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| Title: | **H.BWC Draft 3 Specification Text** | | |
| Purpose: | **Draft Specification** | | |

**Abstract**

This document contains the Draft 3 specification text for H.BWC.

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# Scope

TBA

# Normative references

The following Recommendations and International Standards contain provisions which, through reference in this text, constitute provisions of this Recommendation | International Standard. At the time of publication, the editions indicated were valid. All Recommendations and Standards are subject to revision, and parties to agreements based on this Recommendation | International Standard are encouraged to investigate the possibility of applying the most recent edition of the Recommendations and Standards listed below. Members of IEC and ISO maintain registers of currently valid International Standards. The Telecommunication Standardization Bureau of the ITU maintains a list of currently valid ITU-T Recommendations.

## Identical Recommendations | International Standards

– None.

## Paired Recommendations | International Standards equivalent in technical content

– Rec. ITU-T H.274 | ISO/IEC 23002-7 (in force) *Versatile supplemental enhancement information messages for coded video bitstreams.*

## Additional references

– Rec. ITU-T T.35 (in force), *Procedure for the allocation of ITU-T defined codes for non standard facilities.*

– ISO/IEC 23001-11 (in force), *Information Technology – MPEG Systems technologies — Part 11: Energy-efficient media consumption (green metadata).*

– ISO/IEC 23090-13 (in force), *Information technology – Coded representation of immersive media – Part 13: Video decoding interface for immersive media.*

# Definitions

For the purposes of this Recommendation | International Standard, the following definitions apply.

* 1. **coded waveform sequence (CWS)**:
  2. **context variable**: A variable specified for the *adaptive binary arithmetic decoding* *process* of a *bin* by an equation containing recently decoded *bins*.
  3. **decoder**: An embodiment of a *decoding process*.
  4. **decoding order**: The order in which *syntax elements* are processed by the *decoding process*.
  5. **decoding process**: The process specified in this Specification that reads a *bitstream* and derives *decoded* *pictures* from it.
  6. **dependent frame (DF)**: A *stream packet* with stream\_packet\_type equal to DF\_SPT
  7. **encoder**: An embodiment of an *encoding process*.
  8. **encoding process**: A process not specified in this Specification that produces a *bitstream* conforming to this Specification.
  9. **flag**: A variable or single-bit *syntax element* that can take one of the two possible values: 0 and 1.
  10. **frame**: Either an *independent frame* or a *dependent frame*.
  11. **frame sequence**: A sequence of *frames* that starts with an *independent frame* followed by zero or more *dependent frames*
  12. **independent frame (IF)**: A *stream packet* with stream\_packet\_type equal to IF\_SPT.
  13. **stream packet**: A *syntax structure* containing an indication of the type of data to follow and *bytes* containing that data in the form of an *RBSP*.
  14. **stream packet stream**: A sequence of *stream packets*.
  15. **string of data bits (SODB)**: A sequence of some number of bits representing *syntax elements* present within a *raw byte sequence payload* prior to the *raw byte sequence payload stop bit*, where the left-most bit is considered to be the first and most significant bit, and the right-most bit is considered to be the last and least significant bit.
  16. **syntax element**: An element of data represented in the *bitstream*.
  17. **syntax structure**: Zero or more *syntax elements* present together in the *bitstream* in a specified order*.*
  18. **transform**: A part of the *decoding process* by which a *block* of *transform coefficients* is converted to a *block* of spatial-domain values.
  19. **transform block**: A *block* of samples resulting from a *transform* in the *decoding process*.
  20. **transform coefficient**: A scalar quantity, considered to be in a frequency domain, that is associated with a particular one-dimensional or two-dimensional *frequency index* in a *transform* in the *decoding process*.
  21. **transform coefficient level**: An integer quantity representing the value associated with a particular two‑dimensional frequency index in the *decoding process* prior to *scaling* for computation of a *transform coefficient* value.

# Abbreviations

For the purposes of this Recommendation | International Standard, the following abbreviations apply.

AC Annotation Channel

AM Auxiliary Metadata

CG Channel Group

CRC Cyclic Redundancy Check

CWS Coded Waveform Sequence

DF Dependent Frame

EG Exponential-Golomb

EGk k-th order Exponential-Golomb

EOB End Of Bitstream

EOS End Of Sequence

FL Fixed-Length

IF Independent Frame

LPS Least Probable Symbol

LSB Least Significant Bit

MSB Most Significant Bit

QP Quantization Parameter

RBSP Raw Byte Sequence Payload

SODB String Of Data Bits

TR Truncated Rice

WPS Waveform Parameter Set

# Conventions

## General

The term "this Specification" is used to refer to this Proposed Draft Recommendation.

The word "shall" is used to express mandatory requirements for conformance to this Specification. When used to express a mandatory constraint on the values of syntax elements or the values of variables derived from these syntax elements, it is the responsibility of the encoder to ensure that the constraint is fulfilled.

The word "may" is used to refer to behaviour that is allowed, but not necessarily required.

The word "should" is used to refer to behaviour of an implementation that is encouraged to be followed under anticipated ordinary circumstances, but is not a mandatory requirement for conformance to this Specification.

Content of this Specification that is identified as "informative" does not establish any mandatory requirements for conformance to this Specification and is thus not considered an integral part of this Specification. Informative remarks in the text are, in some cases, set apart and prefixed with the word "note" or "NOTE".

The word "reserved" is used to specify that some values of a particular syntax element are for future use by ITU-T and shall not be used in syntax structures conforming to this version of this Specification, but could potentially be used in syntax structures conforming to future versions of this Specification by ITU‑T.

The word "unspecified" is used to describe some values of a particular syntax element to indicate that the values have no specified meaning in this Specification and are not expected to have a specified meaning in the future as an integral part of future versions of this Specification.

NOTE – The mathematical operators used in this Specification are similar to those used in the C programming language. However, the results of integer division and arithmetic shift operations are defined more precisely, and additional operations are defined, such as exponentiation and real-valued division. Numbering and counting conventions generally begin from 0, e.g., "the first" is equivalent to the 0-th, "the second" is equivalent to the 1-st.

## Arithmetic operators

The following arithmetic operators are defined as follows:

|  |  |
| --- | --- |
| + | addition |
| − | subtraction (as a two-argument operator) or negation (as a unary prefix operator) |
| \* | multiplication, including matrix multiplication |
| xy | exponentiation  Specifies x to the power of y. In other contexts, such notation is used for superscripting not intended for interpretation as exponentiation. |
| / | integer division with truncation of the result toward zero. For example, 7 / 4 and −7 / −4 are truncated to 1 and −7 / 4 and 7 / −4 are truncated to −1. |
| ÷ | division in mathematical equations where no truncation or rounding is intended |
|  | division in mathematical equations where no truncation or rounding is intended |
|  | summation of f( i ) with i taking all integer values from x up to and including y |
| x % y | modulus. Remainder of x divided by y, defined only for integers x and y with x >= 0 and y > 0 |

## Logical operators

The following logical operators are defined as follows:

x && y Boolean logical "and" of x and y

x | | y Boolean logical "or" of x and y

! Boolean logical "not"

x ? y : z if x is TRUE, evaluates to the value of y; otherwise, evaluates to the value of z

When evaluating a logical expression, the value 0 is interpreted as FALSE and any numerical value not equal to 0 is interpreted as TRUE. The result of any logical expression that evaluates as FALSE is the value 0, and the result of any logical expression that evaluates as TRUE is the value 1.

## Relational operators

> greater than

>= greater than or equal to

< less than

<= less than or equal to

= = equal to

!= not equal to

When a relational operator is applied to a syntax element or variable that has been assigned the value "na" (not applicable), the value "na" is treated as a distinct value for the syntax element or variable. The value "na" is considered not to be equal to any other value.

## Bit-wise operators

& bit-wise "and"

When operating on integer arguments, operates on a two's complement representation of the integer value. When operating on a binary argument that contains fewer bits than another argument, the shorter argument is extended by adding more significant bits equal to 0.

| bit-wise "or"

When operating on integer arguments, operates on a two's complement representation of the integer value. When operating on a binary argument that contains fewer bits than another argument, the shorter argument is extended by adding more significant bits equal to 0.

^ bit-wise "exclusive or"

When operating on integer arguments, operates on a two's complement representation of the integer value. When operating on a binary argument that contains fewer bits than another argument, the shorter argument is extended by adding more significant bits equal to 0.

x >> y arithmetic right shift of a two's complement integer representation of x by y binary digits

This function is defined only for non-negative integer values of y. Bits shifted into the most significant bits (MSBs) as a result of the right shift have a value equal to the MSB of x prior to the shift operation.

x << y arithmetic left shift of a two's complement integer representation of x by y binary digits

This function is defined only for non-negative integer values of y. Bits shifted into the least significant bits (LSBs) as a result of the left shift have a value equal to 0.

## Assignment operators

= assignment operator

++ increment, i.e., *x*++ is equivalent to *x* = *x* + 1; when used in an array index, evaluates to the value of the variable prior to the increment operation

− − decrement, i.e., *x*− − is equivalent to *x* = *x* − 1; when used in an array index, evaluates to the value of the variable prior to the decrement operation

+= increment by amount specified, i.e., x += 3 is equivalent to x = x + 3, and x += (−3) is equivalent to x = x + (−3)

−= decrement by amount specified, i.e., x −= 3 is equivalent to x = x − 3, and x −= (−3) is equivalent to x = x − (−3)

## Range notation

x = y..z x takes on integer values starting from y to z, inclusive, with x, y, and z being integer numbers and z being greater than or equal to y.

## Mathematical functions

Abs( x ) = (1)

Ceil( x ) smallest integer greater than or equal to x. (2)

Clip1( x ) = Clip3( 0, ( 1 << BitDepth ) − 1, x ) (3)

Clip3( x, y, z ) = (4)

ClipH( v, w, x ) = (5)

Floor( x ) largest integer less than or equal to x. (6)

Log2( x ) base-2 logarithm of x. (7)

Min( x, y ) = (8)

Max( x, y ) = (9)

Round( x ) = Sign( x ) \* Floor( Abs( x ) + 0.5 ) (10)

Sign( x ) = (11)

Sqrt( x ) square root of x (12)

Swap( x, y ) = ( y, x ) (13)

BitWidth( x ) = (14)

## Order of operation precedence

When order of precedence in an expression is not indicated explicitly by use of parentheses, the following rules apply:

– Operations of a higher precedence are evaluated before any operation of a lower precedence.

– Operations of the same precedence are evaluated sequentially from left to right.

Table 5‑1 specifies the precedence of operations from highest to lowest; a higher position in the table indicates a higher precedence.

NOTE – For those operators that are also used in the C programming language, the order of precedence used in this Specification is the same as used in the C programming language.

Table 5‑1 – Operation precedence from highest (at top of table) to lowest (at bottom of table)

|  |
| --- |
| **Operations (with operands x, y, and z)** |
| "x++", "x− −" |
| "!x", "−x" (as a unary prefix operator) |
| xy |
| "x \* y", "x / y", "x ÷ y", "", "x % y" |
| "x + y", "x − y" (as a two-argument operator), "" |
| "x  <<  y", "x  >>  y" |
| "x < y", "x  <=  y", "x > y", "x  >=  y" |
| "x  = =  y", "x  !=  y" |
| "x & y" |
| "x | y" |
| "x  &&  y" |
| "x  | |  y" |
| "x ? y : z" |
| "x..y" |
| "x = y", "x  +=  y", "x  −=  y" |

## Mathematical functions, operators, and processes for floating-point approximations

### Representation of floating-point approximations

The accuracy of all floating-point approximations is specified by the following constant parameter:

– FPANumDigitsVal specifies the number of significant binary digits in the floating-point approximation. Given the value of FPANumDigitsVal, all calculations for the significand of a floating-point approximation can be implemented using signed integer arithmetic with N = FPANumDigitsVal + 2 bits.

Division operations for floating-point approximations are specified based on a look-up table. The accuracy of division operations is specified by the following two constant parameters:

– FPALog2DivTabSize specifies the binary logarithm of the number of elements in the look-up table. The look-up table used for division operations has (1 << FPALog2DivTabSize) elements.

– FPANumDigitsDivTab specifies the number of significant binary digits for the values of the division look-up table. Given the value of FPANumDigitsDivTab, the elements of the look-up table can be represented as unsigned integers with N = FPANumDigitsDivTab bits or as signed integers with N = FPANumDigitsDivTab +1 bits.

The division look-up table is referred to as FPADivTab. It is determined as specified by the following pseudo-code:

nom = 1  <<  ( FPALog2DivTabSize + FPANumDigitsDivTab – 1 )  
off    = 1  <<  FPALog2DivTabSize  
for( k = 0; k < (1  <<  FPALog2DivTabSize ); k++ ) { (15)  
 denom = off + k  
 FPADivTab[ k ] = ( nom + (denom >> 1 ) ) / denom  
}

where the division represents an integer division with truncation towards zero.

For the following specification, the values FPANumDigitsVal = 30, FPALog2DivTabSize = 8, and FPANumDigitsDivTab = 15 are used. All calculations for the significand of a floating-point approximation can be implemented in 32-bit signed integer arithmetic. The look-up table FPADivTab has 256 elements and each of these elements can be represented as 16-bit signed integer. The total size required for storing the look-up table is 512 bytes.

A floating point approximation is specified as a triple (val, exp, sgn) as follows:

– val is an integer number representing the significant digits of a floating-point approximation, also referred to as significand. The value of val is represented as signed integer number of at least N = FPANumDigitsVal + 2 bits. Even though the actual value of val can always be represented by an unsigned integer of FPANumDigitsVal bits, two additional bits and a signed integer representation is required for intermediate values in calculations with the floating-point approximations. With FPANumDigitsVal = 30, all calculations related to the number val representing the significand of a floating-point approximation can be done using 32-bit signed integers;

– exp is an integer number representing the exponent;

– sgn is a bit representing the sign, where negative numbers have sgn = 1 and positive numbers have sgn = 0.

