



JVCVC-G272
Non-CE10
Core Transform Design for HEVC

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- Core transform design for HEVC, including 4×4 , 8×8 , 16×16 , 32×32 transforms
 - 16 bit representation before and after each transform stage
 - Implementations include full factorization, partial butterfly, and matrix multiplication.
 - 4×4 and 8×8 transforms are orthogonal, 16×16 and 32×32 transforms are nearly orthogonal.
 - $N\times N$ transform matrix is reused as the even part of the $2N\times 2N$ transform matrix.
 - No scaling matrix needed to correct the different norms of basis vectors



- 4×4 transform matrix

$$T_4 = \begin{bmatrix} 128 & 128 & 128 & 128 \\ 167 & 70 & -70 & -167 \\ 128 & -128 & -128 & 128 \\ 70 & -167 & 167 & -70 \end{bmatrix}$$

- 8×8 transform matrix

$$T_8 = \begin{bmatrix} 256 & 256 & 256 & 256 & 256 & 256 & 256 & 256 \\ 360 & 297 & 198 & 72 & -72 & -198 & -297 & -360 \\ 334 & 140 & -140 & -334 & -334 & -140 & 140 & 334 \\ 297 & -72 & -360 & -198 & 198 & 360 & 72 & -297 \\ 256 & -256 & -256 & 256 & 256 & -256 & -256 & 256 \\ 198 & -360 & 72 & 297 & -297 & -72 & 360 & -198 \\ 140 & -334 & 334 & -140 & -140 & 334 & -334 & 140 \\ 72 & -198 & 297 & -360 & 360 & -297 & 198 & -72 \end{bmatrix}$$



- 16×16 transform matrix

$$T_{16} = [$$

1024	1024	1024	1024	1024	1024	1024	1024	1024	1024	1024	1024	1024	1024	1024	1024
1445	1377	1275	1105	935	663	425	119	-119	-425	-663	-935	-1105	-1275	-1377	-1445
1440	1188	792	288	-288	-792	-1188	-1440	-1440	-1188	-792	-288	288	792	1188	1440
1402	886	174	-710	-1270	-1434	-1146	-398	398	1146	1434	1270	710	-174	-886	-1402
1336	560	-560	-1336	-1336	-560	560	1336	1336	560	-560	-1336	-1336	-560	560	1336
1318	86	-1074	-1370	-490	966	1446	622	-622	-1446	-966	490	1370	1074	-86	-1318
1188	-288	-1440	-792	792	1440	288	-1188	-1188	288	1440	792	-792	-1440	-288	1188
1104	-672	-1368	120	1440	432	-1272	-936	936	1272	-432	-1440	-120	1368	672	-1104
1024	-1024	-1024	1024	1024	-1024	-1024	1024	1024	-1024	-1024	1024	1024	-1024	-1024	1024
936	-1272	-432	1440	-120	-1368	672	1104	-1104	-672	1368	120	-1440	432	1272	-936
792	-1440	288	1188	-1188	-288	1440	-792	-792	1440	-288	-1188	1188	288	-1440	792
622	-1446	966	490	-1370	1074	86	-1318	1318	-86	-1074	1370	-490	-966	1446	-622
560	-1336	1336	-560	-560	1336	-1336	560	560	-1336	1336	-560	-560	1336	-1336	560
398	-1146	1434	-1270	710	174	-886	1402	-1402	886	-174	-710	1270	-1434	1146	-398
288	-792	1188	-1440	1440	-1188	792	-288	-288	792	-1188	1440	-1440	1188	-792	288
119	-425	663	-935	1105	-1275	1377	-1445	1445	-1377	1275	-1105	935	-663	425	-119

