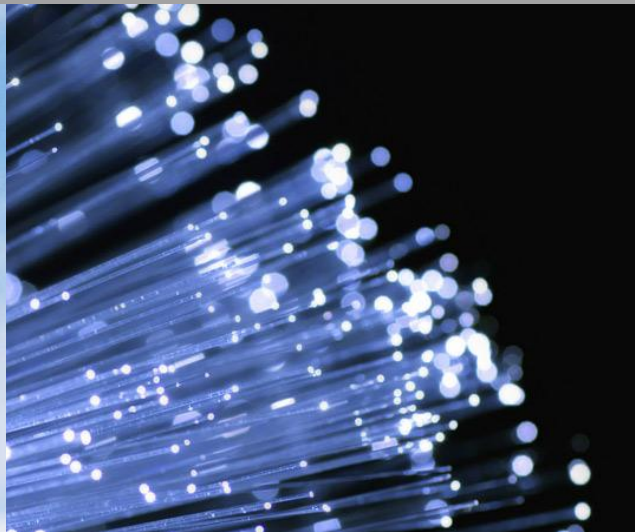


# Reduced-complexity entropy coding of transform coefficient levels using a combination of VLC and PIPE

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- **Proposal deals with entropy coding of transform coefficient levels in HE case**
- **Reduction of computational complexity by**
  - Increasing the number of bins of bypass mode
  - Guaranteeing a much tighter worst case limit on the number of bins per pixel in the worst case

## Overview

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2. **Proposed Scheme**
3. **RD Performance**
4. **Complexity**
5. **Conclusion**

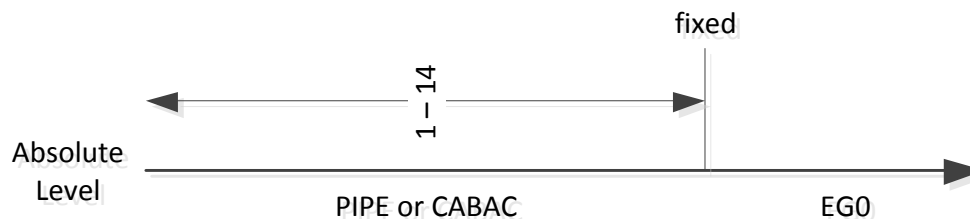
- Coding of absolute transform coefficient levels in HM 1.0 and H.264/AVC

abs_level	Bin string																			
	TU prefix														EG0 suffix					
1	0																			
2	1 0																			
3	1 1 0																			
4	1 1 1 0																			
5	1 1 1 1 0																			
...	... ..																			
...	... ..																			
13	1 1 1 1 1 1 1 1 1 1 1 1 1 0																			
14	1 1 1 1 1 1 1 1 1 1 1 1 1 1 0																			
15	1 1 1 1 1 1 1 1 1 1 1 1 1 1 0																			
16	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0																			
17	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 1																			
18	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0 0																			
19	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0 1																			
20	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 1 0																			
...	... ..																			
bin	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	...

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- **Coding of absolute transform coefficient levels in HM 1.0 and H.264/AVC**

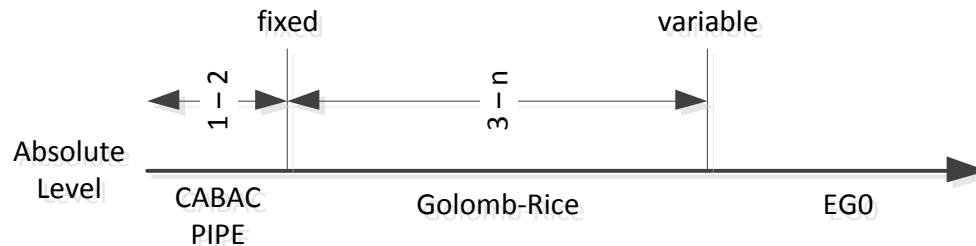


- Fixed-length truncated unary binarization
- Separate context model for 1st bin
- Separate context model for 2nd – 14th bin
- EGO suffix coded in bypass mode

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- **Coding of absolute levels with 3 codes**



- TU prefix with 2 bins
- Remaining level information in bypass mode
- Truncated Golomb-Rice with variable cutoff
- EGO suffix as in HM 1.0 and H.264/AVC
- No changes to sigmap coding
- No changes to absolute level scanning
- No changes to context model selection

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## ■ Code table k=0 and k=1

Abs. Level	P/C	Truncated Golomb-Rice		EG0	P/C	Truncated Golomb-Rice		EG0
	<b>k=0</b>	Prefix	Rem.		<b>k=1</b>	Prefix	Rem.	
1	0				0			
2	10				10			
3	11	0			11	0	0	
4	11	10			11	0	1	
5	11	110			11	10	0	
6	11	1110			11	10	1	
7	11	11110			11	110	0	
8	11	111110			11	110	1	
9	11	1111110			11	1110	0	
10	11	1111111		0	11	1110	1	
11	11	1111111		100	11	1111	0	
12	11	1111111		101	11	1111	1	0
13	11	1111111		11000	11	1111	1	100
14	11	1111111		11001	11	1111	1	101
15	11	1111111		11010	11	1111	1	11000
16	11	1111111		11011	11	1111	1	11001
17	11	1111111		1110000	11	1111	1	11010
18	11	1111111		1110001	11	1111	1	11011
19	11	1111111		1110010	11	1111	1	1110000
20	11	1111111		1110011	11	1111	1	1110001