With x being a floating point representation, the elements of the triple (val, exp, sgn) specifying x are also referred to as x.val, x.exp, and x.sgn, respectively.

The floating-point value fx that is represented by a floating-point approximation x is given by:

fx = (1 – 2 \* x.sgn) \* x.val \* 2^(x.exp). (16)

Note that a value of 0 for the floating-point approximation x is represented by x.val = 0. When x.val = 0, the floating-point approximation represents the value of 0, regardless of the values of x.exp and x.sgn (they don’t have any meaning when x.val is equal to 0).

### Arithmetic operators and functions

In the following x, y, and z represent floating-point approximations and a represents an integer. The following functions and arithmetic operators are specified:

– Conversion of an integer to a floating-point approximation:

x = FPApprox( a ) (17)

The floating-point approximation x is derived by invoking the process for converting an integer to a floating-point approximation as specified in clause 5.10.3.1 with a as input and the output is assigned to x.

– Conversion of a floating-point approximation to an integer:

a = FPAToInteger( x ) (18)

The integer a is derived by invoking the process for converting a floating-point approximation to an integer as specified in clause 5.10.3.2 with a as input and the output is assigned to a.

– Bit-shift to the left:

y = x << a (19)

The floating-point approximation y is derived by invoking the process for shifting a floating-point approximation to the left as specified in clause 5.10.3.3 with x and a as inputs and the output is assigned to y.

– Bit-shift to the right:

y = x >> a (20)

The floating-point approximation y is derived by invoking the process for shifting a floating-point approximation to the right as specified in clause 5.10.3.4 with x and a as inputs and the output is assigned to y.

– Negation:

y = –x (21)

The floating-point approximation y is derived by invoking the process for negating a floating-point approximation as specified in clause 5.10.3.5 with x as input and the output is assigned to y.

– Addition:

z = x + y (22)

The floating-point approximation z is derived by invoking the process for adding two floating-point approximations as specified in clause 5.10.3.6 with x and y as inputs and the output is assigned to z.

– Subtraction:

z = x – y (23)

The floating-point approximation z is derived by invoking the process for subtracting two floating-point approximations as specified in clause 5.10.3.7 with x and y as inputs and the output is assigned to z.

– Multiplication:

z = x \* y (24)

The floating-point approximation z is derived by invoking the process for multiplying two floating-point approximations as specified in clause 5.10.3.8 with x and y as inputs and the output is assigned to z.

– Reciprocal:

y = 1 / x (25)

The floating-point approximation y is derived by invoking the process for deriving the reciprocal of a floating-point approximation as specified in clause 5.10.3.9 with x as input and the output is assigned to y.

– Division:

z = x / y (26)

The floating-point approximation z is derived by invoking the process for dividing two floating-point approximations as specified in clause 5.10.3.10 with x and y as inputs and the output is assigned to z.

The operator precesence for floating-point approximations is the same as specified in clause 5.9.

### Specification of arithmetic operations

#### Process for converting an integer to a floating-point approximation

Input to this process is a signed or unsigned integer value a.

Output of this process is a floating-point approximation x = (x.val, x.exp, x.sgn) representing the integer a.

The output value y is initialized with y.val = 0, y.exp = 0, and y.sgn = 0.

When a is not equal to 0, the output value y is modified as specified by the following pseudo-code:

if( a < 0 ) {  
 absVal = –a  
 y.sgn = 1  
} else  
 absVal = a  
y.exp = BitWidth( absVal ) – FPANumDigitsVal (27)  
if( y.exp < 0 )  
 y.val = absVal << ( –y.exp )  
else  
 y.val = absVal >> y.exp

#### Process for converting a floating-point approximation to an integer

Input to this process is a floating-point approximation x = (x.val, x.exp, x.sgn).

Output of this process is an integer a representing the floating-point approximation x rounded to an integer value.

The value of a is initially set to 0.

When x.val is not equal to 0, the value of a is modified as specified by the following pseudo-code:

if( x.exp >= 0 )  
 a = x.val  <<  x.exp  
else  
 a = ( x.val + ( 1  <<  ( –x.exp – 1 ) ) )  >>  ( –x.exp ) (28)  
if( x.sgn )  
 a = –a

#### Process for shifting a floating-point approximation to the left

Inputs to this process are:

– a floating-point approximation x = (x.val, x.exp, x.sgn), and

– a non-negative integer number a representing a bit shift to the left.

Output of this process is a floating-point approximation y = (y.val, y.exp, y.sgn) representing the result of the bit shift.

The floating-point approximation y is determined as specified by the following pseudo-code:

y.val   = x.val  
y.exp = x.exp + a (29)  
y.sgn = x.sgn

#### Process for shifting a floating-point approximation to the right

Inputs to this process are:

– a floating-point approximation x = (x.val, x.exp, x.sgn), and

– a non-negative integer number a representing a bit shift to the right.

Output of this process is a floating-point approximation y = (y.val, y.exp, y.sgn) representing the result of the bit shift.

The floating-point approximation y is determined as specified by the following pseudo-code:

y.val  = x.val  
y.exp = x.exp – a (30)  
y.sgn = x.sgn

#### Process for negating a floating-point approximation

Input to this process is a floating-point approximation x = (x.val, x.exp, x.sgn).

Output of this process is a floating-point approximation y = (y.val, y.exp, y.sgn) representing the result of the negation of x.

The floating-point approximation y is determined as specified by the following pseudo-code:

y.val  = x.val  
y.exp = x.exp (31)  
y.sgn = 1 – x.sgn

#### Process for adding two floating-point approximations

Input to this process are:

– a floating-point approximation x = (x.val, x.exp, x.sgn) representing the first summand;

– a floating-point approximation y = (y.val, y.exp, y.sgn) representing the second summand.

Output of this process is a floating-point approximation z = (z.val, z.exp, z.sgn) representing the result of the addition of x and y.

If x.val is equal to 0, z is set equal to y, i.e., z.val = y.val, z.exp = y.exp, and z.sgn = y.sgn.

Otherwise, if y.val is equal to 0, z is set equal to x, i.e., z.val = x.val, z.exp = x.exp, and z.sgn = x.sgn.

Otherwise (x.val is not equal to 0 and y.val is not equal to 0), the value of z is first initialized with z.val = 0, z.exp = 0, and z.sgn = 0 and then updated as specified by the following pseudo-code:

if( x.exp >= y.exp ) {  
 s = x.exp – y.exp  
 a = ( y.val + ( ( 1  <<  s ) – 1 ) )  >>  s  
 b = ( 1 – 2 \* x.sgn ) \* x.val + ( 1 – 2 \* y.sgn ) \* a  
 c = x.exp  
} else {  
 s = y.exp – x.exp  
 a = ( x.val + ( ( 1  <<  s ) – 1 ) )  >>  s  
 b = ( 1 – 2 \* x.sgn ) \* a + ( 1 – 2 \* y.sgn ) \* y.val (32)  
 c = y.exp  
}  
if( b < 0 ) {  
 b = –b  
 z.sgn = 1  
}  
if( b > 0 ) {  
 d = BitWidth( b ) – FPANumDigitsVal  
 if( d < 0 )  
 z.val = b  <<  ( –d )  
 else  
 z.val = b  >>  d  
 z.exp = c +d  
}

#### Process for subtracting two floating-point approximations

Input to this process are:

– a floating-point approximation x = (x.val, x.exp, x.sgn) representing the minuend;

– a floating-point approximation y = (y.val, y.exp, y.sgn) representing the subtrahend.

Output of this process is a floating-point approximation z = (z.val, z.exp, z.sgn) representing the result of subtracting y from of x.

The floating point approximation yn is derived by invoking the process for negating a floating-point approximation as specified in clause 5.10.3.5 with y as input and the output is assigned to yn.

The floating point approximation z is derived by invoking the process for adding two floating-point approximations as specified in clause 5.10.3.6 with x and yn as inputs and the output is assigned to z.

#### Process for multiplying two floating-point approximations

Input to this process are:

– a floating-point approximation x = (x.val, x.exp, x.sgn) representing the multiplier;

– a floating-point approximation y = (y.val, y.exp, y.sgn) representing the multiplicand.

Output of this process is a floating-point approximation z = (z.val, z.exp, z.sgn) representing the result of the multiplication of x and y.

If x.val is equal to 0 or y.val is equal to 0, z is set equal to zero, i.e., z.val = 0.

Otherwise (x.val is not equal to 0 and y.val is not equal to 0), the floating-point approximation z is derived as specified by the following pseudo-code:

HSHIFT = FPANumDigitsVal  >>  1  
LMASK = ( 1  <<  HSHIFT )  –  1  
ah = x.val  >>  HSHIFT  
bh = y.val  >>  HSHIFT (33)  
al  = x.val  &  LMASK  
bl  = y.val  &  LMASK  
z.val  = ( ( ah \* bh )  <<  1 ) + ( ( ah \* bl + al \* bh + ( ( al \* bl )  >>  HSHIFT ) )  >>  ( HSHIFT – 1 ) )  
z.exp = x.exp + y.exp + FPANumDigitsVal – 1  
z.sgn = x.sgn ^ y.sgn  
if( z.val >= ( 1  <<  FPANumDigitsVal ) ) {  
 z.val  = z.val  >> 1  
 z.exp = z.exp + 1  
}

#### Process for deriving the reciprocal of a floating-point approximation

Input to this process is a floating-point approximation x = (x.val, x.exp, x.sgn) with x.val being not equal to 0.

Output of this process is a floating-point approximation y = (y.val, y.exp, y.sgn) representing the reciprocal of x.

The floating-point approximation y is derived as specified by the following pseudo-code:

DSHIFT = FPANumDigitsVal – FPALog2DivTabSize – 1  
DADD   = ( 1  <<  ( DSHIFT – 1 ) )  –  ( 1  <<  ( FPANumDigitsVal  – 1 ) )  
DMASK = ( 1  <<  FPALog2DivTabSize ) – 1  
EXSUB  = FPANumDigitsDivTab + FPANumDigitsVal – 2  
a = ( x.val + DADD )  >>  DSHIFT (34)  
b = FPADivTab[ a & DMASK ]  
c = BitWidth( b ) – FPANumDigitsVal  
y.val = b  <<  ( –c )  
y.exp = c – x.exp – ( a  >>  FPALog2DivTabSize ) – EXSUB  
y.sgn = x.sgn

#### Process for dividing two floating-point approximations

Input to this process are:

– a floating-point approximation x = (x.val, x.exp, x.sgn) representing the dividend;

– a floating-point approximation y = (y.val, y.exp, y.sgn), with y.val being not equal to 0, representing the divisor.

Output of this process is a floating-point approximation z = (z.val, z.exp, z.sgn) representing the result of the division of x and y.

The floating point approximation yr is derived by invoking the process for deriving the reciprocal of a floating-point approximation as specified in clause 5.10.3.9 with y as input and the output is assigned to yr.

The floating point approximation z is derived by invoking the process for multiplying two floating-point approximations as specified in clause 5.10.3.10 with x and yr as inputs and the output is assigned to z.

### Processes for solving linear equation systems using floating-point approximations

#### Derivation process for a sub vector

Inputs to this process are:

– an N-dimensional vector vec of floating-point approximations, with N > 1;

– an index r.

Output of this process is an (N – 1)-dimensional vector subVec that is obtained by deleting the r-th element from the vector vec.

The (N – 1)-dimensional vector subVec is obtained as specified by the following peudo-code:

for( k = 0; k < N – 1; k++ ) (35)  
 subVec[ k ] = vec[ k + ( k >= r ? 1 : 0 ) ]

#### Derivation process for a sub-matrix

Inputs to this process are:

– an NxN matrix mat of floating-point approximations, with N > 1;

– a row index r; and

– a column index c.

Output of this process is an (N – 1)x(N – 1) matrix subMat that is obtained by deleting the r-th row and the c-th column from the matrix mat.

The (N – 1)x(N – 1) matrix subMat is obtained as specified by the following peudo-code:

for( k = 0; k < N – 1; k++ )  
 for( n = 0; n < N – 1; n++ ) (36)  
 subMat[ k ][ n ] = mat[ k + ( k >= c ? 1 : 0 ) ][ n + ( n >= r ? 1 : 0 ) ]

#### Derivation process for the determinant of a matrix

Inputs to this process is an NxN matrix mat of floating-point approximations, with N > 0.

Output of this process is a floating-point approximation det that represents the determinant of the matrix mat.

If N is equal to 1, the determinant det is set equal to det = x[ 0 ][ 0 ].

Otherwise (N is greater than 1), the determinant det is derived as specified by the following recursive process:

– The determinant is set equal to det = FPNum( 0 ).

– For k proceeding over the range from 0 to N – 1, inclusive, the following applies:

* The (N – 1)x(N – 1) sub-matrix subMat is derived by invoking the derivation process for a sub-matrix as specified in clause 5.10.4.2 with mat, the row index k, and the column index 0 as inputs and the output is assigned to the sub-matrix subMat.
* The determinant subDet of the (N – 1)x(N – 1) sub-matrix subMat is derived by invoking the derivation process for the determinant of a matrix as specified in this clause with subMat as input and the output is assigned to subDet.
* Depending on k, the determinant det is updated as specified by the following pseudo-code:

if( ( k & 1 )  = =  1 )  
 det = det – mat[ 0 ][ k ] \* subDet (37)  
else  
 det = det + mat[ 0 ][ k ] \* subDet

#### Process for solving a linear equation system with floating-point matrices and vectors

Inputs to this process are:

– an NxN matrix mat of floating-point approximations, with N > 0;

– a N-dimensional vector vec of floating-point approximations;

– an unsigned integer bshift specifying the precision of the output.

Output of this process is an N-dimensional vector res of integer values.

The determinant detMat of the matrix mat is determined by invoking the derivation process for the determinant of a matrix as specified in clause 5.10.4.3 with mat as input and the output is assigned to detMat.

