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| **Joint Collaborative Team on Video Coding (JCT-VC)**  **of ITU-T SG16 WP3 and ISO/IEC JTC1/SC29/WG11**  7th Meeting: Geneva, CH, 21-30 November, 2011 | Document: JCTVC-G719 |

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| *Title:* | **Structured Level Limits** | | |
| *Status:* | Input Document to JCT-VC | | |
| *Purpose:* | Proposal | | |
| *Author(s) or Contact(s):* | Louie Kerofsky, Andrew Segall, Kiran Misra 5750 Pacific Rim Blvd Camas, WA 98607 USA  ElenaAlshina  AlexanderAlshin,  #416 Matean 3-dong, Yeongtong-gu, Suwon-si, Gyeonggi-do, 443-742, Korea | Tel: Email: | +1 360 817 9451  [lkerofsky@sharplabs.com](mailto:lkerofsky@sharplabs.com)  [asegall@sharplabs.com](mailto:asegall@sharplabs.com)  [misrak@sharplabs.com](mailto:misrak@sharplabs.com)  [elena\_a.alshina@samsung.com](mailto:elena_a.alshina@samsung.com)  [alexander\_b.alshin@samsung.com](mailto:alexander_b.alshin@samsung.com) |
| *Source:* | Sharp Laboratories of America & Samsung Electronics, Ltd. | | |

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# Abstract

This proposal introduces limits on the quantization levels. These levels vary with QP parameter and transform size. It is asserted that these limits ensure the dequantized coefficient does not exceed 16-signed bits in dynamic range. A formula defines the limits from 6 basic values using the QP and transform size parameters used in dequantization. The limits are proposed for use in clipping decoded levels to the range specified by the limits and removing the clipping following dequantization It is additionally proposed to place a limit on the maximum absolute value of level independent of QP and block size.

# Introduction

The work in JVCVC-F257 [1] described a process an encoder could use to restrict the dequantized coefficients at the decoder to less than 16-bits. This method is adapted to define constraints on the level values in a bitstream restricting the dequantized coefficients to 16-bits. The structure of the limits is exploited to define a representation requiring only multiplies and bitshifts.

Recall the definitions of dequantization used in HM 4.0 and given in JCTVC-E243 [2].

**Definitions**

B = source bit width (8 or 10 bit in the experiments described below)

DB = B-8 (internal bit-depth increase with 8-bit input)

N = transform size

M = log2(N)

Q = f(QP%6), where f(x) = {26214,23302,20560,18396,16384,14564}, x=0,…,5

IQ = g(QP%6), where g(x) = {40,45,51,57,64,72}, x=0,…,5

coeffQ = ((level\*IQ << (QP/6)) + offset)>>(M-1+DB), offset = 1<<(M-2+DB)

The derivation in JVCVC-257 determined bounds on the level data which guarantee 16-bits is not exceeded in dequantization. These limits depend upon QP and transform size parameter used in dequantization. The formula is repeated below:

iMax(QP,N) = MAX\_C \* 2 (log2N-1 – iQP/6 ) / g\_auiIQ[QP%6]; where g\_auiIQ = {40,45,51,57,64,72}; MAX\_C = 32767and N is the transform size used in dequantization. These limits were proposed for an encoder to limits its output and did not provide any normative limitation. As such these could be used by an encoder to satisfy a dynamic range constraint on coefficient data if such constraint were in place.

# Necessity of restricting dequantized coefficient data.

It has been discussed if clipping is following the dequantization process to ensure that coefficient data does not exceed 16 signed bits. We observed that for some quantizers and residual data, coefficient data resulting from forward and inverse quantization may exceed 16-bits. As an example, consider a 4x4 block (M=2) of residual all 255 and nearest neighbor quantization. The forward transform results in a block of coefficients with a DC coefficient value of coeff = 32640. Using nearest neighbor quantization with QP=27 results in level=72. Dequantize level to obtain coeffQ as coeffQ =32832. The clipping operation following the dequantization process prevents this extreme coefficient from entering the inverse transfrom process. This example does not occur if the method of JCTVC-F257 is applied since iMax(27,4) =71 causing the level to be reduced.

An additional obsevation is that for 10-bit source at fine QP, the maximum level achieving a 16-bit coefficient exceeds 16-bits, level=52424. This would require a multiplier during dequantization to support more than 16-bit input which is undesired.

# Proposed level limits

The level limits described above can be expressed in the following form:

iMax(QP,N) = (MAX\_C / g\_auiIQ[QP%6] )\*2 (log2N-1)/2iQP/6

In JCTVC-F257, these limits are derived using the condition that the dequantized coeficient does not exceed MAX\_C in magnitude. The presence of division may complicate the use of this formula in pracitce.

