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| *Title:* | Dequantization with symmetric reconstruction points. | | |
| *Status:* | Input Document to JCT-VC | | |
| *Purpose:* | Proposal | | |
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# Abstract

This contribution notes that the dequantization formula currently used in HM 4 has the property that the reconstructed values are not always symmetrically distributed about zero. A modification to the dequantization formula is proposed which creates reconstructed values symmetrically distributed about zero under all conditions. The modified dequantization process operates on the absolute value of levels and then applies the sign rather than operating on signed levels. For quantization parameters of the common test conditions, the dequantization results are unchanged for any level or block size.

# Introduction

The dequantization formula presently used in HM is based on JCT-VC-E243 [1]. This formula is summarized below:

**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)

We note that this dequantization formula creates reconstruction values which are not symmetrically distributed about the zero value. That is there are levels where dequant(-|level|) and –dequant(|level|) differ. This happens when the term level\*IQ << (QP/6)) is not divisible by 2^(M-1+DB). This condition depends on block size, QP value and level value. Note that for QP>23, QP/6 is greater than four so that this condition is satisfied for all levels and block sizes (when DB=0). When QP=22, QP%6 = 4 so that IQ=64 and the condition is satisfied for all levels and block sizes. Hence for the common test conditions this asymmetry does not occur. An example of the asymmetry of reconstruction values corresponding to QP=1 and various values of |level| and block size is shown below. Pairs of reconstructed values which are not symmetric are highlighted. Additional examples of reconstruction points are given in the appendix with nonsymmetric pairs highlighted.

Example pairs of reconstruction points for QP=1, |level|<9 and block sizes 4x4, 8x8, 16x16 and 32x32.

|level| 4 8 16 32

1 -22 23 -11 11 -6 6 -3 3

2 -45 45 -22 23 -11 11 -6 6

3 -67 68 -34 34 -17 17 -8 8

4 -90 90 -45 45 -22 23 -11 11

5 -112 113 -56 56 -28 28 -14 14

6 -135 135 -67 68 -34 34 -17 17

7 -157 158 -79 79 -39 39 -20 20

8 -180 180 -90 90 -45 45 -22 23

This formula uses an additive offset of ½ during dequantization with the result that most of the reconstruction points are symmetric about zero. If the offset value is varied and this formula is used directly, the reconstructed points all move in the same direction rather than toward or away from the zero.

# Changes in Dequantization offset

The dequantizaiton design discussed above uses an additive offset prior to a right shift to control rounding of the reconstructed value. The offset used above is independent of the level value and is equivalent to the value ½ which results in rounding to the nearest integer when combined with the right shift. With the offset of ½, the reconstructed points are nearly symmetric about zero with a few exceptions. It has been shown that coding can be improved by adapting the dequantization process in particularly by varying the rounding offset used with dequantization for example [3], [4], and [5] among others. In the development of these methods, the offset is typically a fraction of the quantization bin size and the reconstructed points are symmetrically distributed about zero. Tthe rounding offset influencing the position of the first non-zero reconstructed value. For illustration, we repeat the dequantization form presented in equation (1) of JVT-N011 [3] .

*R*[ *k* ] = sign( *k* ) \* *s \** ((|*k|* + *p*) (1)

Where *p* is the reconstruction offset, k is the quantization level, and s is the quantization step size. Similar results are used by the other references. An important observation is that the sign of the reconstruction point equals the sign of the level and the absolute value of the reconstruction point depends only on the absolute value of the quantization level. As a result, the reconstruction points has the symmetry R[-k] = -R[k]. The reconstruction points move toward or away from zero as the offset value is changed. If the value of the offset is changed in the dequantization formula of JCTVC-E243, the reconstructed points move in the same direction either toward or away from positive infinity.

# Proposed dequantization formula

A change to the dequantization formula can eliminate this asymmetry by separating the sign and magnitude as shown in the dequantization formula shown below:

Equation 1Proposed dequantization formula

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



In this expression, Sgn(0) = 0 unlike the definition of Sign() in the HEVC working draft [2] where Sign(0)=1. Clearly the reconstructed coefficients are symmetrically distributed about zero. Since the sign and absolute value are signaled individually, efficient use of this formula is possible by operating directly on these individual quantities rather than combining them and needing to separate them for dequantization.

Observe that for the QP in the common conditions, QP= {22, 27, 32, 37}, the proposed dequantization formula gives identical results to the present expression. If QP={22,27,32,37} the term IQ<<(QP/6) is always divisible by 2^4 since QP%6 and QP/6 take the values {4,3,2,1} and {3,4,5,6} respectively. Since the right shift by (M-1) is at most 4, the equality of the original and proposed dequantization formula follows. With the proposed formula, the offset can be adjusted and maintain the symmetric property of the reconstruction points. Appropriate text for this proposal based on the current working draft is in a supporting document.

