the luma interpolation mainly by removing right shift operations in the luma filtering process. In total, (W.H+W+H) right shifts, 2W additions and W multiplications by 2 (or left shifts) are removed when LM mode is applied, with W and H being the chroma block width and height. The impact on coding efficiency is reportedly negligible for AI, RA and LD configurations.

\* *AV-BDR is obtained using the following PSNR: PSNRAV = (6\*PSNRY + PSNRU + PSNRV)/8*

### Information

[JCTVC-G511](http://phenix.it-sudparis.eu/jct/doc_end_user/current_document.php?id=3768) Performance Evaluation of Luma-based Chroma Intra Prediction [K. Sato (Sony)]

This document provides data on BD-performance on luma based chroma intra prediction. The original proposal JCTVC-E266 contains result with longer GOP as well as all-intra conditions, but in CE6 performances of related proposals are evaluated just with IT/IT\_Loco.

As simplification methods have been adopted, it is necessary to evaluate its performance once again not only with IT/IT\_Loco but with all conditions.

# Cross-check documents

[JCTVC-G117](http://phenix.it-sudparis.eu/jct/doc_end_user/current_document.php?id=3368) Non-CE6: Cross-verification of Huawei's Modifications to intra frame coding (JCTVC-G119) [K. Chono, H. Aoki (NEC)]

JCTVC-G676 Non-CE6: Crosscheck for Intel's Intra Chroma Prediction in JCTVC-G173 [M. Guo, X. Guo (MediaTek)] [late]

JCTVC-G646 Crosscheck of JCTVC-G244 - Luma-based chroma prediction - Model correction [M. Budagavi (TI)] [late]

JCTVC-G270 Non-CE6a: Cross-checking of JCTVC-G244 - Luma-based chroma prediction - Model correction [P.Bordes, P.Salmon (Technicolor)] [late]

JCTVC-G069 Cross-verification of KDDI's proposal on intra coding (JCTVC-G346) [Masaaki Matsumura, Shohei Matsuo, Seishi Takamura, Hirohisa Jozawa (NTT)]

JCTVC-G911 Cross verification of KDDI's Chroma intra prediction based on residual luma samples (JCTVC-G346) [Y. Chiu, W. Zhang, L. Xu, Y. Han (Intel)] [late]

JCTVC-G886 Cross-verification of ETRI's Inconsistency of intra LM mode between HM and WD (JCTVC-G419) [T. Lee, J. Chen, J. H. Park] [late]

[JCTVC-G273](http://phenix.it-sudparis.eu/jct/doc_end_user/current_document.php?id=3530) Crosscheck for JCTVC-G358 new modes for chroma intra prediction [J. Dong (InterDigital)] [late] [miss]

