

FIG. 1

Four pre-defined transform candidate sets(LUT_IrSetToTrTypeIdx)

Transform Set	TrSetIdx	Transform Candidates	
		pt_{hor, ver}_flag==0	pt_{hor, ver}_flag==1
	0	4 (DST-VII)	2 (DCT-VIII)
	1	4 (DST-VII)	3 (DST-I)
	2	4 (DST-VII)	1 (DCT-V)
	3	2 (DCT-VIII)	4 (DST-VID)
	4	DCT-II	

FOR INTRA PREDICTION

FOR INTER PREDICTION

CASE WHERE ADAPTIVE PRIMARY TRANSFORM IS NOT APPLIED

* TrTypeIdx==0 IS DCT-II

FIG. 2

TrType Idx	Transform Type	Basis function $T_i(j)$, $i, j=0, 1, \dots, N-1$
0	DCT-II	$T_i(j) = \omega_0 \cdot \sqrt{\frac{2}{N}} \cdot \cos\left(\frac{\pi \cdot i \cdot (2j+1)}{2N}\right)$, where $\omega_0 = \begin{cases} \sqrt{\frac{1}{2}} & i=0 \\ 1 & i \neq 0 \end{cases}$
1	DCT-V	$T_i(j) = \omega_0 \cdot \omega_1 \cdot \sqrt{\frac{2}{2N-1}} \cdot \cos\left(\frac{2\pi \cdot i \cdot j}{2N-1}\right)$, where $\omega_0 = \begin{cases} \sqrt{\frac{1}{2}} & i=0 \\ 1 & i \neq 0 \end{cases}$ $\begin{cases} \sqrt{\frac{2}{N}} & j=0 \\ 1 & j \neq 0 \end{cases}$
2	DCT-VIII	$T_i(j) = \sqrt{\frac{4}{2N+1}} \cdot \cos\left(\frac{\pi \cdot (2i+1) \cdot (2j+1)}{4N+2}\right)$
3	DST-I	$T_i(j) = \sqrt{\frac{2}{N+1}} \cdot \sin\left(\frac{\pi \cdot (i+1) \cdot (j+1)}{N+1}\right)$
4	DST-VII	$T_i(j) = \sqrt{\frac{4}{2N+1}} \cdot \sin\left(\frac{\pi \cdot (2i+1) \cdot (j+1)}{2N+1}\right)$

$N=2, 4, 8, 16, \dots, 2^{**M}$
 IN IMPLEMENTATION, VALUE OF EACH COEFFICIENT $T_i(j)$ OF
 ORTHOGONAL TRANSFORM IS HELD WITH k-bit INTEGER PRECISION

FIG. 3

Selected (H)orizontal and (V)ertical transform sets for each Intra prediction mode (LUT_IntraModeToTrSet)

Intra Mode	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
V	2	1	0	1	0	1	0	1	0	1	0	1	0	1	0	0	0	0
H	2	1	0	1	0	1	0	1	0	1	0	1	0	1	2	2	2	2
Intra Mode	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	
V	0	0	0	0	0	1	0	1	0	1	0	1	0	1	0	1	0	
H	2	2	2	2	2	1	0	1	0	1	0	1	0	1	0	1	0	
Intra Mode	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52
V	1	0	1	0	1	0	1	0	1	0	1	2	2	2	2	2	2	2
H	1	0	1	0	1	0	1	0	1	0	1	0	0	0	0	0	0	0
Intra Mode	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67(=IntraBC)			
V	2	2	1	0	1	0	1	0	1	0	1	0	1	0	4(=InterTrSetIdx)			
H	0	0	1	0	1	0	1	0	1	0	1	0	1	0	4(=InterTrSetIdx)			

FIG. 4

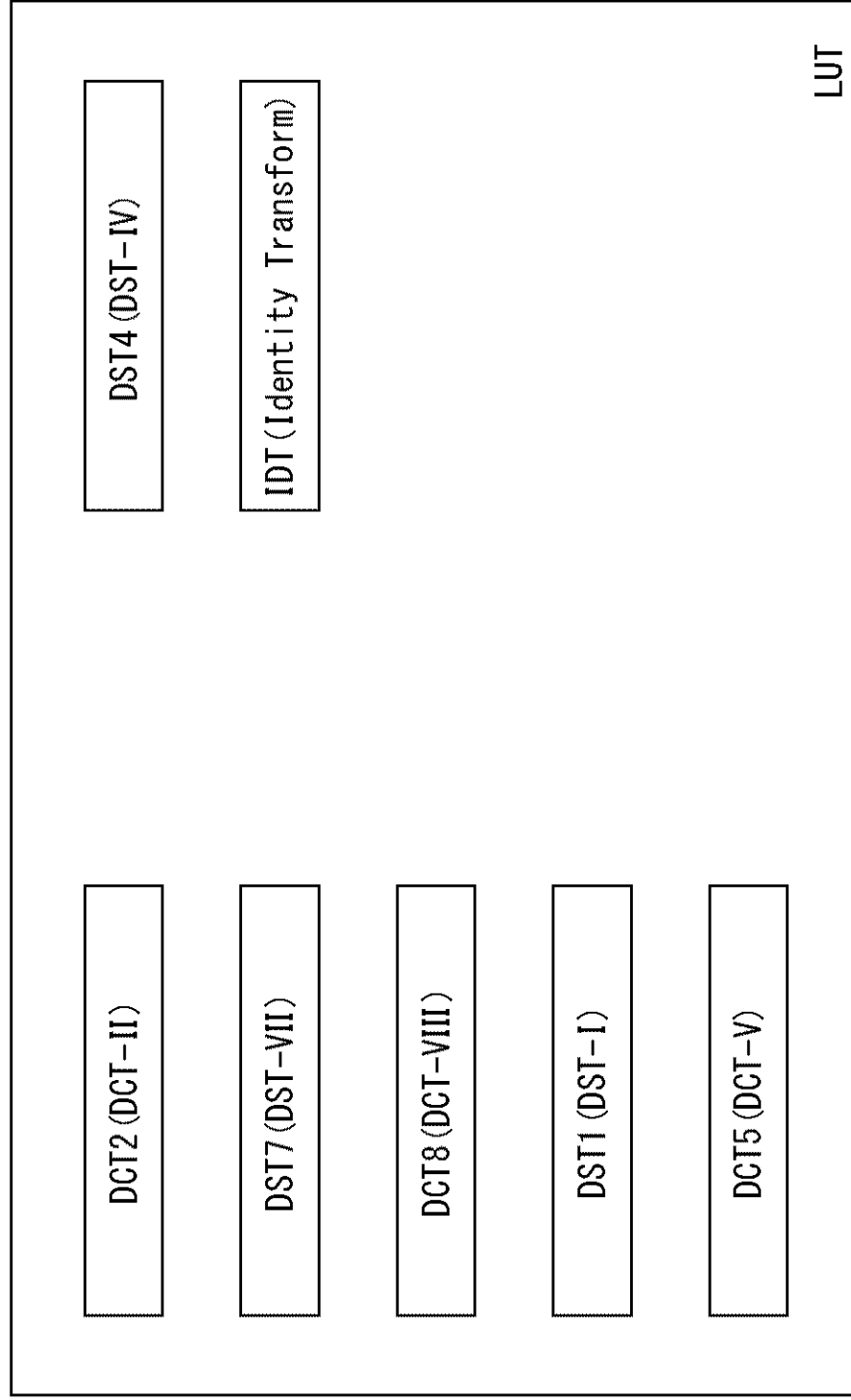


FIG. 5

TRANSFORM SIZE N	NUMBER OF ELEMENTS	TYPE OF TRANSFORMATION MATRIX	BIT PRECISION bit	LUT SIZE bits
2	4	0	8	0
4	16	2	8	256
8	64	1	8	512
16	256	1	8	2048
32	1024	1	8	8192
64	4096	0	8	0
128	16384	0	8	0
TOTAL				11008 ($\approx 1.3\text{KB}$)

FIG. 6

TRANSFORM SIZE N	NUMBER OF ELEMENTS	TYPE OF TRANSFORMATION MATRIX	BIT PRECISION bit	LUT SIZE bits
2	4	1	10	40
4	16	5	10	800
8	64	5	10	3200
16	256	5	10	12800
32	1024	5	10	51200
64	4096	5	10	204800
128	16384	1	10	163840
TOTAL				436680 ($\approx$ 53KB)

A

TRANSFORM SIZE N	NUMBER OF ELEMENTS	TYPE OF TRANSFORMATION MATRIX	BIT PRECISION bit	LUT SIZE bits
2	4	1	10	40
4	16	7	10	1120
8	64	7	10	4480
16	256	7	10	17920
32	1024	7	10	71680
64	4096	7	10	286720
128	16384	1	10	163840
TOTAL				545800 ($\approx$ 67KB)

B

FIG. 7

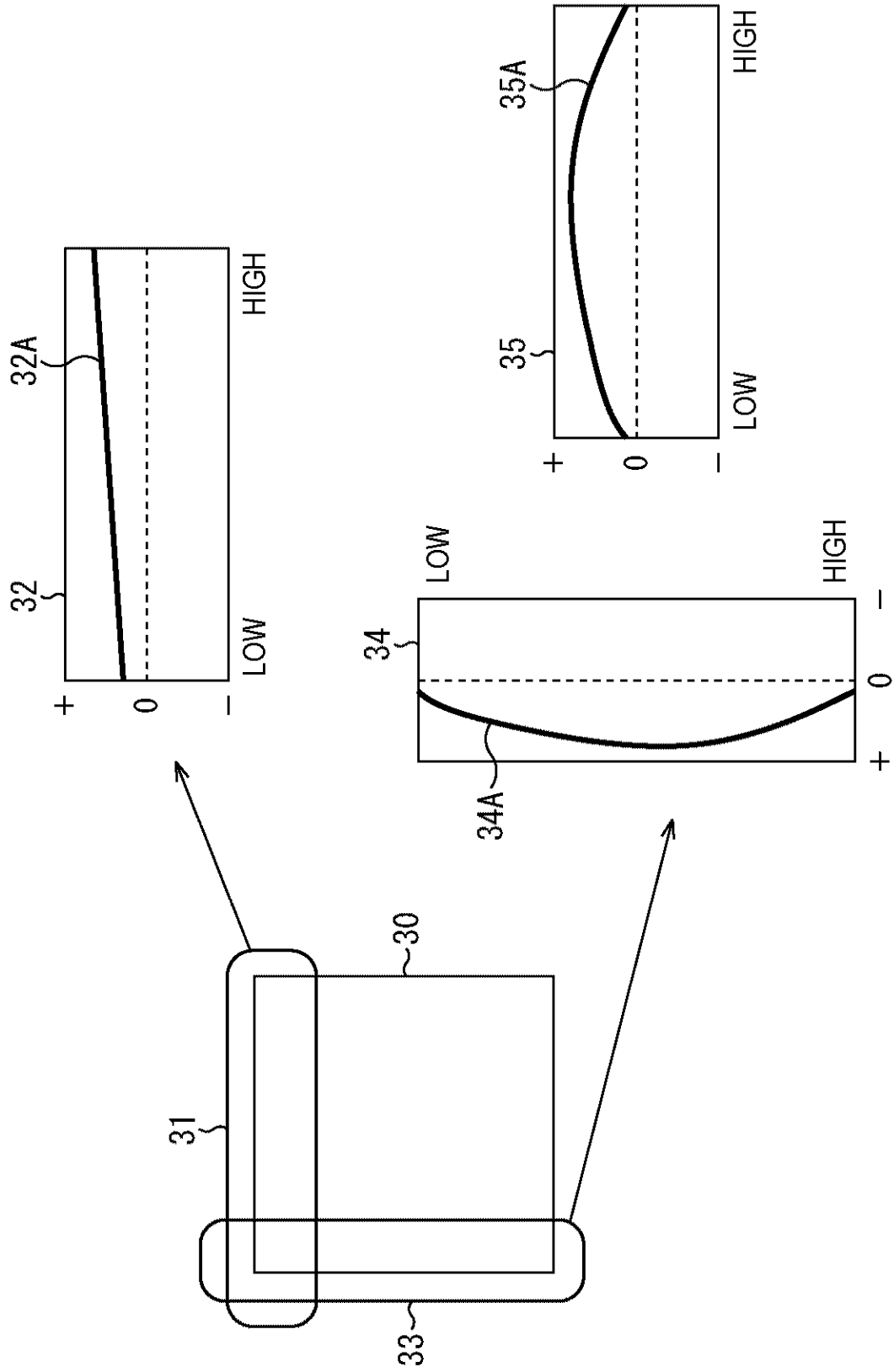


FIG. 8

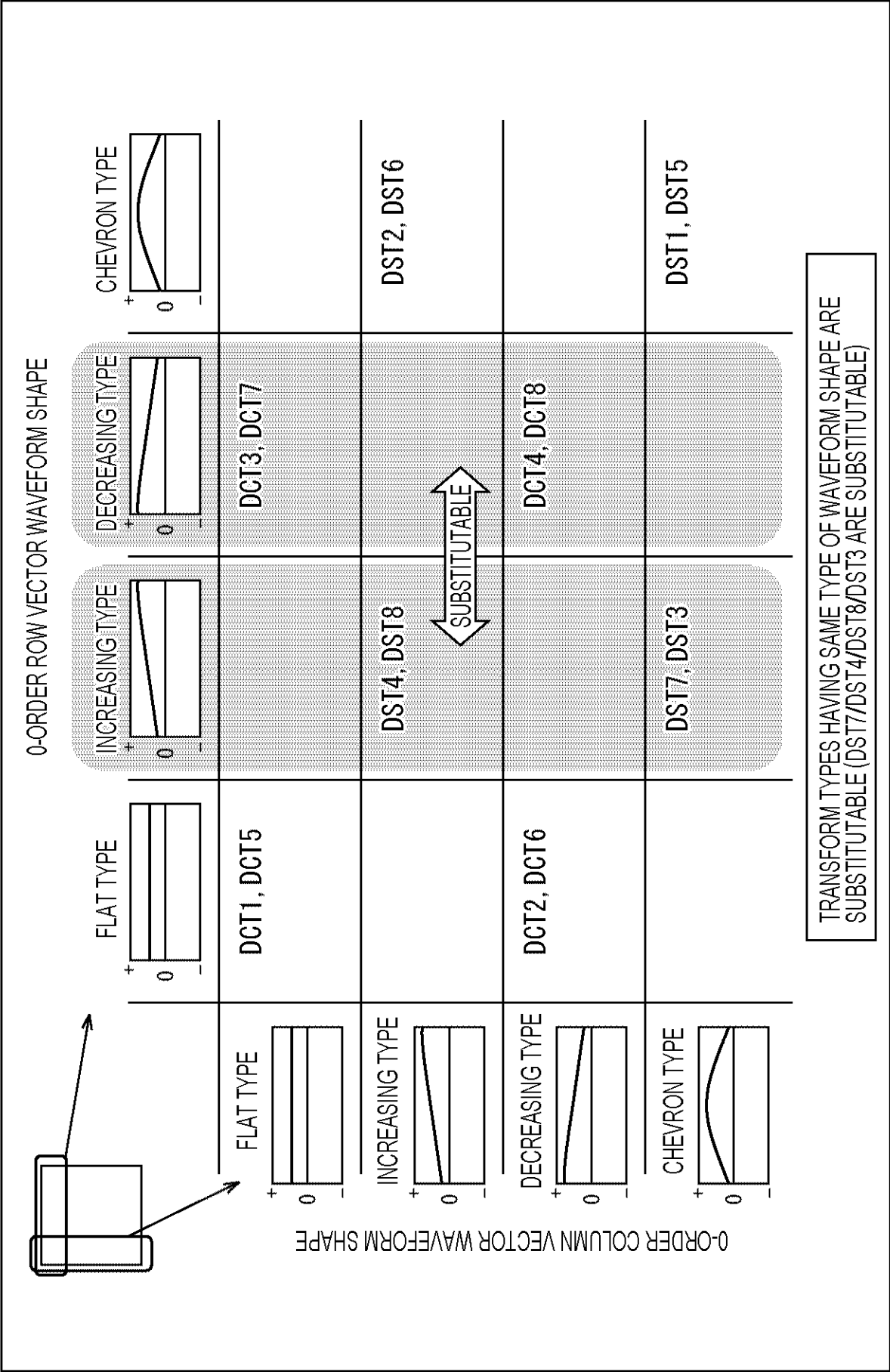


FIG. 9

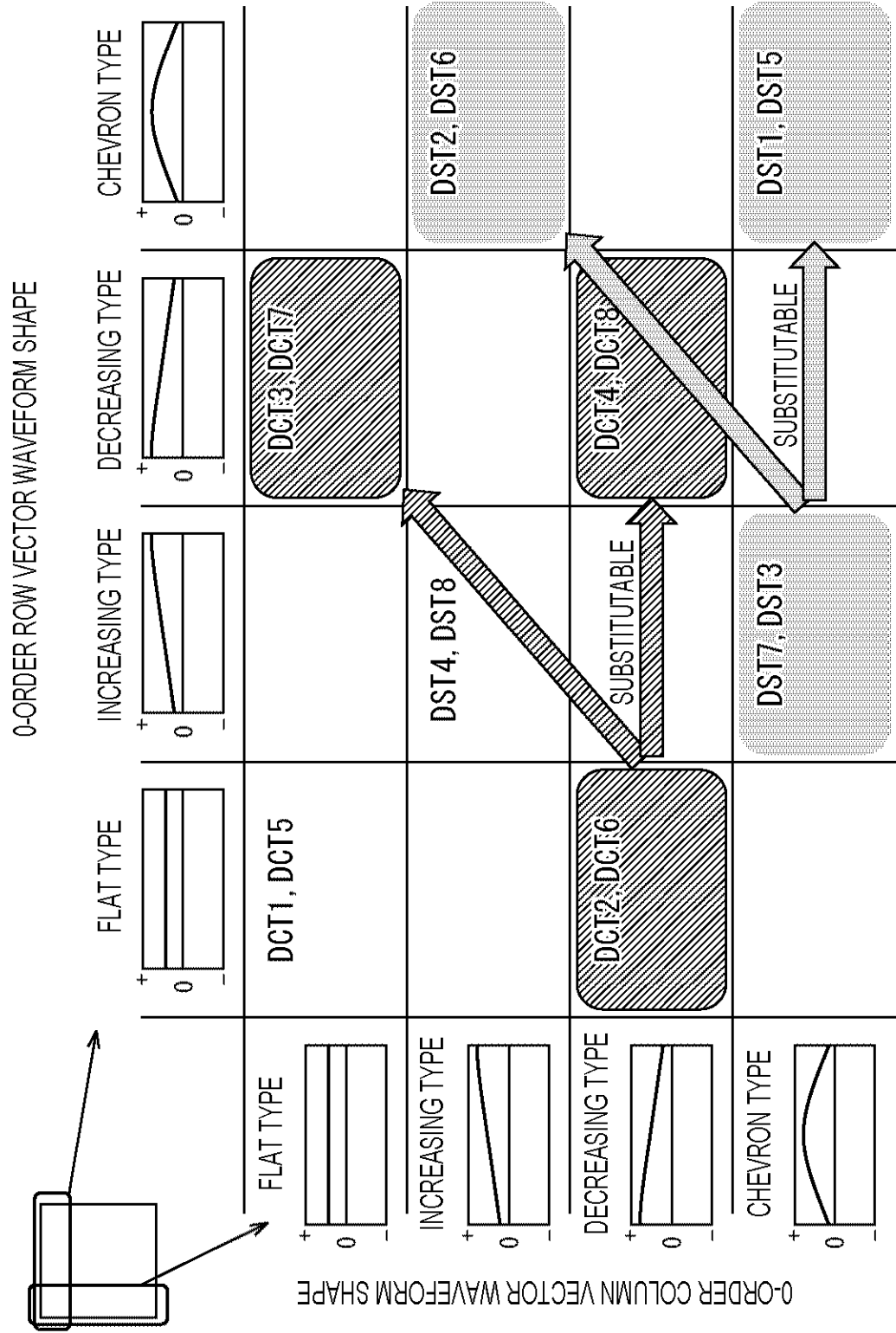


FIG. 10

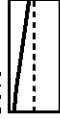
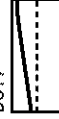
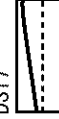
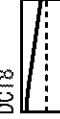
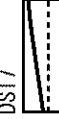
CORRESPONDING EXAMPLE	FIRST TRANSFORM TYPE (BASE TRANSFORM TYPE)	SECOND TRANSFORM TYPE (TRANSFORM TYPE TO BE DERIVED)	SUBSTITUTABLE TRANSFORM TYPE	OPERATION OF BASE TRANSFORMATION MATRIX T_{base}			FOCUS POINT	EFFECT
				FLIP	TRANSPOSITION	SIGN INVERSION		
1-1	DST7	FlipDST7	DCT8 	×			· SIMILARITY BETWEEN LOWEST-ORDER COLUMN VECTOR OF FIRST TRANSFORM TYPE AND LOWEST-ORDER ROW VECTOR OF SECOND TRANSFORM TYPE	· REDUCTION OF UNIQUE TRANSFORM TYPE (REDUCTION OF LUT SIZE) · SECOND TRANSFORM TYPE HAS SIMILAR ENCODING EFFICIENCY TO DCT8 · DERIVE DECREASING-TYPE SUBSTITUTION TRANSFORM BY ONE OPERATION
1-1	DST7	TrDST7	DST1 		×		· SIMILARITY BETWEEN LOWEST-ORDER COLUMN VECTOR OF FIRST TRANSFORM TYPE AND LOWEST-ORDER ROW VECTOR OF SECOND TRANSFORM TYPE	· UNIQUE TRANSFORM TYPE IS REDUCIBLE (REDUCTION OF LUT SIZE) · SECOND TRANSFORM TYPE HAS SIMILAR ENCODING EFFICIENCY TO DST1 · DERIVE DECREASING-TYPE SUBSTITUTION TRANSFORM BY ONE OPERATION
1-2	DST7	DCT8	DCT8 	×		×	· FOCUSING ON CHARACTERISTICS BETWEEN PAIRED DCT/DST - EVEN-NUMBERED ROW VECTORS HAVE AXIAL SYMMETRY - ODD-NUMBERED ROW VECTORS HAVE POINT SYMMETRY	· UNIQUE TRANSFORM TYPE IS REDUCIBLE (REDUCTION OF LUT SIZE) · SECOND TRANSFORM TYPE HAS SIMILAR ENCODING EFFICIENCY TO DCT8 · DERIVE TRANSFORMS TO BE PAIRED BY TWO OPERATIONS
1-3	DCT8	FlipDCT8	DST7 	×			· SIMILARITY BETWEEN LOWEST-ORDER COLUMN VECTOR OF FIRST TRANSFORM TYPE AND LOWEST-ORDER ROW VECTOR OF SECOND TRANSFORM TYPE	· REDUCTION OF UNIQUE TRANSFORM TYPE (REDUCTION OF LUT SIZE) · SECOND TRANSFORM TYPE HAS SIMILAR ENCODING EFFICIENCY TO DST7 · DERIVE DECREASING-TYPE SUBSTITUTION TRANSFORM BY ONE OPERATION
1-3	DCT8	TrFlipDCT8	DST1 	×	×		· SIMILARITY BETWEEN HIGHEST-ORDER COLUMN VECTOR OF FIRST TRANSFORM TYPE AND LOWEST-ORDER ROW VECTOR OF SECOND TRANSFORM TYPE	· REDUCTION OF UNIQUE TRANSFORM TYPE (REDUCTION OF LUT SIZE) · SECOND TRANSFORM TYPE HAS SIMILAR ENCODING EFFICIENCY TO DST1 · DERIVE DECREASING-TYPE SUBSTITUTION TRANSFORM BY ONE OPERATION
1-4	DCT8	DST7	DST7 	×		×	· SIMILARITY BETWEEN PAIRED DCT/DST - EVEN-NUMBERED ROW VECTORS HAVE AXIAL SYMMETRY - ODD-NUMBERED ROW VECTORS HAVE POINT SYMMETRY	· UNIQUE TRANSFORM TYPE IS REDUCIBLE (REDUCTION OF LUT SIZE) · SECOND TRANSFORM TYPE HAS SIMILAR ENCODING EFFICIENCY TO DST7 · DERIVE TRANSFORMS TO BE PAIRED BY TWO OPERATIONS
1-5	DCT2	DCT3	DCT8 		×		· SIMILARITY BETWEEN LOWEST-ORDER COLUMN VECTOR OF FIRST TRANSFORM TYPE AND LOWEST-ORDER ROW VECTOR OF SECOND TRANSFORM TYPE	· UNIQUE TRANSFORM TYPE IS REDUCIBLE (REDUCTION OF LUT SIZE) · SECOND TRANSFORM TYPE HAS SIMILAR ENCODING EFFICIENCY TO DCT8 · DERIVE DECREASING-TYPE SUBSTITUTION TRANSFORM BY ONE OPERATION
1-5	DCT2	FlipDCT3	DST7 	×	×		· SIMILARITY BETWEEN HIGHEST-ORDER COLUMN VECTOR OF FIRST TRANSFORM TYPE AND LOWEST-ORDER ROW VECTOR OF SECOND TRANSFORM TYPE	· REDUCTION OF UNIQUE TRANSFORM TYPE (REDUCTION OF LUT SIZE) · SECOND TRANSFORM TYPE HAS SIMILAR ENCODING EFFICIENCY TO DST7 · DERIVE INCREASING-TYPE SUBSTITUTION TRANSFORM BY TWO OPERATIONS

