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Title: A TRICK FOR THE LAST NON-ZERO

In the Reference Model no 2 quantized and scanned transform indeces are coded with a single VLC. This VLC includes an end-of-block word, transmitted after the last non-zero, such that all high frequency zeroes need not be transmitted.

It is possible to save approximately one bit per coded block, by using a modified VLC for the last non-zero after scanning. In this VLC the code words for EOB and zero are removed such that other code words are shorter.

The trick consists in transmitting the EOB-word BEFORE the last non-zero instead of after. The new meaning of the word will then be "only one component left in the block, which is a non-zero". With this trick it is possible to use another VLC for the last component.

VLC1 is used in the reference model with code word number 1 for zero level and code word number 2 for EOB, see Table 1. It is proposed to use VLC1 for all components except for the last non-zero.

It is possible to use a VLC with the same code word set also for the last non-zero. The interpretation of the code word numbers are then changed as in VLC2. The gains over the reference model for different values of the last non-zero index are:

Index	Gain
+ 1	2 bits
- 1	0 bits
+/-2	2 bits
+/-3 - +/-6	1 bit
+/-7	7 bits
all other	0 bits

It should be noted that other variable length code tables, different from that in VLC2, exist which give slightly larger gain. However, the introduction of a second code word set is not considered worthwhile because of the disadvantages of reduced error resilience and increased hardware complexity.

A slight problem arises for blocks coded "intra".
For these blocks the DC component is coded with a 9 bit FLC.
If an intra block has only DC component (which is always transmitted) and only zero AC components, the obvious thing to do is to transmit the EOB word before the 9 bit FLC word. However, as the 3 bit EOB word is part of the beginning of the 9 bit FLC word this is not possible.

One solution to this problem is to exclude all 9 bit FLC words starting with the EOB word (001). This corresponds to decreasing the number of possible DC values from 512 to 448. The dynamic range of Y is 16-235 (U,V is 16-240); thus the dynamic range of DC transform coefficients is 128-1880 (128-1920). 448 levels is then enough to use stepsize 4.
An alternative solution is to not use this technique on intra coded blocks.

To clarify the procedure of transmission, a few examples are given below:

Scanned data to transmit (X=non-zero)	X 0 0 X 0 X dc	0 X dc	X dc
Codes used when INTER	5 word VLC1 3 bits EOB 1 word VLC2	1 word VLC1 3 bits EOB 1 word VLC2	3 bits EOB 1 word VLC2
Codes used when INTRA	9 bits FLC 4 word VLC1 3 bits EOB 1 word VLC2	9 bits FLC 3 bits EOB 1 word VLC2	3 bits EOB 9 bits FLC

Proposal
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The end-of-block word should be transmitted before the last non-zero. A modified interpretation of the VLC set, with no code words allocated for zero level and end-of-block, is used for the last non-zero.

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code word number	code word	length	quantizer level number. VLC1	VLC2
1	1	1	0	+1
2	001	3	EOB	-1
3	010	3	+1	+2
4	011	3	-1	-2
5	00010	5	+2	+3
6	00011	5	-2	-3
7	000010	6	+3	+4
8	000011	6	-3	-4
9	0000010	7	+4	+5
10	0000011	7	-4	-5
11	00000010	8	+5	+6
12	00000011	8	-5	-6
13	000000010	9	+6	+7
14	000000011	9	-6	-7
15	0000000010000001	16	-7	-8
16	0000000010000010	16	+7	+8
.	.	.		
.	.	.		
39	0000000010111111	16	-19	-20
40	0000000011000000	16	+19	+20
.	.	.		
.	.	.		
137	0000000011111011	16	-68	-69
138	0000000011111100	16	+68	+69
139	0000000011111101	16	-69	---
140	0000000011111110	16	+69	---

Table 1. VLC for quantized and scanned transform indeces.
VLC1 - before last non-zero
VLC2 - for the last non-zero

Comment: The code words are constructed such that 0 in the last bit corresponds to positive values and 1 in the last position corresponds to negative values. However, this does not apply to +1 in VLC2.

Comment: With the current quantizer in the reference model, the quantizer level number +1 corresponds to the reconstruction level +2g etc.