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| *Title:* | **AHG9: On number of bits per LCU limit** | | |
| *Status:* | Input Document to JCT-VC | | |
| *Purpose:* | Proposal | | |
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# Abstract

This contribution advocates imposing number of bits per LCU constraint. It is recommended that for a LCU size of 2Nx2N the number of bits generated by the LCU shall not be greater than (128\*BitDepthY + Raw16x16CUBits)\* (N>>3)\*(N>>3), where Raw16x16CUBits is raw number of bits of a 16x16 CU. The proposed limit is about 28% higher than that of AVC for LCU size of 16x16, 8-bit 4:2:0 video. Experimental results for QP = 4 and 10 revealed that there was no single LCU exceeding the proposed limit in Main configurations; Likewise, there was no single LCU exceeding the proposed limit in HE configurations for QP = -2, and only fewer than 0.03% of the LCUs exceeding the limit in HE configurations with QP equal to -8. It is asserted that the proposed limit won’t impose significantly burden on the encoder side because the probability for a LCU to exceed the limit is extremely low, but can significantly lower decoder bitstream buffer size and the worst case clock-rate for real-time HEVC decoder implementation.

# Introduction

In H.264/AVC, a macroblock after compression cannot be greater than 400 bytes. Such a constraint is critical for real-time decoder implementation for two reasons:

* decoder needs to know the worst case macroblock size after compression so that it can allocate proper size to bitstream buffer that can buffer sufficient number of bits for decoding a macroblock in any case. Without the constraint the bitstream buffer can be much larger which increases the cost
* and large macroblocks in a picture create pipeline bubbles and can significantly slow down decoder speed. It is therefore important to constrain the macroblock size.

In HEVC such a constraint becomes more critical because HEVC can support LCU size 64x64, the large LCU sizes implies large bitstream buffer size (16x more for LCU size 64x64) and more sensitivity to the pipeline bubbles. Study shows that in HEVC a LCU can expand by ~7.4x if LCU size is not capped. Such an expansion will create significant burden for decoder implementation due to huge bitstream buffer size and pipeline bubbles. It is therefore recommended to impose number of bits per LCU constraint in HEVC**.**

# Proposed limit

It is proposed to impose the following limit across all the profile and levels

*For a LCU of 2Nx2N size, the number of bits generated by the LCU shall not be greater than (N>>3)\*(N>>3)\*(*128\*BitDepthY *+ Raw16x16CUBits).*

Where *Raw16x16CUBits is raw number of bits for a 16x16 CU. For example, for 8-bit 4:2:0 Raw16x16CUBits = 8\*384 bits.*

The proposed limit is about 28% higher than that of AVC for LCU size 16x16, 8-bit 4:2:0 video, aimed to reduce the burden for an encoder to conform. Note that increasing the limit will in the meantime decrease the worst case decoder throughput and increase decoder bitstream buffer size.

With the proposed limit, the number of bins per 16x16 is implicitly bounded to 512\*1.3 for 8-bit 4:2:0 video.

# Test Settings and Conditions

The simulations of this document have used HM7.0 software, the simulation platform is LSF equipped with Intel(R) Xeon(R) CPU X5570 64 bits Linux machines of different frequencies, the common test conditions and reference configurations specified in [1] were followed, except for QPs. In the simulation, QP = 4, 10 and QP = -8, -2 were used for Main and HE10 configurations respectively. For Main configurations the number of bits per LCU limit was set to 4096, 16384, and 65536 bits for LCU size 16x16, 32x32 and 64x64, respectively. Likewise, for HE10 configurations the number of bits per LCU limit was set to 5120, 20480, and 81920 bits for LCU size 16x16, 32x32 and 64x64, respectively.

# Experimental results

The experimental results are summarized in Table 1 to Table 4. The proposed limit is proven to be appropriate for addressing implementation concerns from both encoder and decoder sides. For typical high bit-rate setting of QP 10 for Main and QP -2 for HE10, none of LCUs exceeds the limit for LCU size 16x16, 32x32 and 64x64; for extreme high bit-rate setting of QP 4 for Main and QP -8 for HE10, only few LCUs (up to 0.03%) exceed the limit in HE10 configurations of LCU size 16x16 and 32x32 (see Table 4).