FIG. 11

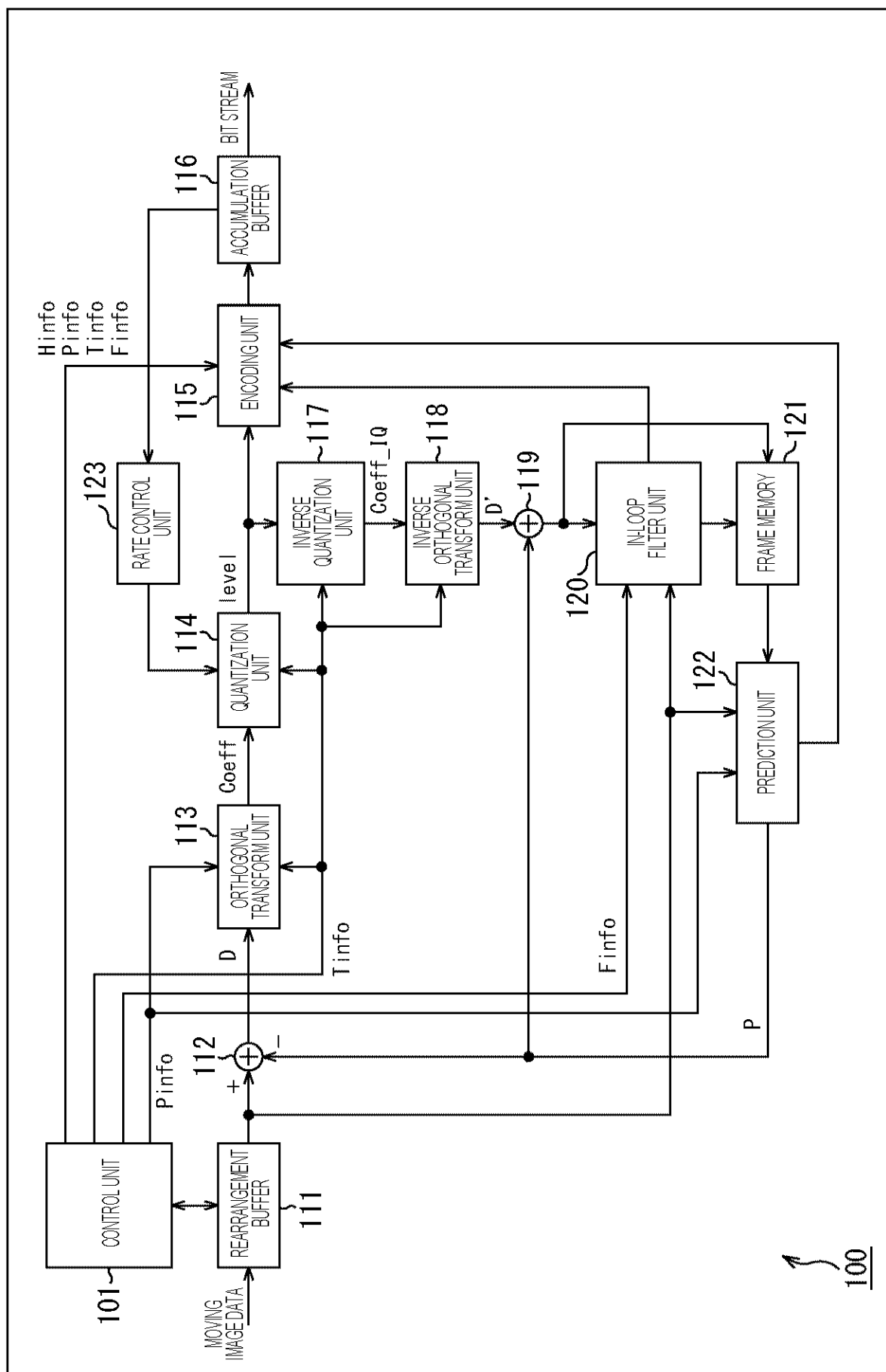


FIG. 12

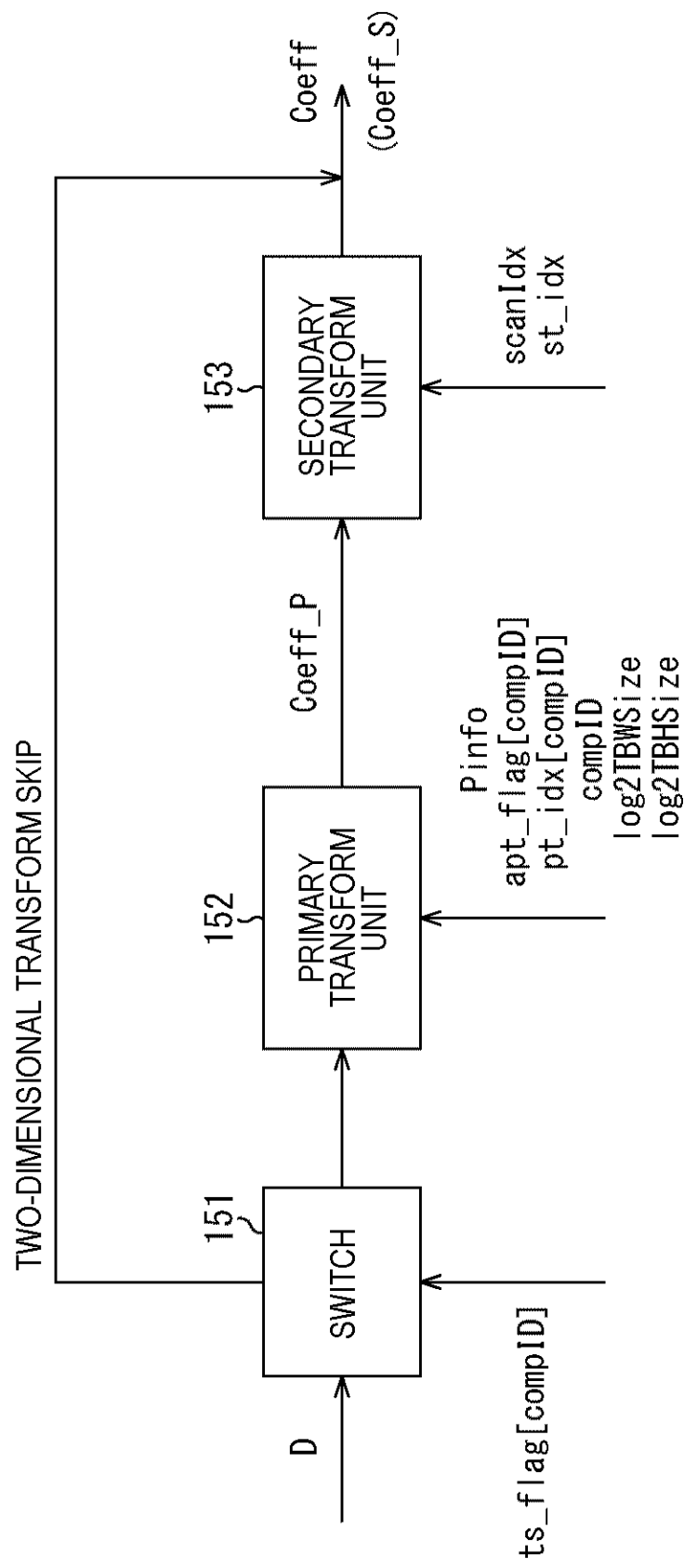


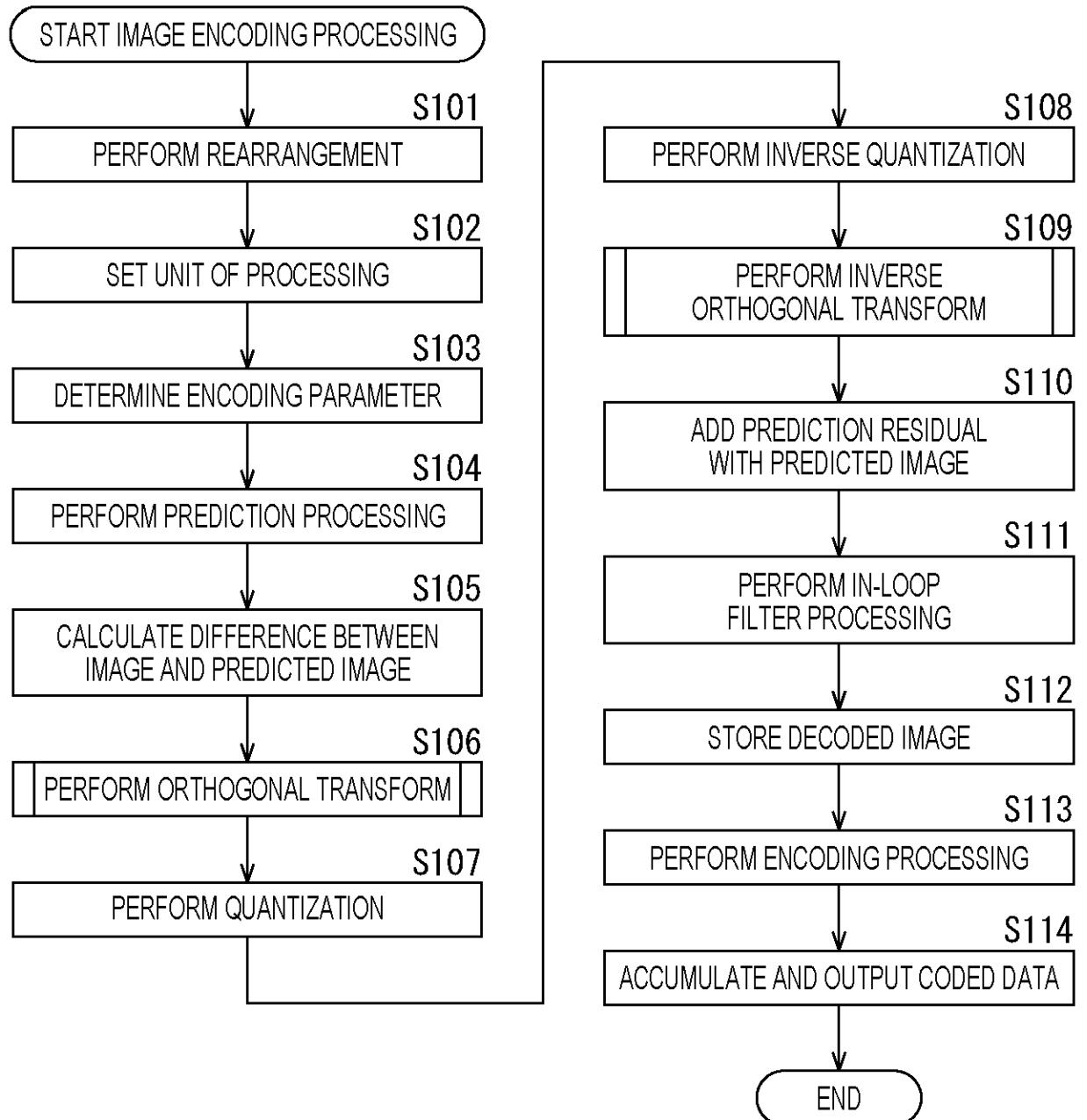
FIG. 13

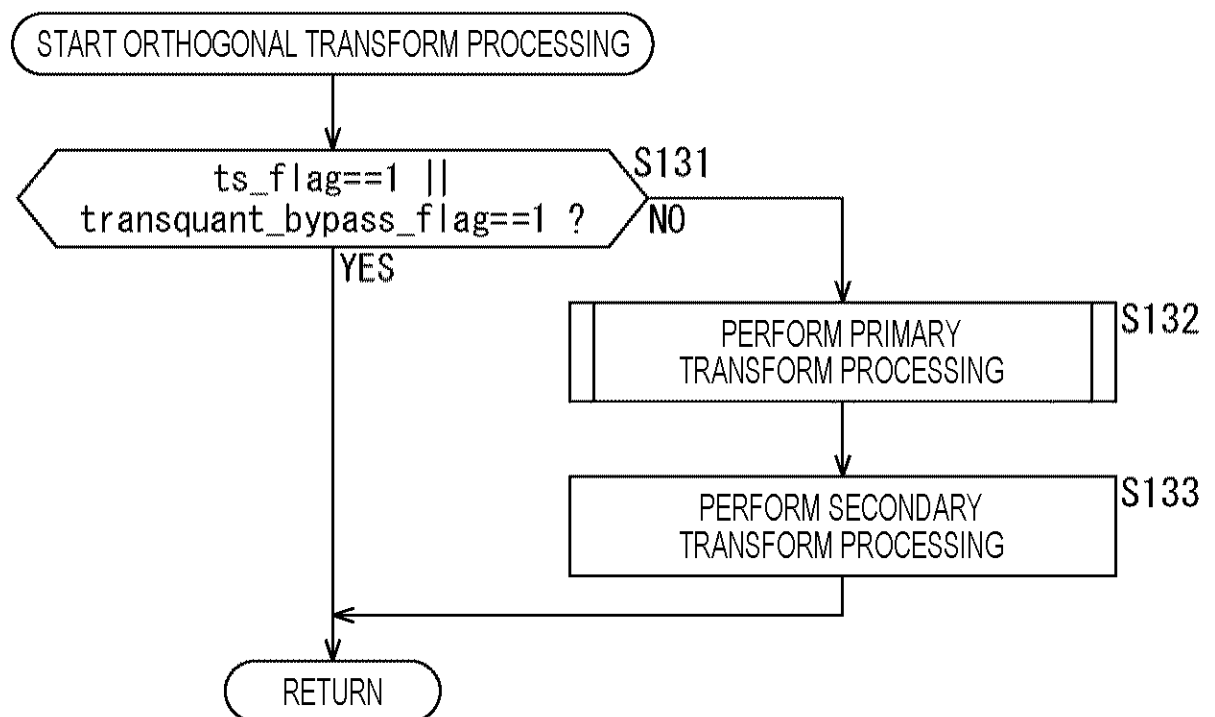
FIG. 14

FIG. 15

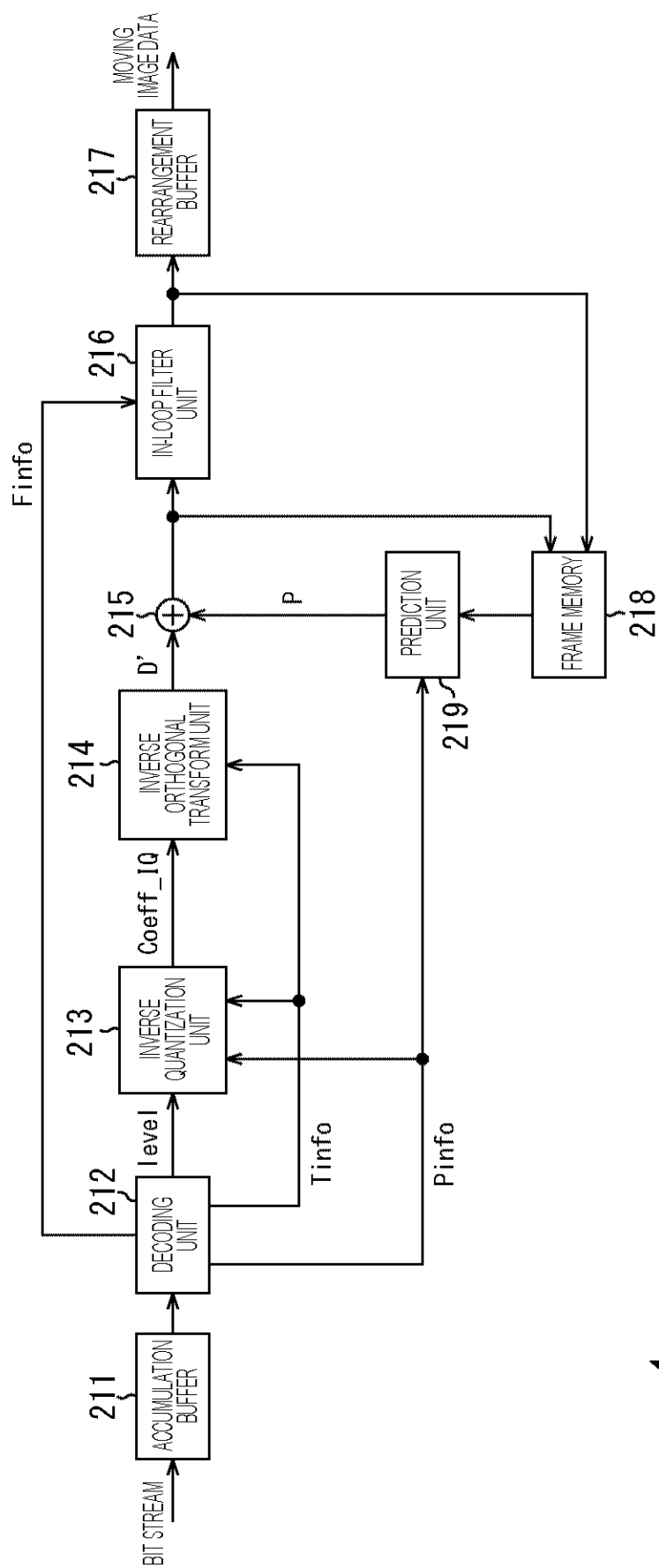
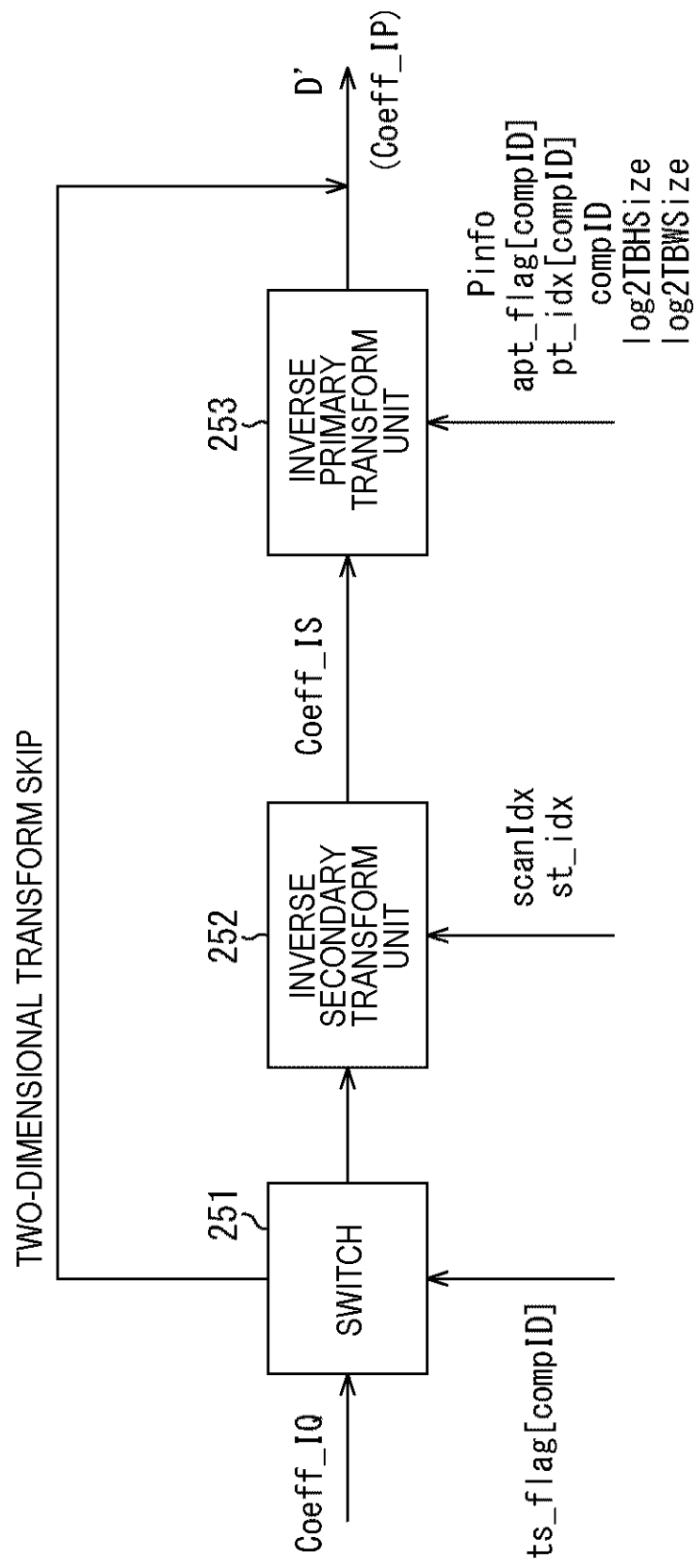


FIG. 16



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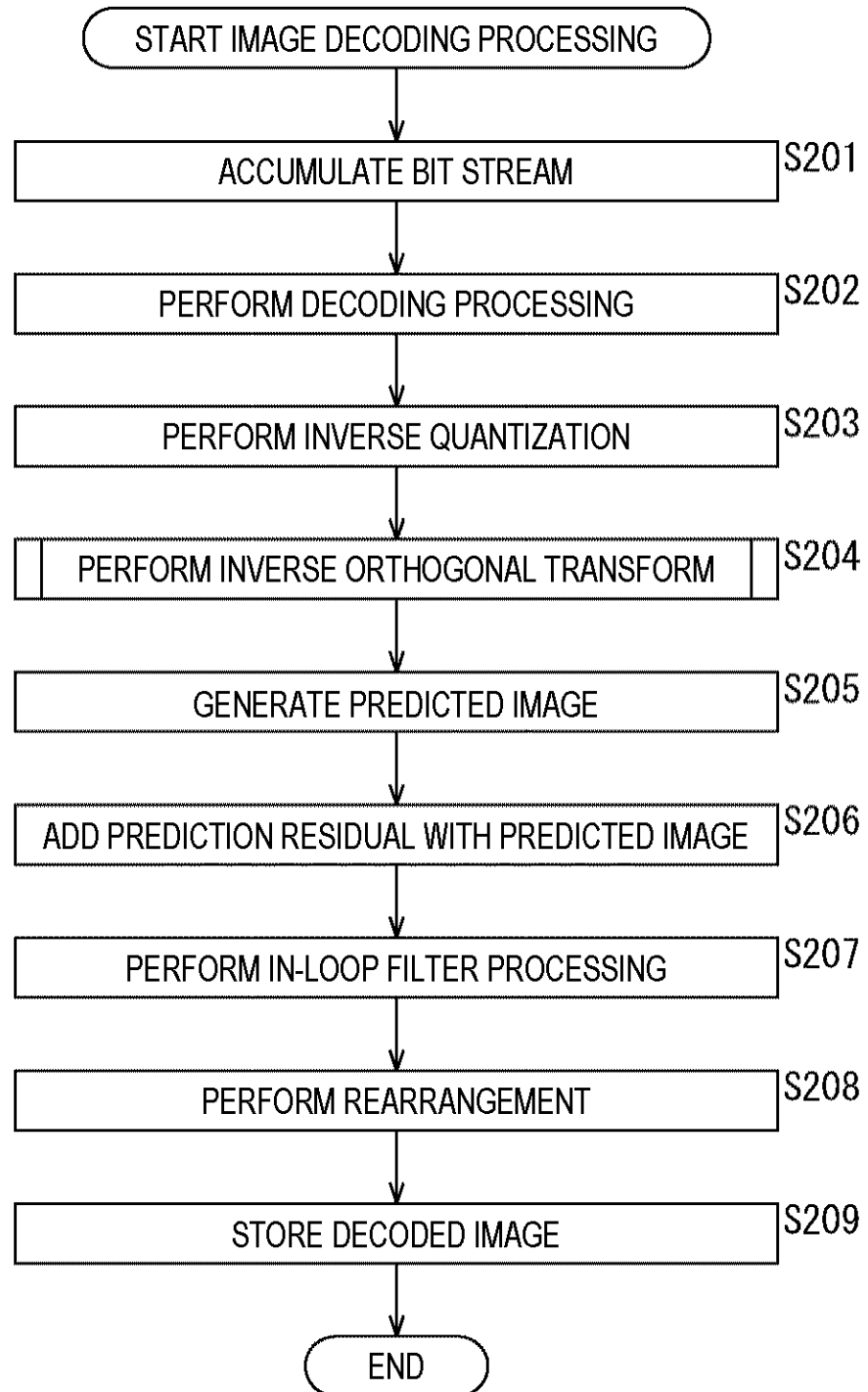
FIG. 17

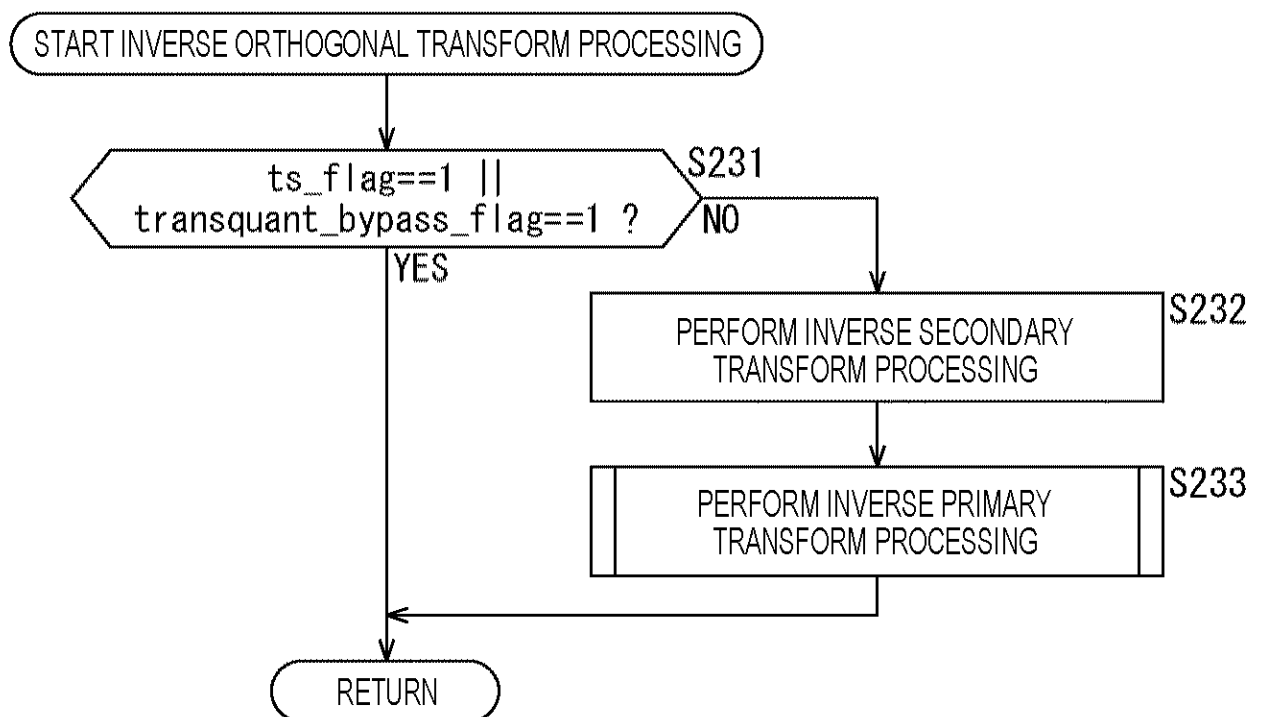
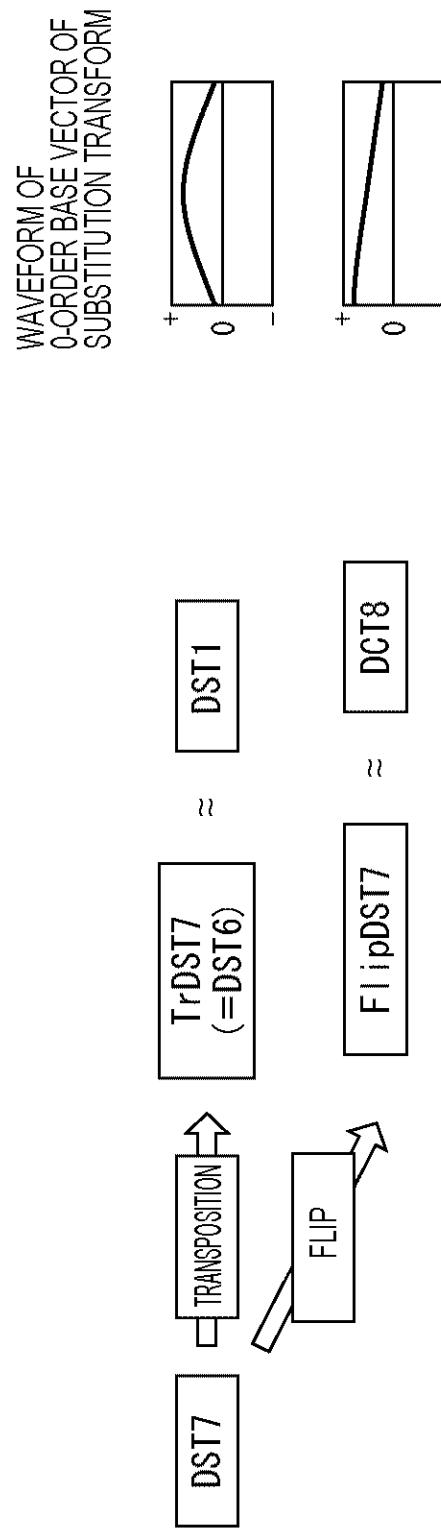
FIG. 18

FIG. 19



≈: WAVEFORM OF LOW-ORDER (ESPECIALLY 0-ORDER) BASE VECTOR IS SIMILAR

FIG. 20

$$\begin{aligned}
 S &= \text{DST7} \quad \downarrow \quad J \quad \downarrow \\
 &\begin{pmatrix} 117 & 219 & 296 & 336 & & & \\ 296 & 296 & 0 & -296 & & & \\ 336 & -117 & -296 & 219 & & & \\ 219 & -336 & 296 & 117 & & & \\ & & & & 1 & & \\ & & & & & 1 & \\ & & & & & & 1 \end{pmatrix} \\
 &= \begin{pmatrix} 336 & 296 & 219 & 117 \\ -296 & 0 & 296 & 296 \\ 219 & -296 & -117 & 336 \\ 117 & 296 & -336 & 219 \end{pmatrix} \\
 &= \text{FlipDST7}
 \end{aligned}$$

$$\begin{aligned}
 S^T &= (\text{DST7})^T \quad \downarrow \\
 &\begin{pmatrix} 117 & 219 & 296 & 336 \\ 296 & 296 & 0 & -296 \\ 336 & -117 & -296 & 219 \\ 219 & -336 & 296 & 117 \end{pmatrix}^T \\
 &= \begin{pmatrix} 117 & 296 & 336 & 219 \\ 219 & 296 & -117 & -336 \\ 296 & 0 & -296 & 296 \\ 336 & -296 & 219 & 117 \end{pmatrix} \\
 &= \text{TrDST7}
 \end{aligned}$$

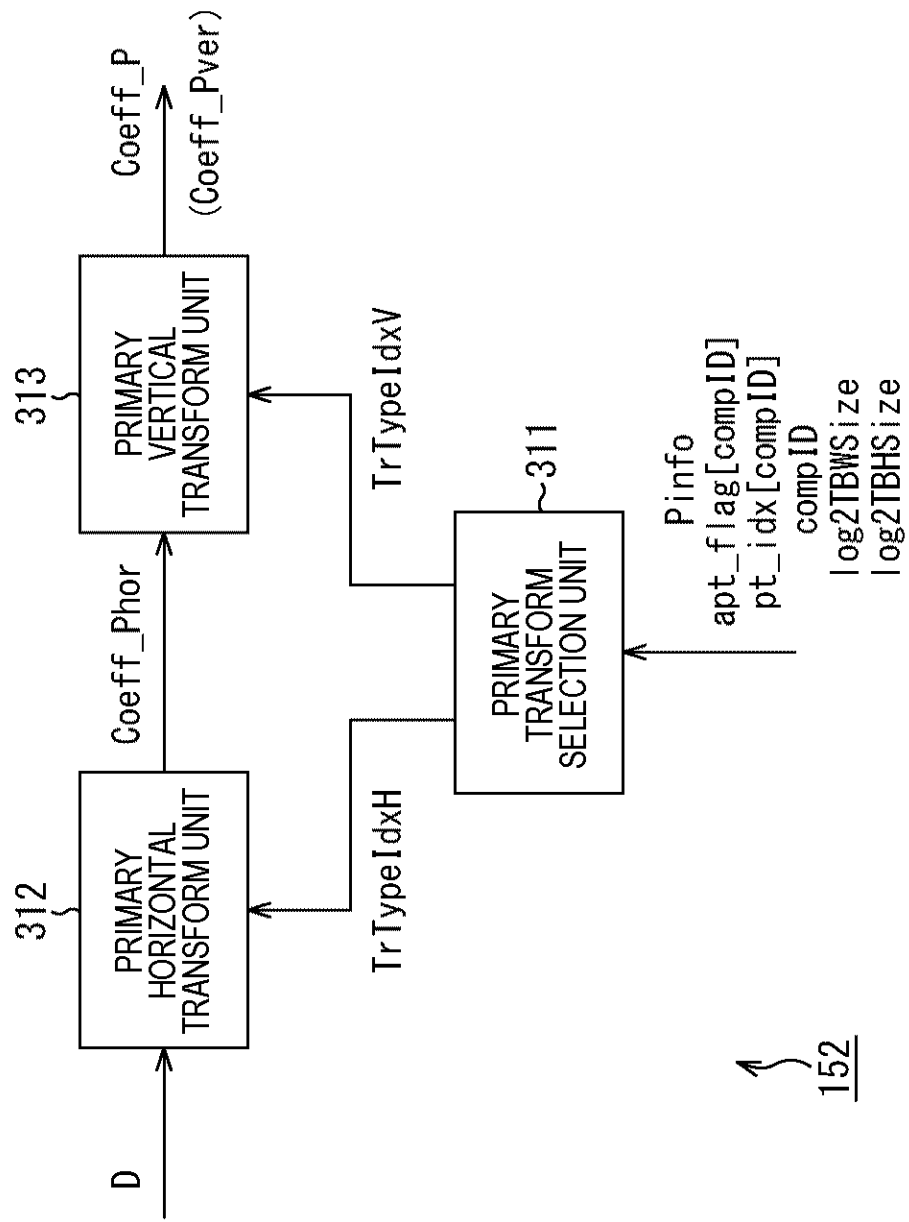
• MATRIX EXPRESSION IS AS FOLLOWS

- $C = D \cdot S \cdot J$
- $S = \text{DST}$
- $C = \text{DCT}$
- $D = \text{diag}(1, -1, \dots, (-1)^{N-1})$
- $J = \text{cross identity matrix}$

FIG. 21

TRANSFORM SIZE N	NUMBER OF ELEMENTS	TYPE OF TRANSFORMATION MATRIX	BIT PRECISION bit	LUT SIZE bits
2	4	1	10	40
4	16	3	10	480
8	64	3	10	1920
16	256	3	10	7680
32	1024	3	10	30720
64	4096	3	10	122880
128	16384	1	10	163840
TOTAL				327560 (≈ 40KB)