If detMat.val is equal to 0, the value of res[ 0 ] is set equal to res[ 0 ] = 0.

Otherwise (detMat.val is not zero), the value of res[ 0 ] is derived as follows:

– The NxN matrix matX of floating-point approximations is derived as specifified by the following pseudo-code:

for( k = 0; k < N; k++ )  
 matX[ 0 ][ k ] = vec[ k ]  
for( c = 1; c < N; c++ ) (38)  
 for( k = 0; k < N; k++ )  
 matX[ c ][ k ] = mat[ c ][ k ]

– The determinant detX of the matrix matX is determined by invoking the derivation process for the determinant of a matrix as specified in clause 5.10.4.3 with matX as input and the output is assigned to detX.

– The value of res[ 0 ] is derived by:

res[0] = FPAToInteger( ( detX / detMat )  <<  bshift ) (39)

When N is greater than 1, the values res[ k ] with k being in the range of 1 to N – 1, inclusive, are determined by the following recursive process:

– The (N – 1)x(N – 1) sub-matrix subMat is determined by invoking the derivation process for a sub-matrix as specified in clause 5.10.4.2 with mat, the row index 0, and the column index 0 as inputs and the output is assigned to the sub-matrix subMat.

– The (N – 1)-dimensional sub-vector subVec is determined by invoking the derivation process for a sub-vector as specified in clause 5.10.4.1 with vec and the index 0 as inputs and the output is assigned to the sub-vector subVec.

– The (N – 1)-dimensional sub-vector subVec is modified as specified by the following pseudo-code:

scale = FPNum( res[ 0 ] )  >>  bshift  
for( k = 0; k < N – 1; k++ ) (40)  
 subVec[ k ] = subVec[ k ] – scale \* mat[ 0 ][ 1 + k ]

– The process for solving a linear equation system with floating-point matrices and vectors as specified in this clause is invoked with the (N – 1)x(N – 1) matrix subMat, the (N – 1)-dimensional vector subVec, and the integer number bshift as input and the output is assigned to the (N – 1)-dimensional integer vector subRes.

– The values res[ k ] with k being in the range of 1 to N – 1, inclusive, are determined by:

for( k = 1; k < N; k++ ) (41)  
 res[ k ] = subRes[ k – 1 ]

#### Process for solving a linear equation system in integer arithmetic

Inputs to this process are:

– an NxN matrix mat of integer values, with N > 0;

– a N-dimensional vector vec of integer values;

– an unsigned integer bshift specifying the precision of the output.

Output of this process is an N-dimensional vector res of integer values.

The NxN matrix fpaMat of floating-point approximations is derived as specified by the following pseudo-code:

for( c = 0; c < N; c++ )  
 for( r = 0; r < N; r++ ) (42)  
 fpaMat[ c ][ r ] = FPApprox( mat[ c ][ r ] )

The N-dimensional vector fpaVec of floating-point approximations is derived as specified by the following pseudo-code:

for( k = 0; k < N; k++ ) (43)  
 fpaVec[ k ] = FPApprox ( vec[ k ] )

The N-dimensional output vector res is derived by invoking the process for solving a linear equation system with floating-point matrices and vectors as specified in clause 5.10.4.4 with fpaMat, fpaVec, and bshift as inputs and the output is assigned to res.

## Variables, syntax elements and tables

Syntax elements in the bitstream are represented in **bold** type. Each syntax element is described by its name (all lower case letters with underscore characters), and one descriptor for its method of coded representation. The decoding process behaves according to the value of the syntax element and to the values of previously decoded syntax elements. When a value of a syntax element is used in the syntax tables or the text, it appears in regular (i.e., not bold) type.

In some cases the syntax tables and semantics use the values of other variables derived from the values of syntax elements. Such variables appear in the syntax tables, or text, named by a mixture of lower case and upper case letter and without any underscore characters. Variables starting with an upper case letter are derived for the decoding of the current syntax structure and all depending syntax structures. Variables starting with an upper case letter could, in some cases, be used in the decoding process for later syntax structures without mentioning the originating syntax structure of the variable. Variables starting with a lower case letter are only used within the clause in which they are derived.

In some cases, "mnemonic" names for syntax element values or variable values are used interchangeably with their numerical values. Sometimes "mnemonic" names are used without any associated numerical values. The association of values and names is specified in the text. The names are constructed from one or more groups of letters separated by an underscore character. Each group starts with an upper case letter and could contain more upper case letters.

NOTE – The syntax is described in a manner that closely follows the C-language syntactic constructs.

Functions that specify properties of the current position in the bitstream are referred to as syntax functions. These functions are specified in clause 7.2 and assume the existence of a bitstream pointer with an indication of the position of the next bit to be read by the decoding process from the bitstream. Syntax functions are described by their names, which are constructed as syntax element names and end with left and right round parentheses including zero or more variable names (for definition) or values (for usage), separated by commas (if more than one variable).

Functions that are not syntax functions (including mathematical functions specified in clause 5.8) are described by their names, which start with an upper case letter, contain a mixture of lower and upper case letters without any underscore character, and end with left and right parentheses including zero or more variable names (for definition) or values (for usage) separated by commas (if more than one variable).

A one-dimensional array is referred to as a list. A two-dimensional array is referred to as a matrix. Arrays can either be syntax elements or variables. Subscripts or square parentheses are used for the indexing of arrays. In reference to a visual depiction of a matrix, the first subscript is used as a row (vertical) index and the second subscript is used as a column (horizontal) index. The indexing order is reversed when using square parentheses rather than subscripts for indexing. Thus, an element of a matrix s at horizontal position x and vertical position y could be denoted either as s[ x ][ y ] or as syx. A single column of a matrix could be referred to as a list and denoted by omission of the row index. Thus, the column of a matrix s at horizontal position x could be referred to as the list s[ x ].

A specification of values of the entries in rows and columns of an array could be denoted by { {...} {...} }, where each inner pair of brackets specifies the values of the elements within a row in increasing column order and the rows are ordered in increasing row order. Thus, setting a matrix s equal to { { 1 6 } { 4 9 }} specifies that s[ 0 ][ 0 ] is set equal to 1, s[ 1 ][ 0 ] is set equal to 6, s[ 0 ][ 1 ] is set equal to 4, and s[ 1 ][ 1 ] is set equal to 9.

Binary notation is indicated by enclosing the string of bit values by single quote marks. For example, '01000001' represents an eight-bit string having only its second and its last bits (counted from the most to the least significant bit) equal to 1.

Hexadecimal notation, indicated by prefixing the hexadecimal number by "0x", is used in some cases instead of binary notation when the number of bits is an integer multiple of 4. For example, 0x41 represents an eight-bit string having only its second and its last bits (counted from the most to the least significant bit) equal to 1.

Numerical values not enclosed in single quotes and not prefixed by "0x" are decimal values.

A value equal to 0 represents a FALSE condition in a test statement. The value TRUE is represented by any value different from zero.

## Text description of logical operations

In the text, a statement of logical operations as would be described mathematically in the following form:

if( condition 0 )  
 statement 0  
else if( condition 1 )  
 statement 1  
...  
else /\* informative remark on remaining condition \*/  
 statement n

is typically described in the following manner:

... as follows / ... the following applies:

– If condition 0, statement 0

– Otherwise, if condition 1, statement 1

– ...

– Otherwise (informative remark on remaining condition), statement n

Each "If ... Otherwise, if ... Otherwise, ..." statement in the text is introduced with "... as follows" or "... the following applies" immediately followed by "If ... ". The last condition of the "If ... Otherwise, if ... Otherwise, ..." is always an "Otherwise, ...". Interleaved "If ... Otherwise, if ... Otherwise, ..." statements can be identified by matching "... as follows" or "... the following applies" with the ending "Otherwise, ...".

In the text, a statement of logical operations as would be described mathematically in the following form:

if( condition 0a && condition 0b )  
 statement 0  
else if( condition 1a | | condition 1b )  
 statement 1  
...  
else  
 statement n

is typically described in the following manner:

... as follows / ... the following applies:

– If all of the following conditions are true, statement 0:

– condition 0a

– condition 0b

– Otherwise, if one or more of the following conditions are true, statement 1:

– condition 1a

– condition 1b

– ...

– Otherwise, statement n

In the text, a statement of logical operations as would be described mathematically in the following form:

if( condition 0 )  
 statement 0  
if( condition 1 )  
 statement 1

is typically described in the following manner:

When condition 0, statement 0

When condition 1, statement 1

## Processes

Processes are used to describe the decoding of syntax elements. A process has a separate specification and invoking. All syntax elements and upper case variables that pertain to the current syntax structure and depending syntax structures are available in the process specification and invoking. A process specification might also have a lower case variable explicitly specified as input. Each process specification has explicitly specified an output. The output is a variable that can either be an upper case variable or a lower case variable.

When invoking a process, the assignment of variables is specified as follows:

– If the variables at the invoking and the process specification do not have the same name, the variables are explicitly assigned to lower case input or output variables of the process specification.

– Otherwise (the variables at the invoking and the process specification have the same name), assignment is implied.

In the specification of a process, a specific coding block is sometimes referred to by the variable name having a value equal to the address of the specific coding block.

# Bitstream and waveform signal format

# Syntax and semantics

## Method of specifying syntax in tabular form

The syntax tables specify a superset of the syntax of all allowed bitstreams. Additional constraints on the syntax might be specified, either directly or indirectly, in other clauses.

NOTE – An actual decoder is expected to implement some means for identifying entry points into the bitstream and some means to identify and handle non-conforming bitstreams. The methods for identifying and handling errors and other such situations are not specified in this Specification.

The following table lists examples of the syntax specification format. When **syntax\_element** appears, it specifies that a syntax element is parsed from the bitstream and the bitstream pointer is advanced to the next position beyond the syntax element in the bitstream parsing process.

|  | Descriptor |
| --- | --- |
| /\* A statement can be a syntax element with an associated descriptor or can be an expression used to specify conditions for the existence, type and quantity of syntax elements, as in the following two examples \*/ |  |
| **syntax\_element** | ue(k) |
| conditioning statement |  |
|  |  |
| /\* A group of statements enclosed in curly brackets is a compound statement and is treated functionally as a single statement. \*/ |  |
| { |  |
| statement |  |
| statement |  |
| ... |  |
| } |  |
|  |  |
| /\* A "while" structure specifies a test of whether a condition is true, and if true, specifies evaluation of a statement (or compound statement) repeatedly until the condition is no longer true \*/ |  |
| while( condition ) |  |
| statement |  |
|  |  |
| /\* A "do ... while" structure specifies evaluation of a statement once, followed by a test of whether a condition is true, and if true, specifies repeated evaluation of the statement until the condition is no longer true \*/ |  |
| do |  |
| statement |  |
| while( condition ) |  |
|  |  |
| /\* An "if ... else" structure specifies a test of whether a condition is true and, if the condition is true, specifies evaluation of a primary statement, otherwise, specifies evaluation of an alternative statement. The "else" part of the structure and the associated alternative statement is omitted if no alternative statement evaluation is needed \*/ |  |
| if( condition ) |  |
| primary statement |  |
| else |  |
| alternative statement |  |
|  |  |
| /\* A "for" structure specifies evaluation of an initial statement, followed by a test of a condition, and if the condition is true, specifies repeated evaluation of a primary statement followed by a subsequent statement until the condition is no longer true. \*/ |  |
| for( initial statement; condition; subsequent statement ) |  |
| primary statement |  |

## Specification of syntax functions and descriptors

The functions presented in this clause are used in the specification of the syntax. These functions are expressed in terms of the value of a bitstream pointer that indicates the position of the next bit to be read by the decoding process from the bitstream.

byte\_aligned( ) is specified as follows:

– If the current position in the bitstream is a byte-aligned position, i.e., the current position is an integer multiple of 8 bits from the position of the first bit in the bitstream, the return value of byte\_aligned( ) is equal to TRUE.

– Otherwise, the return value of byte\_aligned( ) is equal to FALSE.

more\_data\_in\_payload( ) is specified as follows:

– If byte\_aligned( ) is equal to TRUE and the current position in the sei\_payload( ) or vui\_payload( ) syntax structure is 8 \* payloadSize bits from the beginning of the syntax structure, the return value of more\_data\_in\_payload( ) is equal to FALSE.

– Otherwise, the return value of more\_data\_in\_payload( ) is equal to TRUE.

more\_rbsp\_data( ) is specified as follows:

– If there is no more data in the raw byte sequence payload (RBSP), the return value of more\_rbsp\_data( ) is equal to FALSE.

– Otherwise, the RBSP data are searched for the last (least significant, right-most) bit equal to 1 that is present in the RBSP. Given the position of this bit, which is the first bit (rbsp\_stop\_one\_bit) of the rbsp\_trailing\_bits( ) syntax structure, the following applies:

– If there is more data in an RBSP before the rbsp\_trailing\_bits( ) syntax structure, the return value of more\_rbsp\_data( ) is equal to TRUE.

– Otherwise, the return value of more\_rbsp\_data( ) is equal to FALSE.

The method for enabling determination of whether there is more data in the RBSP is specified by the application.

more\_rbsp\_trailing\_data( ) is specified as follows:

– If there is more data in an RBSP, the return value of more\_rbsp\_trailing\_data( ) is equal to TRUE.

– Otherwise, the return value of more\_rbsp\_trailing\_data( ) is equal to FALSE.

next\_bits( n ) provides the next bits in the bitstream for comparison purposes, without advancing the bitstream pointer. Provides a look at the next n bits in the bitstream with n being its argument..

payload\_extension\_present( ) is specified as follows:

– If the current position in the sei\_payload( ) or vui\_payload( ) syntax structure is not the position of the last (least significant, right-most) bit that is equal to 1 that is less than 8 \* payloadSize bits from the beginning of the syntax structure (i.e., the position of the sei\_payload\_bit\_equal\_to\_one or vui\_payload\_bit\_equal\_to\_one syntax element), the return value of payload\_extension\_present( ) is equal to TRUE.