As shown in Table 1 and Table 2, for large LCU size 32x32 and 64x64 the proposed limit provides enough margins for encoder to conform.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| QP=4 | Cfg | max total bins per LCU | | | max total bits per LCU | bins/bits ratio | max bitrate (Mbps) | number of LCU greater than limit | % of LCU that exceed limit | margin relative to limit |
| **Max** |  | total | context | bypass |  |  |  |  |  |  |
| LCU16 | AI\_MAIN | 3589 | 790 | 2798 | 3136 | 1.14 | 1152 | 0 | 0.00% | 23.44% |
|  | RA\_MAIN | 3620 | 795 | 2824 | 3144 | 1.15 | 1047 | 0 | 0.00% | 23.24% |
|  | LB\_MAIN | 3628 | 797 | 2830 | 3088 | 1.17 | 429 | 0 | 0.00% | 24.61% |
| LCU32 | AI\_MAIN | 13437 | 3065 | 10422 | 11392 | 1.18 | 1127 | 0 | 0.00% | 30.47% |
|  | RA\_MAIN | 13384 | 3093 | 10403 | 11400 | 1.17 | 1014 | 0 | 0.00% | 30.42% |
|  | LB\_MAIN | 13262 | 3059 | 10268 | 11256 | 1.18 | 427 | 0 | 0.00% | 31.30% |
| LCU64 | AI\_MAIN | 39765 | 12122 | 27642 | 32536 | 1.22 | 1127 | 0 | 0.00% | 50.35% |
|  | RA\_MAIN | 39312 | 12165 | 27539 | 32720 | 1.20 | 1013 | 0 | 0.00% | 50.07% |
|  | LB\_MAIN | 38124 | 12200 | 25971 | 31640 | 1.20 | 427 | 0 | 0.00% | 51.72% |

Table 1. Experimental results for Main configurations with QP = 10

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| QP=-2 | Cfg | max total bins per LCU | | | max total bits per LCU | bins/bits ratio | max bitrate (Mbps) | number of LCU greater than limit | % of LCU that exceed limit | margin relative to limit |
| LCU16 | AI\_HE10 | 4870 | 836 | 4035 | 4232 | 1.15 | 1880 | 0 | 0.00% | 17.34% |
|  | RA\_HE10 | 4869 | 837 | 4037 | 4176 | 1.17 | 1817 | 0 | 0.00% | 18.44% |
|  | LB\_HE10 | 4344 | 858 | 3485 | 3808 | 1.14 | 853 | 0 | 0.00% | 25.63% |
| LCU32 | AI\_HE10 | 17517 | 3212 | 14336 | 15392 | 1.14 | 1839 | 0 | 0.00% | 24.84% |
|  | RA\_HE10 | 16386 | 3201 | 13312 | 14232 | 1.15 | 1775 | 0 | 0.00% | 30.51% |
|  | LB\_HE10 | 15685 | 3159 | 12534 | 13160 | 1.19 | 843 | 0 | 0.00% | 35.74% |
| LCU64 | AI\_HE10 | 59975 | 12577 | 47832 | 50008 | 1.20 | 1835 | 0 | 0.00% | 38.96% |
|  | RA\_HE10 | 60119 | 12678 | 47834 | 50664 | 1.19 | 1771 | 0 | 0.00% | 38.15% |
|  | LB\_HE10 | 58424 | 12691 | 45736 | 48592 | 1.20 | 842 | 0 | 0.00% | 40.68% |

Table 2. Experimental results for HE10 configurations with QP = -2

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| QP=10 | Cfg | max total bins per LCU | | | max total bits per LCU | bins/bits ratio | max bitrate (Mbps) | number of LCU greater than limit | % of LCU that exceed limit | margin relative to limit |
| **Max** |  | total | context | bypass |  |  |  |  |  |  |
| LCU16 | AI\_MAIN | 4473 | 793 | 3679 | 3992 | 1.12 | 1641 | 0 | 0.00% | 2.54% |
|  | RA\_MAIN | 4446 | 815 | 3659 | 3992 | 1.11 | 1506 | 0 | 0.00% | 2.54% |
|  | LB\_MAIN | 4417 | 805 | 3638 | 3944 | 1.12 | 645 | 0 | 0.00% | 3.71% |
| LCU32 | AI\_MAIN | 16788 | 3074 | 13767 | 14568 | 1.15 | 1640 | 0 | 0.00% | 11.08% |
|  | RA\_MAIN | 16855 | 3109 | 13828 | 14616 | 1.15 | 1498 | 0 | 0.00% | 10.79% |
|  | LB\_MAIN | 16524 | 3141 | 13528 | 14320 | 1.15 | 643 | 0 | 0.00% | 12.60% |
| LCU64 | AI\_MAIN | 49419 | 12221 | 37197 | 40512 | 1.22 | 1640 | 0 | 0.00% | 38.18% |
|  | RA\_MAIN | 48928 | 12415 | 36774 | 40696 | 1.20 | 1497 | 0 | 0.00% | 37.90% |
|  | LB\_MAIN | 47974 | 12477 | 35704 | 39608 | 1.21 | 643 | 0 | 0.00% | 39.56% |