FIG. 22



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FIG. 23

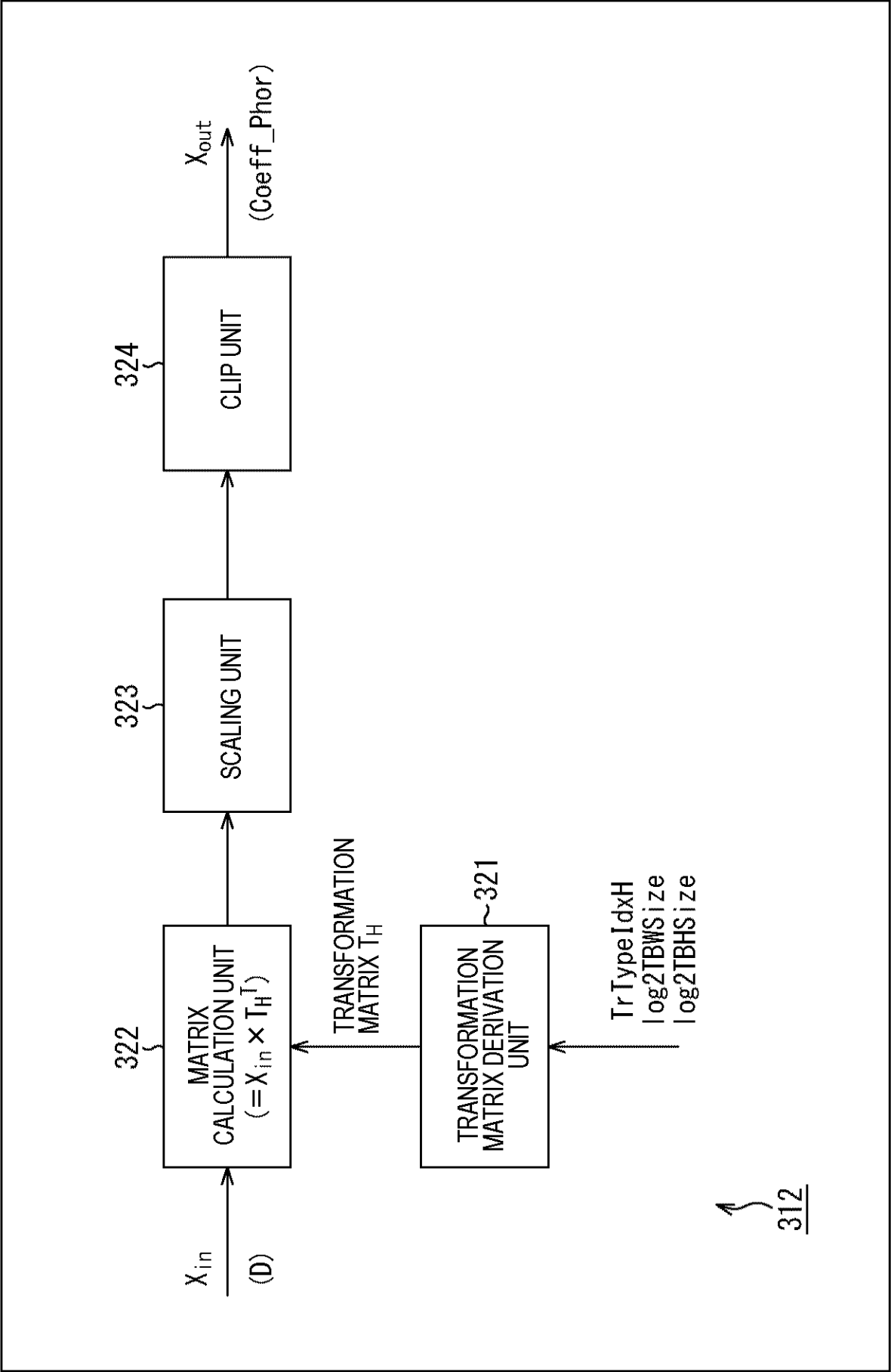


FIG. 24

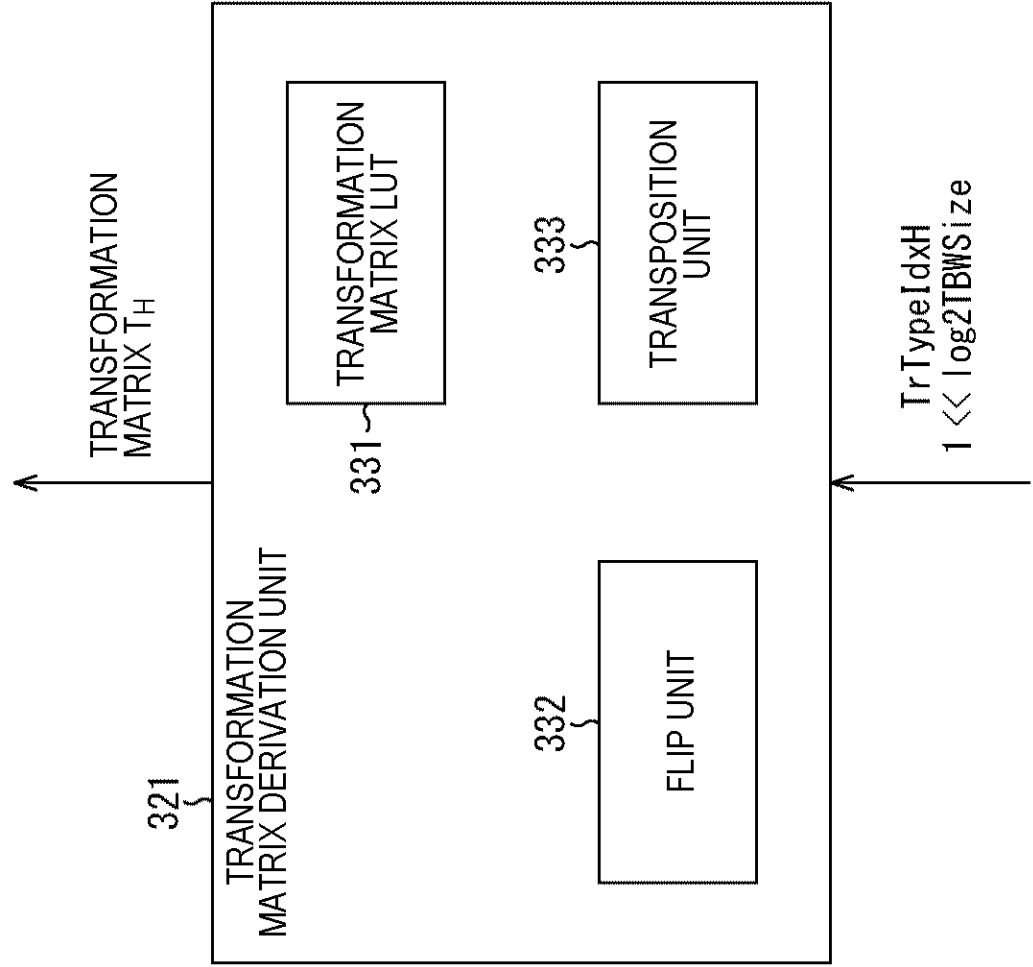


FIG. 25

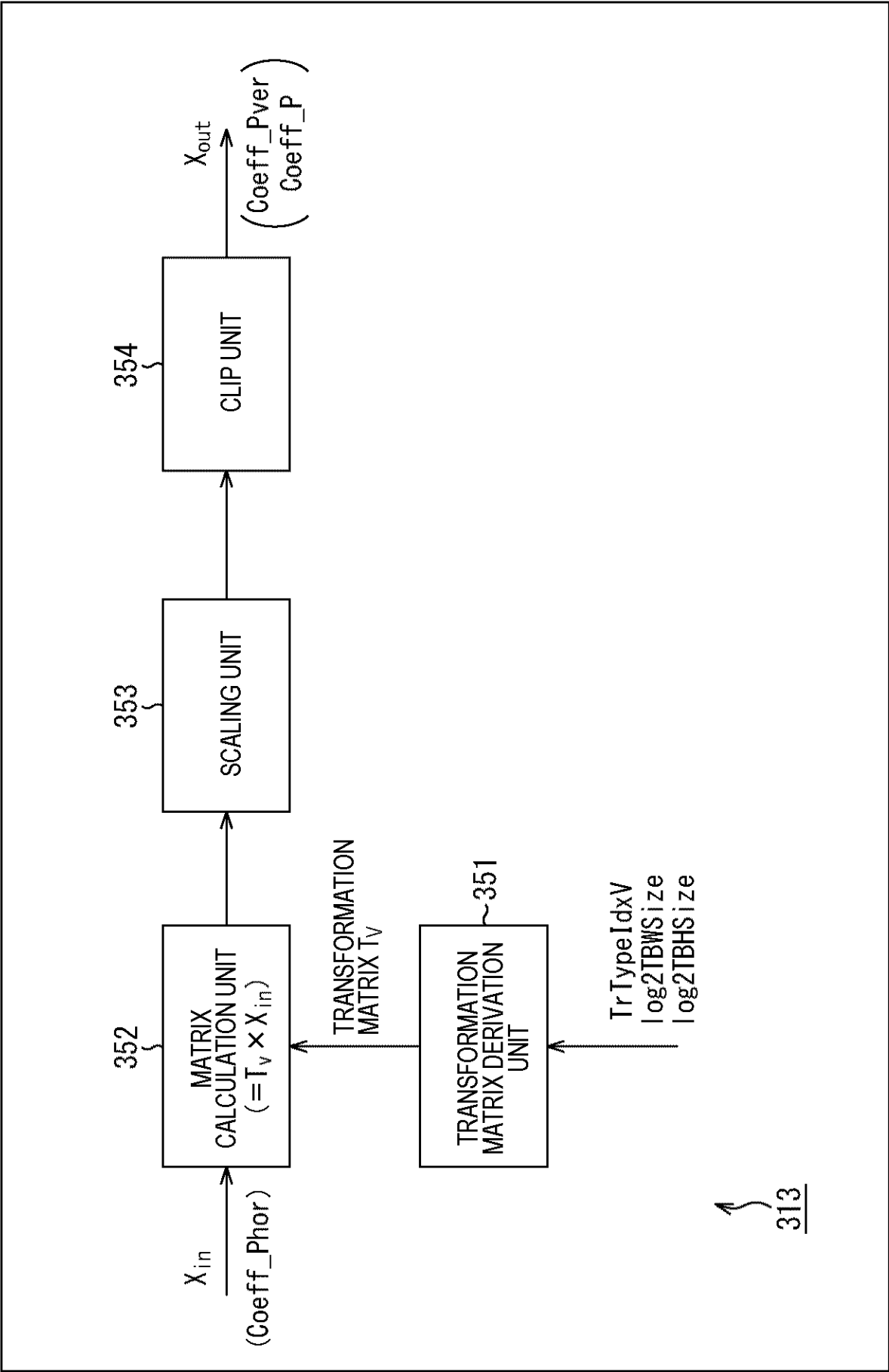


FIG. 26

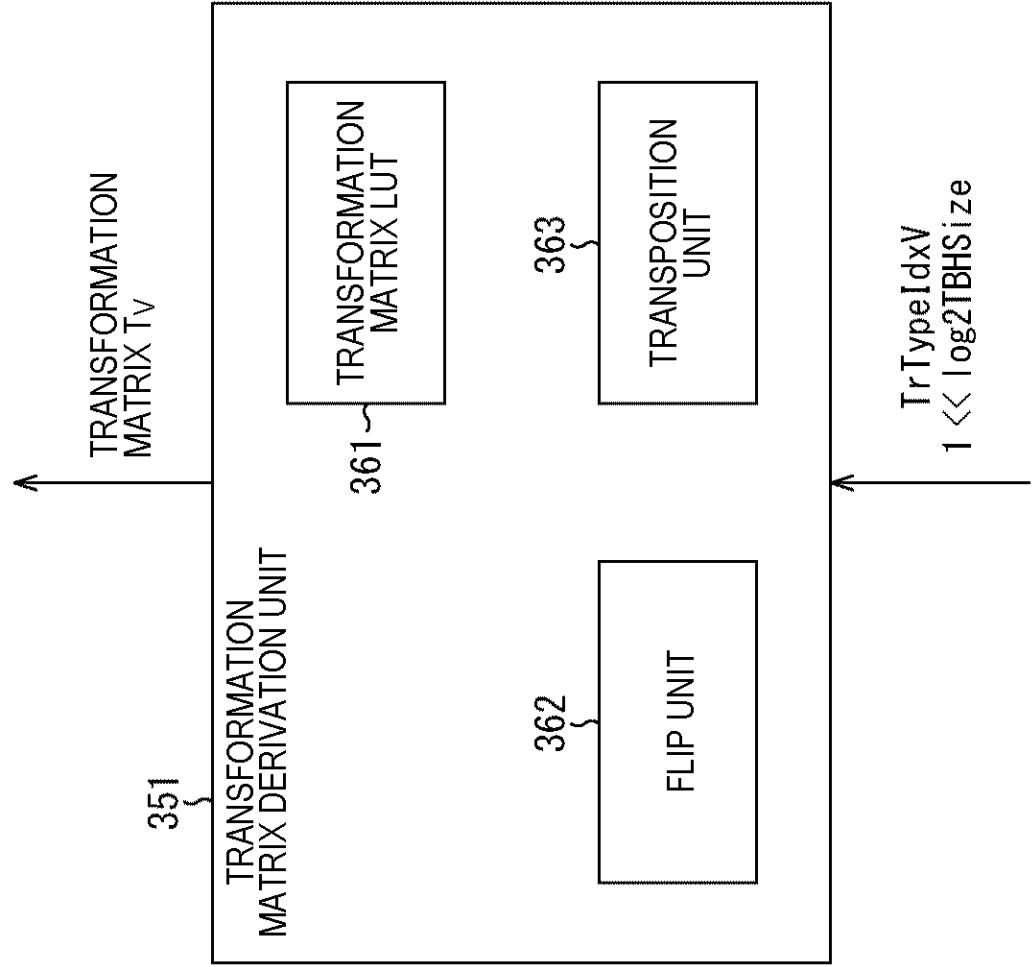


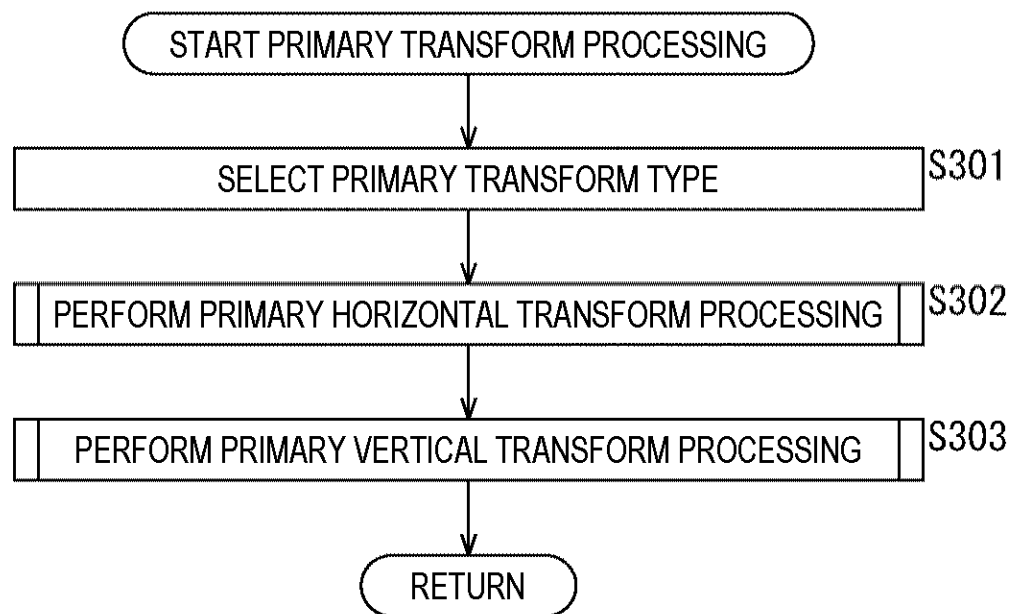
FIG. 27

FIG. 28

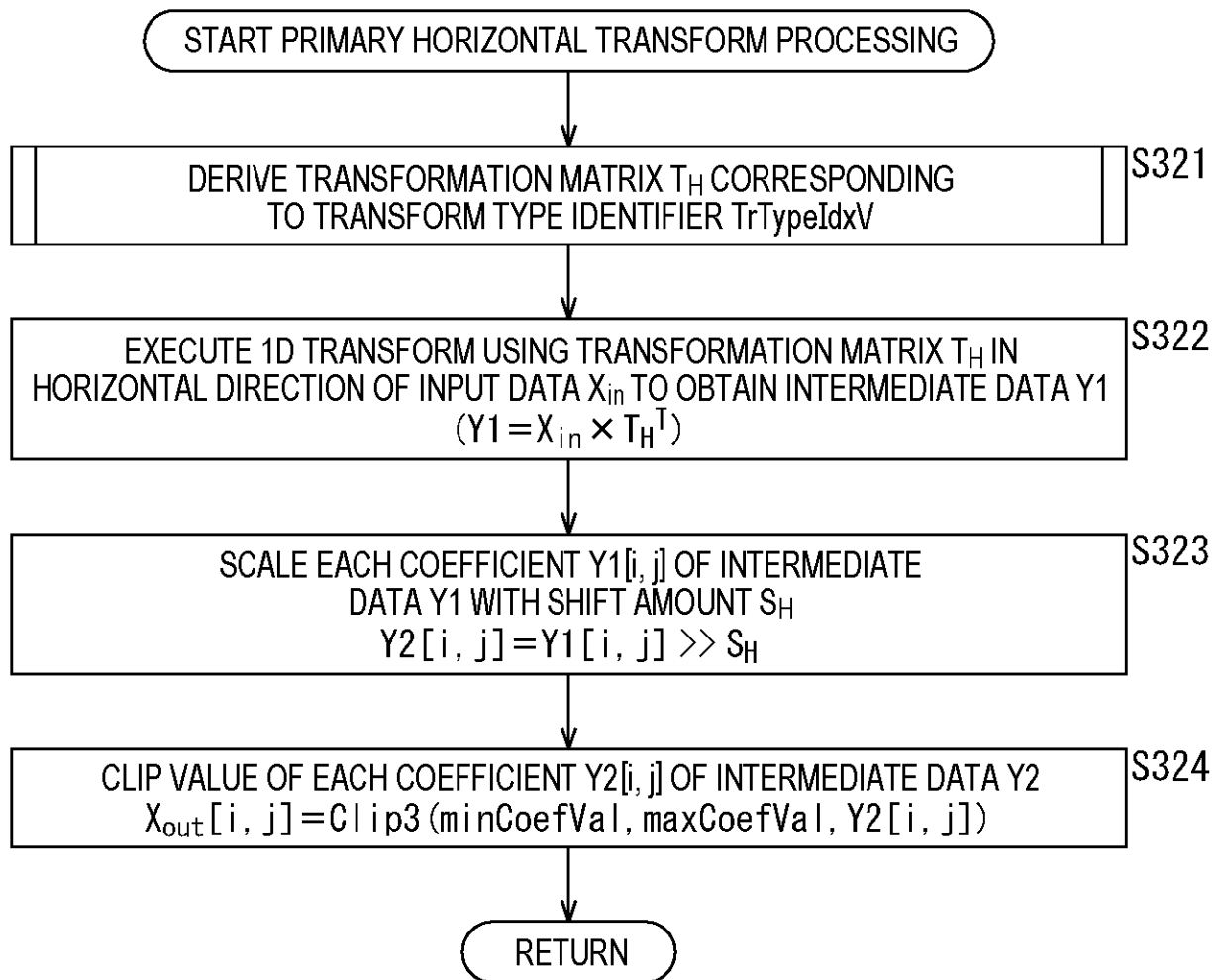


FIG. 29

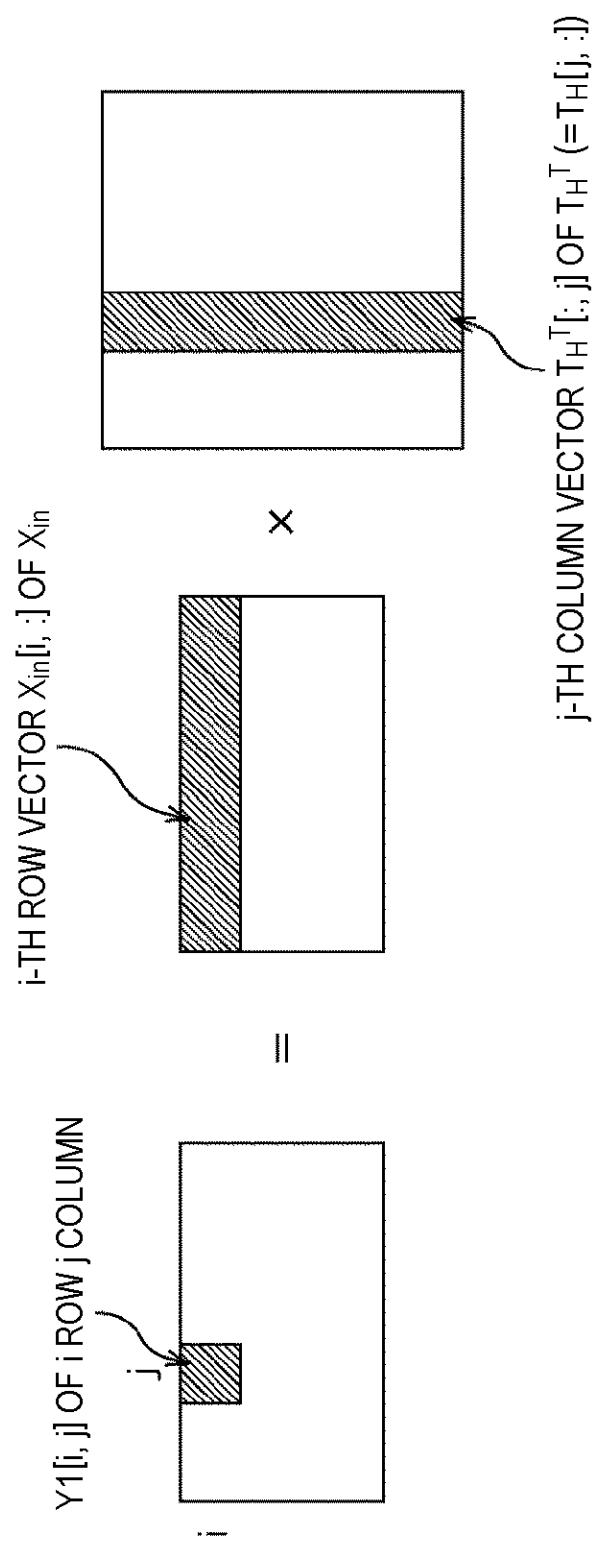


FIG. 30

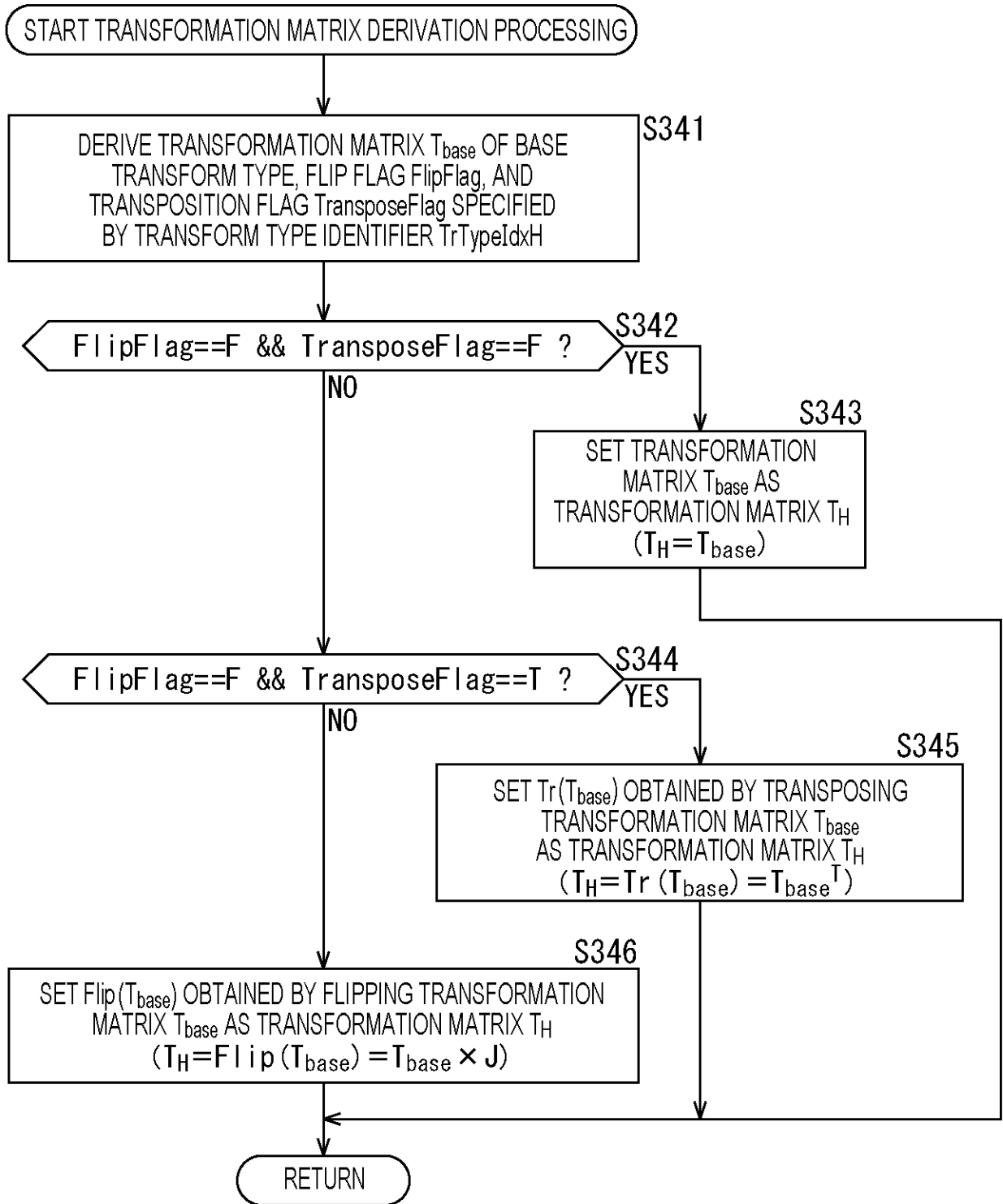


FIG. 31

TrTypeIdx	TRANSFORM TYPE TrType	BASE TRANSFORM TYPE BaseTrType	BASE TRANSFORMATION MATRIX T _{base}	FLIP FLAG FlipFlag	TRANSPOSITION FLAG TransposeFlag
0	DCT2	DCT2	T _{N, DCT2}	F	F
1	DST7	DST7	T _{N, DST7}	F	F
2	FlipDST7	DST7	T _{N, DST7}	T	F
3	TrDST7	DST7	T _{N, DST7}	F	T
4	DCT5	DCT5	T _{N, DCT5}	F	F