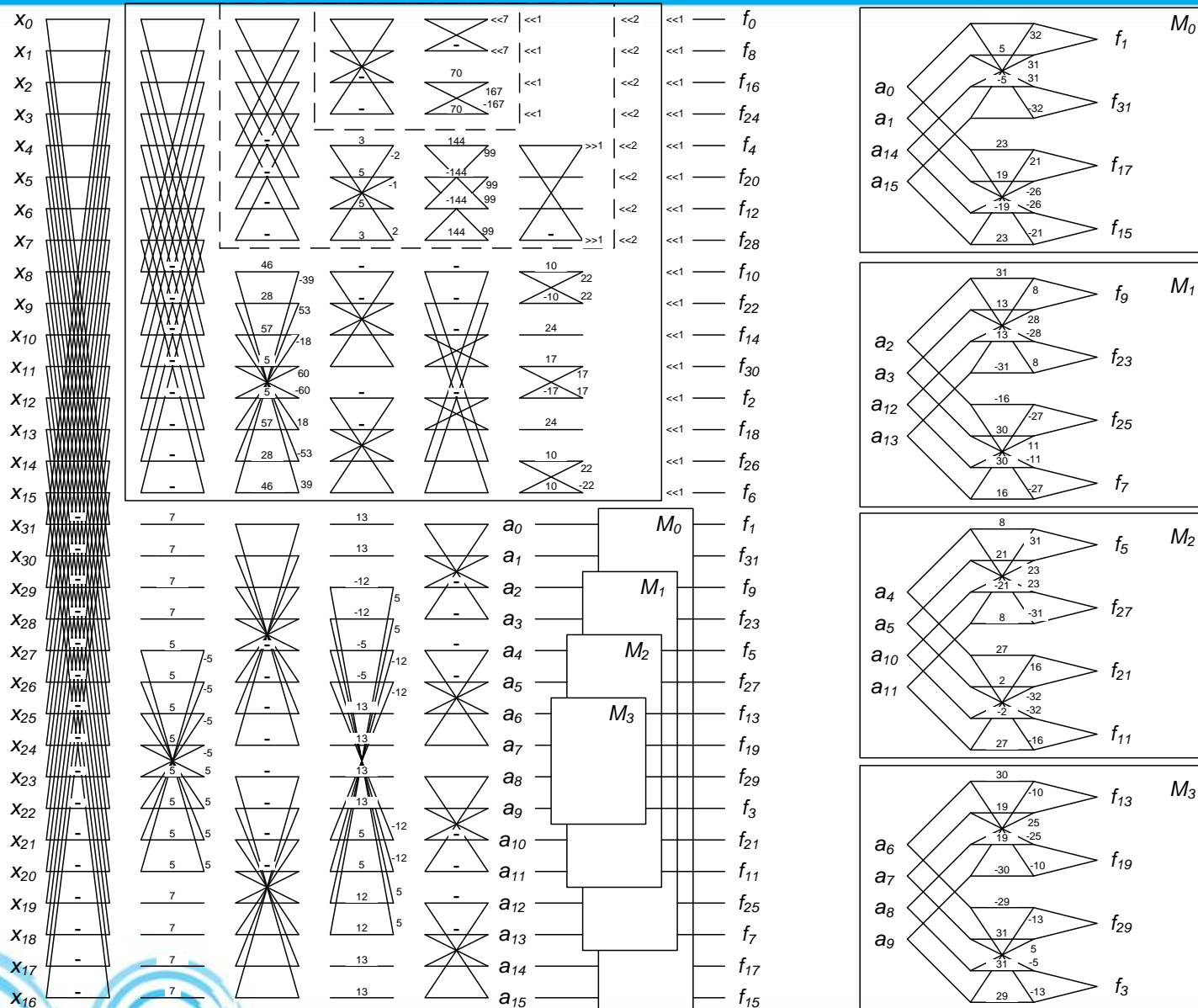
$$]$$

- 32×32 transform matrix

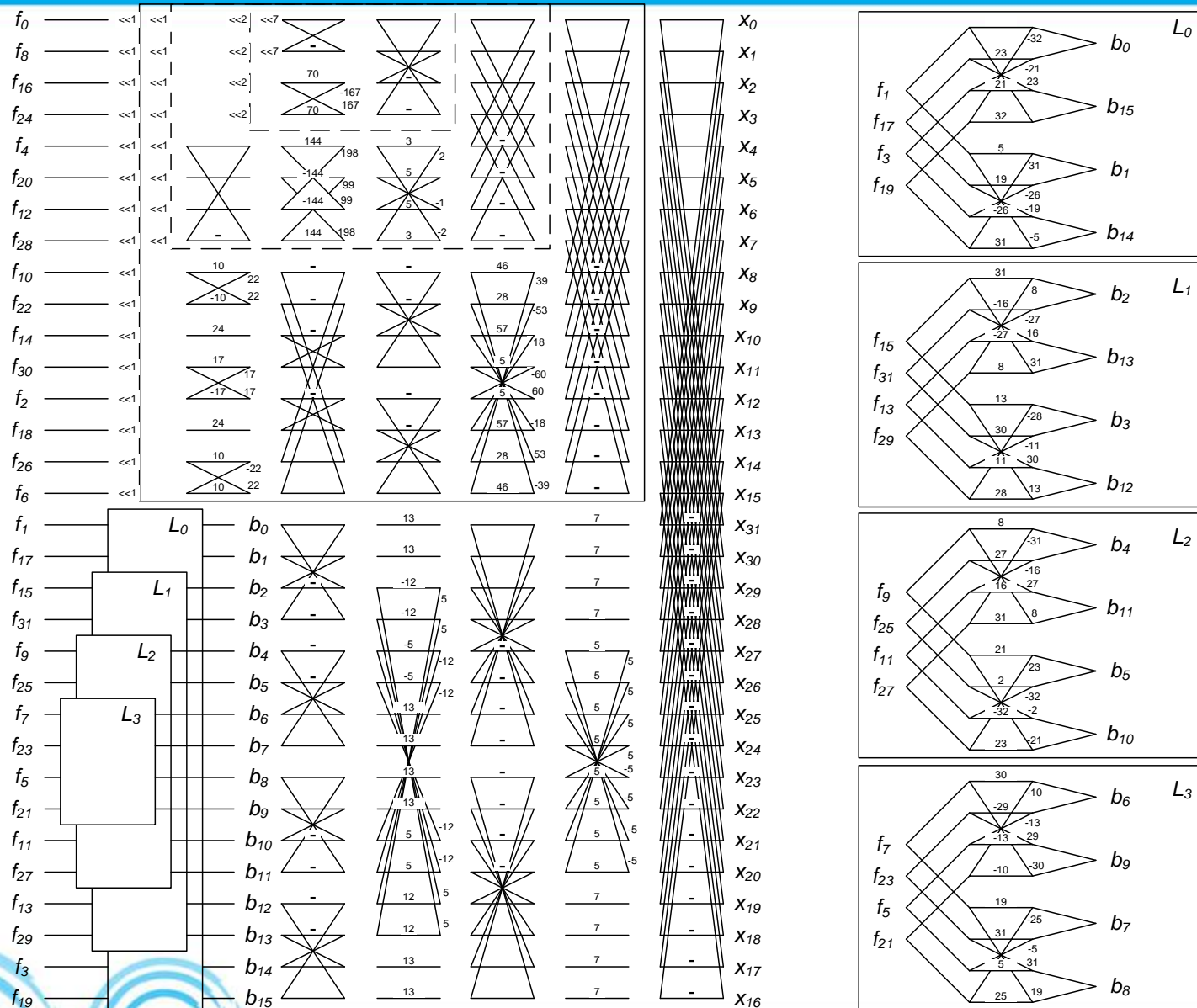
- DC basis vector has the magnitude of 2048.