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## ■ Code table k=2 and k=3

Abs. Level	P/C	Truncated Golomb-Rice		EGO	P/C	Truncated Golomb-Rice		EGO
	<b>k=2</b>	Prefix	Rem.		<b>k=3</b>	Prefix	Rem.	
1	0				0			
2	10				10			
3	11	0	00		11	0	000	
4	11	0	01		11	0	001	
5	11	0	10		11	0	010	
6	11	0	11		11	0	011	
7	11	10	00		11	0	100	
8	11	10	01		11	0	101	
9	11	10	10		11	0	110	
10	11	10	11		11	0	111	
11	11	11	00		11	1	000	
12	11	11	01		11	1	001	
13	11	11	10		11	1	010	
14	11	11	11	0	11	1	011	
15	11	11	11	100	11	1	100	
16	11	11	11	101	11	1	101	
17	11	11	11	11000	11	1	110	
18	11	11	11	11001	11	1	111	0
19	11	11	11	11010	11	1	111	100
20	11	11	11	11011	11	1	111	101

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- Golomb-Rice parameter selection
- Start with  $k = 0$
- Update if specific absolute level is coded
- Limit to  $k = 3$

$$k_{t+1} = \begin{cases} 0 & value_t \in [0,1] \wedge k_t < 1 \\ 1 & value_t \in [2,3] \wedge k_t < 2 \\ 2 & value_t \in [4,5] \wedge k_t < 3 \\ 3 & value_t > 5 \wedge k_t < 4 \\ k_t & otherwise \end{cases}$$

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## TMuC 0.9

	Intra			Random access			Low delay		
	Y BD-rate	U BD-rate	V BD-rate	Y BD-rate	U BD-rate	V BD-rate	Y BD-rate	U BD-rate	V BD-rate
Class A	-0.07	-0.10	-0.13	-0.02	0.15	0.10			
Class B	0.03	0.05	0.04	0.01	0.12	0.03	0.06	0.37	0.10
Class C	-0.01	-0.02	-0.03	0.04	0.11	0.14	0.03	0.37	0.40
Class D	-0.07	-0.10	-0.11	-0.01	0.06	0.37	0.09	0.34	0.79
Class E	-0.01	-0.06	-0.11				-0.17	1.46	0.36
All	-0.02	-0.03	-0.05	0.01	0.10	0.16	0.02	0.57	0.40
Enc Time[%]	104%			102%			103%		
Dec Time[%]	98%			96%			97%		

## HM 1.0

	Intra			Random access			Low delay		
	Y BD-rate	U BD-rate	V BD-rate	Y BD-rate	U BD-rate	V BD-rate	Y BD-rate	U BD-rate	V BD-rate
Class A	-0.07	-0.07	-0.09	-0.06	-0.06	-0.09			
Class B	0.03	0.07	0.06	-0.01	0.05	-0.21	0.04	0.10	0.03
Class C	0.00	0.02	-0.01	0.00	0.01	0.06	0.02	-0.03	-0.11
Class D	-0.06	-0.05	-0.08	-0.01	-0.07	0.31	0.05	-0.40	0.39
Class E	0.00	0.06	-0.05				0.03	0.42	0.88
All	-0.01	0.01	-0.02	-0.01	-0.01	0.02	0.03	0.00	0.24
Enc Time[%]	100%			102%			101%		
Dec Time[%]	100%			102%			99%		

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## ■ Theoretical Worst Case Limit

- 2 bins/pixel (bpp) side information
- Current scheme: 24 bpp for TC levels
- Overall 26 bpp in worst case
- Proposed scheme: 6 bpp for TC levels

## ■ Further tests for $QP = 0$

<i>bin/pixel</i>	anchor	proposed
<i>min</i>	1.52 bpp	1.21 bpp
<i>max</i>	8.13 bpp	3.64 bpp
<i>average</i>	<b>4.29 bpp</b>	<b>2.84 bpp</b>

<i>% EP bins</i>	anchor	proposed
<i>Intra</i>	20.20%	45.98%
<i>Random</i>	17.91%	34.90%
<i>LowDelay</i>	17.42%	35.68%
<i>average</i>	<b>18.52%</b>	<b>39.02%</b>

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- Number of EP bins for QP = {22,27,32,37}

QP	22		27	
% EP bins	anchor	proposed	anchor	proposed
<i>Intra</i>	15.39 %	23.48 %	14.66 %	20.41 %
<i>Random</i>	14.58 %	17.87 %	13.73 %	16.49 %
<i>LowDelay</i>	13.97 %	15.23 %	12.50 %	13.22 %
<i>average</i>	<b>14.68 %</b>	<b>19.15 %</b>	<b>13.67 %</b>	<b>16.86 %</b>
QP	32		37	
% EP bins	anchor	proposed	anchor	proposed
<i>Intra</i>	13.68 %	17.05 %	12.53 %	14.67 %
<i>Random</i>	12.88 %	14.69 %	12.01 %	13.13 %
<i>LowDelay</i>	11.40 %	11.64 %	10.22 %	9.89 %
<i>average</i>	<b>12.69 %</b>	<b>14.56 %</b>	<b>11.62 %</b>	<b>12.69 %</b>

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- **Golomb-Rice remainder part can be read directly from bitstream**
- **Complexity reduction with real bypass**
- **1 add and 1 shift for value reconstruction**

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- **Better worst-case behavior in terms of maximum bins per pixel/sample**
- **Better throughput due to increase in number of EP/bypassed bins**
- **No RD loss for common test conditions**
- **Has been cross-checked by Qualcomm (JCTVC-D429)**

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