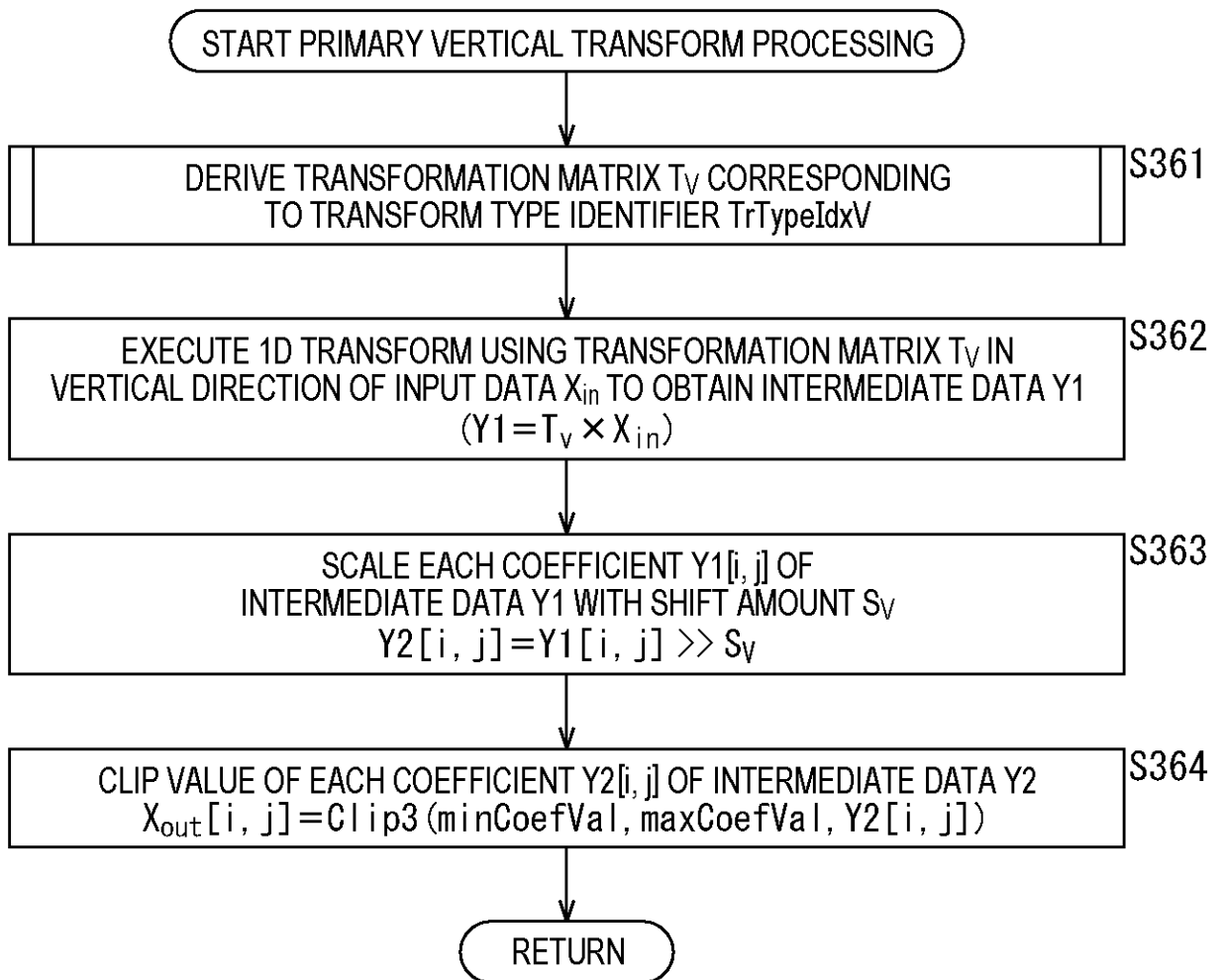
FIG. 32

FIG. 33

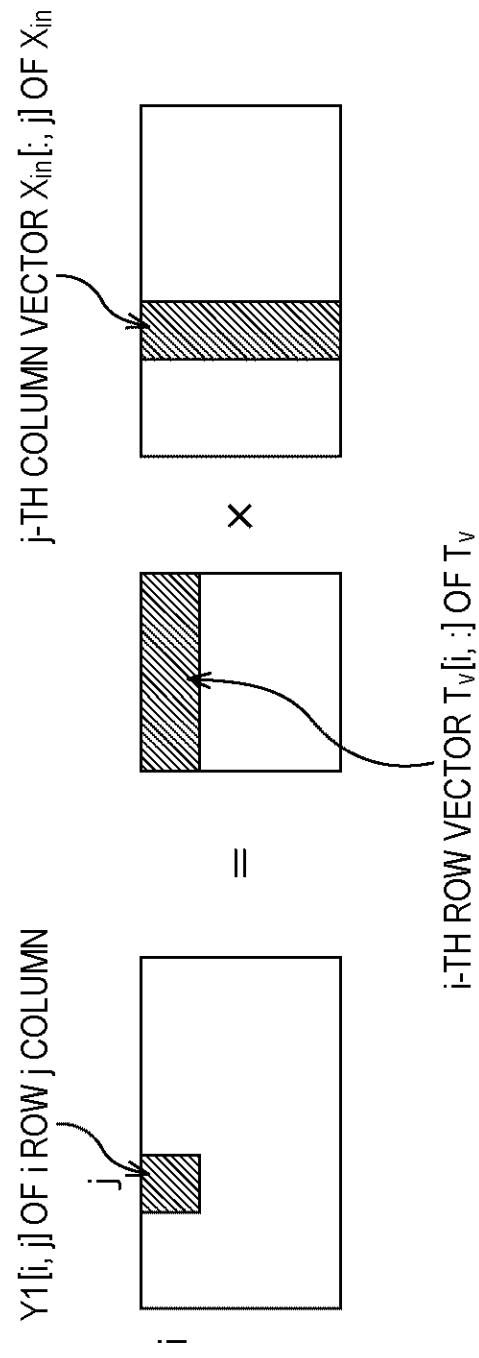


FIG. 34

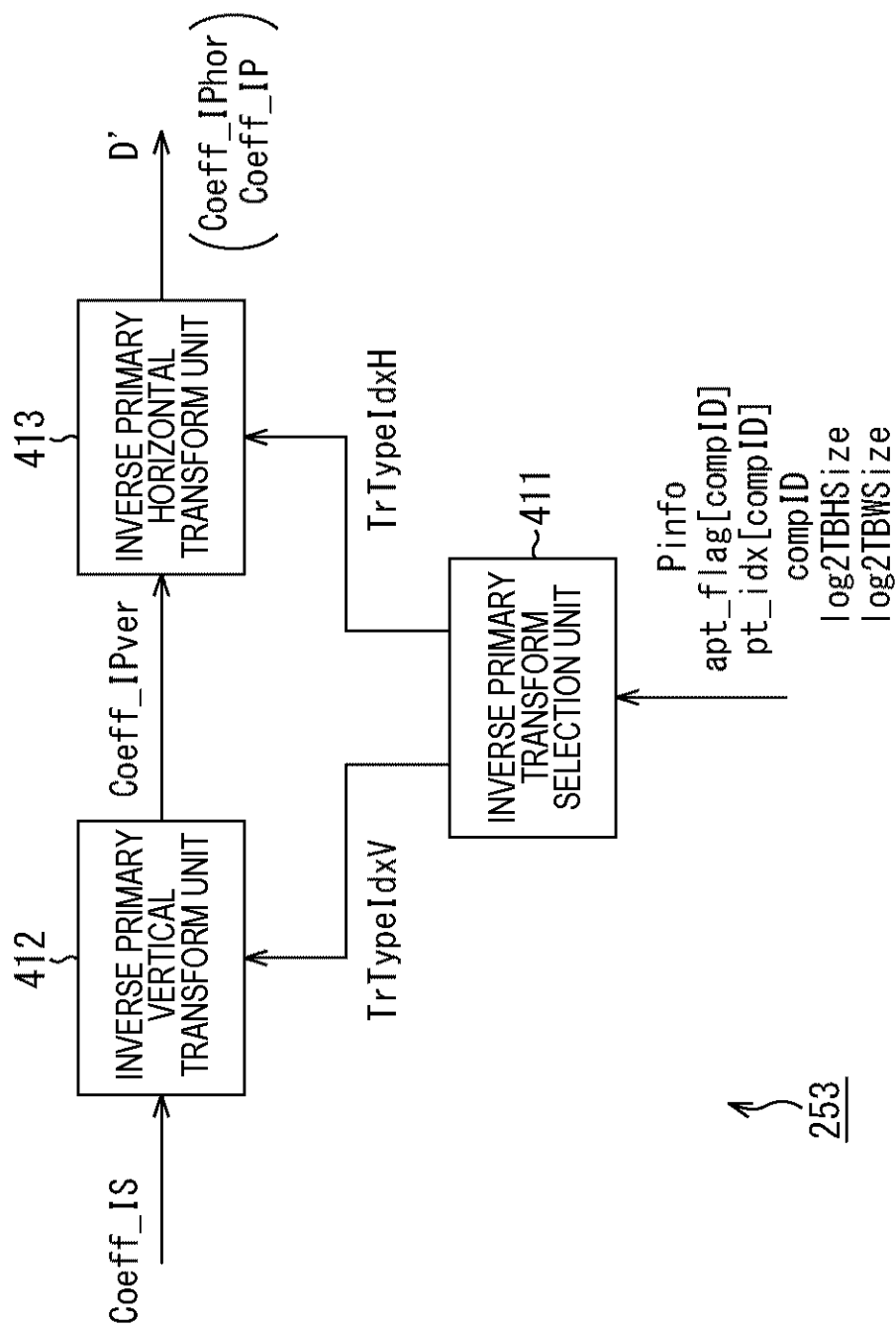


FIG. 35

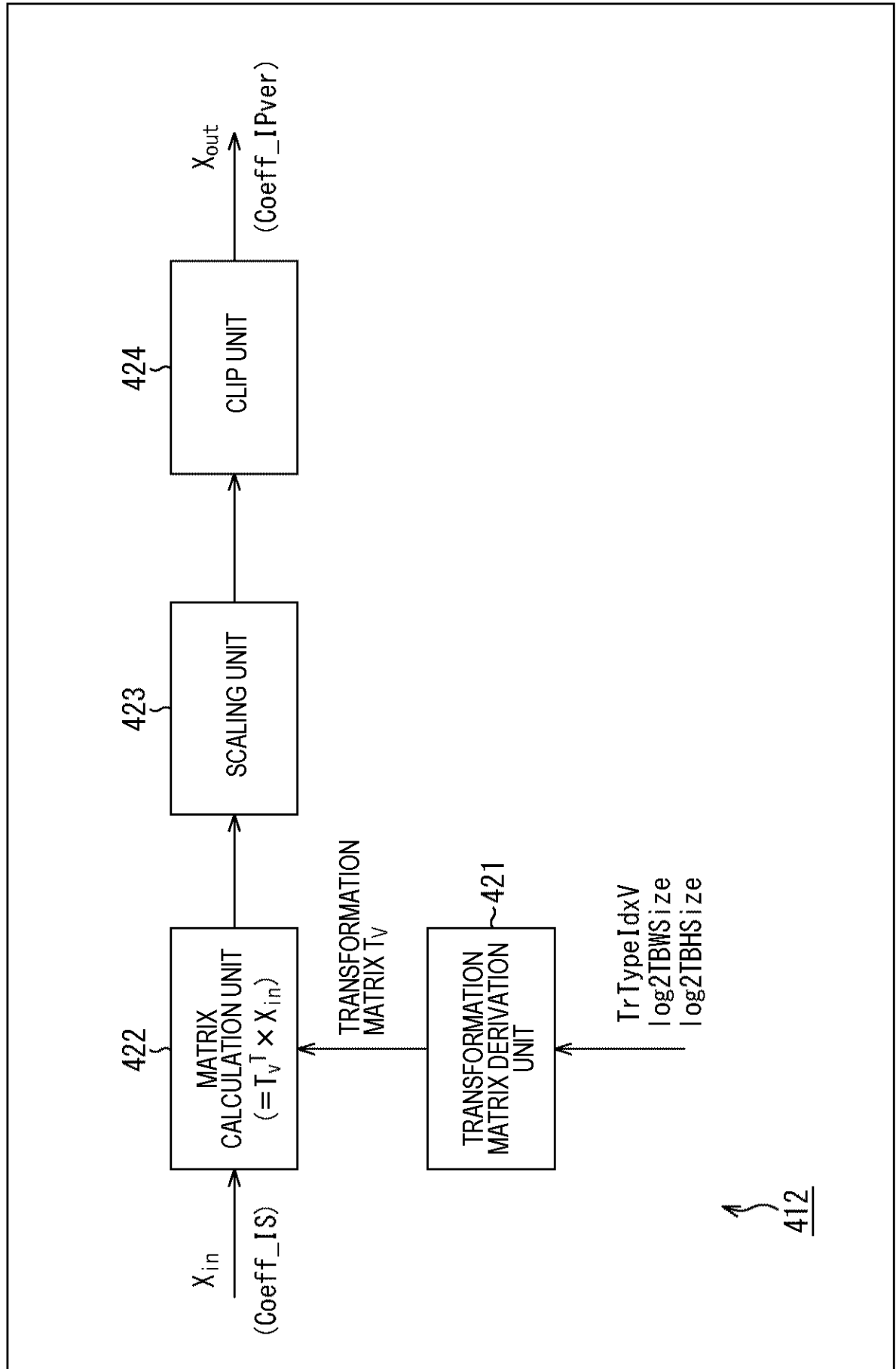


FIG. 36

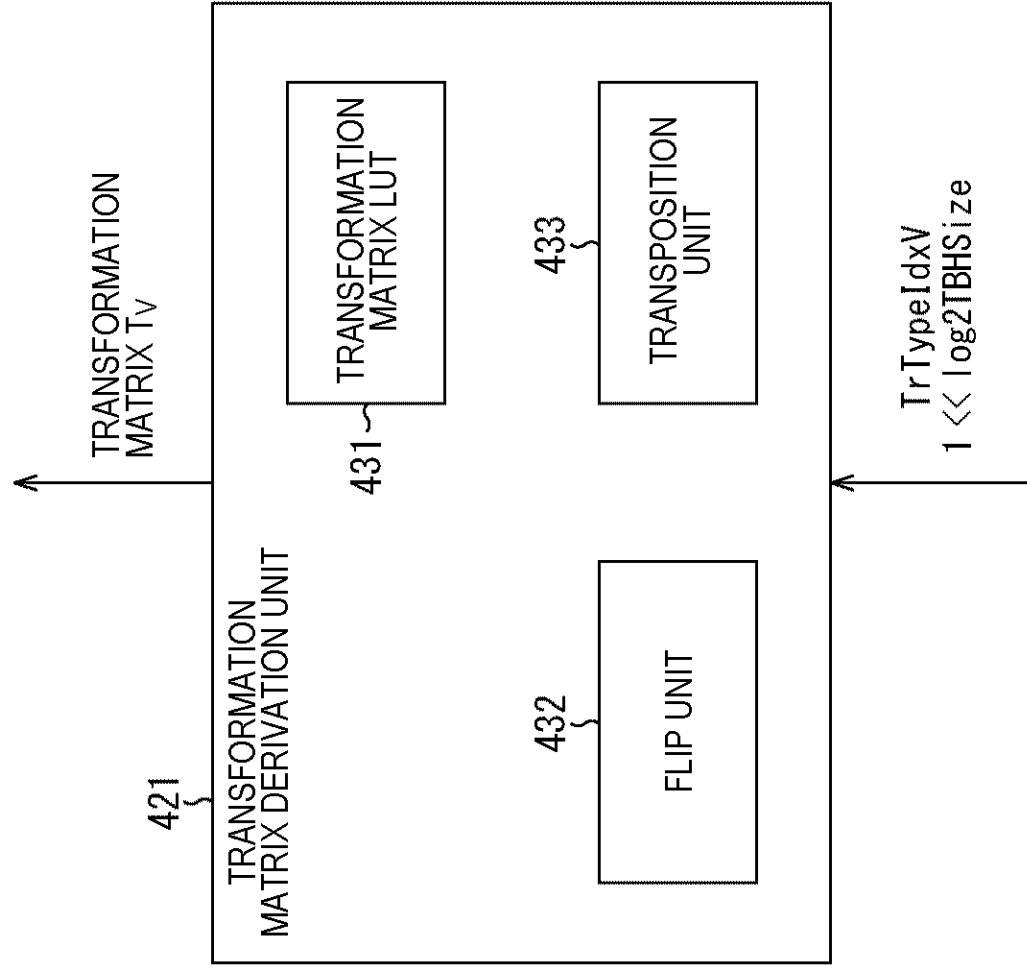


FIG. 37

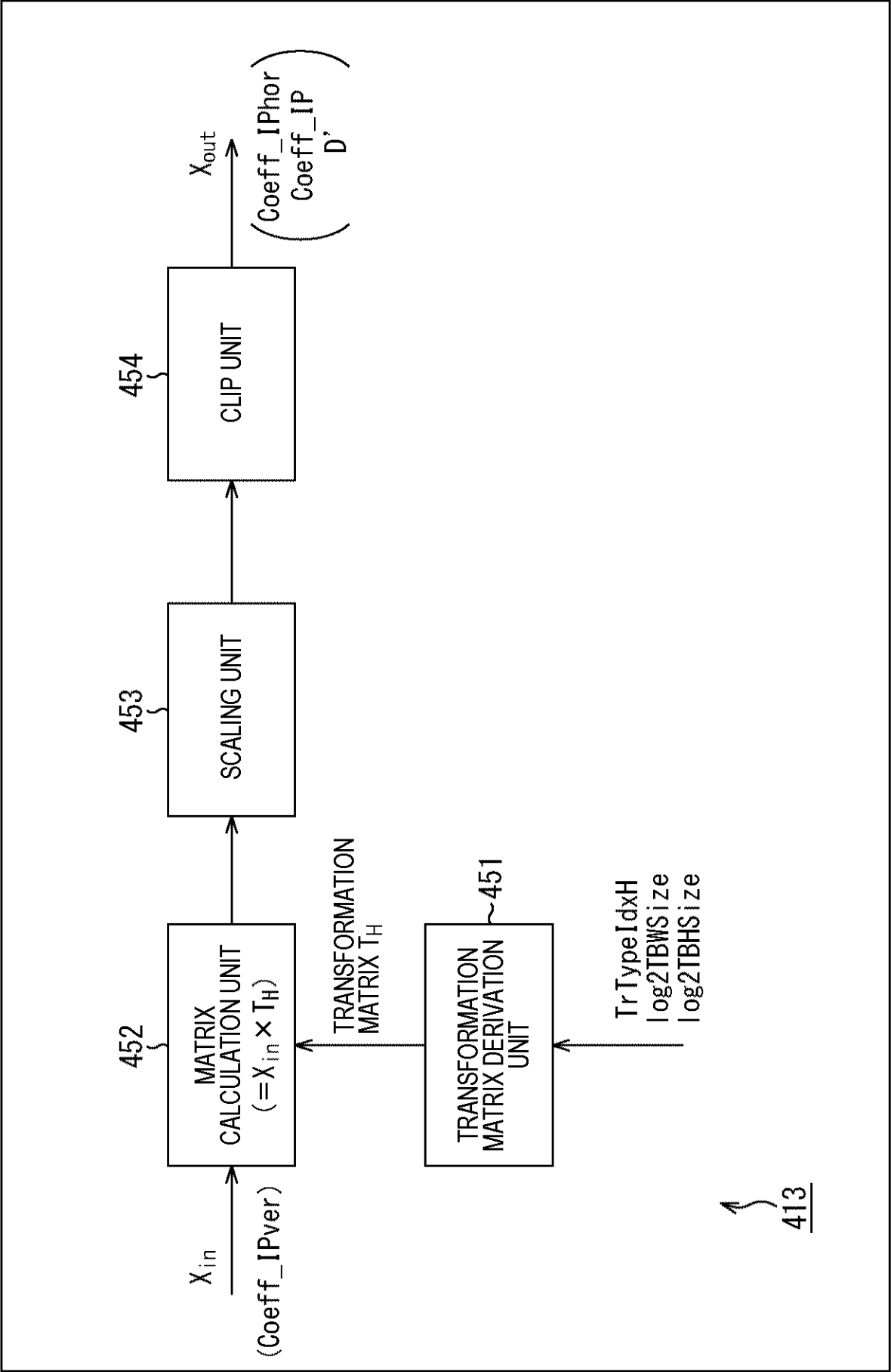


FIG. 38

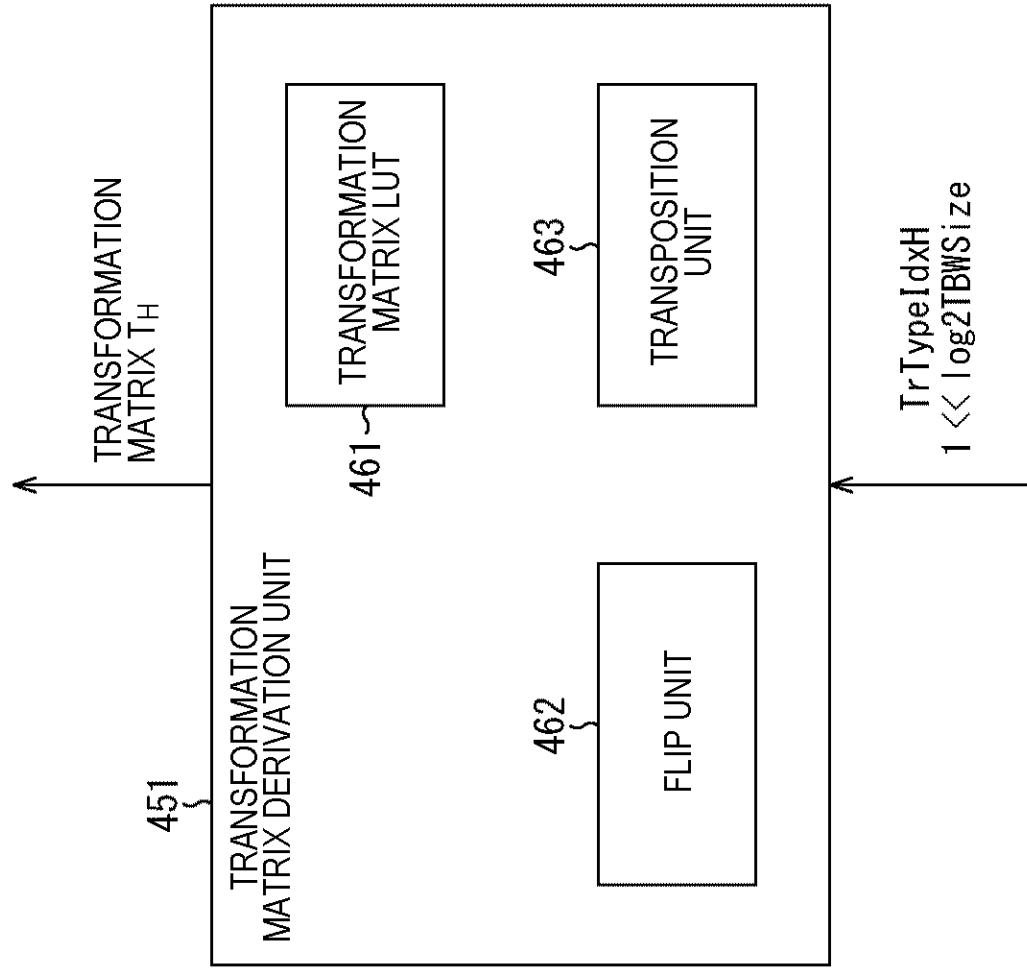


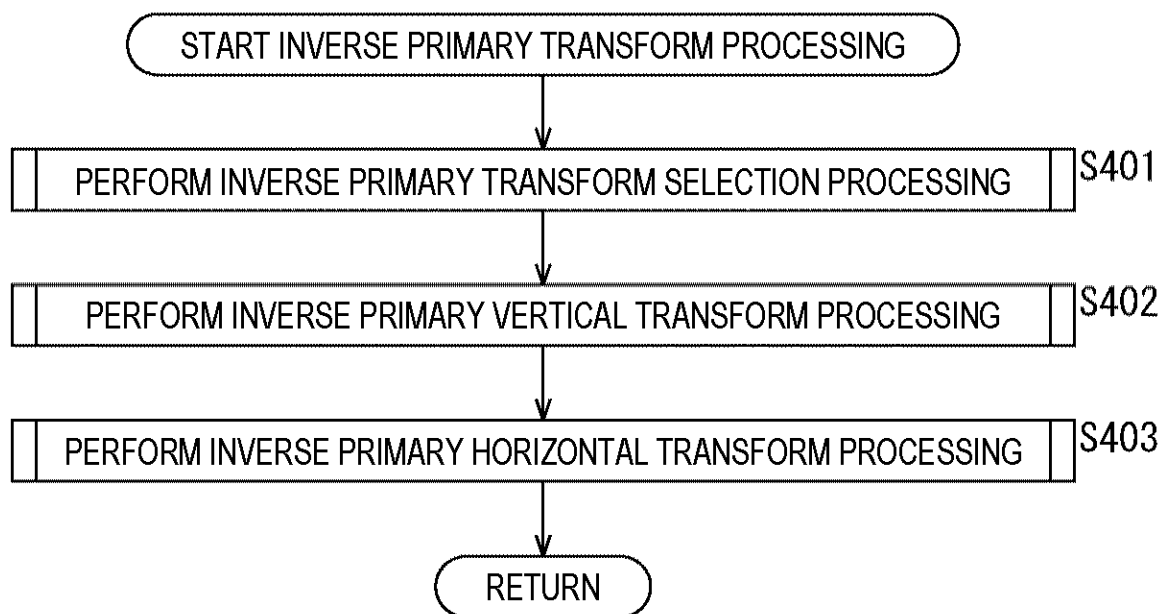
FIG. 39

FIG. 40

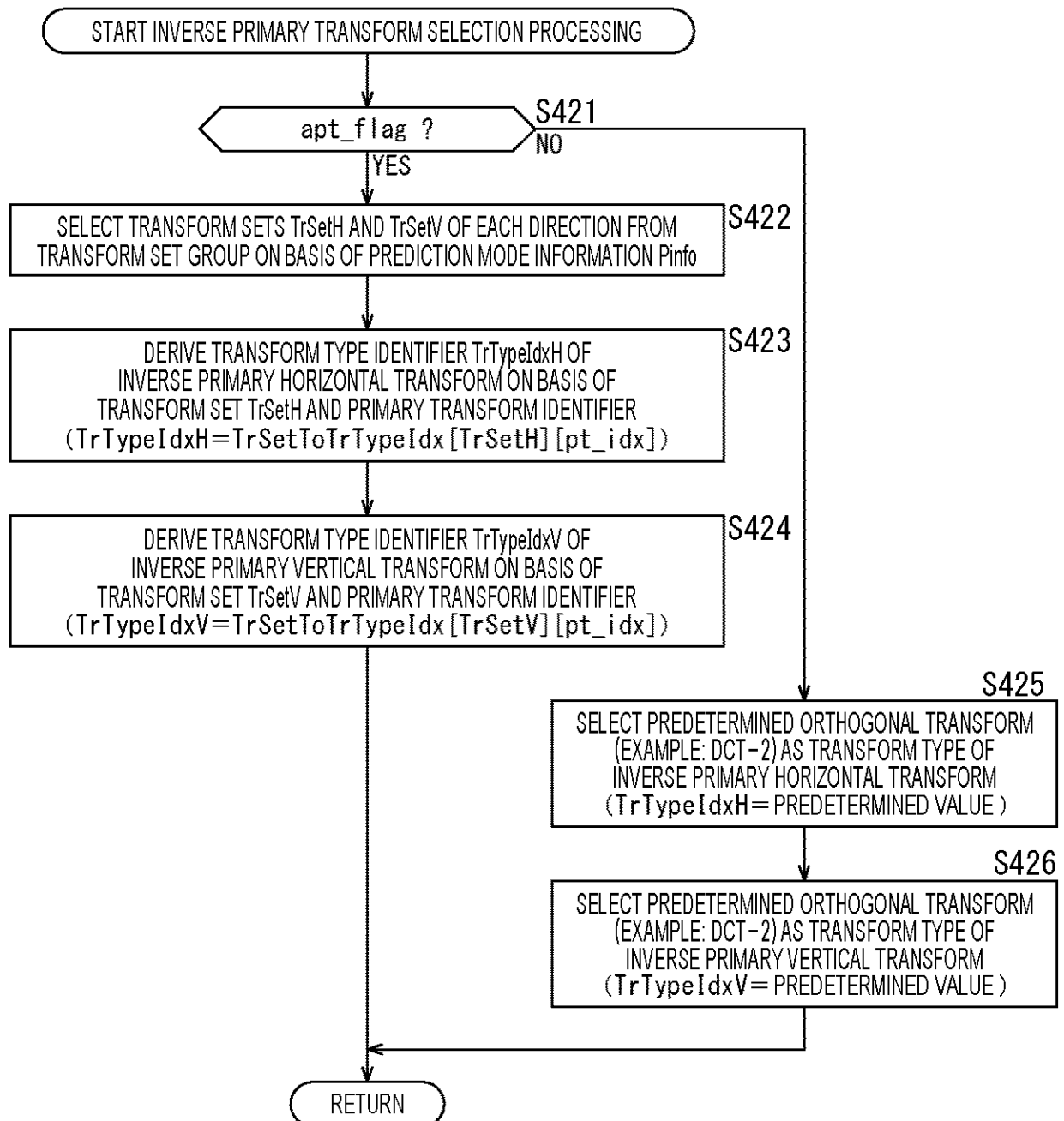


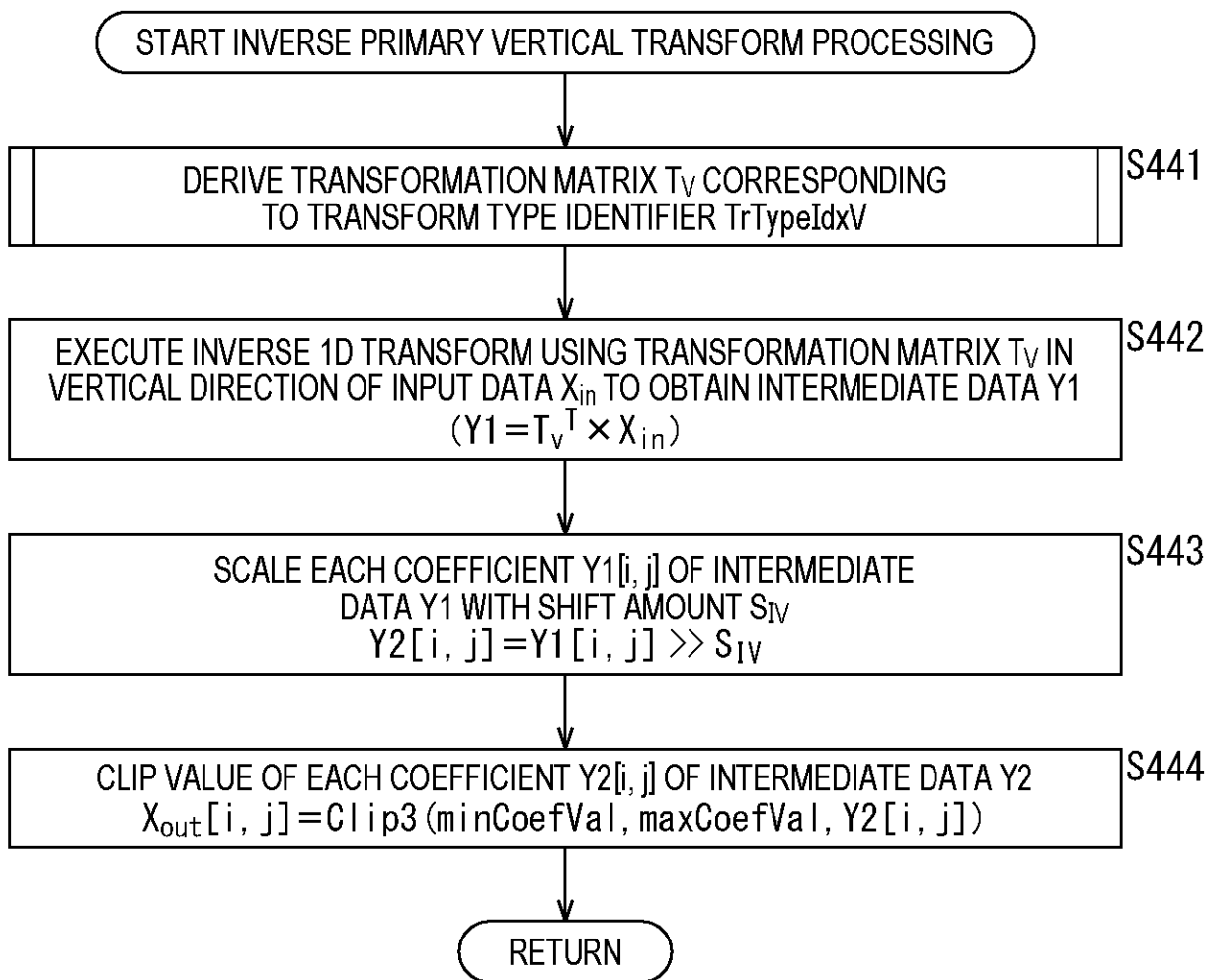
FIG. 41

FIG. 42

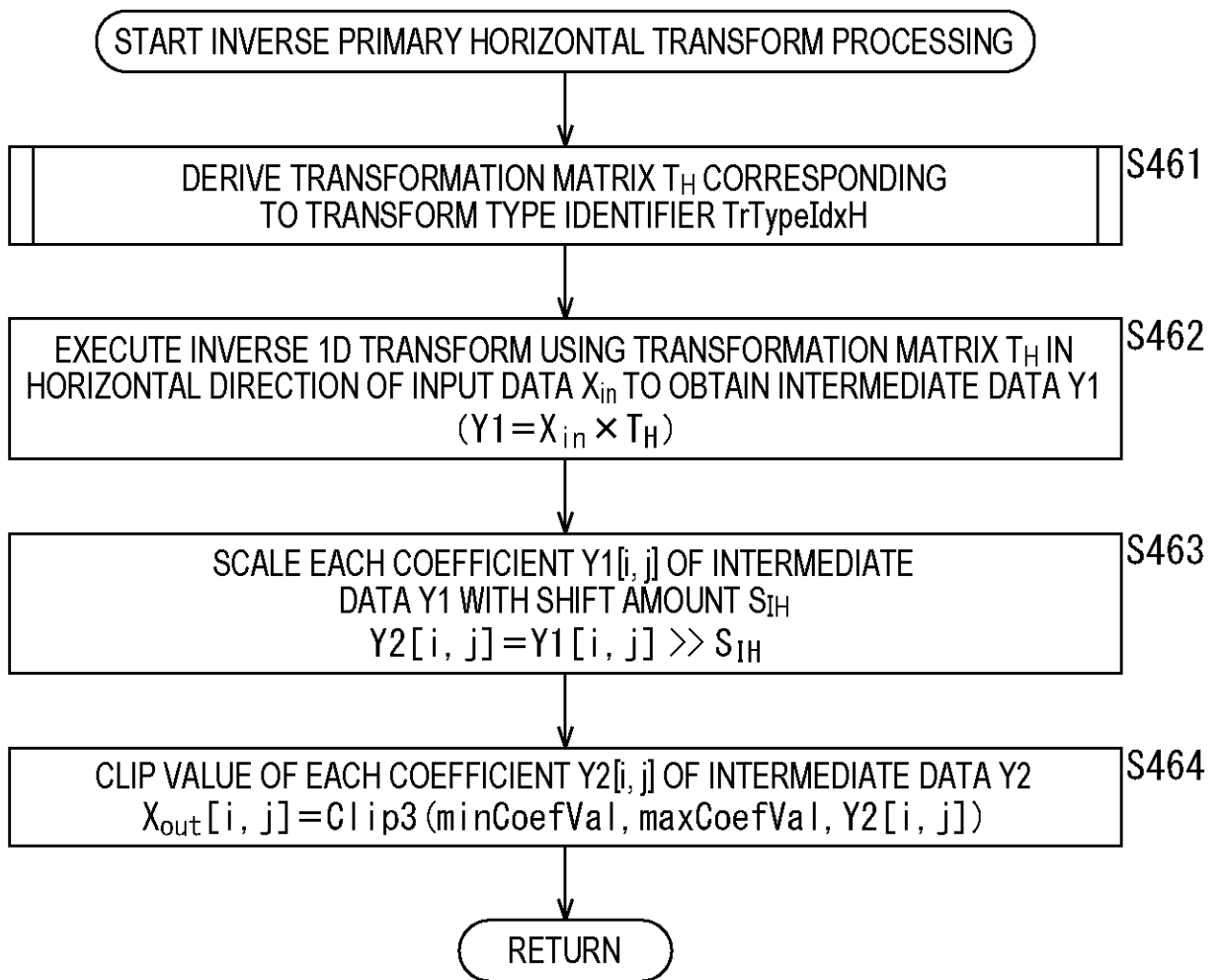
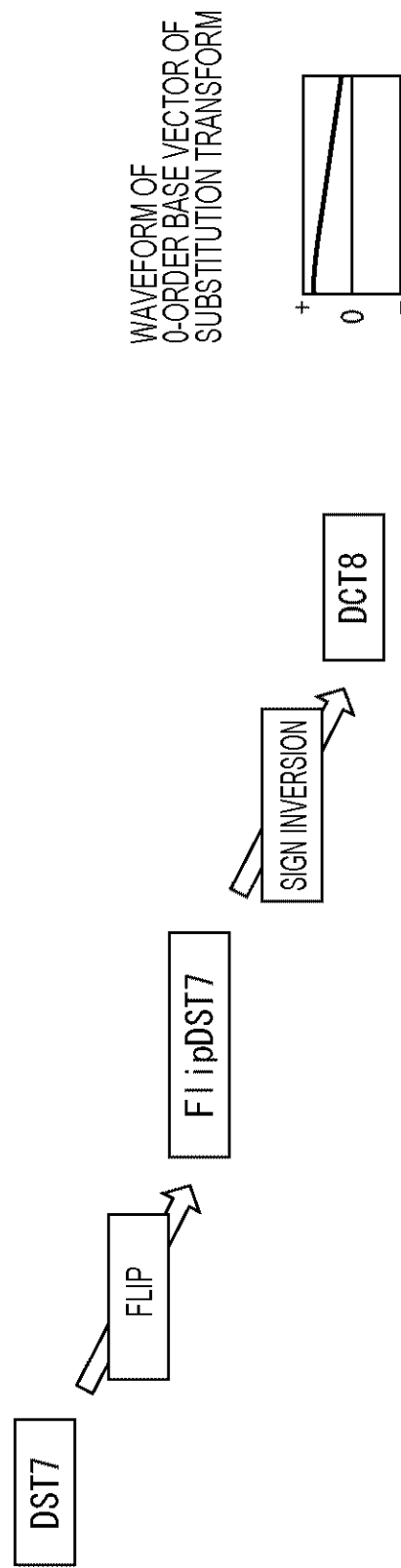


FIG. 43



SIGN INVERSION: INVERT SIGN OF ODD-ORDER BASE VECTOR

FIG. 45

TRANSFORM SIZE N	NUMBER OF ELEMENTS	TYPE OF TRANSFORMATION MATRIX	BIT PRECISION/bit	LUT SIZE bits
2	4	1	10	40
4	16	4	10	640
8	64	4	10	2560
16	256	4	10	10240
32	1024	4	10	40960
64	4096	4	10	163840
128	16384	1	10	163840
TOTAL				382120 (≈ 47KB)