– Otherwise, the return value of payload\_extension\_present( ) is equal to FALSE.

read\_bits( n ) reads the next n bits from the bitstream and advances the bitstream pointer by n bit positions. When n is equal to 0, read\_bits( n ) is specified to return a value equal to 0 and to not advance the bitstream pointer.

The following descriptors specify the parsing process of each syntax element:

– ae(v): context-adaptive arithmetic entropy-coded syntax element. The parsing process for this descriptor is specified in clause 9.4.

– b(8): byte having any pattern of bit string (8 bits). The parsing process for this descriptor is specified by the return value of the function read\_bits( 8 ).

– f(n): fixed-pattern bit string using n bits written (from left to right) with the left bit first. The parsing process for this descriptor is specified by the return value of the function read\_bits( n ).

– i(n): signed integer using n bits. When n is "v" in the syntax table, the number of bits varies in a manner dependent on the value of other syntax elements. The parsing process for this descriptor is specified by the return value of the function read\_bits( n ) interpreted as a two's complement integer representation with most significant bit written first.

– se(v): signed integer 0-th order Exp-Golomb-coded syntax element with the left bit first. The parsing process for this descriptor is specified in clause 9.3 with the order k equal to 0.

– st(v): null-terminated string encoded as universal coded character set (UCS) transmission format-8 (UTF-8) characters as specified in ISO/IEC 10646. The parsing process is specified as follows: st(v) begins at a byte-aligned position in the bitstream and reads and returns a series of bytes from the bitstream, beginning at the current position and continuing up to but not including the next byte-aligned byte that is equal to 0x00, and advances the bitstream pointer by ( stringLength + 1 ) \* 8 bit positions, where stringLength is equal to the number of bytes returned.

NOTE The st(v) syntax descriptor is only used in this document when the current position in the bitstream is a byte-aligned position

– u(n): unsigned integer using n bits. When n is "v" in the syntax table, the number of bits varies in a manner dependent on the value of other syntax elements. The parsing process for this descriptor is specified by the return value of the function read\_bits( n ) interpreted as a binary representation of an unsigned integer with most significant bit written first.

– ue(v): unsigned integer 0-th order Exp-Golomb-coded syntax element with the left bit first. The parsing process for this descriptor is specified in clause 9.3 with the order k equal to 0.

– ev(k,n,m): unsigned integer coded using escaped values. The parsing process for this descriptor is specified in clause 9.2.

## Syntax in tabular form

### Stream packet syntax

#### General stream packet unit syntax

|  |  |
| --- | --- |
| stream\_packet( ) { | Descriptor |
| stream\_packet\_header( ) |  |
| NumBytesInRbsp = stream\_packet\_length |  |
| for( i = 0; i < NumBytesInRbsp; i++ ) |  |
| **rbsp\_byte**[ i ] | b(8) |
| } |  |

#### Stream packet header syntax

|  |  |
| --- | --- |
| stream\_packet\_header( ) { | Descriptor |
| **stream\_packet\_type** | ev(3,8,8) |
| **stream\_packet\_label** | ev(2,8,32) |
| **stream\_packet\_length** | ev(11,24,24) |
| } |  |

### Raw byte sequence payloads, trailing bits and byte alignment syntax

#### Waveform parameter set RBSP syntax

|  |  |
| --- | --- |
| waveform\_parameter\_set\_rbsp( ) { | Descriptor |
| **wps\_waveform\_parameter\_set\_id** | u(4) |
| NumChannelGroups = 0 |  |
| TotalNumChannels = 0 |  |
| do { |  |
| **wps\_num\_channels\_in\_next\_group\_minus1** | ue(v) |
| **wps\_num\_channel\_group\_repetitions** | ue(v) |
| for( j = 0; j <= wps\_num\_channel\_group\_repetitions; j++ ) { |  |
| NumChannels[ NumChannelGroups ] =  wps\_num\_channels\_in\_next\_group\_minus1 + 1 |  |
| ChannelGroupStartingPos[ NumChannelGroups++ ]= TotalNumChannels |  |
| TotalNumChannels += wps\_num\_channels\_in\_next\_group\_minus1 + 1 |  |
| } |  |
| **wps\_more\_channel\_groups\_present\_flag** | u(1) |
| } while( wps\_more\_channel\_groups\_present\_flag ) |  |
| **wps\_channel\_reordering\_flag** | u(1) |
| if( wps\_channel\_reordering\_ flag ) { |  |
| **wps\_num\_channel\_swaps\_minus1** | ue(v) |
| for( i = 0; i <= wps\_num\_channel\_swaps\_minus1; i++ ) { |  |
| **wps\_swap\_frst\_idx**[ i ] | ue(v) |
| **wps\_swap\_scnd\_idx\_min\_frst\_idx\_min1**[ i ] | ue(v) |
| } |  |
| } |  |
| **wps\_num\_annotation\_channels** | ue(v) |
| for( j = 0; j < wps\_num\_annotation\_channels; j++ ) |  |
| AnnotationChannelNumSamples[ j ] = 0 | ue(v) |
| rbsp\_trailing\_bits( ) |  |
| } |  |

#### Channel group parameter set RBSP syntax

|  |  |
| --- | --- |
| channel\_group\_parameter\_set\_rbsp( ) { | Descriptor |
| **cgps\_channel\_group\_parameter\_set\_id** | u(8) |
| **cgps\_waveform\_parameter\_set\_id** | u(4) |
| **cgps\_length\_signal\_mode\_flag** | u(1) |
| **cgps\_frame\_length\_shift** | u(2) |
| **cgps\_max\_min\_block\_size** | u(6) |
| **cgps\_max\_min\_bit\_depth** | u(6) |
| **cgps\_allow\_cross\_channel\_pred\_flag** | u(1) |
| if( cgps\_allow\_cross\_channel\_pred\_flag ) { |  |
| **cgps\_cc\_pred\_filtering\_mode** | u(2) |
| **cgps\_allow\_cc\_pred\_mult\_hyp\_flag** | u(1) |
| } |  |
| **cgps\_allow\_block\_matching\_pred\_flag** | u(1) |
| if( cgps\_allow\_block\_matching\_pred\_flag ) { |  |
| **cgps\_bm\_pred\_filtering\_mode** | u(2) |
| **cgps\_allow\_bm\_pred\_mult\_hyp\_flag** | u(1) |
| **cgps\_allow\_bm\_offset\_pred\_prev\_ch\_flag** | u(1) |
| } |  |
| **cgps\_allow\_lpf** | u(1) |
| if( cgps\_ allow\_lpf ){ |  |
| **cgps\_lpf\_allow\_prev\_ch\_flag** | u(1) |
| if( cgps\_lpf\_allow\_prev\_ch\_flag ) |  |
| **cgps\_lpf\_max\_num\_minus\_1\_prev\_ch** | u(5) |
| } |  |
| **cgps\_residual\_quant\_mode** | u(2) |
| **cgps\_ch\_indep\_interval\_idx** | u(4) |
| DepChMask = ( 2 << cgps\_ch\_indep\_interval\_idx ) – 1 |  |
| **cgps\_max\_abs\_delta\_qp\_idx** | u(3) |
| MaxAbsDeltaQP = ( 1 << cgps\_max\_abs\_delta\_qp\_idx ) – 1 |  |
| **cgps\_qp** | u(10) |
| **cgps\_ctx\_init\_flag** | u(1) |
| **cgps\_lms\_order** | u(6) |
| rbsp\_trailing\_bits( ) |  |
| } |  |

#### Independent frame RBSP syntax

|  |  |
| --- | --- |
| independent\_frame\_rbsp( ) { | Descriptor |
| **if\_channel\_group\_parameter\_set\_id** | u(8) |
| if(NumChannelGroups > 1 ) |  |
| **if\_channel\_group\_id** | u(v) |
| for( ch = 1; ch < NumChannels[ if\_channel\_group\_id ]; ch++ ) { |  |
| **if\_mean\_per\_channel**[ ch ] | u(16) |
| } |  |
| if( cgps\_allow\_cross\_channel\_pred\_flag ) { |  |
| for( ch = 1; ch < NumChannels[ if\_channel\_group\_id ]; ch++ ) { |  |
| for( n = 0; n <= cgps\_allow\_cc\_pred\_mult\_hyp\_flag; n++ ) { |  |
| CrossChannelPredInputChDistMinus1[ ch ][ n ] = 0 |  |
| } |  |
| } |  |
| } |  |
| if( cgps\_allow\_block\_matching\_pred\_flag ) { |  |
| for( ch = 0; ch < NumChannels[ if\_channel\_group\_id ]; ch++ ) { |  |
| for( n = 0; n <=cgps\_allow\_bm\_pred\_mult\_hyp\_flag; n++ ) { |  |
| BlockMatchingPredOffsetMinusBlocksSize[ ch][ n ] = 0 |  |
| Log2BlockMatchingPredBlockSize[ ch][ n ] = 0 |  |
| } |  |
| } |  |
| } |  |
| if( cgps\_allow\_lpf ){ |  |
| LPFMaxNumWeightsNoPrevCh = 16 |  |
| for( ch = 0; ch < NumChannels[ if\_channel\_group\_id ]; ch++ ) { |  |
| for( n = 0; n <=LPFMaxNumWeightsNoPrevCh; n++ ) { |  |
| LPFWeightsNoPrevChPred[ ch ] [ n ] = 0 |  |
| } |  |
| } |  |
| } |  |
| if( cgps\_length\_signal\_mode\_flag ) |  |
| **if\_indep\_num\_samples\_per\_channel\_minus1** | u(32) |
| if( cgps\_ctx\_init\_flag ) |  |
| **if\_ctx\_init\_mode** | u(1) |
| for( i = 0; i < NumChannels[ if\_channel\_group\_id ]; i++ ) { |  |
| CurrBlockQP[ i ] = cgps\_qp |  |
| CurrZeroLSB[ i ] = 0 |  |
| } |  |
| byte\_alignment( ) |  |
| frame\_data( NumChannels[ if\_channel\_group\_id ] ) |  |
| rbsp\_trailing\_bits( ) |  |
| } |  |

#### Dependent frame RBSP syntax

|  |  |
| --- | --- |
| dependent\_frame\_rbsp( ) { | Descriptor |
| if( NumChannels > 1 ) |  |
| **df\_channel\_group\_id** | u(v) |
| frame\_data( NumChannels[ df\_channel\_group\_id ] ) |  |
| rbsp\_trailing\_bits( ) |  |
| } |  |

#### Annotation channel RBSP syntax

|  |  |
| --- | --- |
| annotation\_channel\_rbsp( ) { | Descriptor |
| **ac\_waveform\_parameter\_set\_id** | u(4) |
| **ac\_annotation\_channel\_id** | ue(v) |
| **ac\_num\_annotation\_bytes\_div2\_minus1** | ue(v) |
| byte\_alignment() |  |
| annotation\_channel\_data( ) |  |
| } |  |

#### Timestamp RBSP syntax

|  |  |
| --- | --- |
| time\_stamp\_rbsp( ) { | Descriptor |
| **ts\_channel\_group\_parameter\_set\_id** | u(8) |
| if(NumChannelGroups > 1 ) |  |
| **ts\_channel\_group\_id** | u(v) |
| **ts\_type** | u(3) |
| if (ts\_type == FEAT\_RBSP) |  |
| **ts\_time\_idx** | ue(v) |
| **ts\_time\_type** | u(7) |
| TimeType = ts\_time\_type |  |
| **ts\_offset\_type\_flag** | u(1) |
| if (TimeType == TIME\_LONG) { |  |
| **ts\_time\_long** | ev(12,16,32) |
| **ts\_time\_offset** | u(12) |
| } |  |
| else if (TimeType == TIME\_SHORT) { |  |
| **ts\_time\_short** | ev(4,8,8) |
| **ts\_time\_offset** | ev(4,8,8) |
| } |  |
| else if (TimeType == TIME\_UXT) { |  |
| **ts\_time\_uxt** | se(v) |
| **ts\_time\_offset** | se(v) |
| } |  |
| else if (TimeType == TIME\_TAI) { /\* acc. ISO/IEC 23001-17 \*/ |  |
| **ts\_time\_tai** | u(64) |
| **ts\_status\_bits** | u(8) |
| } |  |
| else if (TimeType == TIME\_UTC) { |  |
| **ts\_time\_utc** | st(v) |
| } |  |
| rbsp\_trailing\_bits( ) |  |
| } |  |

#### Segment metadata RBSP syntax

|  |  |
| --- | --- |
| segment\_metadata\_rbsp( ) { | Descriptor |
| **sm\_channel\_group\_parameter\_set\_id** | u(8) |
| if(NumChannelGroups > 1 ) |  |
| **sm\_channel\_group\_id** | u(v) |
| **sm\_signal\_type** | ev(3,8,8) |
| **sm\_segment\_stat\_flag** | u(1) |
| if (sm\_segment\_stat\_flag) { |  |
| **sm\_num\_blocks\_per\_segment** | ue(v) |
| **sm\_block\_size**[0] | ue(v) |
| if (sm\_num\_blocks\_per\_segment > 1) { |  |
| **sm\_delta\_GR\_param** | ae(v) |
| for( n = 1; n < sm\_num\_blocks\_per\_segment; n++ ) { |  |
| **sm\_abs\_delta** | ae(v) |
| **sm\_sign\_delta** | ae(v) |
| delta = (sm\_sign\_delta == 1) ? -sm\_abs\_delta : sm\_abs\_delta |  |
| **sm\_block\_size**[n] = sm\_block\_size[n-1] + delta |  |
| } |  |
| } |  |
| } |  |
| **sm\_distortion\_measure\_flag** | u(1) |
| if(sm\_distortion\_measure\_flag) { |  |
| **sm\_num\_distortion\_measure** | ev(3,8,8) |
| for( ch = 0; ch < NumChannels[ sm\_channel\_group\_id ]; ch++ ) { |  |
| **sm\_variance**[ch] | u(8) |
| **sm\_squared\_error**[ch] | u(8) |
| for( i = 0; i < sm\_num\_distortion\_measures; i++ ) { |  |
| **sm\_distortion\_measure\_type**[ch][i] | st(v) |
| **sm\_distortion\_measure**[ch][i] | se(v) |
| } |  |
| } |  |
| } |  |
| byte\_alignment( ) |  |
| } |  |