Table 3. Experimental results for Main configurations with QP = 4

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| QP=-8 | Cfg | max total bins per LCU | | | max total bits per LCU | bins/bits ratio | max bitrate (Mbps) | number of LCU greater than limit | % of LCU that exceed limit | margin relative to limit |
| LCU16 | AI\_HE10 | 6210 | 790 | 5433 | 5616 | 1.11 | 2401 | 401 | 0.03% | -9.69% |
|  | RA\_HE10 | 6519 | 780 | 5791 | 5928 | 1.10 | 2310 | 207 | 0.01% | -15.78% |
|  | LB\_HE10 | 6076 | 795 | 5304 | 5504 | 1.10 | 1092 | 11 | 0.00% | -7.50% |
| LCU32 | AI\_HE10 | 23360 | 3044 | 20357 | 20824 | 1.12 | 2364 | 2 | 0.00% | -1.68% |
|  | RA\_HE10 | 23769 | 3015 | 20783 | 21344 | 1.11 | 2279 | 8 | 0.00% | -4.22% |
|  | LB\_HE10 | 22784 | 3131 | 19678 | 20656 | 1.10 | 1084 | 1 | 0.00% | -0.86% |
| LCU64 | AI\_HE10 | 75259 | 12179 | 63543 | 65232 | 1.15 | 2361 | 0 | 0.00% | 20.37% |
|  | RA\_HE10 | 76609 | 12249 | 65279 | 66904 | 1.15 | 2275 | 0 | 0.00% | 18.33% |
|  | LB\_HE10 | 74721 | 12361 | 62688 | 64256 | 1.16 | 1083 | 0 | 0.00% | 21.56% |

Table 4. Experimental results for HE10 configurations with QP = -8

# Conclusions

# The proposed bits per LCU limit is appropriate for addressing implementation concerns from the both encoder and decoder sides, it is recommended to adopt the proposed limit into HEVC.

# References

[1] F. Bossen, “Common test conditions and software reference configurations,” JCT-VC Document, JCTVC-I1100, 9th Meeting: Geneva, Switzerland, 27 April – 07 May, 2012

[2] [B. Bross](mailto:benjamin.bross@hhi.fraunhofer.de), [W.-J. Han](mailto:wjhan.han@samsung.com), [J.-R. Ohm](mailto:ohm@ient.rwth-aachen.de), [G. J. Sullivan](mailto:garysull@microsoft.com), [T. Wiegand](mailto:thomas.wiegand@hhi.fraunhofer.de) “High Efficiency Video Coding (HEVC) text specification draft 7,” JCT-VC Document, JCTVC-I1003, 9th Meeting: Geneva, Switzerland, 27 April – 07 May, 2012.

# Patent rights declaration(s)

**Texas Instruments, Inc. does not have IPR relating to the technology described in this contribution and, conditioned on reciprocity.**

# CD text

A.3.2 Main profile (changes are marked in yellow)

Bitstreams conforming to the Main profile shall obey the following constraints:

* Sequence parameter sets shall have chroma\_format\_idc equal to 1 only.
* Sequence parameter sets shall have bit\_depth\_luma\_minus8 equal to 0 only.
* Sequence parameter sets shall have bit\_depth\_chroma\_minus8 equal to 0 only.
* Sequence parameter sets shall have adaptive\_loop\_filter\_enabled\_flag equal to 0 only.
* Sequence parameter sets shall have chroma\_pred\_from\_luma\_enabled\_flag equal to 0 only.
* Sequence parameter sets shall have inter\_4x4\_enabled\_flag equal to 0 only.
* Sequence parameter sets shall have asymmetric\_motion\_partitions\_enabled\_flag equal to 0 only.

[Ed. (KM): Confirm that this flag has been defined. (GJS): It is now in the SPS, but not yet connected to the decoding process.]

* Sequence parameter sets shall have nsrqt\_enabled\_flag equal to 0 only.
* Sequence parameter sets shall have seq\_parameter\_set\_id in the range of 0 to 15, inclusive.
* Log2CtbSize shall be in the range from 4 to 6, inclusive.
* SliceGranularity shall be equal to 0.
* Picture parameter sets shall have tiles\_or\_entropy\_coding\_sync\_idc in the range of 0 to 1, inclusive.
* Picture parameter sets shall have dependent\_slice\_enabled\_flag equal to 0.

Number of bits generated by a coded tree block shall not be greater than 512\*(bit\_depth\_luma\_minus8 + 8) \*( 1 << (Log2CtbSize- 4))\*( 1 << (Log2CtbSize- 4)).

* When tiles\_or\_entropy\_coding\_sync\_idc is equal to 1, ColumnWidthInLumaSamples[ i ] shall be greater than or equal to 384 for any i in the range of 0 to num\_tile\_columns\_minus1, inclusive.

[Ed. (KM): Confirm that this is the best formulation]

* Picture parameter sets shall have pic\_parameter\_set\_id in the range of 0 to 63, inclusive.
* Adaptation parameter sets shall have aps\_id in the range of 0 to 63, inclusive.
* The level constraints specified for the Main profile in subclause shall be fulfilled.

Conformance of a bitstream to the Main profile is indicated by profile\_idc being equal to 1.

Decoders conforming to the Main profile at a specific level (identified by a specific value of level\_idc) shall be capable of decoding all bitstreams in which the profile\_idc is equal to 1 and level\_idc represents a level lower than or equal to the specified level. For purposes of comparison of level capabilities, a particular level shall be considered to be a lower level than some other level if the level\_idc of the particular level is less than the level\_idc of the other level.