FIG. 46

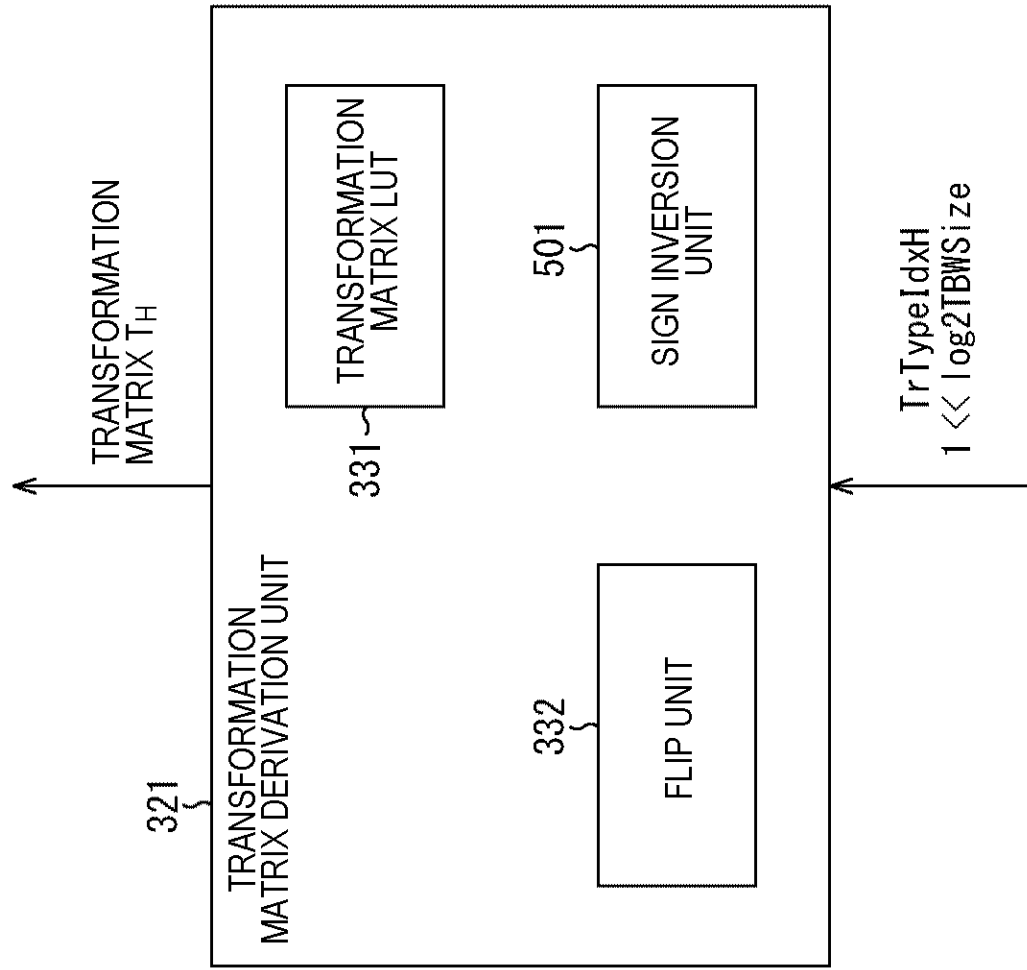


FIG. 47

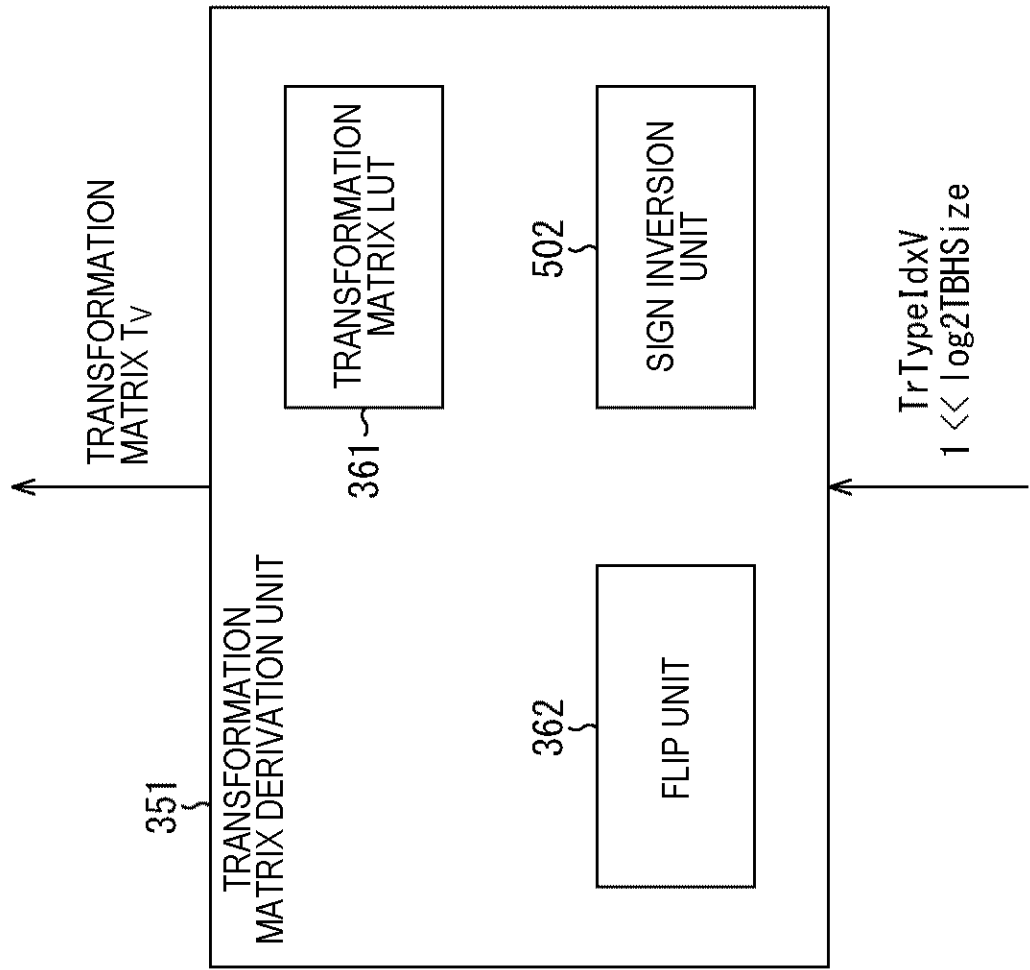


FIG. 48

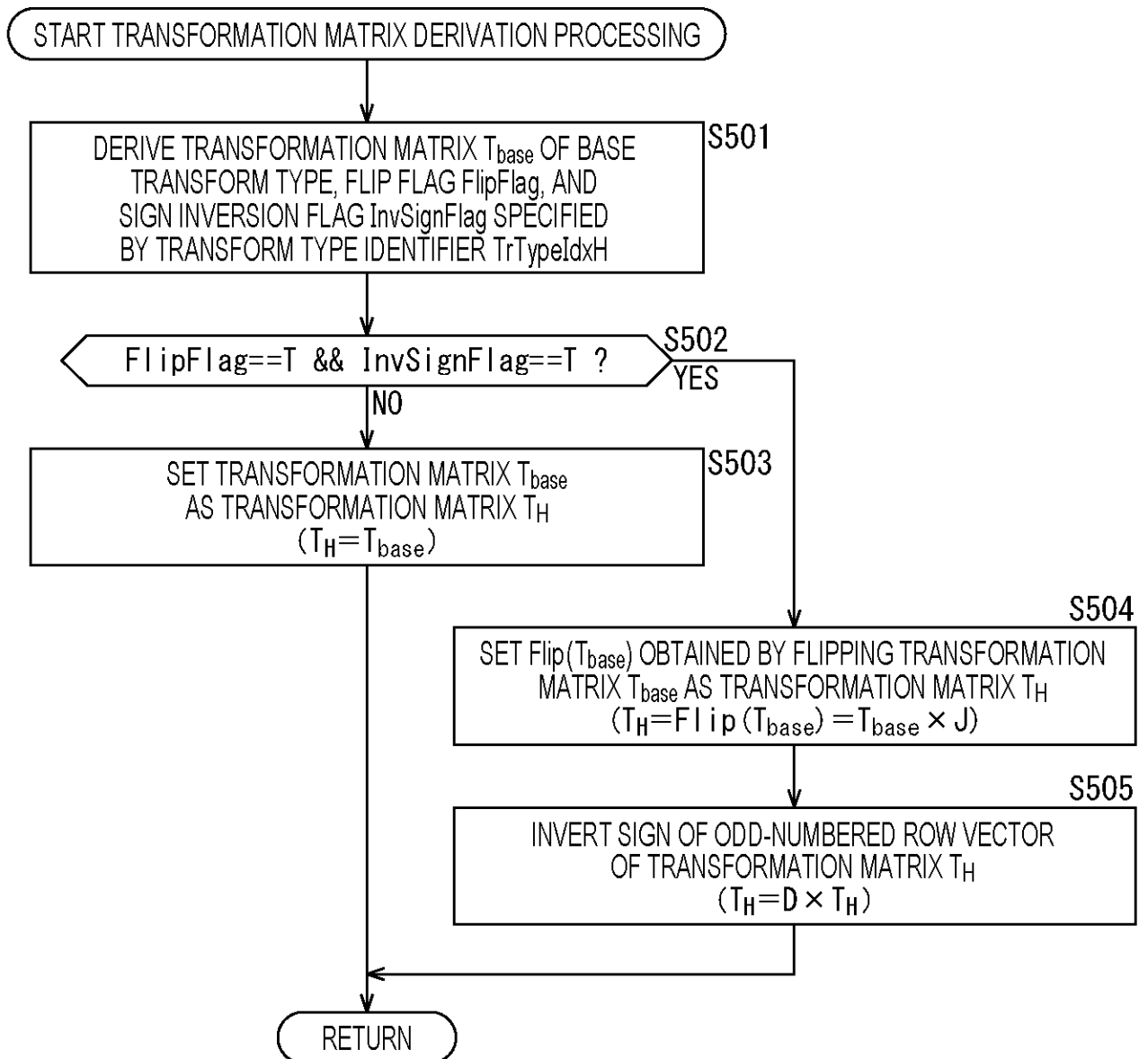


FIG. 49

TrTypeIdx	TRANSFORM TYPE TrType	BASE TRANSFORM TYPE BaseTrType	BASE TRANSFORMATION MATRIX T _{base}	FLIP FLAG FlipFlag	SIGN INVERSION FLAG InvSignFlag
0	DCT2	DCT2	T _{N, DCT2}	F	F
1	DST7	DST7	T _{N, DST7}	F	F
2	DCT8	DST7	T _{N, DST7}	T	T
3	DST1	DST1	T _{N, DST1}	F	F
4	DCT5	DCT5	T _{N, DCT5}	F	F

FIG. 50

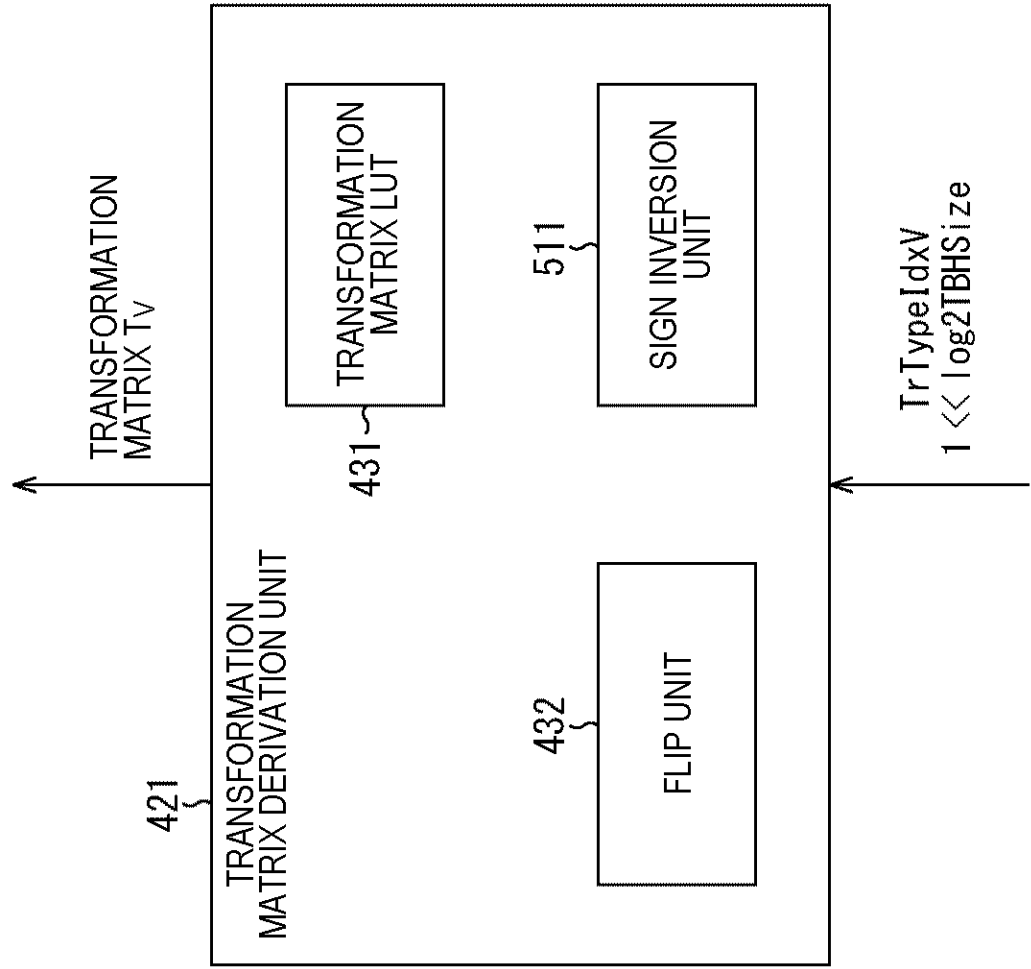


FIG. 51

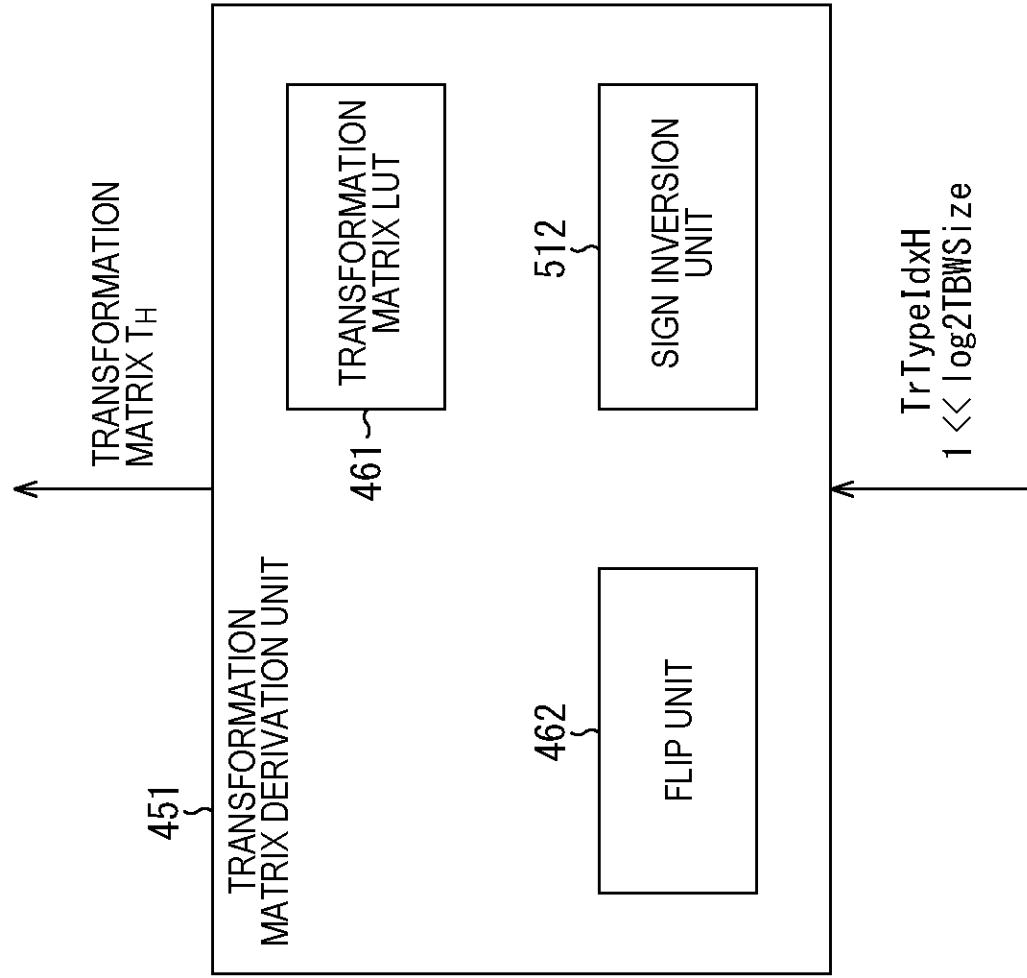
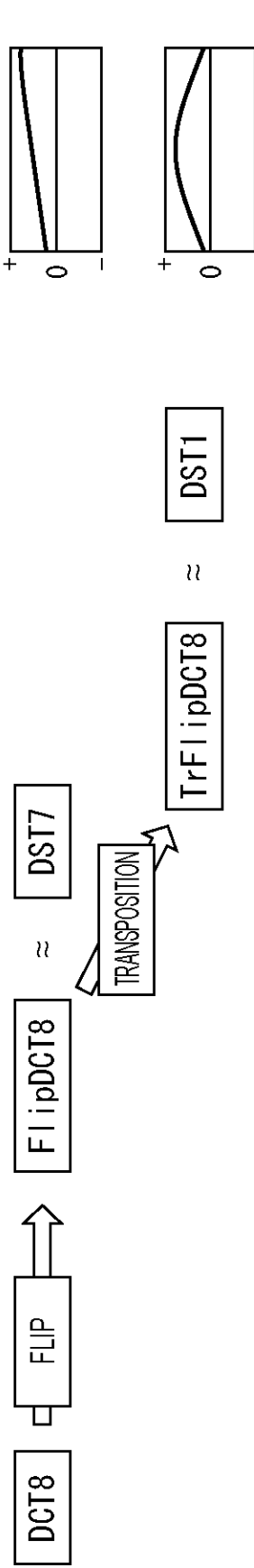


FIG. 52



≈: WAVEFORM OF LOW-ORDER (ESPECIALLY 0-ORDER) BASE VECTOR IS SIMILAR

FIG. 53

TRANSFORM SIZE N	NUMBER OF ELEMENTS	TYPE OF TRANSFORMATION MATRIX	BIT PRECISION bit	LUT SIZE bits
2	4	1	10	40
4	16	3	10	480
8	64	3	10	1920
16	256	3	10	7680
32	1024	3	10	30720
64	4096	3	10	122880
128	16384	1	10	163840
TOTAL				327560 (≈ 40KB)

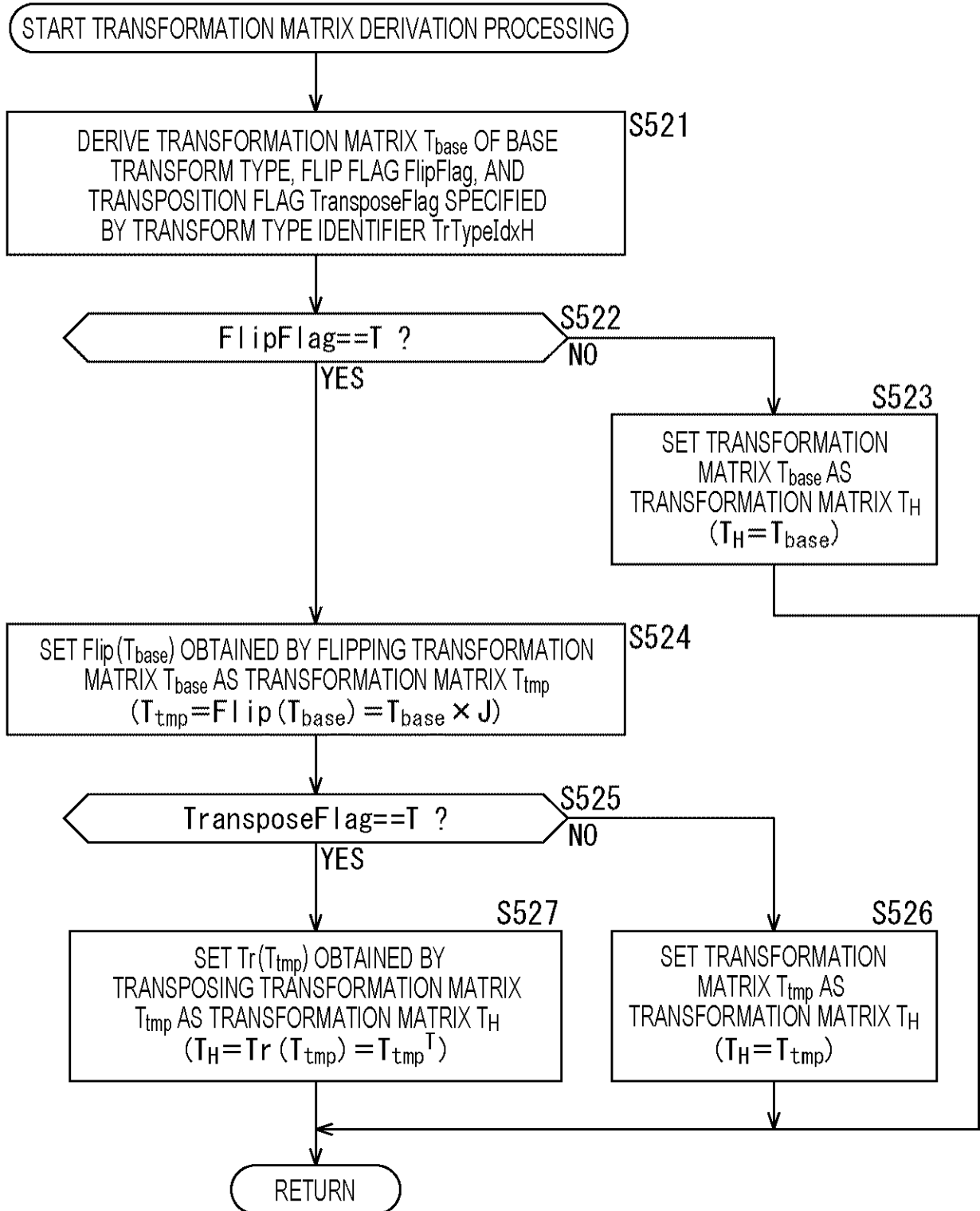
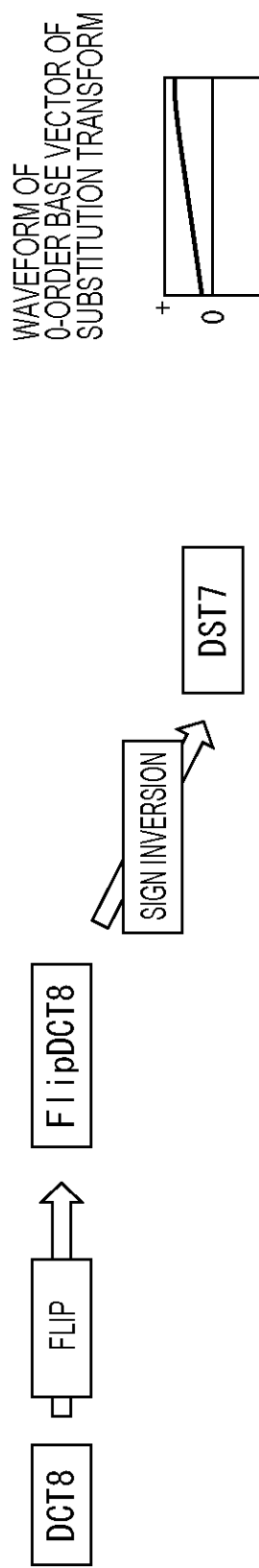
FIG. 54

FIG. 55

TrTypeIdx	TRANSFORM TYPE TrType	BASE TRANSFORM TYPE BaseTrType	BASE TRANSFORMATION MATRIX T _{base}	FLIP FLAG FlipFlag	TRANSPOSITION FLAG TransposeFlag
0	DCT2	DCT2	T _N , DCT2	F	F
1	DCT8	DCT8	T _N , DCT8	F	F
2	FlipDCT8	DCT8	T _N , DCT8	T	F
3	TrFlipDCT8	DCT8	T _N , DCT8	T	T
4	DCT5	DCT5	T _N , DCT5	F	F

FIG. 56



SIGN INVERSION: INVERT SIGN OF ODD-ORDER BASE VECTOR

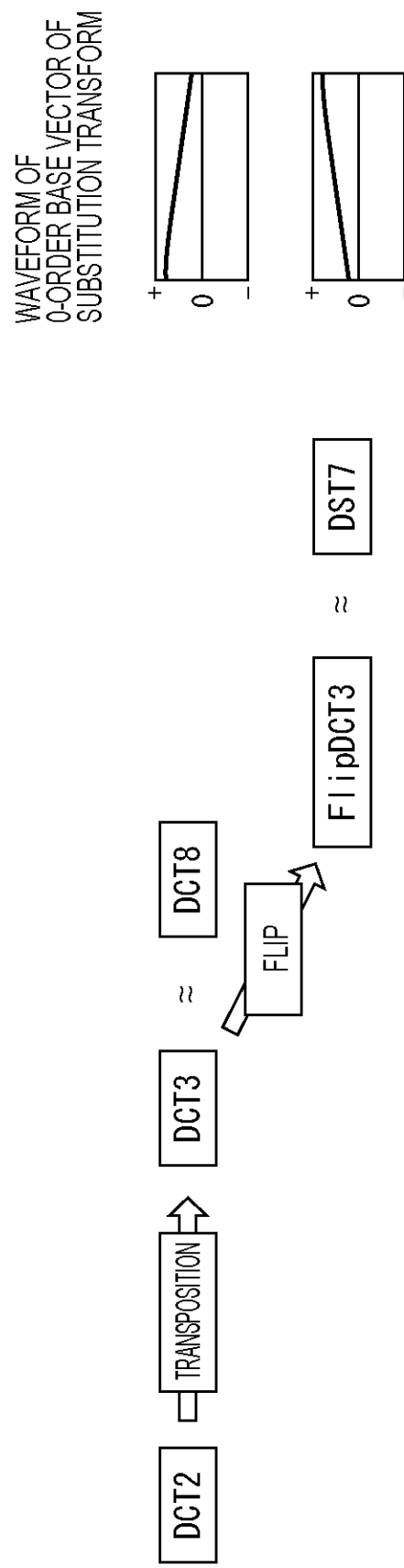
FIG. 57

TRANSFORM SIZE N	NUMBER OF ELEMENTS	TYPE OF TRANSFORMATION MATRIX	BIT PRECISION bit	LUT SIZE bits
2	4	1	10	40
4	16	4	10	640
8	64	4	10	2560
16	256	4	10	10240
32	1024	4	10	40960
64	4096	4	10	163840
128	16384	1	10	163840
TOTAL				382120 (≈ 47KB)

FIG. 58

TrTypeIdx	TRANSFORM TYPE TrType	BASE TRANSFORM TYPE BaseTrType	BASE TRANSFORMATION MATRIX T _{base}	FLIP FLAG FlipFlag	SIGN INVERSION FLAG InvSignFlag
0	DCT2	DCT2	T _{N, DCT2}	F	F
1	DST7	DCT8	T _{N, DCT8}	T	T
2	DCT8	DCT8	T _{N, DCT8}	F	F
3	DST1	DST1	T _{N, DST1}	F	F
4	DCT5	DCT5	T _{N, DCT5}	F	F

FIG. 59



≈: WAVEFORM OF LOW-ORDER (ESPECIALLY 0-ORDER) BASE VECTOR IS SIMILAR

FIG. 60

TRANSFORM SIZE N	NUMBER OF ELEMENTS	TYPE OF TRANSFORMATION MATRIX	BIT PRECISION bit	LUT SIZE bits
2	4	1	10	40
4	16	3	10	480
8	64	3	10	1920
16	256	3	10	7680
32	1024	3	10	30720
64	4096	3	10	122880
128	16384	1	10	163840
TOTAL				327560 ($\approx$ 40KB)

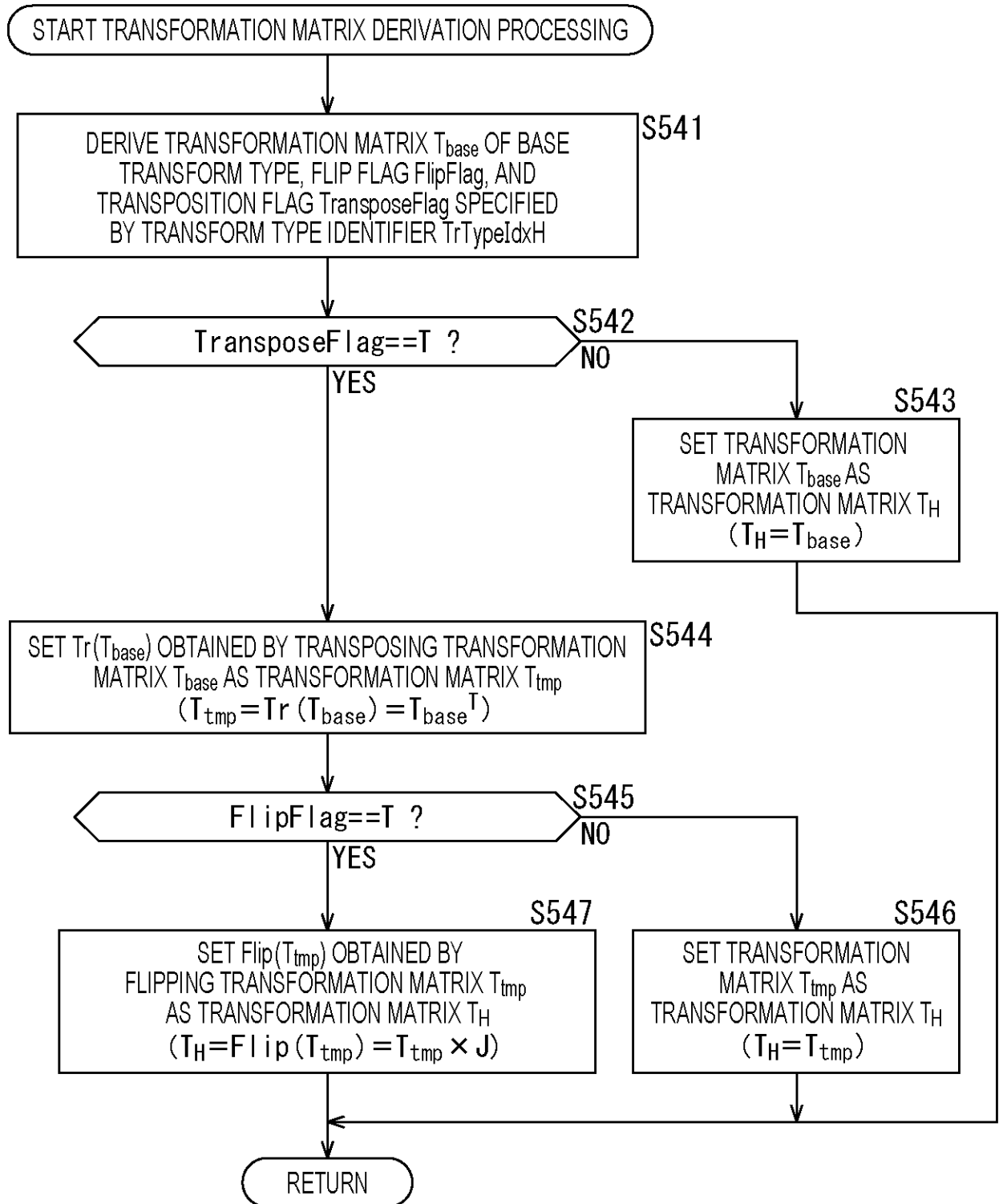
FIG. 61

FIG. 62

TrTypeIdx	TRANSFORM TYPE TrType	BASE TRANSFORM TYPE BaseTrType	BASE TRANSFORMATION MATRIX T_{base}	FLIP FLAG FlipFlag	TRANSPOSITION FLAG TransposeFlag
0	DCT2	DCT2	$T_N, DCT2$	F	F
1	DCT3 (TrDCT2)	DCT2	$T_N, DCT2$	F	T
2	FlipDCT3 (FlipTrDCT2)	DCT2	$T_N, DCT2$	T	T
3	DST1	DST1	$T_N, DST1$	F	F
4	DCT5	DCT5	$T_N, DCT5$	F	F

FIG. 63

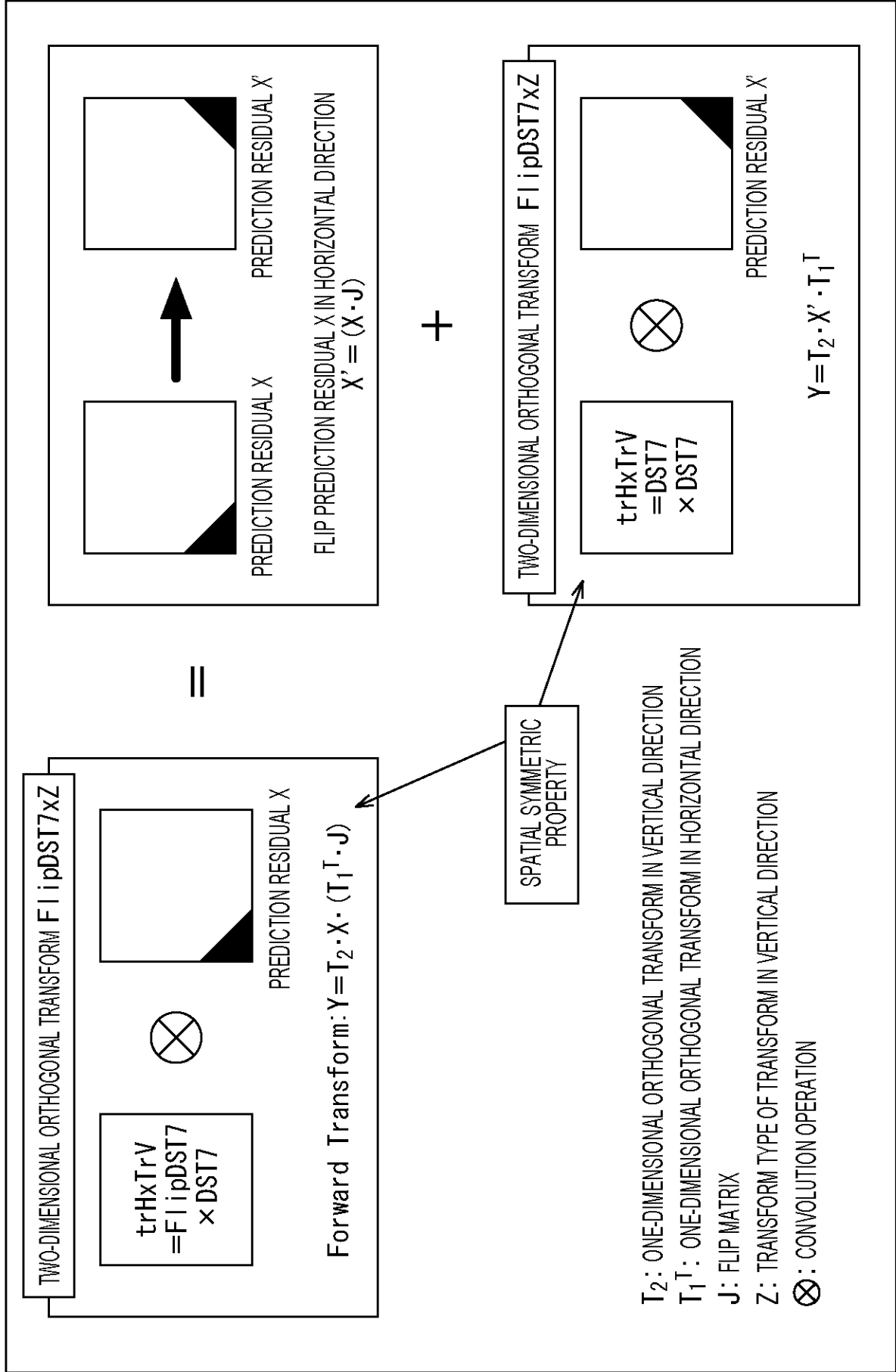
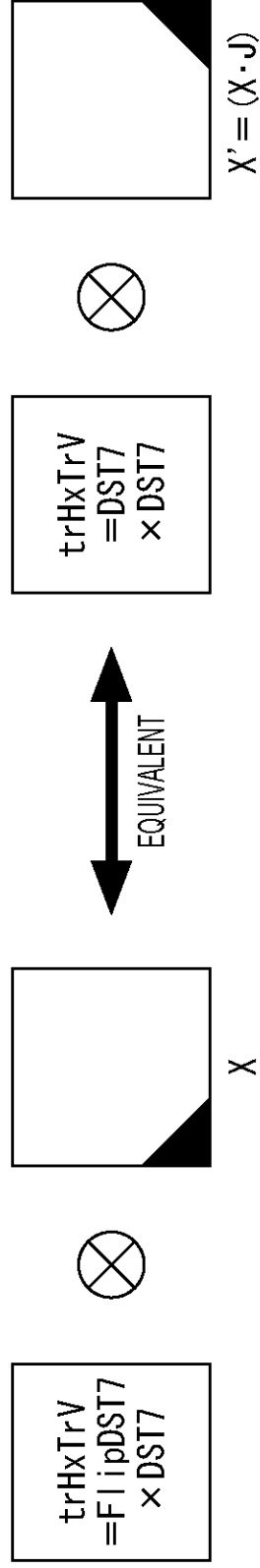