# Multiplier requirements in Dequant

We examine the multiplier bit-depth needed in the existing and proposed dequantization designs. Note that the largest level value occurs with QP=0, 10-bit source i.e. DB=2, and 32x32 block size i.e. M=5. In this case, the level value has absolute value 52424. Note that this value requires 17-bits including sign but requires only 16-bits for an unsigned representation. Dequantization using the current design uses the signed level requiring a multiplication of the signed level value and the IQ value. The multiplier must support signed input requiring 17-bits. In the proposed design, the dequantization process operates on the absolute value of the level and applies the sign to the final result. As a result, an unsigned 16-bit multiplication is used during dequantization. A 17-bit multiplier is typically unavailible to a SW implementation forcing the use of a 32-bit signed multiplier rather than a 16-bit unsigned multiplier during dequantization.

# References

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# Patent rights declaration(s)

**SHARP may have current or pending patent rights relating to the technology described in this contribution and, conditioned on reciprocity, is prepared to grant licenses under reasonable and non-discriminatory terms as necessary for implementation of the resulting ITU-T Recommendation | ISO/IEC International Standard (per box 2 of the ITU-T/ITU-R/ISO/IEC patent statement and licensing declaration form).**

# Appendix

Additional pairs of reconstruction points are shown for QP values in the range 0-5 and values of |level| with absolute value less than 9. Pairs which are not symmetric are highlighted.

Example reconstruction points for QP=0

|level| 4 8 16 32

1 -20 20 -10 10 -5 5 -2 3

2 -40 40 -20 20 -10 10 -5 5

3 -60 60 -30 30 -15 15 -7 8

4 -80 80 -40 40 -20 20 -10 10

5 -100 100 -50 50 -25 25 -12 13

6 -120 120 -60 60 -30 30 -15 15

7 -140 140 -70 70 -35 35 -17 18

8 -160 160 -80 80 -40 40 -20 20

Example reconstruction points for QP=1

|level| 4 8 16 32

1 -22 23 -11 11 -6 6 -3 3

2 -45 45 -22 23 -11 11 -6 6

3 -67 68 -34 34 -17 17 -8 8

4 -90 90 -45 45 -22 23 -11 11

5 -112 113 -56 56 -28 28 -14 14

6 -135 135 -67 68 -34 34 -17 17

7 -157 158 -79 79 -39 39 -20 20

8 -180 180 -90 90 -45 45 -22 23

Example reconstruction points for QP=2

|level| 4 8 16 32

1 -25 26 -13 13 -6 6 -3 3

2 -51 51 -25 26 -13 13 -6 6

3 -76 77 -38 38 -19 19 -10 10

4 -102 102 -51 51 -25 26 -13 13

5 -127 128 -64 64 -32 32 -16 16

6 -153 153 -76 77 -38 38 -19 19

7 -178 179 -89 89 -45 45 -22 22

8 -204 204 -102 102 -51 51 -25 26

Example reconstruction points for QP=3

|level| 4 8 16 32

1 -28 29 -14 14 -7 7 -4 4

2 -57 57 -28 29 -14 14 -7 7

3 -85 86 -43 43 -21 21 -11 11

4 -114 114 -57 57 -28 29 -14 14

5 -142 143 -71 71 -36 36 -18 18

6 -171 171 -85 86 -43 43 -21 21

7 -199 200 -100 100 -50 50 -25 25

8 -228 228 -114 114 -57 57 -28 29

Example reconstruction points for QP=4

|level| 4 8 16 32

1 -32 32 -16 16 -8 8 -4 4

2 -64 64 -32 32 -16 16 -8 8

3 -96 96 -48 48 -24 24 -12 12

4 -128 128 -64 64 -32 32 -16 16

5 -160 160 -80 80 -40 40 -20 20

6 -192 192 -96 96 -48 48 -24 24

7 -224 224 -112 112 -56 56 -28 28

8 -256 256 -128 128 -64 64 -32 32

Example reconstruction points for QP=5

|level| 4 8 16 32

1 -36 36 -18 18 -9 9 -4 5

2 -72 72 -36 36 -18 18 -9 9

3 -108 108 -54 54 -27 27 -13 14

4 -144 144 -72 72 -36 36 -18 18

5 -180 180 -90 90 -45 45 -22 23

6 -216 216 -108 108 -54 54 -27 27

7 -252 252 -126 126 -63 63 -31 32

8 -288 288 -144 144 -72 72 -36 36