#### Feature set RBSP syntax

|  |  |
| --- | --- |
| feature\_set\_rbsp( ) { | Descriptor |
| **ft\_channel\_group\_parameter\_set\_id** | u(8) |
| if(NumChannelGroups > 1 ) |  |
| **ft\_channel\_group\_id** | u(v) |
| **ft\_signal\_type** | ev(3,8,8) |
| **ft\_sampling\_frequency** | u(16) |
| **ft\_num\_features** | ev(3,8,8) |
| for( i = 0; i < ft\_num\_features; i++ ) { |  |
| **ft\_feature\_annotation\_type**[i] | u(2) |
| if( ft\_feature\_annotation\_type == 0 ) { |  |
| **ft\_annotation\_str** | st(v) |
| } else if( ft\_feature\_annotation\_type == 1 ) { |  |
| **ft\_annotation\_uri** | st(v) |
| } else if( ft\_feature\_annotation\_type == 2 ) { |  |
| **ft\_annotation\_channel\_waveform\_parameter\_set\_id** | u(4) |
| **ft\_annotation\_channel\_id** | ue(v) |
| } else { |  |
| **ft\_feature\_type\_enum** | ev(3,8,8) |
| } |  |
| feature\_type[i] = feat\_extract() |  |
| **ft\_feature\_marking\_present\_flag**[i] | u(1) |
| if( ft\_feature\_marking\_present\_flag[i] ) { |  |
| **ft\_feature\_start**[i] | ue(v) |
| **ft\_feature\_length**[i] | ue(v) |
| } |  |
| } |  |
| byte\_alignment( ) |  |
| } |  |

#### Synchronization RBSP syntax

|  |  |
| --- | --- |
| synchronization\_rbsp( ) { | Descriptor |
| **syncword** | u(8) |
| } |  |

#### User identifier RBSP syntax

|  |  |
| --- | --- |
| user\_identifier\_rbsp( ) { | Descriptor |
| universally\_unique\_identifier( ) |  |
| rbsp\_trailing\_bits( ) |  |
| } |  |

#### Stream identifier RBSP syntax

|  |  |
| --- | --- |
| stream\_identifier\_rbsp( ) { | Descriptor |
| universally\_unique\_identifier( ) |  |
| rbsp\_trailing\_bits( ) |  |
| } |  |

#### Universally unique identifier syntax

|  |  |
| --- | --- |
| universally\_unique\_identifier( ) { | Descriptor |
| **uuid\_segment\_start\_flag** | u(1) |
| **uuid\_segment\_stop\_flag** | u(1) |
| **reserved** | u(2) |
| **uuid\_segment\_length\_minus1** | u(4) |
| **uuid\_data** | u(8) \* (**uuid\_segment\_length\_minus1**+1) |
| rbsp\_trailing\_bits( ) |  |
| } |  |

#### Authentication start RBSP syntax

|  |  |
| --- | --- |
| authentication\_start\_rbsp( ) { | Descriptor |
| **aust\_id** | u(8) |
| **aust\_sequence\_id** | u(1) |
| **aust\_hash\_type** | ev(4,8,8) |
| **aust\_key\_id** | ev(3,8,8) |
| **aust\_prov\_id** | ev(8,8,16) |
| if ( aust\_prov\_id == 0) { |  |
| **aust\_key\_source\_uri** | st(v) |
| } |  |
| **aust\_frame\_types\_present\_flag** | u(1) |
| if( aust\_frame\_types\_present\_flag ) { |  |
| **aust\_inclusion\_types\_flag** | u(1) |
| **aust\_pactype\_list\_length\_minus1** | u(6) |
| for( i = 0; i <= aust\_pactype\_length\_minus1; i++ ) |  |
| **aust\_packet\_type**[ i ] | ev(8,8,8) |
| }else { |  |
| **reserved** | u(7) |
| } |  |
| **aust\_multi\_stream\_flag** | u(1) |
| if( aust\_multi\_stream\_flag ) { |  |
| **aust\_inclusion\_labels\_flag** | u(1) |
| **aust\_label\_list\_length\_minus1** | u(6) |
| for( i = 0; i <= aust\_label\_list\_length\_minus1; i++ ) |  |
| **aust\_add\_packet\_label**[ i ] | ev(8,8,32) |
| } |  |
| rbsp\_trailing\_bits( ) |  |
| } |  |

#### Authentication signature RBSP syntax

|  |  |
| --- | --- |
| authentication\_signature\_rbsp( ) { | Descriptor |
| **ausig\_id** | u(8) |
| **ausig\_sequence\_id** | u(1) |
| **ausig\_partial\_sig\_flag** | u(1) |
| if( ausig\_partial\_sig\_flag ) { |  |
| **ausig\_segment\_start\_flag** | u(1) |
| **ausig\_segment\_stop\_flag** | u(1) |
| **ausig\_segment\_length\_minus1** | u(6) |
| **ausig\_sig\_partial** | u(8)\*(**ausig\_segment\_length\_minus1**+1) |
| } else { |  |
| **ausig\_length\_minus1** | u(6) |
| **ausig\_sig\_complete** | u(8) \* (**ausig\_length\_minus1**+1) |
| } |  |
| rbsp\_trailing\_bits( ) |  |
| } |  |

#### Auxiliary metadata RBSP syntax

|  |  |
| --- | --- |
| auxiliary\_metadata\_rbsp( ) { | Descriptor |
| **am\_fourcc\_id\_last\_three\_bytes** /\* Equal to 0x415743\*/ | u(24) |
| **am\_header\_crc32** | u(32) |
| **am\_reserved\_flag** | u(1) |
| **am\_waveform\_type** | u(2) |
| **am\_length\_signal\_mode** | u(1) |
| **am\_allow\_reconfig\_flag** | u(1) |
| **am\_copyright\_flag** | u(1) |
| **am\_original\_flag** | u(1) |
| **am\_private\_flag** | u(1) |
| **am\_stream\_max\_sampling\_rate\_minus1** | u(24) |
| **am\_stream\_max\_num\_channels\_minus1** | u(16) |
| if( am\_length\_signal\_mode ) |  |
| **am\_stream\_num\_samples\_per\_ch** | u(32) |
| if( am\_waveform\_type = = WT\_BS2088 ) { |  |
| **am\_metadata\_reserved\_flag** | u(1) |
| **am\_metadata\_num\_bytes\_minus1** | u(31) |
| for( i = 0; i <= am\_metadata\_num\_bytes\_minus1; i++ ) |  |
| **am\_metadata\_payload\_bytes**[ i ] | u(8) |
| } else if( am\_waveform\_typt = = WT\_EDF\_PLUS ) { |  |
| **am\_num\_channels\_edf** | u(16) |
| for( i = 0; i < 256 \* ( am\_num\_channels\_edf + 1); i++ ) |  |
| **am\_edf\_header\_payload\_bytes**[ i ] | u(8) |
| } |  |
| **am\_signal\_type** | u(8) |
| **am\_extension\_present\_flag** | u(1) |
| } |  |

#### RBSP trailing bits syntax

|  |  |
| --- | --- |
| rbsp\_trailing\_bits( ) { | Descriptor |
| **rbsp\_stop\_one\_bit** /\* equal to 1 \*/ | f(1) |
| while( !byte\_aligned( ) ) |  |
| **rbsp\_alignment\_zero\_bit** /\* equal to 0 \*/ | f(1) |
| } |  |

#### Byte alignment syntax

|  |  |
| --- | --- |
| byte\_alignment( ) { | Descriptor |
| **byte\_alignment\_bit\_equal\_to\_one** /\* equal to 1 \*/ | f(1) |
| while( !byte\_aligned( ) ) |  |
| **byte\_alignment\_bit\_equal\_to\_zero** /\* equal to 0 \*/ | f(1) |
| } |  |

### Frame data syntax

#### General frame data syntax

|  |  |
| --- | --- |
| frame\_data( numChannels ) { | Descriptor |
| FrameNumSamplesPerChannel = 0 |  |
| Log2BlockSizeLast = –1 |  |
| do { |  |
| if( FrameNumSamplesPerChannel > 0 ) |  |
| **end\_of\_frame\_sequence\_flag** | ae(v) |
| if( !end\_of\_frame\_sequence\_flag ) { |  |
| if( MaxSplitDepth > 0 ) |  |
| **block\_split\_log2** | ae(v) |
| Log2BlockSize = Log2MaxBlockSize - block\_split\_log2 |  |
| **lpc\_huffman\_flag** | ae(v) |
| if( lpc\_huffman\_flag ) |  |
| lpc\_huffman\_coding\_block ( numChannels ) |  |
| else |  |
| prediction\_trafo\_data\_block( numChannels ) |  |
| FrameNumSamplesPerChannel += 1 << Log2BlockSize |  |
| **end\_of\_truncated\_frame\_sequence\_flag** | ae(v) |
| if( end\_of\_truncated\_frame\_sequence\_flag ) |  |
| **num\_samples\_per\_channel\_to\_discard** | u(v) |
| if( !end\_of\_truncated\_frame\_sequence\_flag &&  FrameNumSamplesPerChannel = = ( 1 << Log2FrameLength ) ) |  |
| **end\_of\_frame\_one\_bit**  /\* equal to 1 \*/ | ae(v) |
| } |  |
| } while( !end\_of\_frame\_sequence\_flag && !end\_of\_truncated\_frame\_sequence\_flag &&  !end\_of\_frame\_one\_bit ) |  |
| } |  |

#### Lpc Huffman coding block syntax

|  |  |
| --- | --- |
| lpc\_huffman\_coding\_block (numChannels) { | Descriptor |
| **mean\_mode** | ae(v) |
| if(mean\_mode == 0x1){ |  |
| if(numChannels == 1){ |  |
| **abs\_mean\_value\_single\_channel** | ae(v) |
| NumMeanBits = BitDepthMax – floor(cgps\_qp / 32 ) |  |
| MeanValueSingleChannel = abs\_mean\_value\_single\_channel – (1 << (NumMeanBits – 1) ) |  |
| } |  |
| else{ |  |
| **mean\_GR\_param** | ae(v) |
| for(n = 0; n < numChannels; n ++){ |  |
| **abs\_mean\_value\_multi\_channel** | ae(v) |
| if( abs\_mean\_value\_multi\_channel>0 ) |  |
| **mean\_value\_sign\_multi\_channel** | ae(v) |
| MeanValues[n] = (mean\_value\_sign == 1) ? – abs\_mean\_value\_multi\_channel:   abs\_mean\_value\_multi\_channel |  |
| } |  |
| } |  |
| } |  |
| for(n = 0; n < numChannels; n ++){ |  |
| if(n > 0){ |  |
| **enable\_IC**[n] | ae(v) |
| if(enable\_IC){ |  |
| **ref\_channel\_IC**[n] | ae(v) |
| **pred\_gain\_IC**[n] | ae(v) |
| } |  |
| } |  |
| **order\_LPC**[n] | ae(v) |
| for(k = 0; k < order\_LPC[n]; k ++){ |  |
| **reflection\_coeff**[n][k] | ae(v) |
| } |  |
| } |  |
| /\* Residual data \*/ |  |
| for(n = 0; n < numChannels; n ++){ |  |
| if(cgps\_qp > 0) { |  |
| **num\_regions** | ae(v) |
| } |  |
| else{ |  |
| **num\_regions** = max\_num\_regions |  |
| } |  |
| **reg\_cb\_zero** | ae(v) |
| RegCBIdx[0] = reg\_cb\_zero |  |
| for(k = 1; k < num\_regions; k ++){ |  |
| **delta\_reg\_cb** | ae(v) |
| RegCBIdx[k] = RegCBIdx[k – 1] + delta\_reg\_cb – 22 |  |
| } |  |
| posIdx = 0 |  |
| for(k = 0; k < num\_regions; k ++){ |  |
| if(RegCBIdx[k] > 0){ |  |
| if(RegCBIdx [k] < =2){ |  |
| **huff\_array\_signed\_sz4** | ae(v) |
| for(m = 0; m < region\_length[k]; m += 4, posIdx += 4){ |  |
| TCoeffLpcLms[posIdx] = huff\_array\_signed\_sz4[ 0 ] |  |
| TCoeffLpcLms[posIdx + 1] = huff\_array\_signed\_sz4[ 1 ] |  |
| TCoeffLpcLms[posIdx + 2] = huff\_array\_signed\_sz4[ 2 ] |  |
| TCoeffLpcLms[posIdx + 3] = huff\_array\_signed\_sz4[ 3 ] |  |
| } |  |
| } |  |
| else if(RegCBIdx[k] <= 4){ |  |
| **huff\_array\_unsigned\_sz4** | ae(v) |
| for(m = 0; m < region\_length[k]; m += 4, posIdx += 4){ |  |
| for( q = 0; q < 4; q++){ |  |
| if( huff\_array\_unsigned\_sz4[q] != 0) |  |
| **huff\_coeff\_sign** | ae(v) |
| TCoeffLpcLms[posIdx + q] = (huff\_coeff\_sign==0) ?   huff\_array\_unsigned\_sz4[q] :   – huff\_array\_unsigned\_sz4[q] |  |
| } |  |
| } |  |
| } |  |
| else if(RegCBIdx[k] <=6){ |  |
| **huff\_array\_signed\_sz2** | ae(v) |
| for(m = 0; m < region\_length[k]; m += 2, posIdx += 2){ |  |
| TCoeffLpcLms[posIdx] = huff\_array\_signed\_sz2[ 0 ] |  |
| TCoeffLpcLms[posIdx + 1] = huff\_array\_signed\_sz2[ 1 ] |  |
| } |  |
| } |  |
| else if(RegCBIdx[k] <= 10){ |  |
| **huff\_array\_unsigned\_sz2** | ae(v) |
| for(m = 0; m < region\_length[k]; m += 2, posIdx += 2){ |  |
| for( q=0; q < 2; q++ ){ |  |
| if( huff\_array\_unsigned\_sz2[q] != 0) |  |
| **huff\_coeff\_sign** | ae(v) |
| TCoeffLpcLms[posIdx + q] = (huff\_coeff\_sign==0) ?   huff\_array\_unsigned\_sz2[q] :   – huff\_array\_unsigned\_sz2[q] |  |
| } | ae(v) |
| } |  |
| } |  |
| else if(RegCBIdx[k] <= 31){ |  |
| for( q=0; q< region\_length[k]; q++, posIdx++){ |  |
| **val\_gr\_lpc\_lms** | ae(v) |
| if( val\_gr\_lpc\_lms > 0) |  |
| **gr\_lpc\_lms\_sign\_flag** | ae(v) |
| TCoeffLpcLms[posIdx] = (gr\_lpc\_lms\_sign\_flag ==1) ?   – val\_gr\_lpc\_lms : val\_gr\_lpc\_lms |  |
| } |  |
| } |  |
| } |  |
| } |  |
| } |  |
| } |  |