FIG. 64

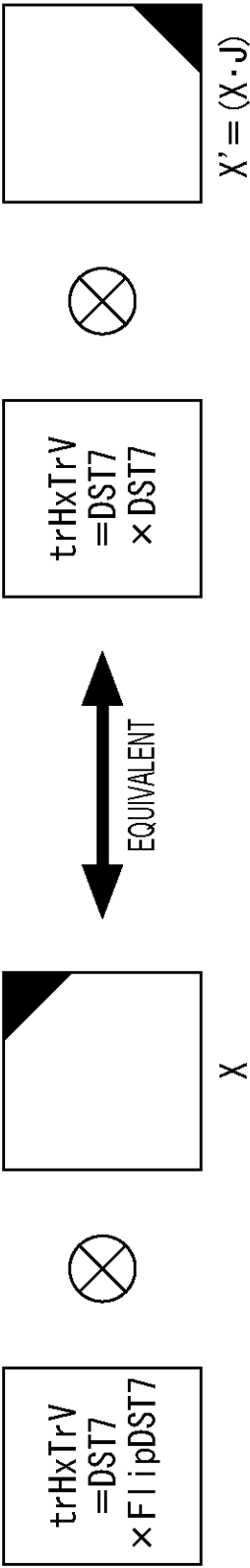


Forward Transform: $Y = T_2 \cdot X \cdot (T_1 \cdot J)^T$

$Y = T_2 \cdot (X \cdot J) \cdot T_1^T$

- T_2 : ONE-DIMENSIONAL ORTHOGONAL TRANSFORM IN VERTICAL DIRECTION
- T_1^T : ONE-DIMENSIONAL ORTHOGONAL TRANSFORM IN HORIZONTAL DIRECTION
- J: FLIP MATRIX
- $\otimes$: CONVOLUTION OPERATION

FIG. 65



Forward Transform: $Y = (T_2 \cdot J) \cdot X \cdot T_1^T$

$Y = T_2 \cdot (J \cdot X) \cdot T_1^T$

- T_2 : ONE-DIMENSIONAL ORTHOGONAL TRANSFORM IN VERTICAL DIRECTION
 T_1^T : ONE-DIMENSIONAL ORTHOGONAL TRANSFORM IN HORIZONTAL DIRECTION
 J : FLIP MATRIX
 $\otimes$: CONVOLUTION OPERATION

FIG. 66

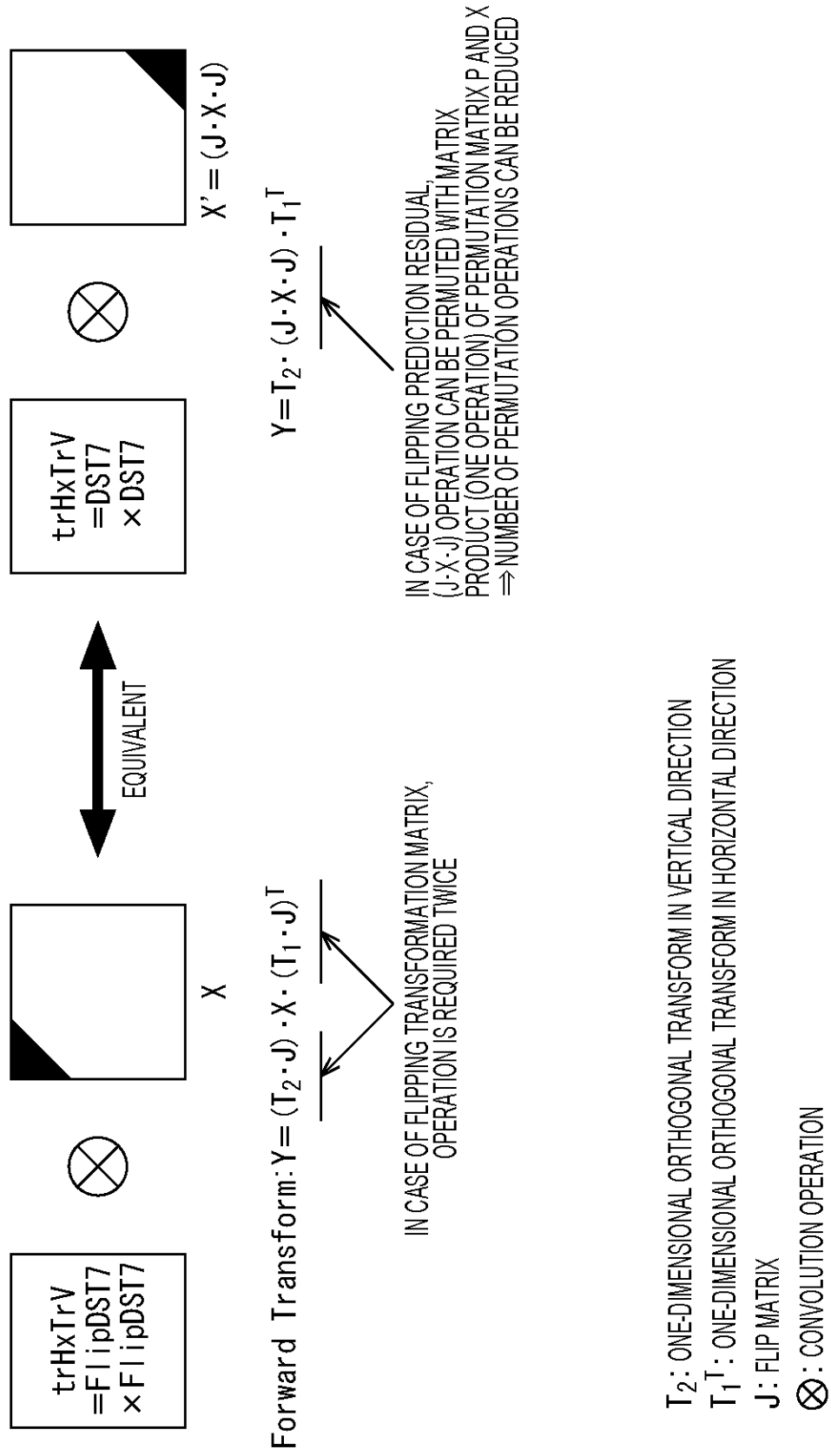


FIG. 67

CORRESPONDING EXAMPLE	FIRST TRANSFORM TYPE (BASE TRANSFORM TYPE)	SECOND TRANSFORM TYPE (TRANSFORM TYPE TO BE DERIVED)	SUBSTITUTABLE TRANSFORM TYPE	OPERATION OF BASE TRANSFORMATION MATRIX T_{base}		OPERATION OF PREDICTION RESIDUAL	FOCUS POINT	EFFECT
				TRANSPOSITION	SIGN INVERSION			
2-1	DST7	FlipDST7	FlipDST7 			×	• TWO DIFFERENT TWO-DIMENSIONAL ORTHOGONAL TRANSFORMS HAVE AXIAL SYMMETRY BETWEEN ONE-DIMENSIONAL ORTHOGONAL TRANSFORMS IN CERTAIN DIRECTION (HORIZONTAL OR VERTICAL) (DST7 ↔ FlipDST7)	• REDUCTION OF UNIQUE TRANSFORM TYPE (REDUCTION OF LUT SIZE) (SAME AS INVENTION #) • SECOND TRANSFORM TYPE HAS SIMILAR ENCODING EFFICIENCY TO DST8 • NUMBER OF FLIP OPERATIONS IS REDUCIBLE (REDUCTION OF PROCESSING AMOUNT) BECAUSE TWO-DIMENSIONAL FLIP OPERATION CAN BE COLLECTIVELY PERFORMED FOR PREDICTION RESIDUAL, AS COMPARED WITH FLIP OPERATION FOR TRANSFORMATION MATRIX OF ONE-DIMENSIONAL ORTHOGONAL TRANSFORM (- PROCESSING AMOUNT IS SMALLER THAN 2-2)
2-2 (1-2)	DST7	DCT8	DCT8 		×	×	• TWO DIFFERENT TWO-DIMENSIONAL ORTHOGONAL TRANSFORMS HAVE SIMILARITY BETWEEN ONE-DIMENSIONAL ORTHOGONAL TRANSFORMS IN CERTAIN DIRECTION (HORIZONTAL OR VERTICAL) - EVEN-NUMBERED ROW VECTORS HAVE AXIAL SYMMETRY - ODD-NUMBERED ROW VECTORS HAVE POINT SYMMETRY	• UNIQUE TRANSFORM TYPE IS REDUCIBLE (REDUCTION OF LUT SIZE) • SECOND TRANSFORM TYPE HAS SIMILAR ENCODING EFFICIENCY TO DST8 (- PROCESSING AMOUNT INCREASES BY AMOUNT OF SIGN INVERSION, AS COMPARED WITH 2-1)
2-3 (1-3)	DCT8	FlipDCT8	FlipDCT8 			×	• TWO DIFFERENT TWO-DIMENSIONAL ORTHOGONAL TRANSFORMS HAVE AXIAL SYMMETRY BETWEEN ONE-DIMENSIONAL ORTHOGONAL TRANSFORMS IN CERTAIN DIRECTION (HORIZONTAL OR VERTICAL) (DCT8 ↔ FlipDCT8)	• REDUCTION OF UNIQUE TRANSFORM TYPE (REDUCTION OF LUT SIZE) • SECOND TRANSFORM TYPE HAS SIMILAR ENCODING EFFICIENCY TO DCT7 • NUMBER OF FLIP OPERATIONS IS REDUCIBLE (REDUCTION OF PROCESSING AMOUNT) BECAUSE TWO-DIMENSIONAL FLIP OPERATION CAN BE COLLECTIVELY PERFORMED FOR PREDICTION RESIDUAL, AS COMPARED WITH FLIP OPERATION FOR TRANSFORMATION MATRIX OF ONE-DIMENSIONAL ORTHOGONAL TRANSFORM (- PROCESSING AMOUNT IS SMALLER THAN 2-3)
2-4 (1-4)	DCT8	DST7	DST7 		×	×	• TWO DIFFERENT TWO-DIMENSIONAL ORTHOGONAL TRANSFORMS HAVE SIMILARITY BETWEEN ONE-DIMENSIONAL ORTHOGONAL TRANSFORMS IN CERTAIN DIRECTION (HORIZONTAL OR VERTICAL) - EVEN-NUMBERED ROW VECTORS HAVE AXIAL SYMMETRY - ODD-NUMBERED ROW VECTORS HAVE POINT SYMMETRY	• UNIQUE TRANSFORM TYPE IS REDUCIBLE (REDUCTION OF LUT SIZE) • SECOND TRANSFORM TYPE HAS SIMILAR ENCODING EFFICIENCY TO DCT7 (- ENCODING EFFICIENCY IS BETTER BUT PROCESSING AMOUNT INCREASES BY AMOUNT OF SIGN INVERSION, AS COMPARED WITH 2-3)

FIG. 68

TRANSFORM SIZE N	NUMBER OF ELEMENTS	TYPE OF TRANSFORMATION MATRIX	BIT PRECISION bit	LUT SIZE bits
2	4	1	10	40
4	16	4	10	640
8	64	4	10	2560
16	256	4	10	10240
32	1024	4	10	40960
64	4096	4	10	163840
128	16384	1	10	163840
TOTAL				382120 ($\approx$ 47KB)

FIG. 69

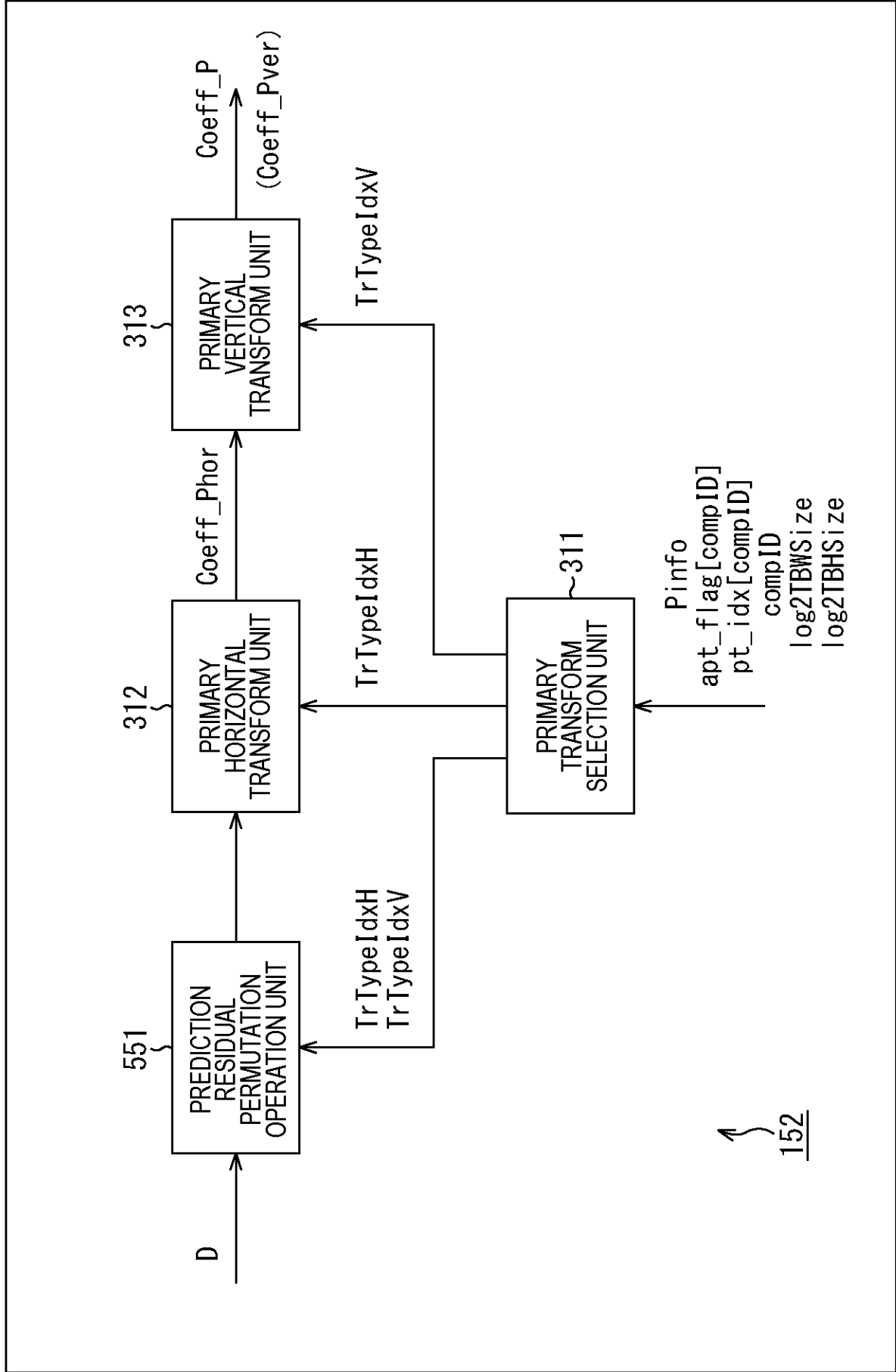


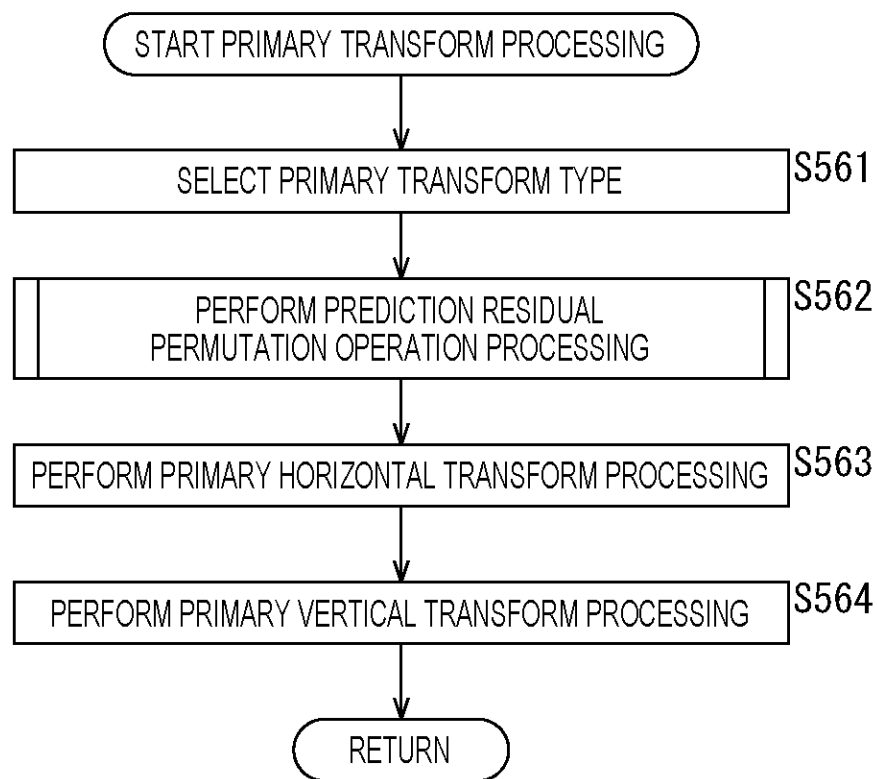
FIG. 70

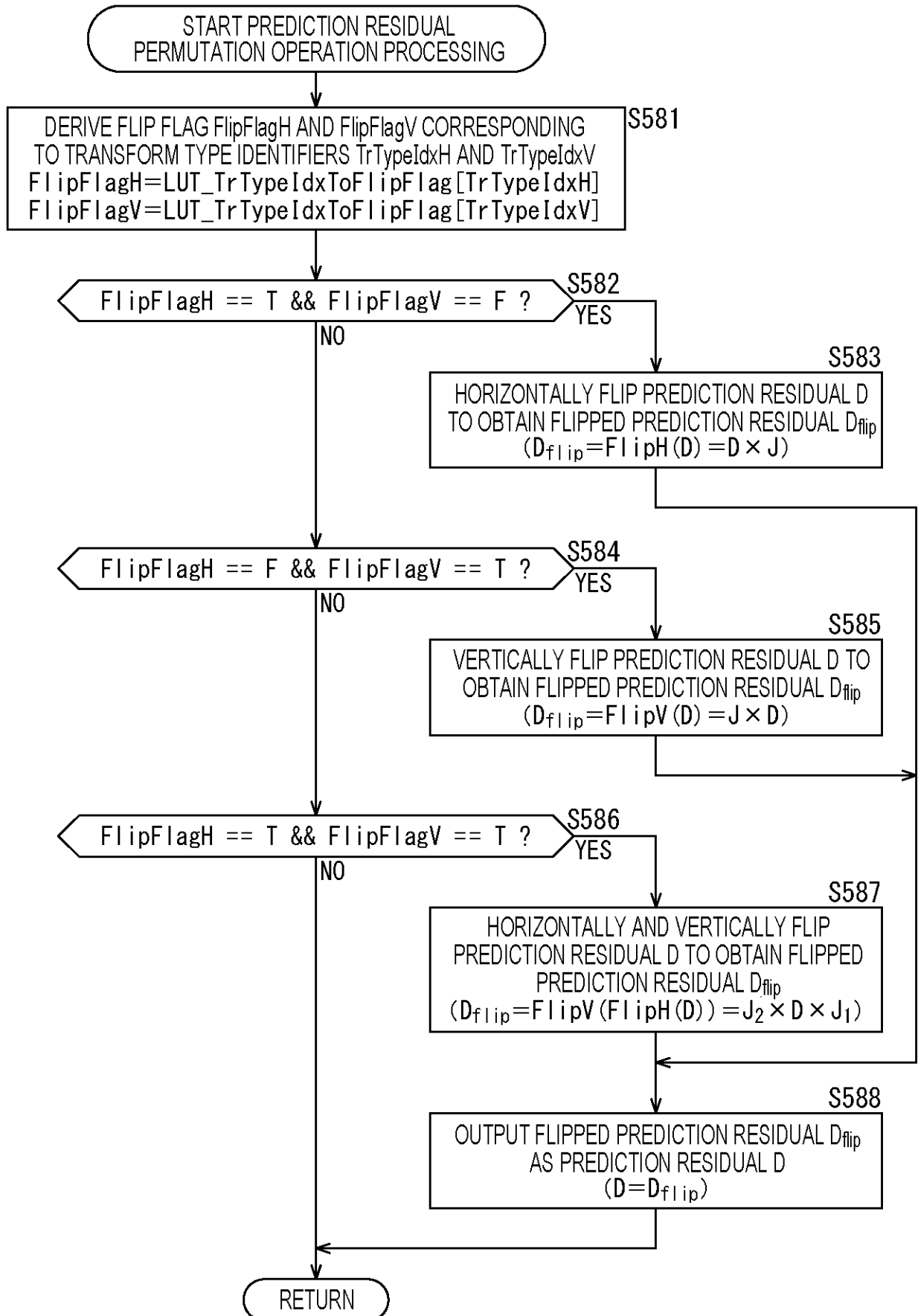
FIG. 71

FIG. 72

TrTypeIdx	TRANSFORM TYPE TrType	BASE TRANSFORM TYPE BaseTrType	BASE TRANSFORMATION MATRIX T _{base}	FLIP FLAG FlipFlag
0	DCT2	DCT2	T _{N, DCT2}	F
1	DST7	DST7	T _{N, DST7}	F
2	FlipDST7	DST7	T _{N, DST7}	T
3	DST1	DST1	T _{N, DST1}	F
4	DCT5	DCT5	T _{N, DCT5}	F

FIG. 73

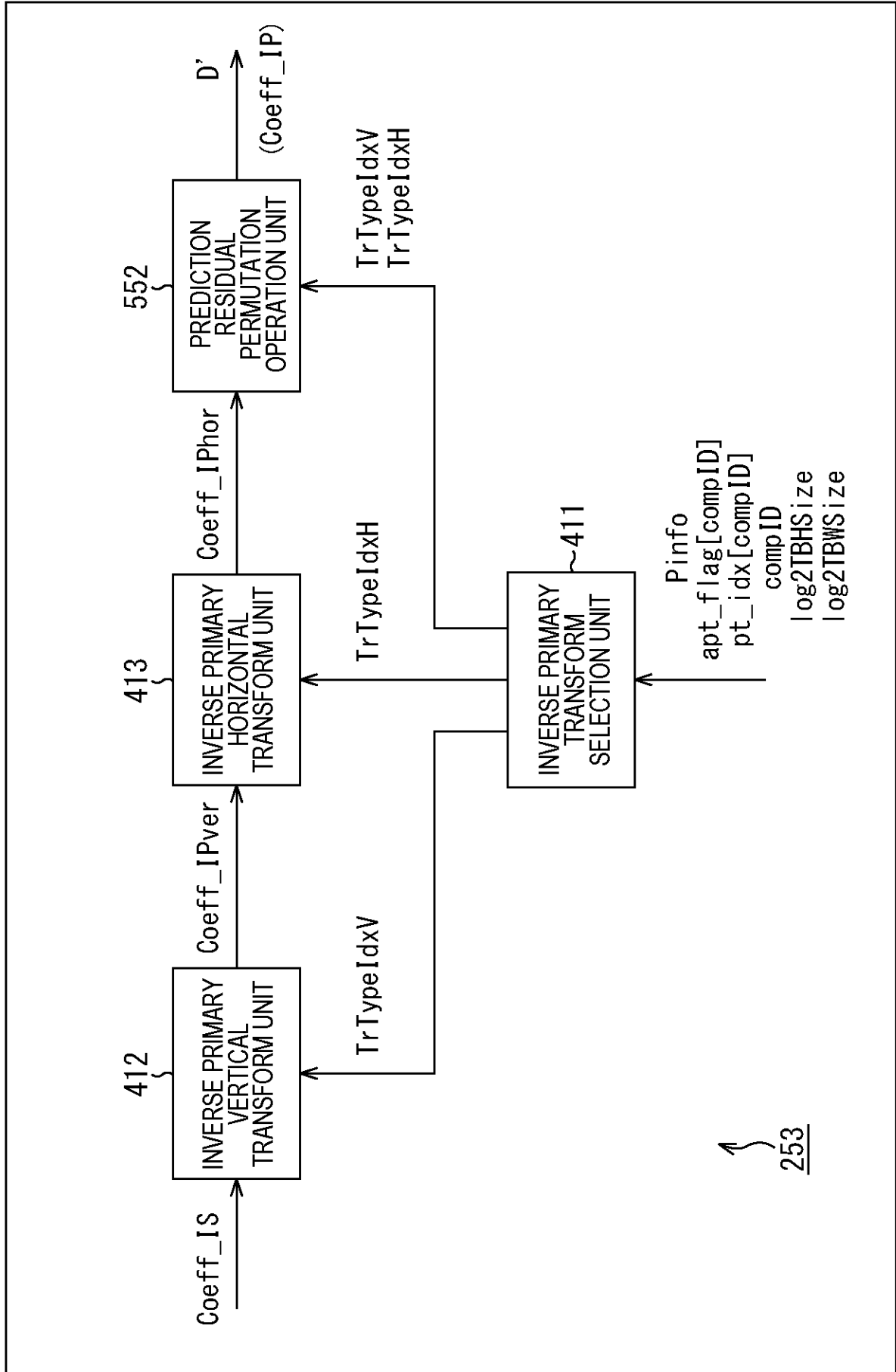


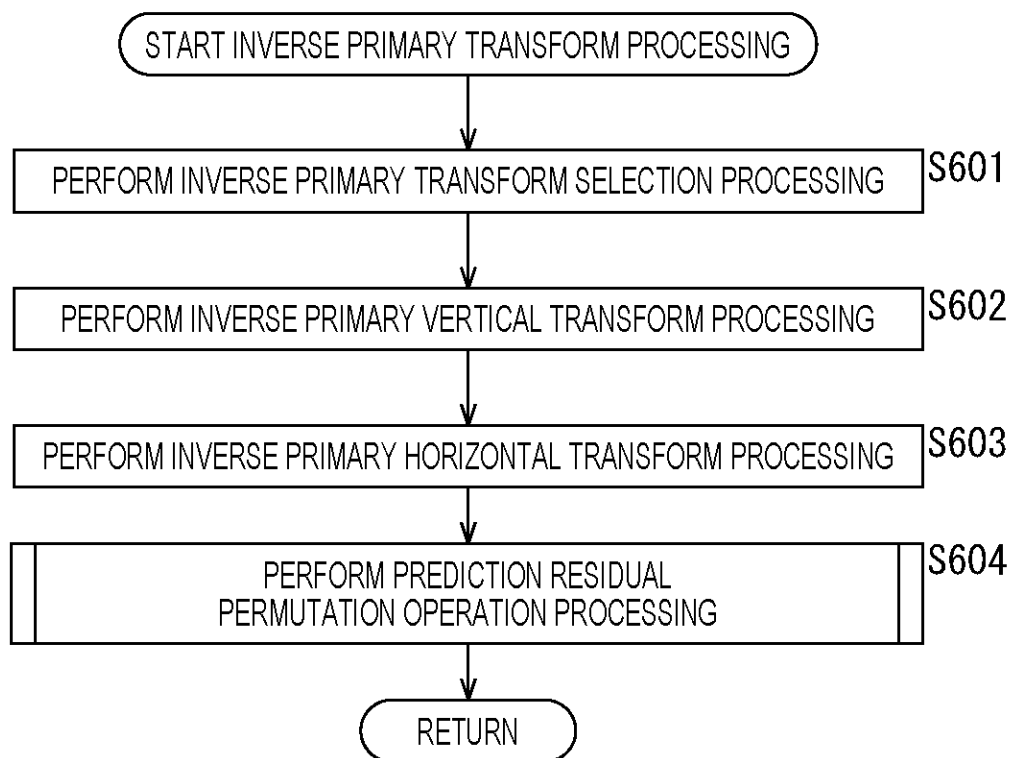
FIG. 74

FIG. 75

TRANSFORM SIZE N	NUMBER OF ELEMENTS	TYPE OF TRANSFORMATION MATRIX	BIT PRECISION bit	LUT SIZE bits
2	4	1	10	40
4	16	4	10	640
8	64	4	10	2560
16	256	4	10	10240
32	1024	4	10	40960
64	4096	4	10	163840
128	16384	1	10	163840
TOTAL				382120 (≈47KB)