This can be compactly written in a structured form without division as:

LevelBound (QP,M) =LB[QP%6]>>(M-5+QP/6) (1)

where LB(x) = {13106,11650,10279,9197,8191,7281} for x=0,1,2,3,4,5

(A supporting excel sheet shows the equaltiy of the limits for all QP and block sizes)

These limits were previoulsy shown not to impact coding performanace. The parameter occuring as the block size in this formula is the parameter used in dequantization. Thus with the nonsquare transform N1xN2 the appropriate parameter should be used i.e. M=(log2(N1)+log2(N2))/2 [3]

Extension to accommodate higher internal bit-depth is straightforward by replacing modifying the value of L32x3by the factor of (1<<DB-8) in the formula above.

In addition to limiting the magnitude of dequantized coefficients, the bit-width used during dequantization is lower than placing the clip following the dequantization process. For a given block size, the level bound halves each time the QP value increase by six. For each block size M, consider two approaches to limiting the levels. In the first approach, a single limit on the level is assumed for all QP. In this case, the level should be large enough to support the level value which occurs at finest QP. The bits needed for dequantization are shown in the second row of Table 1 and occur when this highest level is combined with the largest QP value. In the second approach, a limit on the level varies with QP according to the proposal. In this case, as the step size doubles, the maximum level is halved. The bits needed for dequantization are show in the second row of table 1. The number of bits needed for dequantization is reduced by 9 when using QP based limits on levels.

Table Dequant bit requirement (QP 0 through 51)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Transform size (M) | 4 | 8 | 16 | 32 |
| Bits for Dquant  (single level limit) | 26 | 27 | 28 | 29 |
| Bits for Dquant  (QP based level limit) | 17 | 18 | 19 | 20 |

# Use of structured level limits

## Two concepts.

Two concepts for the use of the structured level limits are presented. The first, is for bounding levels within a conforming bitstream. The second is for replacing the clipping following dequantization with clipping of the level data prior to dequantization.

## Encoder constraints

The level limits (1) may be used to define a conformant bitstream. These limits ensure that a conforming bitstream does not exceed the desired bound, MAX\_C=32767 in this derivation, following dequantization. A statement of the form below together with the definition of the LevelBound as described in this proposal would be needed:

“A bitstream conforming to this Recommendation | International Standard shall not contain data that results in any element level that exceeds the range of integer values from LevelBound(QP,M), inclusive.”

## Clipping levels

The level level limits are proposed for use in processing the decoded coefficient data. The levels in the bitstream are restricted by a single bound independent of block size and QP. The value 13104 is sufficient for the extreme case of transform block size 32 and lowest QP=0 for 8-bit source operation. When the source bit-depth is increase to 10, the largest level value in this extreme case is 52416, which exceeds 16-signed bits. This provides a uniform bound to the entropy decoder for all coefficient data. Following, decoding a level value, the value is clipped to a range determined by the LevelBound(QP,M). The clipped value is then provided to the dequantization process. The clipping is applied to the absolute value of the level before the sign is applied simplifying the clipping process since there are no negative values. The sign is applied later.

* Entropy decode of level given transform size to get absolute level and sign.
* Compute LevelBound(QP,M) as defined in this proposal.
* Clip absolute level to specified range
* Apply dequantization process with modified absolute level and sign.

level = sign(level)\*clip(abs(level),LevelBound (QP,M))

Related to the coefficient dynamic range prior to the 1st inverse transform, the only bitstream conformance requirement is that the levels in the bitstream satisfy a single bound independent of QP. The clipping operation guarantees the dynamic range of the quantities seen by the dequantization and the 1st inverse transform regardless of the bitstream contents thus, clipping following the dequant process is replaced by clipping the decoded levels depending upon QP and transform size. The design is robust eliminating all concern of who and how made bit-stream. This also minimizes the bits needed during dequantization.

# Conclusions

We propose using the structured level limits to clip levels prior to dequantization removing the clip following dequantization. This normatively limits the dynamic range of coefficient data and reduces the number of bits needed for dequantization.

A supporting document provides proposed text. Note exact text depends on the details of transform and dequantization design but the basic method is illustrated by an example.

# References

1. A.Alshin E.Alshina, “About clip operation removal from de-quantization part of HM”, JCTVC-F257, Torino, IT, 14-22 July, 2011.
2. A. Fuldseth, G. Bjøntegaard, M. Sadafale, M. Budagavi, “Transform design for HEVC with 16 bit intermediate data representation” JCTVC-E243, Geneva, Switzerland, March 2011.
3. Y. Tsinghua et al. “CE2: Non-Square Quadtree Transform for symmetric and asymmetric motion partition”, JCTVC-F412, Torino, IT, 14-22 July, 2011.

# Patent rights declaration(s)

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