#### Predictive transform coding block syntax

##### Prediction trafo block data syntax

|  |  |
| --- | --- |
| prediction\_trafo\_data\_block ( ) { | Descriptor |
| for( ch = 0; ch < numChannels; ch++ ) { |  |
| if( cgps\_allow\_block\_matching\_pred\_flag | | ( cgps\_allow\_cross\_channel\_pred\_flag &&  ( ch & DepChMask ) > 0 ) ) |  |
| **block\_matching\_or\_cross\_channel\_pred\_flag** | ae(v) |
| if( block\_matching\_or\_cross\_channel\_pred\_flag ) { |  |
| if( cgps\_allow\_block\_matching\_pred\_flag &&   cgps\_allow\_cross\_channel\_pred\_flag  && ( ch & DepChMask ) > 0 ) |  |
| **cross\_channel\_pred\_flag** | ae(v) |
| if( cross\_channel\_pred\_flag ) |  |
| cross\_channel\_prediction\_data( ch ) |  |
| else |  |
| block\_matching\_prediction\_data( ch ) |  |
| }else |  |
| **block\_pred\_mode** | ae(v) |
| if( block\_matching\_or\_cross\_channel\_pred\_flag | |  ( block\_pred\_mode = = BPM\_OFF ) ) { |  |
| sample\_pred\_mode( ) |  |
| if( spred\_lpf\_flag ) |  |
| linear\_predictive\_filtering\_data( ch ) |  |
| } |  |
| if( cgps\_max\_abs\_delta\_qp\_idx > 0 ) { |  |
| **block\_abs\_delta\_qp** | ae(v) |
| if( block\_abs\_delta\_qp > 0 ) |  |
| **block\_delta\_qp\_sign\_flag** | ae(v) |
| blockDeltaQP = block\_delta\_qp\_sign\_flag ?  –block\_abs\_delta\_qp : block\_abs\_delta\_qp |  |
| CurrBlockQP[ ch ] =  Clip3( 0, 1023, CurrBlockQP[ ch ] + blockDeltaQP ) |  |
| } |  |
| if( spred\_lpf\_or\_diff\_flag | | ( spred\_rem\_mode\_idx = = 2 ) ) { |  |
| if( spred\_lpf\_or\_diff\_flag && CurrBlockQP[ ch ] = = 0 ) { |  |
| **block\_delta\_zlsb\_present\_flag** | ae(v) |
| if(block\_delta\_zlsb\_present\_flag ){ |  |
| **block\_delta\_zlsb\_sign\_flag** | ae(v) |
| deltaLSB = block\_delta\_zlsb\_sign\_flag ? -1 : 1 |  |
| CurrZeroLSB[ ch ] = Clip3( 0, BitDepthMax - BitDepthMin,  CurrZeroLSB[ ch ] + deltaLSB ) |  |
| } |  |
| } else { |  |
| **transform\_present\_flag** | ae(v) |
| TransformMode = TM\_OFF |  |
| if ( transform\_present\_flag ){ |  |
| **transform\_dst\_flag** | ae(v) |
| TransformMode = ( transform\_dst\_flag = = 1 ? TM\_DST : TM\_DCT ) |  |
| } |  |
| } |  |
| } |  |
| if(TransformMode = = TM\_DCT){ |  |
| **lms\_flag** | ae(v) |
| if(lms\_flag){ |  |
| **enable\_lms\_split** | ae(v) |
| if(enable\_lms\_split == 1){ |  |
| **enable\_ar\_lms**[0] | ae(v) |
| **enable\_ar\_lms**[1] | ae(v) |
| if(ch > 0){ |  |
| **enable\_ic\_lms**[0] | ae(v) |
| **enable\_ic\_lms**[1] | ae(v) |
| } |  |
| } |  |
| else{ |  |
| **enable\_ar\_lms**[0] | ae(v) |
| if(ch > 0) |  |
| **enable\_ic\_lms**[0] | ae(v) |
| } |  |
| } |  |
| } |  |
| quant\_res\_sample\_data( ) |  |
| } |  |
| } |  |

##### Cross channel prediction data syntax

|  |  |
| --- | --- |
| cross\_channel\_prediction\_data( ch ) { | Descriptor |
| **cc\_pred\_offset\_only\_flag** | ae(v) |
| if( cgps\_cc\_pred\_filtering\_mode > 0 **)** |  |
| **cc\_pred\_filter\_flag** | ae(v) |
| if( cgps\_cc\_pred\_filtering\_mode = = 2 && cc\_pred\_filter\_flag ) |  |
| **cc\_pred\_filter\_idx** | ae(v) |
| if( (ch & DepChMask) > 1 ) { |  |
| if( cgps\_allow\_cc\_pred\_mult\_hyp\_flag ) |  |
| **cc\_pred\_mult\_hyp\_flag** | ae(v) |
| if( !cc\_pred\_mult\_hyp\_flag | | ( ch & DepChMask ) > 2 ) { |  |
| for( n = 0; n <= cc\_pred\_mult\_hyp\_flag; n++ ) { |  |
| **cc\_pred\_abs\_chd\_greater0\_flag**[ n ] | ae(v) |
| if( cc\_pred\_abs\_chd\_greater0\_flag[ n ] ) { |  |
| **cc\_pred\_abs\_chd\_minus1**[ n ] | ae(v) |
| **cc\_pred\_chd\_sign\_flag**[ n ] | ae(v) |
| } |  |
| cCPredInputChDistDiffSign = cc\_pred\_chd\_sign\_flag[ n ] ? –1 : 1 |  |
| cCPredInputChDistDiff = cc\_pred\_abs\_chd\_greater0\_flag[ n ] ?  cCPredInputChDistDiffSign \* (cc\_pred\_abs\_chd\_minus1[ n ] +1 ) : 0 |  |
| CrossChannelPredInputChDistMinus1[ ch ][ n ] =  max( 0, min ( ( ch & DepChMask ) – 1, cCPredInputChDistDiff +  CrossChannelPredInputChDistMinus1[ ch ][ n ] ) ) |  |
| } |  |
| } |  |
| } |  |
| } |  |

##### Block matching prediction data syntax

|  |  |
| --- | --- |
| block\_matching\_prediction\_data( ch ) { | Descriptor |
| if( cgps\_allow\_bm\_pred\_mult\_hyp\_flag **)** |  |
| **bm\_pred\_mult\_hyp\_flag** | ae(v) |
| **bm\_pred\_add\_offset\_flag** | ae(v) |
| for( n = 0; n <= bm\_pred\_mult\_hyp\_flag; n++ ) { |  |
| if( cgps\_bm\_pred\_filtering\_mode > 0 **)** |  |
| **bm\_pred\_filter\_flag**[ n ] | ae(v) |
| if( bm\_pred\_filter\_flag[ n ] && cgps\_bm\_pred\_filtering\_mode = = 2 ) |  |
| **bm\_pred\_filter\_idx**[ n ] | ae(v) |
| if( cgps\_allow\_bm\_offset\_pred\_prev\_ch\_flag && ( ch & DepChMask ) > 0 ) |  |
| **bm\_pred\_off\_pred\_prev\_ch\_flag**[ n ] | ae(v) |
| **bm\_pred\_abs\_offd\_greater0\_flag**[ n ] | ae(v) |
| if( bm\_pred\_abs\_offd\_greater0\_flag[ n ] ) { |  |
| **bm\_pred\_abs\_offd\_minus1**[ n ] | ae(v) |
| **bm\_pred\_offd\_sign\_flag**[ n ] | ae(v) |
| } |  |
| bmOffsetMinusBlockSizeDiffSign = bm\_pred\_offd\_sign\_flag[ n ] ? –1 :1 |  |
| bmOffsetMinusBlockSizeDiff = bm\_pred\_abs\_offd\_greater0\_flag[ n ] ?  bmOffsetMinusBlockSizeDiffSign \*( bm\_pred\_abs\_offd\_minus1 + 1 ) : 0 |  |
| bmOffsetMinusBlockSizePred = bm\_pred\_off\_pred\_prev\_ch\_flag[ n ] ?  BlockMatchingPredOffsetMinusBlocksSize [ ch – 1 ][ n ] :  BlockMatchingPredOffsetMinusBlocksSize [ ch ][ n ] |  |
| log2BMBlockSizePred = bm\_pred\_off\_pred\_prev\_ch\_flag[ n ] ?  Log2BlockMatchingPredBlockSize[ ch – 1 ][ n ] :  Log2BlockMatchingPredBlockSize[ ch ][ n ] |  |
| if( ( log2BMBlockSizePred = = Log2BlockSize ) | |  ( log2BMBlockSizePred = = 0 ) ) { |  |
| BlockMatchingPredOffsetMinusBlocksSize[ ch ][ n ] =  bmOffsetMinusBlockSizePred + bmOffsetMinusBlockSizeDiff |  |
| } else { |  |
| bmOffsetPred = bmOffsetMinusBlockSizePred + ( 1 << log2BMBlockSizePred ) |  |
| if( log2BMBlockSizePred > Log2BlockSize && bmOffsetMinusBlockSizePred >  ( Log2BlockSize << 6 ) ) |  |
| bmOffsetPred = bmOffsetPred >> ( log2BMBlockSizePred – Log2BlockSize ) |  |
| if( bmOffsetPred < ( 1 << Log2BlockSize ) ) |  |
| bmOffsetPred = bmOffsetPred << ( Log2BlockSize – log2BMBlockSizePred ) |  |
| BlockMatchingPredOffsetMinusBlocksSize[ ch ][ n ] =  bmOffsetPred – ( 1 << Log2BlockSize ) + bmOffsetMinusBlockSizeDiff |  |
| } |  |
| BlockMatchingPredOffsetMinusBlocksSize[ ch ][ n ] = Clip3( 0, (1 << 16) – 1,  BlockMatchingPredOffsetMinusBlocksSize[ ch ][ n ] ) |  |
| Log2BlockMatchingPredBlockSize[ ch ][ n ] = Log2BlockSize |  |
| } |  |
| } |  |

##### Sample pred mode syntax

|  |  |
| --- | --- |
| sample\_pred\_mode( ) { | Descriptor |
| **spred\_lpf\_or\_diff\_flag** | ae(v) |
| if( cgps\_allow\_lpf && spred\_lpf\_or\_diff\_flag ) |  |
| **spred\_lpf\_flag** | ae(v) |
| if( !spred\_lpf\_or\_diff\_flag ) |  |
| **spred\_rem\_mode\_idx** | ae(v) |
| } |  |

##### Linear predictive filtering data syntax

|  |  |
| --- | --- |
| linear\_predictive\_filtering\_data( ch ) { | Descriptor |
| if**(** !block\_matching\_or\_cross\_channel\_pred\_flag && ( ch & DepChMask ) > 0 &&  cgps\_lpf\_allow\_prev\_ch\_flag **)** |  |
| **lpf\_prev\_ch\_flag** | ae(v) |
| if( !lpf\_prev\_ch\_flag ) |  |
| **lpf\_delta\_coding\_flag** | ae(v) |
| **lpf\_num\_weights\_idx** | ae(v) |
| LPFNumWeightsCurr = ( ( lpf\_num\_weights\_idx + 1 ) << 1 ) +  lpf\_prev\_ch\_flag ? min(cgps\_lpf\_max\_num\_minus\_1\_prev\_ch + 1, ch  & DepChMask ) + 1 : 0 |  |
| for( n = 0; n < LPFNumWeightsCurr; n++ ) { |  |
| **abs\_lpf\_weight\_greater0\_flag**[ n ] | ae(v) |
| if( abs\_lpf\_weight\_greater0\_flag[ n ] ) { |  |
| **abs\_lpf\_weight\_minus1**[ n ] | ae(v) |
| **lpf\_weight\_sign\_flag**[ n ] | ae(v) |
| } |  |
| lpfWeightSign = lpf\_weight\_sign\_flag[ n ] ? – 1 : 1 |  |
| currentVal = abs\_lpf\_weight\_greater0\_flag[ n ] ?  lpfWeightSign \* (abs\_lpf\_weight\_minus1[ n ] + 1 ) : 0 |  |
| if(lpf\_delta\_coding\_flag**)** |  |
| LPFWeightsCurr[ n ] = Clip3(– 64, 64,   currentVal + LPFWeightsNoPrevChPred[ ch ] [ n ] ) |  |
| else |  |
| LPFWeightsCurr[ n ] = currentVal |  |
| } |  |
| if( !lpf\_prev\_ch\_flag ){ |  |
| for( n = 0; n <LPFMaxNumWeightsNoPrevCh; n++ ){ |  |
| LPFWeightsNoPrevChPred[ ch ] [ n ] = (n < LPFNumWeightsCurr) ?   LPFWeightsCurr[ n ] : 0 |  |
| } |  |
| } |  |
| } |  |