FIG. 76

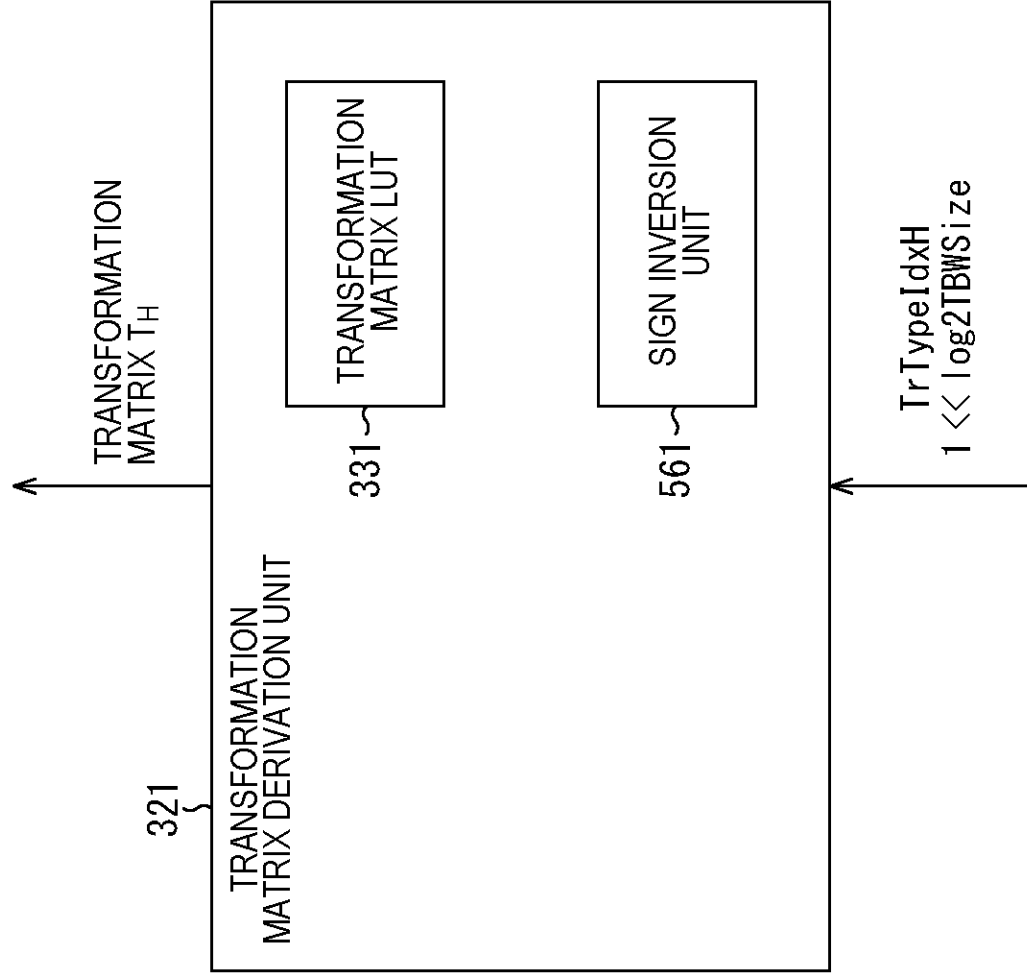


FIG. 77

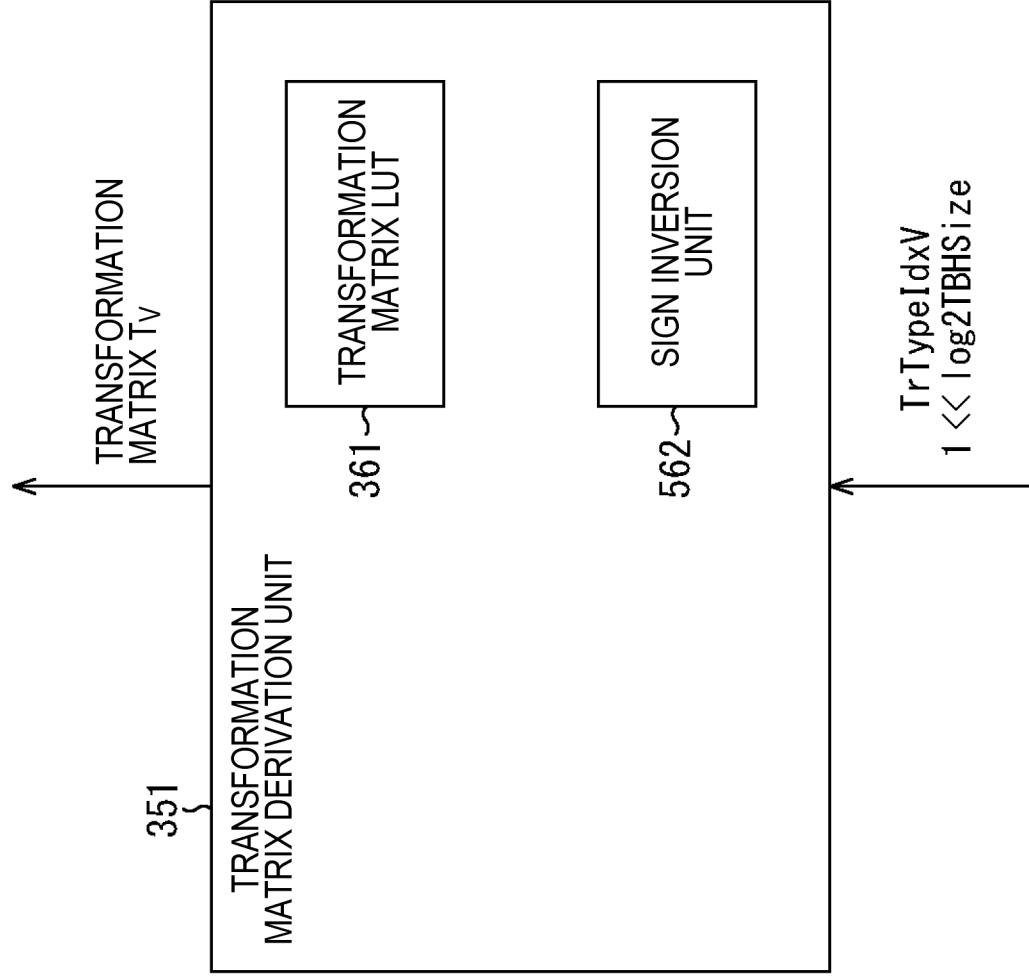


FIG. 78

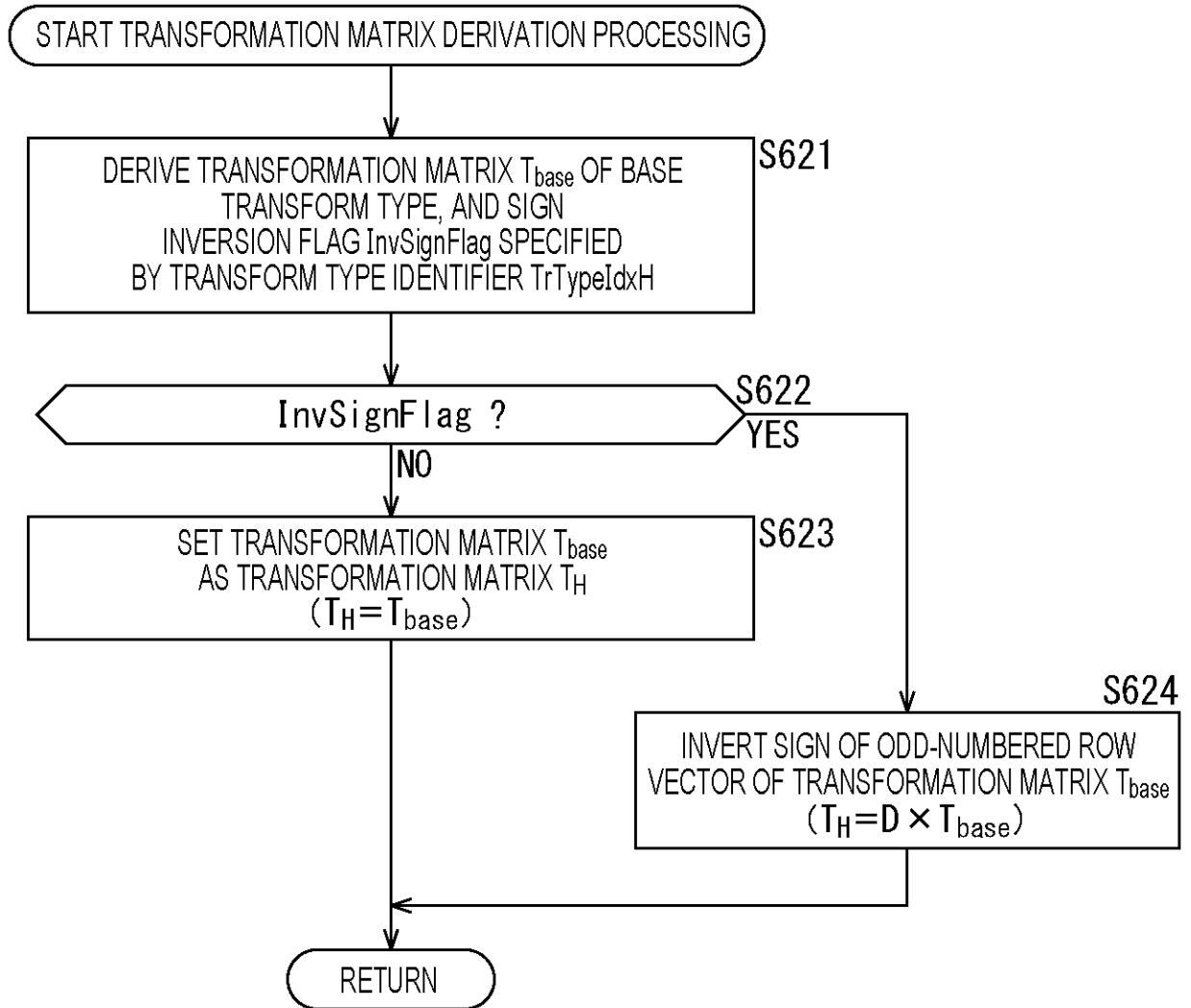


FIG. 79

TrTypeIdx	TRANSFORM TYPE TrType	BASE TRANSFORM TYPE BaseTrType	BASE TRANSFORMATION MATRIX T_{base}	FLIP FLAG FlipFlag	SIGN INVERSION FLAG InvSignFlag
0	DCT2	DCT2	$T_{N, DCT2}$	F	F
1	DST7	DST7	$T_{N, DST7}$	F	F
2	DCT8	DST7	$T_{N, DST7}$	T	T
3	DST1	DST1	$T_{N, DST1}$	F	F
4	DCT5	DCT5	$T_{N, DCT5}$	F	F

FIG. 80

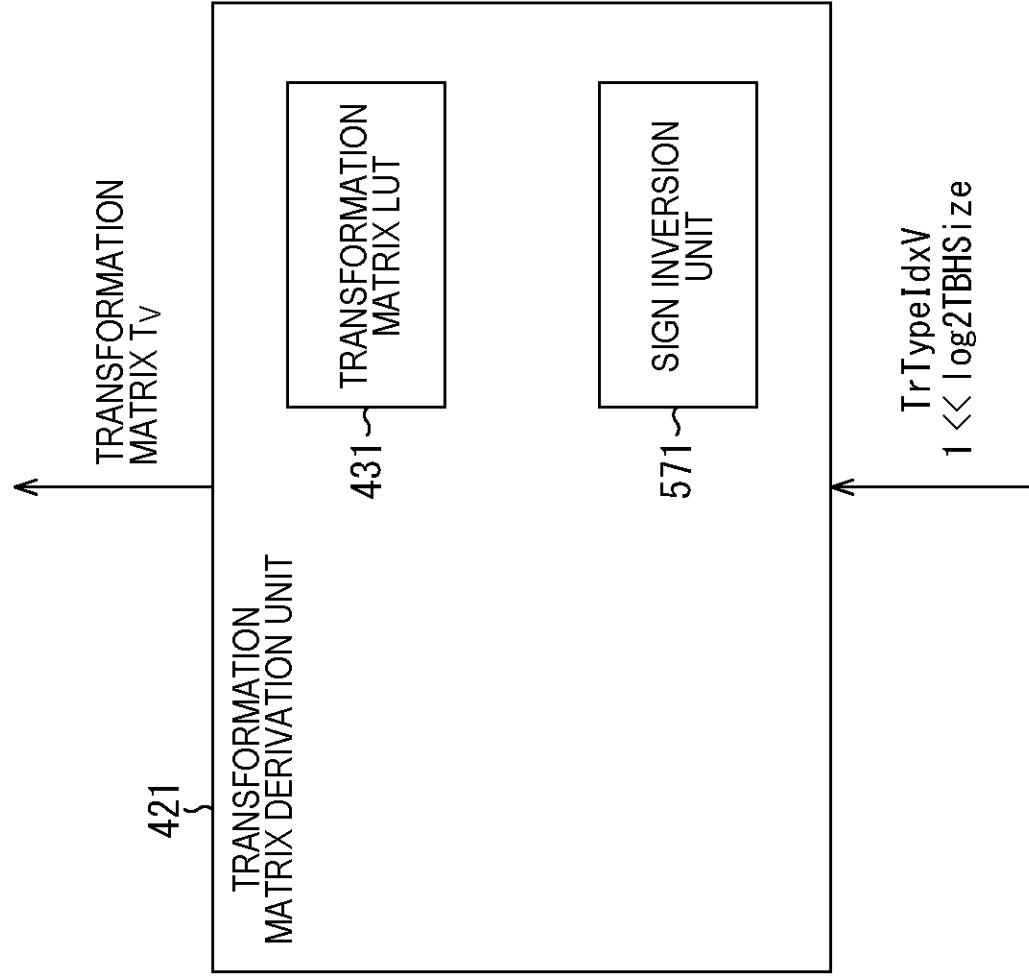


FIG. 81

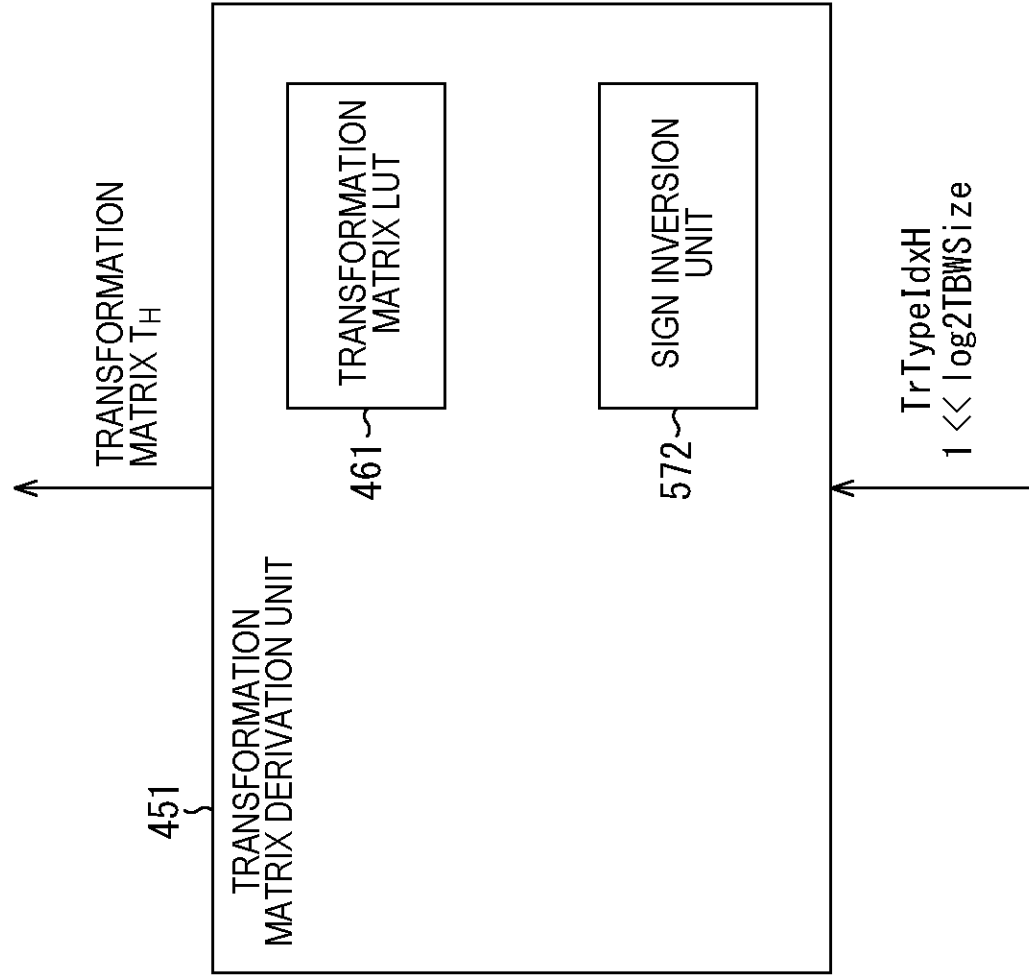


FIG. 82

TrTypeIdx	TRANSFORM TYPE TrType	BASE TRANSFORM TYPE BaseTrType	BASE TRANSFORMATION MATRIX T _{base}	FLIP FLAG FlipFlag
0	DCT2	DCT2	T _N , DCT2	F
1	FlipDCT8	DCT8	T _N , DCT8	T
2	DCT8	DCT8	T _N , DCT8	F
3	DST1	DST1	T _N , DST1	F
4	DCT5	DCT5	T _N , DCT5	F

FIG. 83

TrTypeIdx	TRANSFORM TYPE TrType	BASE TRANSFORM TYPE BaseTrType	BASE TRANSFORMATION MATRIX T _{base}	FLIP FLAG FlipFlag	SIGN INVERSION FLAG InvSignFlag
0	DCT2	DCT2	T _{N, DCT2}	F	F
1	DST7	DCT8	T _{N, DCT8}	T	T
2	DCT8	DCT8	T _{N, DCT8}	F	F
3	DST1	DST1	T _{N, DST1}	F	F
4	DCT5	DCT5	T _{N, DCT5}	F	F

FIG. 84

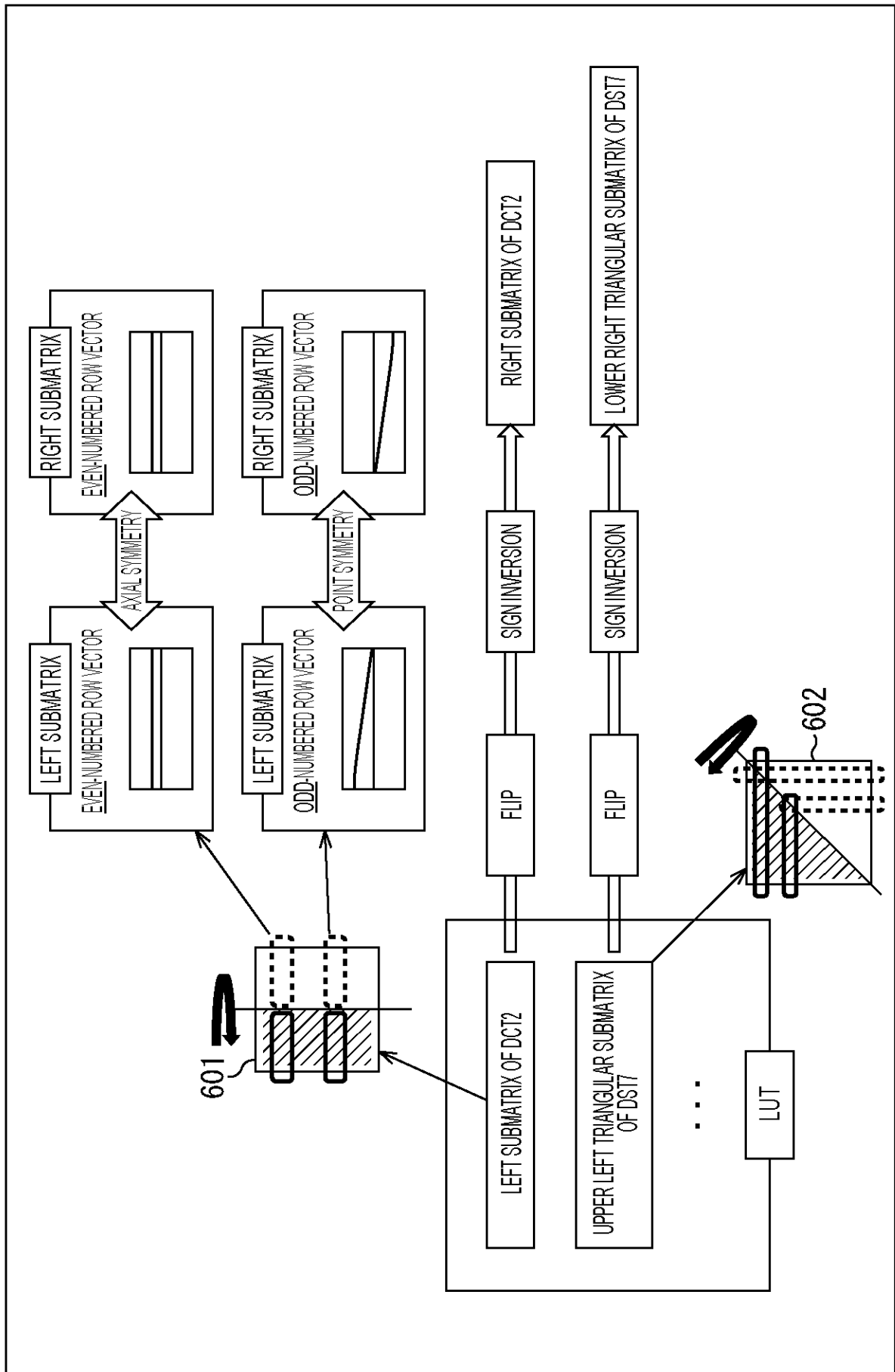
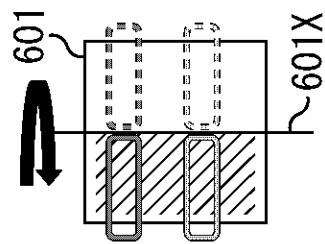


FIG. 85

EXAMPLE	TRANSFORM TYPE TO BE DERIVED	HELD SUBMATRIX (BASE SUBMATRIX)	SUBMATRIX TO BE GENERATED	OPERATION FOR TRANSFORMATION MATRIX					FOCUS POINT	EFFECT
				HORIZONTAL FLIP	VERTICAL FLIP	TRANSPPOSITION	ROTATION	SIGN INVERSION		
3-1	DCT2, DST2	LEFT SUBMATRIX	RIGHT SUBMATRIX	×				×	- AXIAL SYMMETRIC PROPERTY TO VERTICAL AXIS	- SAME ENCODING EFFICIENCY - REDUCTION OF RIGHT HALF IN TRANSFORMATION MATRIX - LUT SIZE REQUIRED TO HOLD TARGET TRANSFORM TYPE BECOMES 1/2
3-2	DCT1, DCT3, DST1, DST3	UPPER SUBMATRIX	LOWER SUBMATRIX		×			×	- SYMMETRIC PROPERTY TO HORIZONTAL AXIS	- SAME ENCODING EFFICIENCY - REDUCTION OF LOWER SUBMATRIX IN TRANSFORMATION MATRIX
3-3	DCT4, DST4	UPPER SUBMATRIX	LOWER SUBMATRIX	×	×		(×)	×	- POINT SYMMETRIC PROPERTY	- SAME ENCODING EFFICIENCY - REDUCTION OF LOWER SUBMATRIX IN TRANSFORMATION MATRIX
3-4	DCT5, DST5 (DCT4), DCT8	UPPER RIGHT TRIANGULAR SUBMATRIX	LOWER LEFT TRIANGULAR SUBMATRIX			×			- AXIAL SYMMETRIC PROPERTY TO DIAGONAL AXIS	- SAME ENCODING EFFICIENCY - REDUCTION OF LOWER LEFT TRIANGULAR MATRIX IN TRANSFORMATION MATRIX - SIGN INVERSION IS UNNECESSARY
3-5	DST7, DST6	UPPER LEFT TRIANGULAR SUBMATRIX	LOWER RIGHT TRIANGULAR SUBMATRIX	×	×		(×)	×	- AXIAL SYMMETRIC PROPERTY TO DIAGONAL AXIS AT CROSS POSITION	- SAME ENCODING EFFICIENCY - REDUCTION OF LOWER RIGHT TRIANGULAR MATRIX IN TRANSFORMATION MATRIX
3-6a	DST1, DCT1	UPPER LEFT SUBMATRIX	UPPER RIGHT SUBMATRIX	×				×	- AXIAL SYMMETRIC PROPERTY TO VERTICAL AXIS	- SAME ENCODING EFFICIENCY - REDUCTION OF UPPER RIGHT SUBMATRIX IN TRANSFORMATION MATRIX (REDUCTION RATE OF LUT IS LARGER BUT PROCESSING IS MORE COMPLICATED THAN GENERATION OF DCT1/DST1 BY 3-2)
3-6b		UPPER LEFT SUBMATRIX	LOWER LEFT SUBMATRIX		×			×	- AXIAL SYMMETRIC PROPERTY TO HORIZONTAL AXIS	- SAME ENCODING EFFICIENCY - REDUCTION OF LOWER LEFT SUBMATRIX IN TRANSFORMATION MATRIX (REDUCTION RATE OF LUT IS LARGER BUT PROCESSING IS MORE COMPLICATED THAN GENERATION OF DCT1/DST1 BY 3-2)
3-6c		UPPER LEFT SUBMATRIX	LOWER RIGHT SUBMATRIX	×	×		(×)	×	- POINT SYMMETRIC PROPERTY	- SAME ENCODING EFFICIENCY - REDUCTION OF LOWER RIGHT SUBMATRIX IN TRANSFORMATION MATRIX (REDUCTION RATE OF LUT IS LARGER BUT PROCESSING IS MORE COMPLICATED THAN GENERATION OF DCT1/DST1 BY 3-2)

FIG. 86



LEFT SUBMATRIX OF 8-pt DCT2

91	91	91	91
126	106	71	25
118	49	-49	-118
106	-25	-126	-71
91	-91	-91	91
71	-126	25	106
49	-118	118	-49
25	-71	106	-126

601A

RIGHT SUBMATRIX OF 8-pt DCT2

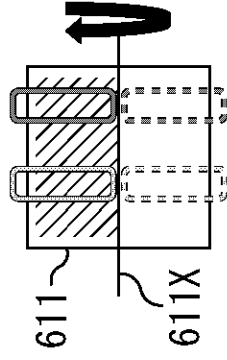
91	91	91	91
-25	-71	-106	-126
-118	-49	49	118
71	126	25	-106
91	-91	-91	91
-106	-25	126	-71
-49	118	-118	49
126	-106	71	-25

601B

FLIP IN HORIZONTAL DIRECTION

FLIP IN HORIZONTAL DIRECTION + SIGN INVERSION

FIG. 87



UPPER SUBMATRIX OF 8-pt DST1

611A

41	78	105	119	105	78	41
78	119	105	41	-105	-119	-78
105	105	0	-105	0	105	105
119	41	-105	-78	78	105	-41
119	-41	-105	78	-105	-41	119
05	-105	0	105	-105	0	105
78	-119	105	-41	105	-119	78
41	-78	105	-119	119	-105	78

FLIP IN VERTICAL DIRECTION

41	78	105	119	105	78	41
78	119	105	41	-105	-119	-78
05	105	0	-105	0	105	05
119	41	-105	-78	78	105	-41
119	-41	-105	78	-105	-41	119
105	-105	0	105	-105	0	105
78	-119	105	-41	105	-119	78
41	-78	105	-119	119	-105	78

611B

FLIP IN VERTICAL DIRECTION + SIGN INVERSION

LOWER SUBMATRIX OF 8-pt DST1

FIG. 88

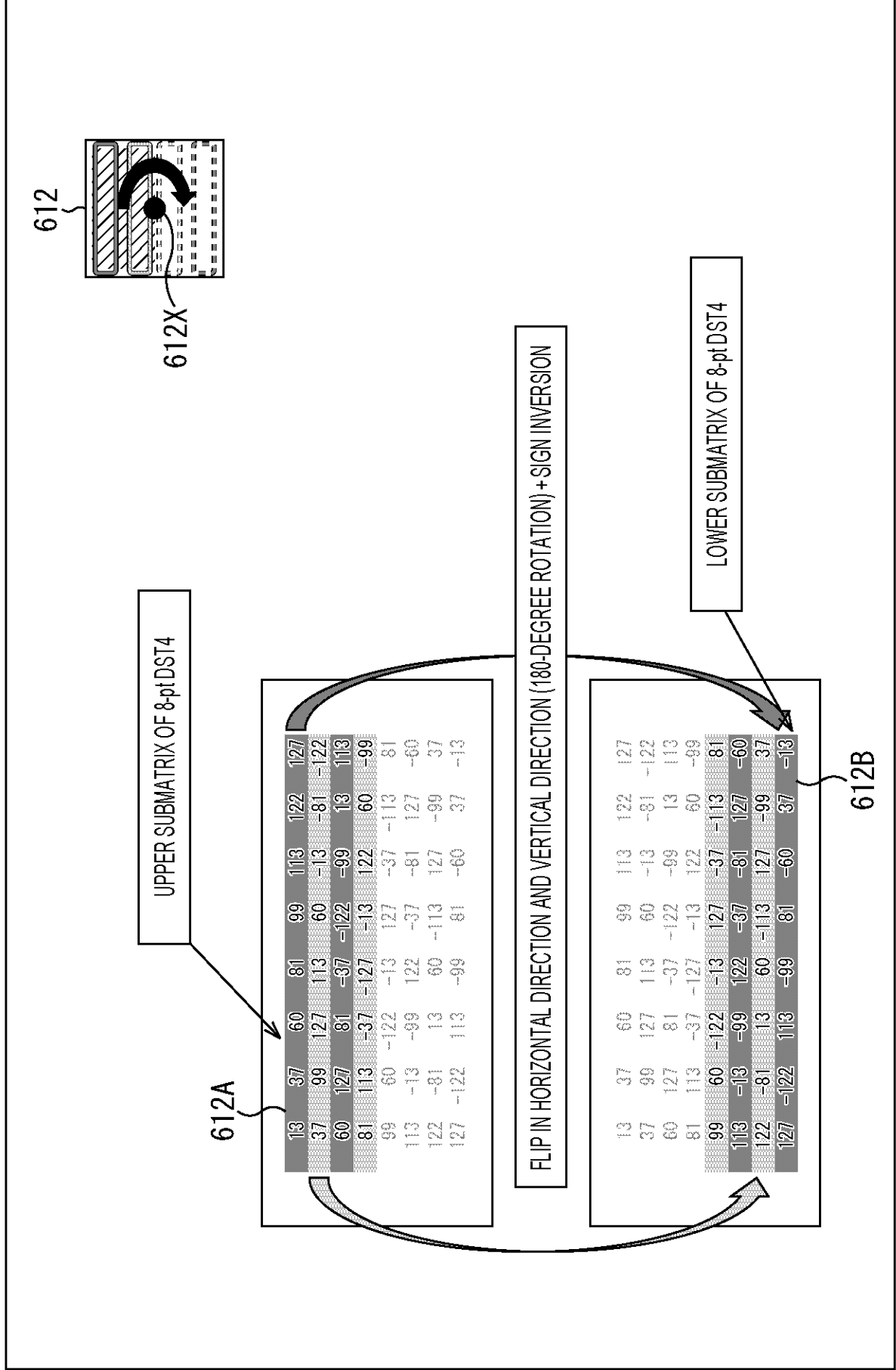


FIG. 89

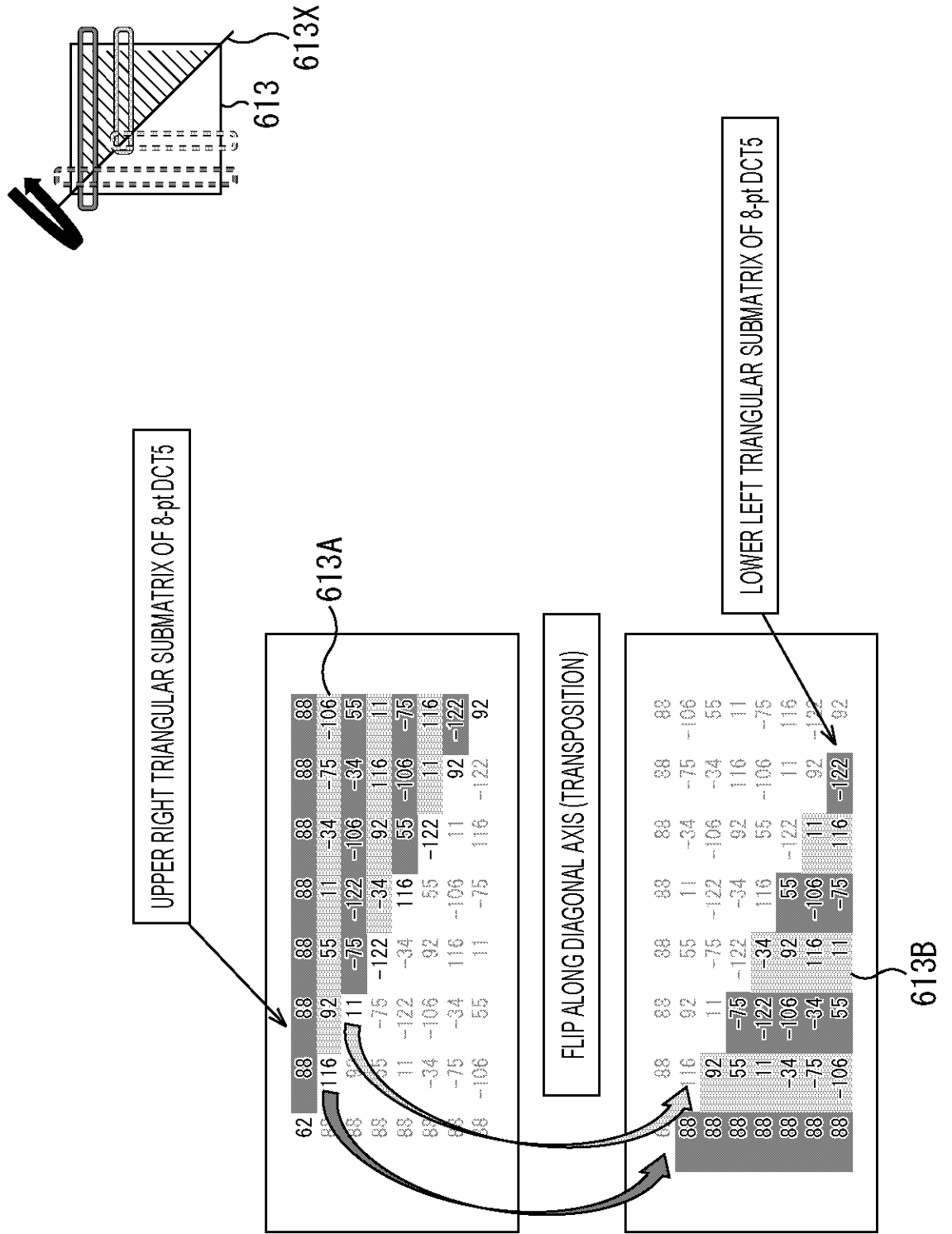
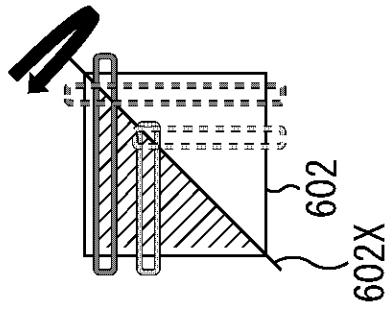