Full Factorization of Forward Transform



Full Factorization of Inverse Transform



- Comparison of operation numbers for N -point 1-D transform ($N = 4, 8, 16, \text{ or } 32$)

		Matrix Multiplication	Partial Butterfly	Factorization in JCTVC-G579	Factorization in JCTVC-G737	Proposed Factorization
4-point	Addition	12	8	9	9	9
	Multiplication	16	6	3	3	3
8-point	Addition	56	28	26	29	31
	Multiplication	64	22	12	11	11
16-point	Addition	240	100	72	81	93
	Multiplication	256	86	36	31	21
32-point	Addition	992	372	186	229	279
	Multiplication	1024	342	92	87	56



BD-Rate Performance (All Intra and Random Access)

	All Intra HE			All Intra LC		
	Y	U	V	Y	U	V
Class A	0.4%	0.3%	0.1%	0.7%	0.2%	-0.1%
Class B	0.1%	0.1%	0.1%	0.2%	0.1%	0.1%
Class C	0.1%	0.1%	0.1%	0.1%	0.0%	0.0%
Class D	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%
Class E	0.1%	0.2%	0.2%	0.2%	0.0%	0.1%
Overall	0.1%	0.1%	0.1%	0.2%	0.1%	0.0%
	0.1%	0.1%	0.1%	0.2%	0.1%	0.0%

	Random Access HE			Random Access LC		
	Y	U	V	Y	U	V
Class A	0.2%	-0.1%	0.0%	0.3%	0.4%	-0.1%
Class B	0.1%	0.1%	0.0%	0.1%	0.0%	0.1%
Class C	0.1%	0.0%	0.2%	0.1%	0.0%	0.1%
Class D	0.1%	0.0%	-0.2%	0.0%	0.0%	0.3%
Class E						
Overall	0.1%	0.0%	0.0%	0.1%	0.1%	0.1%
	0.1%	0.0%	0.0%	0.1%	0.1%	0.1%



BD-Rate Performance (Low Delay B and P)

	Low delay B HE			Low delay B LC		
	Y	U	V	Y	U	V
Class A						
Class B	0.1%	0.0%	-0.4%	0.1%	0.1%	0.3%
Class C	0.1%	0.1%	0.0%	0.0%	0.1%	0.0%
Class D	0.1%	-0.1%	-0.2%	0.0%	0.1%	0.1%
Class E	0.1%	-0.9%	1.1%	0.0%	0.4%	-0.4%
Overall	0.1%	-0.2%	0.0%	0.0%	0.1%	0.0%
	0.1%	-0.1%	0.0%	0.0%	0.1%	0.0%

	Low delay P HE			Low delay P LC		
	Y	U	V	Y	U	V
Class A						
Class B	0.1%	0.3%	-0.1%	0.1%	0.1%	0.1%
Class C	0.1%	0.2%	0.2%	0.0%	0.0%	0.2%
Class D	0.2%	0.2%	0.0%	0.0%	0.1%	-0.1%
Class E	0.1%	-0.1%	0.0%	0.1%	-0.4%	-0.3%
Overall	0.1%	0.1%	0.0%	0.1%	0.0%	0.0%
	0.1%	0.1%	0.0%	0.1%	0.0%	0.0%



- Core transform design for HEVC, including 4×4 , 8×8 , 16×16 , 32×32 transforms
 - Lower complexity
 - Comparable R-D performance
- Suggest to include in CE