##### Quant res sample data syntax

|  |  |
| --- | --- |
| quant\_res\_sample\_data( ) { | Descriptor |
| NumQuantIndices = 1  <<  Log2BlockSize |  |
| if( block\_pred\_mode = = BPM\_OFF && TransformMode = = TM\_OFF &&  sample\_pred\_mode = = SPM\_OFF ) { |  |
| IntBitDepth = BitDepthMax – CurrZeroLSB[ ch ] |  |
| offset = (1 << IntBitDepth ) >> 1 |  |
| for( k = 0; k < NumQuantIndices; k = k + 1 ) { |  |
| **coeff\_bypass\_value**[ k ] | ae(v) |
| QuantIndices[ k ] = coeff\_bypass\_value[ k ] – offset |  |
| } |  |
| } else if( TransformMode = = TM\_OFF ) { |  |
| numLevels = 0 |  |
| sumAbsLevels = 0 |  |
| TSkipRiceParameter = 1 |  |
| for( k = NumQuantIndices – 1; k >= 0; k = k – 1 ) { |  |
| **abs\_tskip\_coeff\_gt0\_flag**[ k ] | ae(v) |
| QuantIndices[ k ] = abs\_tskip\_coeff\_gt0\_flag[ k ] |  |
| if( QuantIndices[ k ] > 0 ) { |  |
| **abs\_tskip\_coeff\_offset**[ k ] | ae(v) |
| QuantIndices[ k ] += abs\_tskip\_coeff\_offset[ k ] |  |
| } |  |
| if( QuantIndices[ k ] = = NumTSkipGtxFlags + 1 ) { |  |
| **abs\_tskip\_coeff\_rem\_prefix**[ k ] | ae(v) |
| QuantIndices[ k ] += ( abs\_tskip\_coeff\_rem\_prefix[ k ]  <<  RiceParameter ) |  |
| if( abs\_tskip\_coeff\_rem\_prefix[ k ] < MaxTSkipRemPrefix ) |  |
| if( TSkipRiceParameter > 0 ) { |  |
| **abs\_tskip\_coeff\_rem\_fl\_suffix**[ k ] | ae(v) |
| QuantIndices[ k ] += abs\_tskip\_coeff\_rem\_rice\_suffix[ k ] |  |
| } |  |
| else { |  |
| **abs\_tskip\_coeff\_rem\_eg0\_suffix**[ k ] | ae(v) |
| QuantIndices[ k ] += abs\_tskip\_coeff\_rem\_eg0\_suffix[ k ] |  |
| } |  |
| } |  |
| if( QuantIndices[ k ] > 0 ) { |  |
| **tskip\_coeff\_sign\_flag**[ k ] | ae(v) |
| if( tskip\_coeff\_sign\_flag[ k ] ) |  |
| QuantIndices[ k ] = –QuantIndices[ k ] |  |
| } |  |
| numLevels += 1 |  |
| sumAbsLevels += Abs( QuantIndices[ k ] ) |  |
| if( sumAbsLevels > 15 \* numLevels ) |  |
| TSkipRiceParameter = 4 |  |
| else if( sumAbsLevels > 5 \* numLevels ) |  |
| TSkipRiceParameter = 3 |  |
| else if( sumAbsLevels > 2 \* numLevels ) |  |
| TSkipRiceParameter = 2 |  |
| else |  |
| TSkipRiceParameter = 1 |  |
| } |  |
| } else { |  |
| mean\_value\_trafo\_block( ) |  |
| **last\_pos\_index\_gt0\_flag** | ae(v) |
| if( last\_pos\_index\_gt0\_flag ) { |  |
| **last\_pos\_index\_rem** | ae(v) |
| if( Log2BlockSize > 8  &&   Log2BlockSize  = =  Log2BlockSizeLast ) { |  |
| **last\_pos\_index\_sign** | ae(v) |
| } |  |
| last\_scan\_pos = 1 + last\_pos\_index\_rem |  |
| if( last\_pos\_index\_sign ) { |  |
| last\_scan\_pos = – last\_scan\_pos |  |
| } |  |
| last\_scan\_pos  = last\_scan\_pos + LastScanPosPrev |  |
| } else { |  |
| last\_scan\_pos = 0 |  |
| } |  |
| if( Log2BlockSize > 8 ) { |  |
| LastScanPosPrev = last\_scan\_pos |  |
| Log2BlockSizeLast = Log2BlockSize |  |
| } |  |
| for( k = 0; k < NumQuantIndices; k = k + 1 ) |  |
| QuantIndices[ k ] = 0 |  |
| QState = 0 |  |
| if( templateSum[ k ] > 3 ) { |  |
| pShift = 1 |  |
| } else { |  |
| pShift = 0 |  |
| } |  |
| for( k = last\_scan\_pos; k >= 0; k = k – 1 ) { |  |
| if( k  = =  last\_scan\_pos  &&  k > 0 ) |  |
| QuantIndices[ k ] = 1 |  |
| else { |  |
| **abs\_trafo\_coeff\_gt0\_flag**[ k ] | ae(v) |
| QuantIndices[ k ] = abs\_trafo\_coeff\_gt0\_flag[ k ] |  |
| } |  |
| if( pShift > 0 ) { |  |
| **abs\_trafo\_parity\_flag**[ k ] | ae(v) |
| QuantIndices[ k ] += 1  –  abs\_trafo\_parity\_flag[ k ] |  |
| if( abs\_trafo\_parity\_flag[ k ] ) { |  |
| NumTCoeffGtxFlags = NumTCoeffGtxFlags  <<  1 |  |
| } |  |
| } |  |
| if( QuantIndices[ k ] > 0 ) { |  |
| **abs\_trafo\_coeff\_offset**[ k ] | ae(v) |
| QuantIndices[ k ] += abs\_trafo\_coeff\_offset[ k ]   <<  pShift |  |
| } |  |
| if( QuantIndices[ k ] = = NumTCoeffGtxFlags + 1 ) { |  |
| **abs\_trafo\_coeff\_remainder**[ k ] | ae(v) |
| QuantIndices[ k ] += abs\_trafo\_coeff\_remainder[ k ]   <<  pShift |  |
| } |  |
| if( QuantIndices[ k ] > 0 ) { |  |
| **trafo\_coeff\_sign\_flag**[ k ] | ae(v) |
| if( trafo\_coeff\_sign\_flag[ k ] > 0 ) |  |
| QuantIndices[ k ] = –QuantIndices[ k ] |  |
| } |  |
| QState = QStateTransTab[ QState ][ QuantIndices[ k ] & 1 ] |  |
| } |  |
| } |  |
|  |  |
|  |  |

##### Mean value trafo block syntax

|  |  |
| --- | --- |
| mean\_value\_trafo\_block ( ) { | Descriptor |
| MeanValueTrafoBlock = 0 |  |
| **mean\_value\_sig\_flag** | ae(v) |
| if ( mean\_value\_sig\_flag = = 1 ) { |  |
| **mean\_value\_abs\_rem** | ae(v) |
| **mean\_value\_sign\_flag** | ae(v) |
| MeanValueTrafoBlock = (mean\_value\_sign\_flag = =0 ) ? mean\_value\_abs\_rem + 1 :   – ( mean\_value\_abs\_rem + 1 ) |  |
| } |  |
| } |  |

### Annotation channel data syntax

|  |  |
| --- | --- |
| annotation\_channel\_data( ) { | Descriptor |
| offset = AnnotationChannelNumSamples[ ac\_annotation\_channel\_id ] |  |
| for( i = 0; i < 2 \* ( ac\_num\_annotation\_bytes\_div2\_minus1 + 1 ); i++ ) { |  |
| **am\_annotation\_byte** | u(8) |
| AnnotationChannelBytes[ ac\_annotation\_channel\_id ][ offset + i ] = am\_annotation\_byte |  |
| AnnotationChannelNumSamples[ ac\_annotation\_channel\_id ]++ |  |
| } |  |
| } |  |

## Semantics

### General

Semantics associated with the syntax structures and with the syntax elements within these structures are specified in clause 7.4. When the semantics of a syntax element are specified using a table or a set of tables, any values that are not specified in the table(s) shall not be present in the bitstream unless otherwise specified in this Specification.

### Stream packet semantics

#### General stream packet semantics

**rbsp\_byte**[ i ] is the i-th byte of an RBSP. An RBSP is specified as an ordered sequence of bytes as follows:

The RBSP contains a string of data bits (SODB) as follows:

– If the SODB is empty (i.e., zero bits in length), the RBSP is also empty.

– Otherwise, the RBSP contains the SODB as follows:

1) The first byte of the RBSP contains the first (most significant, left-most) eight bits of the SODB; the next byte of the RBSP contains the next eight bits of the SODB, etc., until fewer than eight bits of the SODB remain.

2) The rbsp\_trailing\_bits( ) syntax structure is present after the SODB as follows:

i) The first (most significant, left-most) bits of the final RBSP byte contain the remaining bits of the SODB (if any).

ii) The next bit consists of a single bit equal to 1 (i.e., rbsp\_stop\_one\_bit).

iii) When the rbsp\_stop\_one\_bit is not the last bit of a byte-aligned byte, one or more zero-valued bits (i.e., instances of rbsp\_alignment\_zero\_bit) are present to result in byte alignment.

3) One or more rbsp\_cabac\_zero\_word 16-bit syntax elements equal to 0x0000 could be present in some RBSPs after the rbsp\_trailing\_bits( ) at the end of the RBSP.

Syntax structures having these RBSP properties are denoted in the syntax tables using an "\_rbsp" suffix. These structures are carried within stream packets as the content of the rbsp\_byte[ i ] data bytes..

NOTE 1 – When the boundaries of the RBSP are known, the decoder could extract the SODB from the RBSP by concatenating the bits of the bytes of the RBSP and discarding the rbsp\_stop\_one\_bit, which is the last (least significant, right-most) bit equal to 1, and discarding any following (less significant, farther to the right) bits that follow it, which are equal to 0. The data necessary for the decoding process is contained in the SODB part of the RBSP.

The last byte of the stream packet shall not be equal to 0x00.

#### Stream packet header semantics

**stream\_packet\_type** specifies the stream packet type, i.e., the type of RBSP data structure contained in the stream packet as specified in Table 7‑1.

Stream packets that have stream\_packet\_type in the range of UNSPEC\_16..UNSPEC\_85, inclusive, and UNSPEC\_87..UNSPEC\_517, inclusive, for which semantics are not specified, shall not affect the decoding process specified in this Specification.

Table 7‑1 – Stream packet types

| **stream\_packet\_type** | **Name of stream\_packet\_type** | **Content of stream packet and RBSP syntax structure** |
| --- | --- | --- |
| 0 | FORBIDDEN\_SPT | Forbidden stream packet type for start code emulation prevention |
| 1 | WPS\_SPT | Waveform parameter set waveform\_parameter\_set\_rbsp( ) |
| 2 | CGPS\_SPT | Channel group parameter set channel\_group\_parameter\_set\_rbsp( ) |
| 3 | AM\_SPT | Auxiliary metadata auxiliary\_metadata\_rbsp( ) |
| 4 | IF\_SPT | Independent frame independent\_frame\_rbsp( ) |
| 5 | DF\_SPT | Dependent frame dependent\_frame\_rbsp( ) |
| 6 | AC\_SPT | Annotation channel annotation\_channel\_rbsp( ) |
| 7 | TIMESTAMP\_SPT | Timestamp time\_stamp\_rbsp( ) |
| 8 | FEATURE\_SPT | Feature Set feature\_set\_rbsp( ) |
| 9 | SYNC\_SPT | Synchronization syncronization\_rbsp() |
| 10 | CRC16\_SPT | CRC 16 crc16\_rbsp( ) |
| 11 | CRC32\_SPT | CRC 32 crc32\_rbsp( ) |
| 12 | UUID\_U\_SPT | User identifier user\_identifier\_rbsp( ) |
| 13 | UUID\_S\_SPT | Stream identifier stream\_identifier\_rbsp( ) |
| 14 | GLOBAL\_CRC16\_SPT | Global CRC 16 global\_crc16\_rbsp( ) |
| 15 | GLOBAL\_CRC32\_SPT | Global CRC 32 global\_crc32\_rbsp( ) |
| 16 | AUTH\_START\_SPT | Authentication start authentication\_start\_rbsp( ) |
| 17 | AUTH\_SIG\_SPT | Authentication signature authentication\_signature\_rbsp( ) |
| 18 | SEGMENT\_SPT | Segment metadata  segment\_metadata\_rbsp( ) |
| 19..517 | UNSPEC\_19.. UNSPEC\_517 | Unspecified stream packet types |

**stream\_packet\_label** specifies a sub-stream indication. For values of 1 and higher, this element provides an indication of which packets in a stream belong together (so called sub-streams). In addition, packets with stream\_packet\_label set to a value of 0 apply to all sub-streams.

**stream\_packet\_length** indicates the length of the stream\_packet\_payload in bytes. It specifies the number pf RBSP bytes in the stream packet.

#### Encapsulation of an SODB within an RBSP (informative)

This clause does not form an integral part of this Specification.

The form of encapsulation of an SODB within an RBSP and the use of the emulation\_prevention\_three\_byte for encapsulation of an RBSP within a stream packet is described for the following purposes:

– To prevent the emulation of start codes within stream packets while allowing any arbitrary SODB to be represented within a stream packet,

– To enable identification of the end of the SODB within the stream packet by searching the RBSP for the rbsp\_stop\_one\_bit starting at the end of the RBSP,

– To enable a stream packet to have a size greater than that of the SODB under some circumstances (using one or more rbsp\_cabac\_zero\_word syntax elements).