FIG. 90



UPPER LEFT TRIANGULAR SUBMATRIX OF 8-pt DST7

602A

23	65	99	119	124	111	84	45
45	111	119	65	-23	-99	-124	-84
65	124	45	-84	-119	-23	99	111
84	99	-65	-111	45	119	-23	-124
99	45	-124	111	-84	-45	-65	119
111	-23	-84	124	-65	-45	119	-99
119	-84	23	45	99	124	-111	65
124	-119	111	-99	84	-65	45	-23

FLIP ALONG DIAGONAL AXIS FROM UPPER RIGHT TOWARD LOWER LEFT
(FLIP IN HORIZONTAL DIRECTION AND VERTICAL DIRECTION) + SIGN INVERSION

LOWER RIGHT TRIANGULAR SUBMATRIX OF 8-pt DST7

602B

23	65	99	119	124	111	84	45
45	111	119	65	-23	-99	-124	-84
65	124	45	-84	-119	-23	99	111
84	99	-65	-111	45	119	-23	-124
99	45	-124	111	-84	-45	-65	119
111	-23	-84	124	-65	-45	119	-99
119	-84	23	45	99	124	-111	65
124	-119	111	-99	84	-65	45	-23

FIG. 91

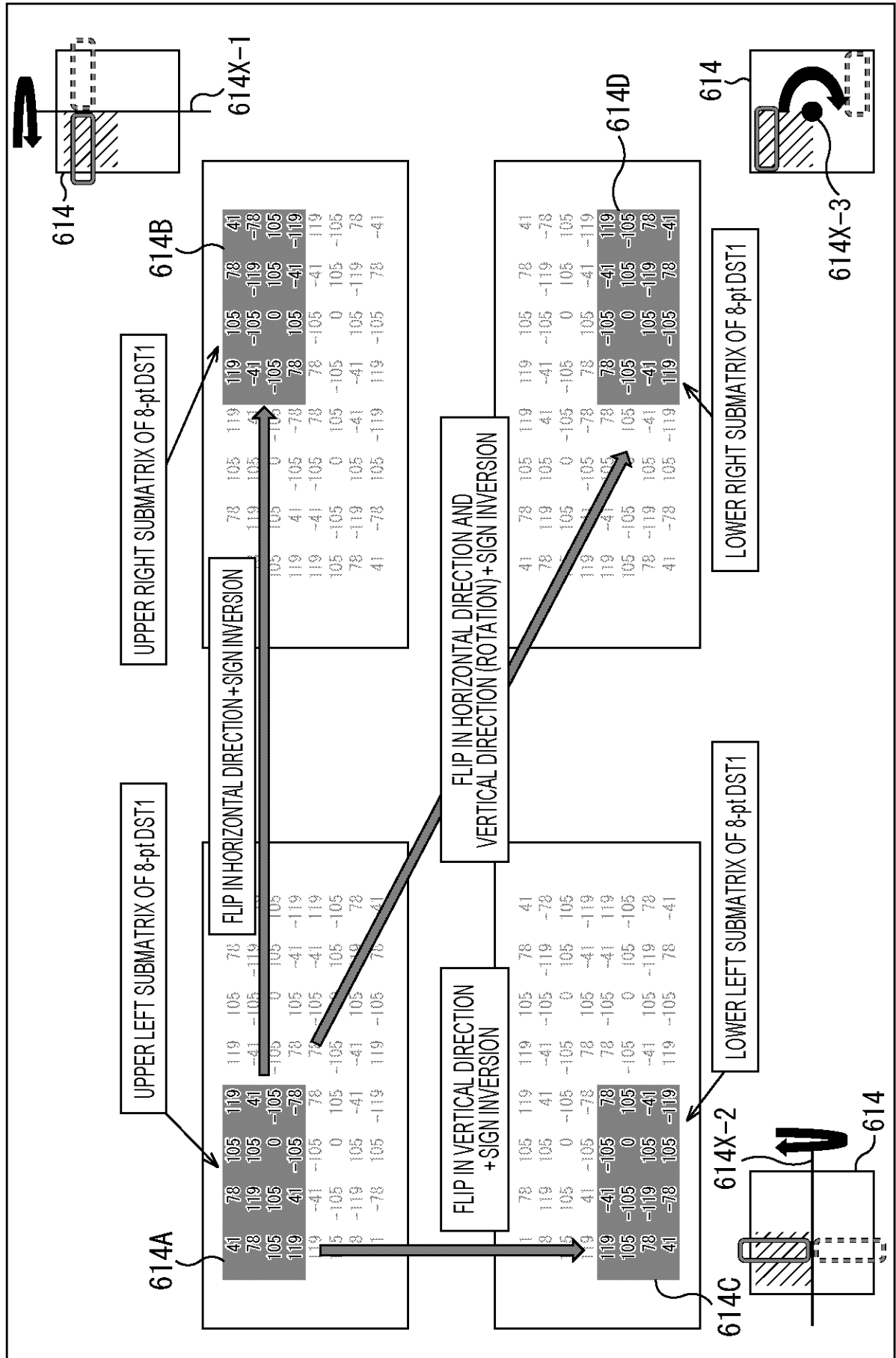


FIG. 92

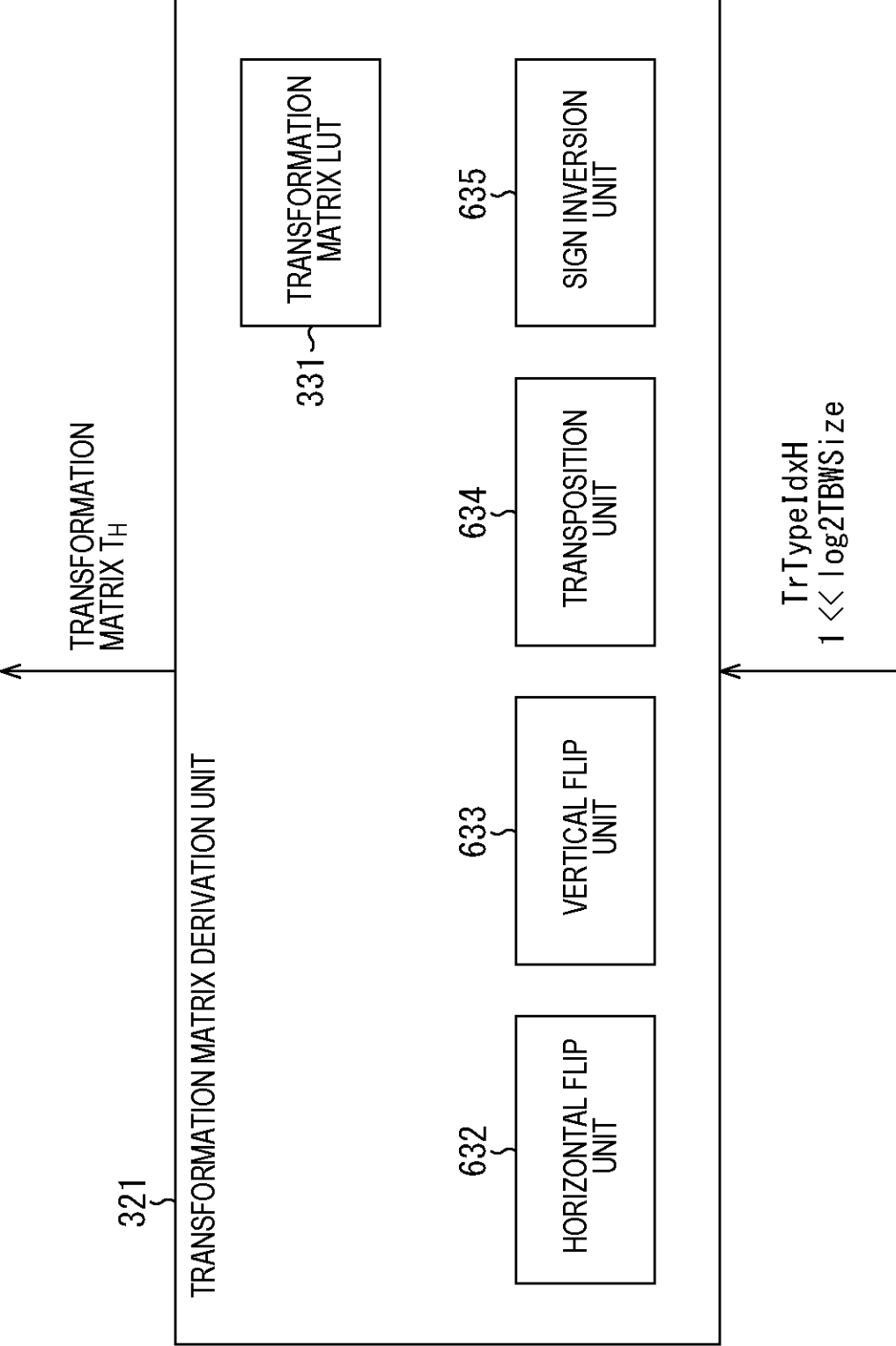


FIG. 93

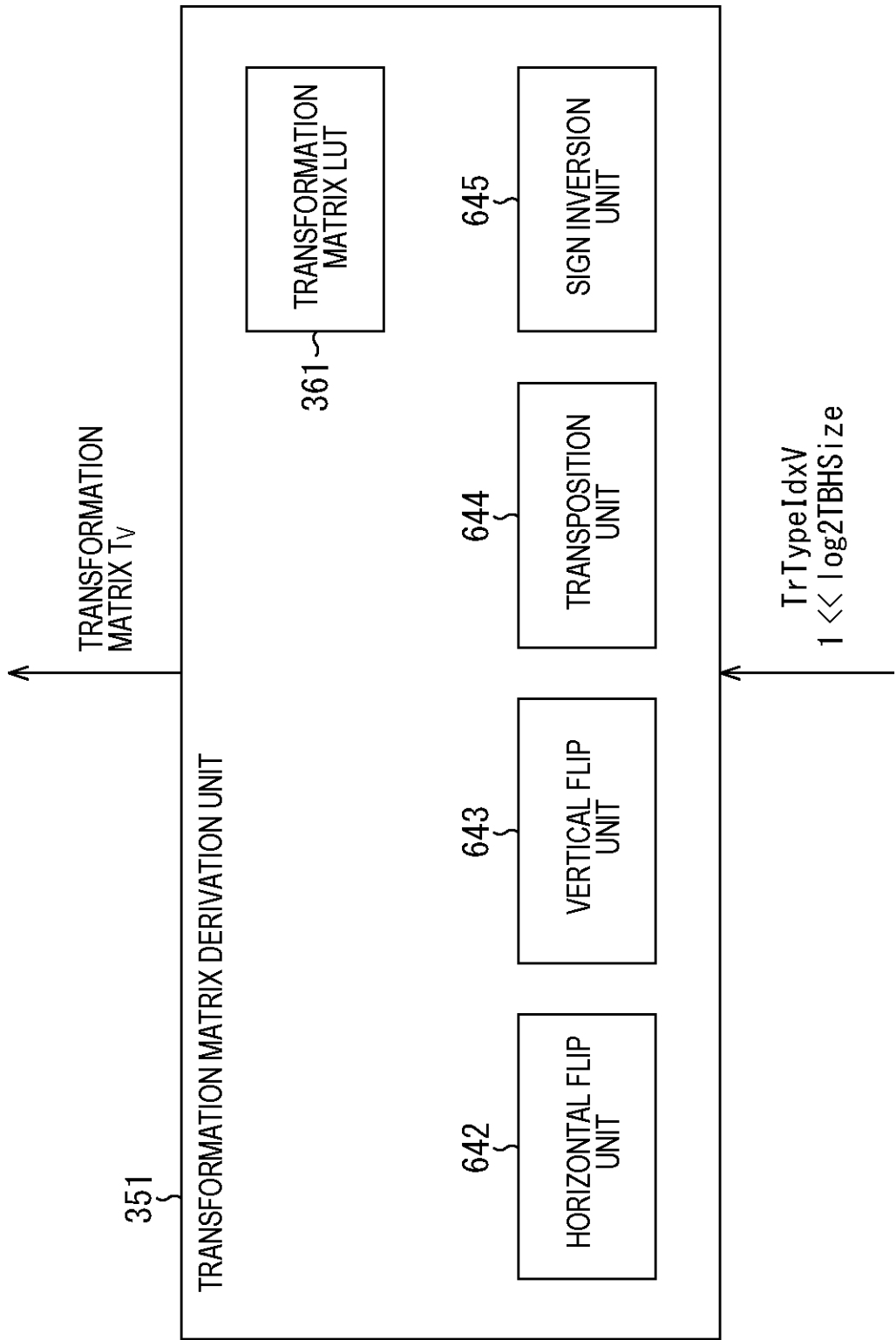


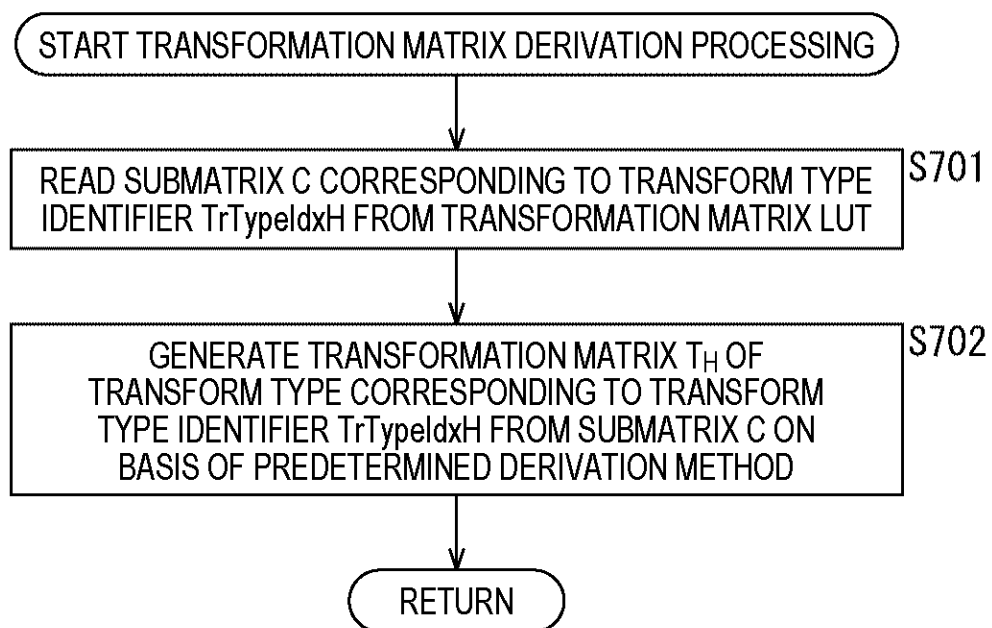
FIG. 94

FIG. 95

TrTypeIdx	TRANSFORM TYPE TrType	BASE SUBMATRIX C	METHOD OF DERIVING NxN TRANSFORMATION MATRIX T CORRESPONDING TO TRANSFORM TYPE TrType FROM BASE SUBMATRIX
0	DCT2	G _{DCT2}	EXECUTE BY METHOD DESCRIBED IN EXAMPLE #3-1
1	DST7	G _{DST7}	EXECUTE BY METHOD DESCRIBED IN EXAMPLE #3-5
2	DCT8	G _{DCT8}	EXECUTE BY METHOD DESCRIBED IN EXAMPLE #3-4
3	DST1	G _{DST1}	EXECUTE BY METHOD DESCRIBED IN EXAMPLE #3-2
4	DCT5	G _{DCT5}	EXECUTE BY METHOD DESCRIBED IN EXAMPLE #3-4
...	...	...	...
X	TRANSFORM Z	G _Z	EXECUTE BY METHOD CORRESPONDING TO TRANSFORM Z
...	...	...	...

FIG. 96

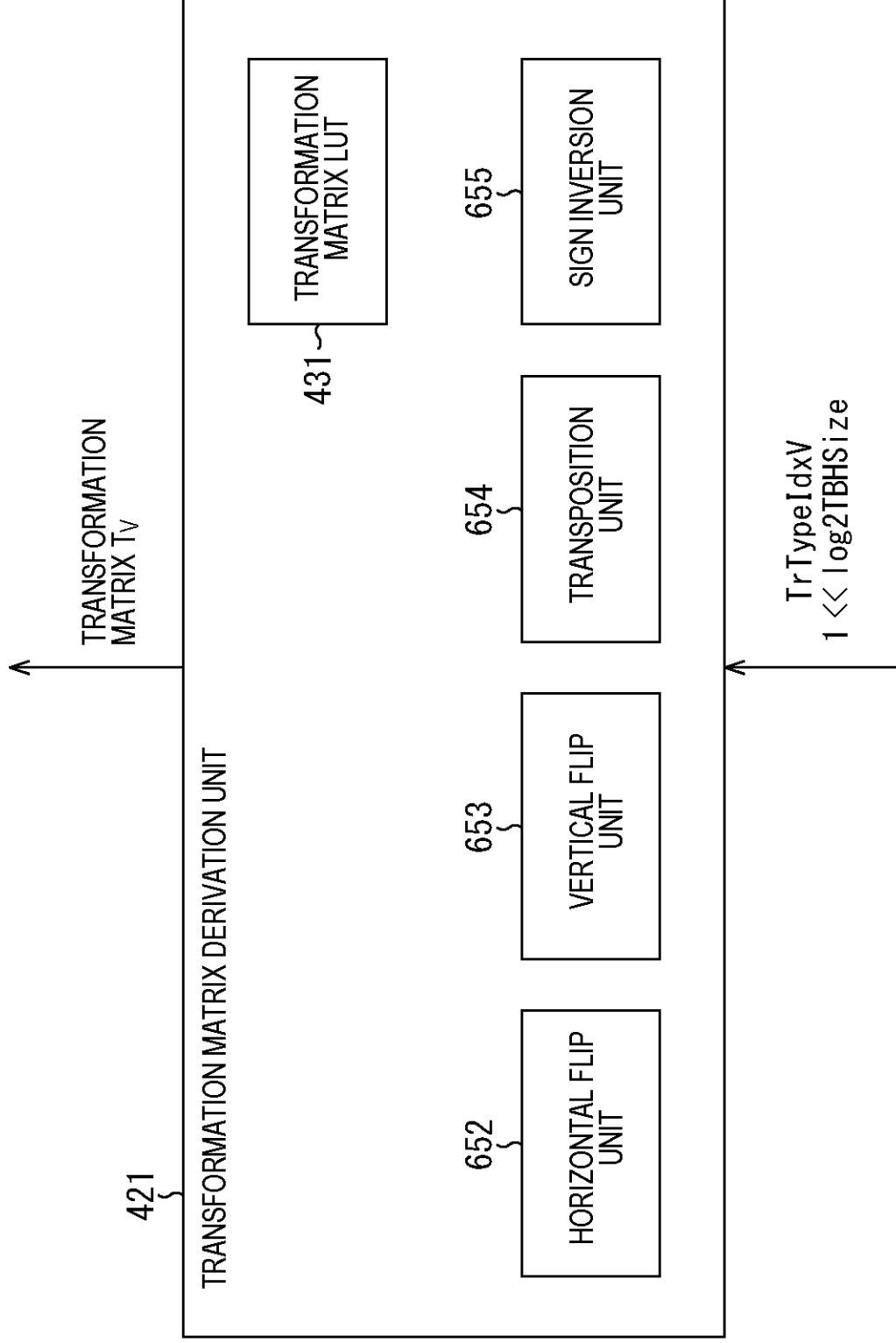


FIG. 97

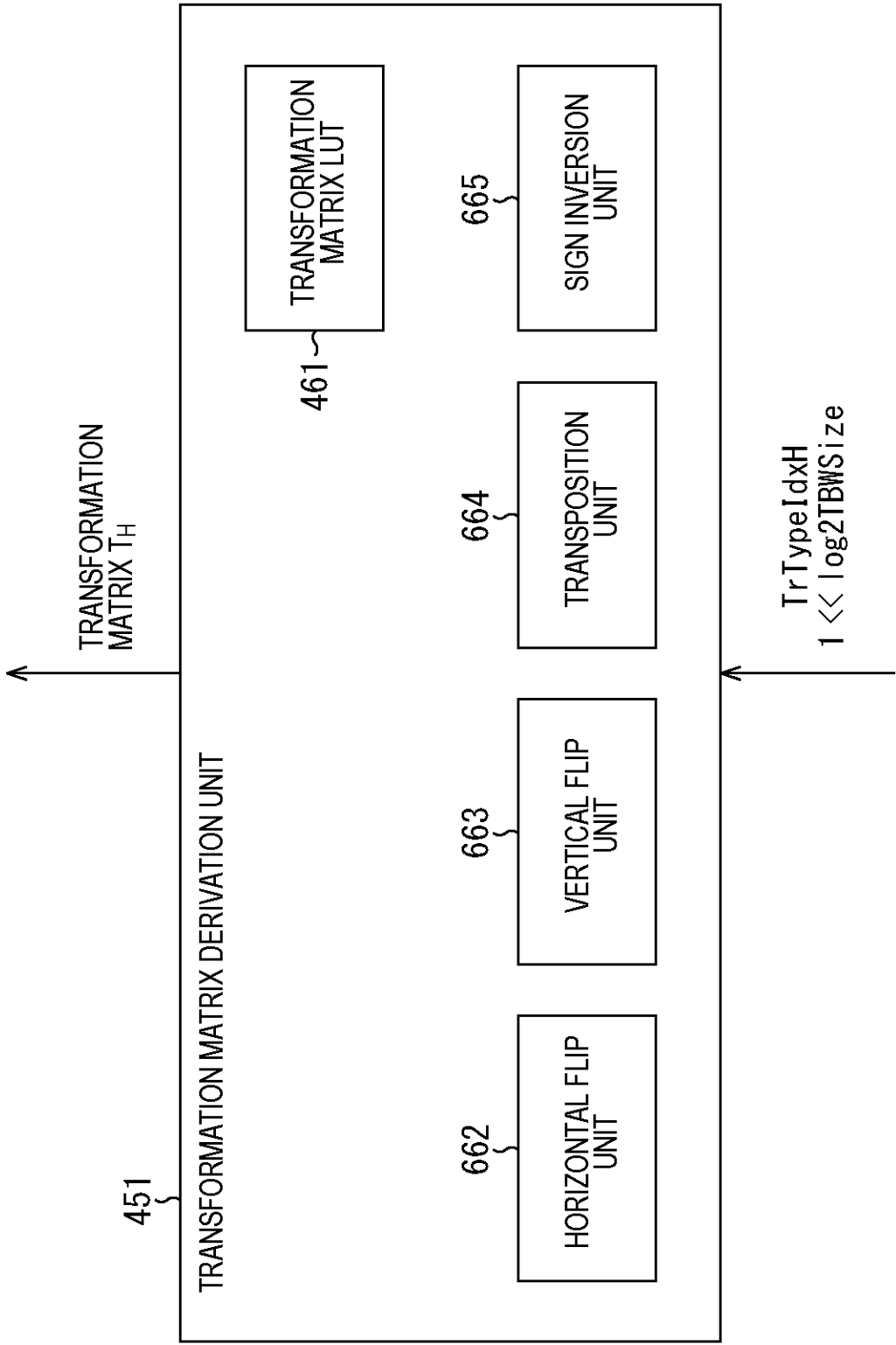


FIG. 98

TRANSFORM SIZE N	NUMBER OF ELEMENTS PER ONE TRANSFORMATION MATRIX	NUMBER OF ELEMENTS OF HELD SUBMATRIX	TYPE OF BASE SUBMATRIX	BIT PRECISION bit	LUT SIZE bits
2	4	2	1	10	20
4	16	ABOUT 8	3	10	240
8	64	ABOUT 32	3	10	960
16	256	ABOUT 128	3	10	3840
32	1024	ABOUT 512	3	10	15356
64	4096	ABOUT 2048	3	10	61440
128	16384	ABOUT 8192	1	10	81920
TOTAL					163780 (≈ 20KB)

FIG. 99

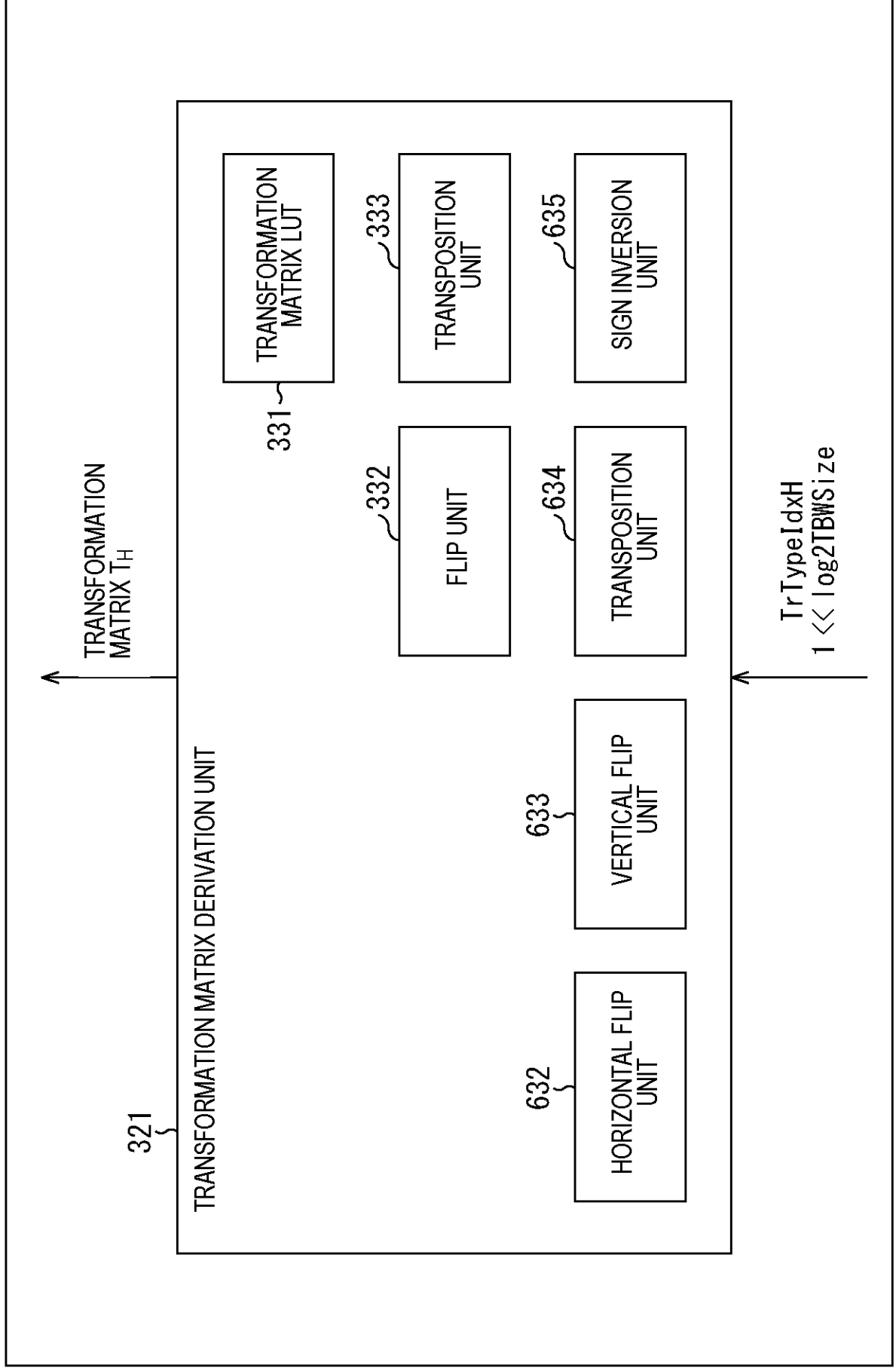


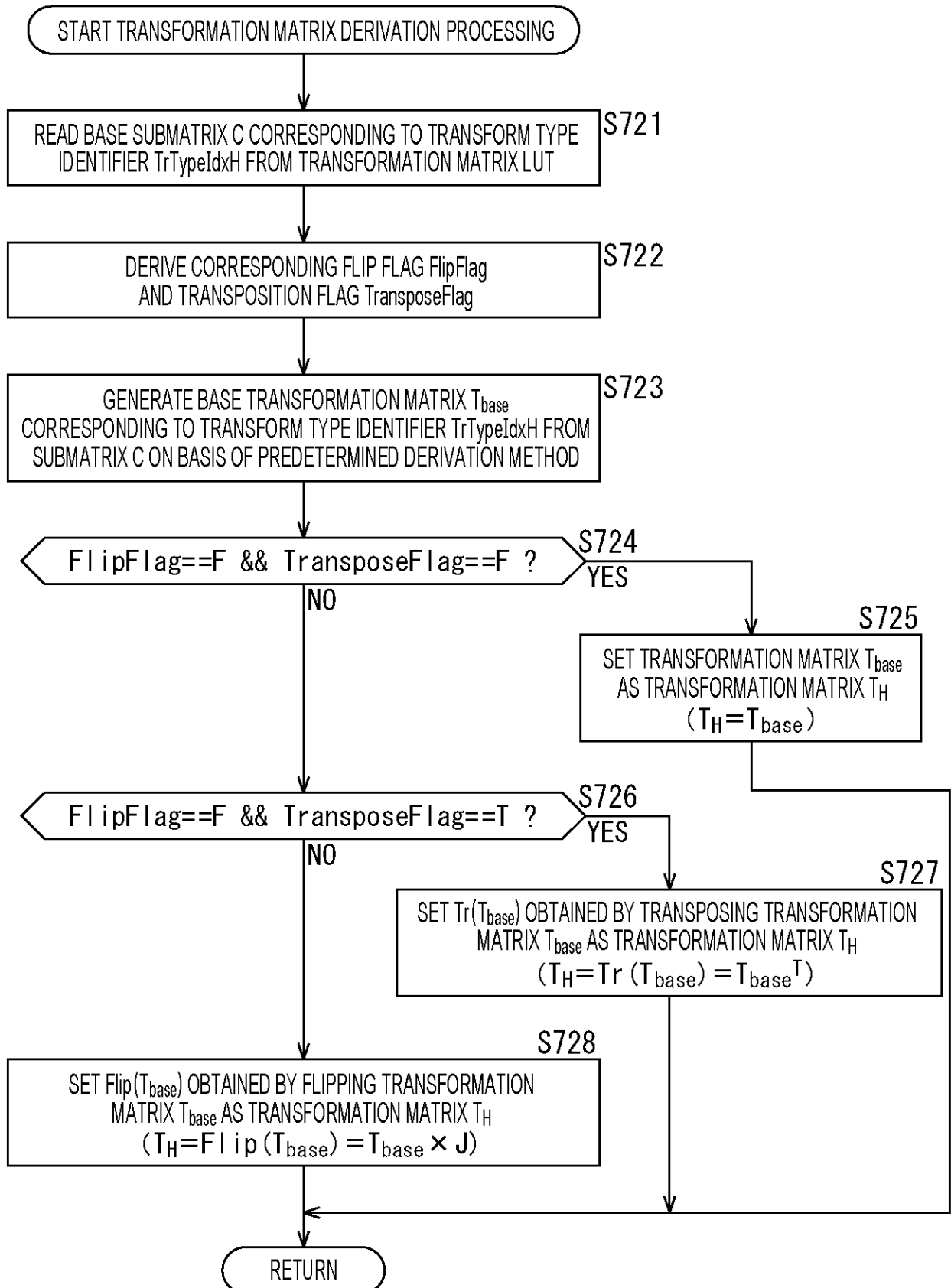
FIG. 100

FIG. 101

TrTypeIdx	TRANSFORM TYPE TrType	BASE TRANSFORM TYPE BaseTrType	BASE SUBMATRIX C	FLIP FLAG FlipFlag	TRANSPPOSITION FLAG Transpose Flag	METHOD OF DERIVING NXN TRANSFORMATION MATRIX T CORRESPONDING TO BASE TRANSFORM TYPE BaseTrType FROM BASE SUBMATRIX
0	DCT2	DCT2	C _{DCT2}	F	F	EXECUTE BY METHOD DESCRIBED IN EXAMPLE 3-1
1	DST7	DST7	C _{DST7}	F	F	EXECUTE BY METHOD DESCRIBED IN EXAMPLE 3-5
2	FlipDST7	DST7	C _{DCT8}	T	F	EXECUTE BY METHOD DESCRIBED IN EXAMPLE 3-4
3	TrDST1	DST7	C _{DST1}	F	T	EXECUTE BY METHOD DESCRIBED IN EXAMPLE 3-2
4	DCT5	DCT5	C _{DCT5}	F	F	EXECUTE BY METHOD DESCRIBED IN EXAMPLE 3-4

FIG. 102

