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| *Title:* | **Structured Level Limits** | | |
| *Status:* | Input Document to JCT-VC | | |
| *Purpose:* | Proposal | | |
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# Abstract

This proposal introduces limits on the quantization levels for a conforming bitstream. 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 defining conformance. Clipping the limits to the range specified by the limits and removing the clipping following dequantization is proposed.

# 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.

As a note 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.

# 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

A slightly lower bound can be expressed with fixed point opeartions by:

LevelBound (QP,M) = (floor(MAX\_C / g\_auiIQ[QP%6] )<<(M-1))>>(QP/6)

This can be compactly written in a structured form as:

LevelBound (QP,M) =(L4[QP%6]<<(M-1))>>(QP/6) (1)

where L4(x) =floor(MAX\_C/ g\_auiIQ(x)) = {819,728,642,574,511,455} for x=0,1,2,3,4,5

The structured limits are always less than the level limits defined before but nearly the same. For M=2 i.e. 4x4 block size, they differ by one only at QP=8 or 9 and are identical otherwise. For QP above 22 they are identical for all blocks sizes. (See provided an excel sheet showing this difference for all QP and block sizes)

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 M-1 by M-1+DB 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 example, assume for each block size, the levels are limited to below the highest level value achieving a 16-bit coefficient following dequantization with any QP (Single level limit in the table below). Compare this to limits on the level which vary with QP in addition to transform block size (QP based level limit in table below); the number of bits needed for dequant calculation using these bounds are presented in the table below. Proportionally to bit-width of input data h/w cost (G/C) of de-quantization process will be reduced.

Table Dequant bit requirement

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Transform size | 4 | 8 | 16 | 32 |
| Bits for Dquant  (single level limit) | 25 | 26 | 27 | 28 |
| 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 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. 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 can be 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 this consists of the following aspects:

1. Remove the clipping process currently used following dequantization.
2. Define a single limit on maximum level appropriate for all QP and transform sizes. Currently a value of 13104 is appropriate but the specific value will depend on the final dequantization and transform design. It may be desirable to express this limit as the nearest power of 2 since the design is robust to this choice.
3. Define the level limits based on QP and transform size as:

LevelBound (QP,M,DB) =(L4[QP%6]<<(M-1+DB))>>(QP/6) where L4(x) = {819,728,642,574,511,455} for x=0,1,2,3,4,5 QP is the quantization parameter and M=log2(N) where N is the transform size. Correct specification of this parameter for NSQT must be done.

1. Define the clipping process occurring before the dequantization process so that the levels are clipped to the range specified by the bound: level = sign(level)\*clip(abs(level),LevelBound (QP,M))

# 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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