The encoder can produce a stream packet from an RBSP by the following procedure:

1. The RBSP data are searched for byte-aligned bits of the following binary patterns:

'00000000 00000000 000000xx' (where 'xx' represents any two-bit pattern: '00', '01', '10', or '11'),

and a byte equal to 0x03 is inserted to replace the bit pattern with the pattern:

'00000000 00000000 00000011 000000xx',

and finally, when the last byte of the RBSP data is equal to 0x00 (which can only occur when the RBSP ends in a rbsp\_cabac\_zero\_word), a final byte equal to 0x03 is appended to the end of the data. The last zero byte of a byte‑aligned three-byte sequence 0x000000 in the RBSP (which is replaced by the four-byte sequence 0x00000300) is taken into account when searching the RBSP data for the next occurrence of byte-aligned bits with the binary patterns of the form '00000000 00000000 000000xx'.

1. The resulting sequence of bytes is then prefixed with the stream packet header, within which the nal\_unit\_type indicates the type of RBSP data structure in the stream packet.

This procedure results in the construction of the entire content of the stream packet that follows the stream packet header.

This process can allow any SODB to be represented in a stream packet while ensuring both of the following:

– No byte-aligned start code prefix is emulated within the stream packet.

* No sequence of 8 zero-valued bits followed by a start code prefix, regardless of byte-alignment, is emulated within the stream packet.

### Raw byte sequence payloads, trailing bits and byte alignment semantics

#### Waveform parameter set RBSP semantics

A WPS RBSP shall be available to the decoding process prior to it being referenced by either of the following:

* an channel group parameter set RBSP with cgps\_waveform\_parameter\_set\_id equal to the value of wps\_waveform\_parameter\_set\_id in the WPS RBSP,
* an annotation channel RBSP with ac\_waveform\_parameter\_set\_id equal to the value of wps\_waveform\_parameter\_set\_id in the WPS RBSP.

All WPS stream packets with a particular value of wps\_waveform\_parameter\_set\_id in a CWS shall have the same content.

**wps\_waveform\_parameter\_set\_id** provides an identifier for the WPS for reference by other syntax elements.

**wps\_num\_channels\_in\_next\_group\_minus1** plus 1 specifies the number of channels in the next channel group in the sequence of channel groups.

**wps\_num\_channel\_group\_repetitions** specifies the number of channel groups that follow the previous channel group. Each of these channel groups has the same number of channels as the previous channel group.

**wps\_more\_channel\_groups\_present\_flag** equal to 1 specifies that more channel groups are specified on the WPS.

**wps\_channel\_reordering\_flag** equal to 1 specifies that syntax elements for reordering the channels in the decoded waveform sequence is present.

**wps\_num\_channel\_swaps\_minus1** plus 1 specifies the number of channel swaps to be carried out in order to perform channel reordering on the decoded waveform sequence.

**wps\_swap\_frst\_idx**[ i ] specifies the first channel of channel pair i to be swpped.

**wps\_swap\_scnd\_idx\_min\_frst\_idx\_min1**[ i ] plus 1 plus wps\_swap\_frst\_idx[ i ] specifies the second channel of channel pair i to be swapped.

**wps\_num\_annotation\_channels** specifies the number of annotation channels present in the bitstream.

#### Channel group parameter set RBSP semantics

A CGPS RBSP shall be available to the decoding process prior to it being referenced by either of the following:

* an independent frame RBSP with if\_channel\_group\_parameter\_set\_id equal to the value of cgps\_channel\_group\_parameter\_set\_id in the CGPS RBSP,
* a dependent frame RBSP with df\_channel\_group\_parameter\_set\_id equal to the value of cgps\_channel\_group\_parameter\_set\_id in the CGPS RBSP,
* a timestamp RBSP with ts\_channel\_group\_parameter\_set\_id equal to the value of cgps\_channel\_group\_parameter\_set\_id in the CGPS RBSP,
* a segment metadata RBSP with sm\_channel\_group\_parameter\_set\_id equal to the value of cgps\_channel\_group\_parameter\_set\_id in the CGPS RBSP,
* a feature set RBSP with ft\_channel\_group\_parameter\_set\_id equal to the value of cgps\_channel\_group\_parameter\_set\_id in the CGPS RBSP.

All CGPS stream packets with a particular value of cgps\_channel\_group\_parameter\_set\_id in a coded channel group segment shall have the same content.

**cgps\_channel\_group\_parameter\_set\_id** provides an identifier for the CGPS for reference by other syntax elements.

**cgps\_waveform\_parameter\_set\_id** specifies the value of wps\_waveform\_parameter\_set\_id for the WPS in use.

**cgps\_length\_signal\_mode\_flag** equal to 1 specifies that a syntax element if\_indep\_num\_samples\_per\_channel\_minus1 is present.

**cgps\_frame\_length\_shift** specifies an offset for deriving the variable Log2FrameLength as follows:

Log2FrameLength = Log2MaxBlockSize + cgps\_frame\_length\_shift (44)

**cgps\_max\_min\_block\_size** specifies an index for deriving variable Log2MaxBlockSize as follows:

Log2MaxBlockSize = LutBlockSizeMaxLog2[ cgps\_max\_min\_block\_size ] (45)

The value of cgps\_max\_min\_block\_size shall be in the range of 0 to 62, inclusive.

The array LutBlockSizeMaxLog2[ ] is specified as follows:

LutBlockSizeMaxLog2[ ] = (46)

{

4, 5, 5, 6, 6, 6, 7, 7, 7, 7, 8, 8, 8, 8, 8, 9,

9, 9, 9, 9, 9, 10, 10, 10, 10, 10, 10, 10, 11, 11, 11, 11,

11, 11, 11, 11, 12, 12, 12, 12, 12, 12, 12, 12, 12, 13, 13, 13,

13, 13, 13, 13, 13, 13, 14, 14, 14, 14, 14, 14, 14, 14, 14

}

The array LutBlockSizeMinLog2[ ] is specified as follows:

LutBlockSizeMinLog2[ ] = (47)

{

4, 4, 5, 4, 5, 6, 4, 5, 6, 7, 4, 5, 6, 7, 8, 4,

5, 6, 7, 8, 9, 4, 5, 6, 7, 8, 9, 10, 4, 5, 6, 7,

8, 9, 10, 11, 4, 5, 6, 7, 8, 9, 10, 11, 12, 5, 6, 7,

8, 9, 10, 11, 12, 13, 6, 7, 8, 9, 10, 11, 12, 13, 14

}

The variable MaxSplitDepth is derived as follows:

MaxSplitDepth = Log2MaxBlockSize - LutBlockSizeMinLog2[ cgps\_max\_min\_block\_size ] (48)

**cgps\_max\_min\_bit\_depth** specifies an index for deriving the variables BitDepthMax and BitDepthMin as follows:

BitDepthMax = LutBitDepthMax[ cgps\_max\_min\_bit\_depth ] (49)

BitDepthMin = LutBitDepthMin[ cgps\_max\_min\_bit\_depth ] (50)

The value of cgps\_max\_min\_bit\_depth shall be in the range of 0 to 62, inclusive.

The array LutBitDepthMax[ ] is specified as follows:

LutBitDepthMax[ ] = (51)

{

3, 4, 4, 8, 8, 8, 8, 8, 8, 12, 12, 12, 12, 12, 12, 12,

12, 12, 12, 16, 16, 16, 16, 16, 16, 16, 16, 16, 16, 16, 20, 20,

20, 20, 20, 20, 20, 20, 20, 20, 20, 24, 24, 24, 24, 24, 24, 24,

24, 24, 24, 24, 28, 28, 28, 28, 28, 28, 28, 28, 28, 28, 28

}

The array LutBitDepthMin[ ] is specified as follows:

LutBitDepthMin[ ] = (52)

{

2, 2, 3, 2, 3, 4, 5, 6, 7, 2, 3, 4, 5, 6, 7, 8,

9, 10, 11, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 9, 10,

11, 12, 13, 14, 15, 16, 17, 18, 19, 13, 14, 15, 16, 17, 18, 19,

20, 21, 22, 23, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27

}

**cgps\_allow\_cross\_channel\_pred\_flag** equal to 1 specifies that the cross channel prediction mode is allowed.

**cgps\_cc\_pred\_filtering\_mode** specifies the allowed filtering options that may be applied to the cross channel prediction signal as follows:

* If cgps\_cc\_pred\_filtering\_mode is equal to 0, no filtering may be applied to the cross channel prediction signal.
* Otherwise, if cgps\_cc\_pred\_filtering\_mode is equal to 1, a half-pel filtering of the cross channel prediction signal is allowed.
* Otherwise (cgps\_cc\_pred\_filtering\_mode is equal to 2), a half-pel filtering and a full-pel filtering of the cross channel prediction signal are allowed.

The value of cgps\_cc\_pred\_filtering\_mode shall lie in the range from 0 to 2 inclusively.

**cgps\_allow\_cc\_pred\_mult\_hyp\_flag** equal to 1 specifies that cross channel prediction with two input channels is allowed.

**cgps\_allow\_block\_matching\_pred\_flag** equal to 1 specifies that the block matching prediction mode is allowed.

**cgps\_bm\_pred\_filtering\_mode** specifies the allowed filtering options that may be applied to the block matching prediction signal as follows:

* If cgps\_bm\_pred\_filtering\_mode is equal to 0, no filtering may be applied to the block matching prediction.
* Otherwise, if cgps\_bm\_pred\_filtering\_mode is equal to 1, a half-pel filtering of the block matching prediction signal is allowed.
* Otherwise (cgps\_bm\_pred\_filtering\_mode is equal to 2), a half-pel filtering and a full-pel filtering of the block matching prediction signal are allowed.

The value of cgps\_bm\_pred\_filtering\_mode shall lie in the range from 0 to 2 inclusively.

**cgps\_allow\_bm\_pred\_mult\_hyp\_flag** equal to 1 specifies that block matching prediction with two hypothesis is allowed.

**cgps\_allow\_bm\_offset\_pred\_prev\_ch\_flag** equal to 1 specifies that offsets for the block matching prediction can be predicted from offsets for the block matching prediction of the previous channel.

**cgps\_allow\_lpf** equal to 1 specifies that linear predictive filtering is allowed.

**cgps\_lpf\_allow\_prev\_ch\_flag** equal to 1 specifies that linear predictive filtering using input samples from a given number of previous channels is allowed.

**cgps\_lpf\_max\_num\_minus\_1\_prev\_ch** specifies the maximum number of previous channels minus 1 that the linear predictive filtering is allowed to use.

**cgps\_residual\_quant\_mode** specifies the quantization mode.

**cgps\_ch\_indep\_interval\_idx** specifies the variable DepChMask = ( 2 << cps\_ch\_indep\_interval\_idx ) – 1. For the decoding process of clause 8, the channels can be grouped into consecutive groups of channels, each consisting of at most DepChMask +1 many channels, such that each group of channels can be processed independently from each other group of channels.

**cgps\_max\_abs\_delta\_qp\_idx** specifies the Variable MaxAbsDeltaQP = ( 1 << cgps\_max\_abs\_delta\_qp\_idx ) – 1.

**cgps\_qp** specifies the initial quantization parameter.

**cgps\_ctx\_init\_flag** equal to 1 specifies that if\_ctx\_init\_mode is present.

**cgps\_lms\_order** specifies the LMS predictor order. As the LMS can operate on mulitple block lengths, the cgps\_lms\_order parameter is scaled relative to a block length of 2048. The calculation to scale the cpgs\_lms\_order is as follows:

lms\_order = (cgps\_lms\_order << log2\_block\_length) >> 11

lms\_order = max(lms\_order,4)

If cgps\_lms\_order is 0, then default values are used that depand on the block length as shown in Table 7‑2

Table 7‑2 Default LMS Predictor Order

|  |  |
| --- | --- |
| **Block Length** | **Default LMS Order** |
| 32 | 4 |
| 64 | 4 |
| 128 | 4 |
| 256 | 4 |
| 512 | 10 |
| 1024 | 20 |
| 2048 | 40 |

#### Independent frame RBSP semantics

**if\_channel\_group\_parameter\_set\_id** specifies the value of cgps\_channel\_group\_parameter\_set\_id for the CGPS in use.

**if\_channel\_group\_id** identifies the channel group to which the current independent frame belongs. When if\_channel\_group\_id is not present, it is inferred to be equal to 0.

**if\_mean\_per\_channel** specifies the coded data sample mean per channel.

**if\_indep\_num\_samples\_per\_channel\_minus1** plus 1 specifies the number of samples per channel present in the current frame sequence.

**if\_ctx\_init\_mode** indicates which parameters are used for context initialization.

#### Dependent frame RBSP semantics

A DP RBSP unit shall only occur in the bitstream if at least one IF RBSP occurs before for which all of the following conditions are fulfilled:

* Syntax element if\_channel\_group\_parameter\_set\_id of the IF RBSP is equal to the value of df\_channel\_group\_parameter\_set\_id of the current DP RBSP.

**df\_channel\_group\_id** identifies the channel group to which the current independent frame belongs.

#### Annotation channel RBSP semantics

**ac\_waveform\_parameter\_set\_id** specifies the value of wps\_waveform\_parameter\_set\_id for the WPS in use.

**ac\_annotation\_channel\_id** specifies the annotation channel index.

**ac\_num\_annotation\_bytes\_div2\_minus1** is used to determine the number of syntax elements am\_annotaion\_bytes present in the current AC RBSP as 2 \* ( ac\_num\_annotation\_bytes\_div2\_minus1 + 1).

#### Timestamp RBSP semantics

The timestamp shall be used for, but not limited to, the following cases:

* Indicating the timing information related to the generation of a (first) sample of the signals (acquisition/recording time)
* Indicating the timing information related to the generation of coded data (encoding time)
* Indicating the true signal length or period triggered by an event (e.g., in the presence of discontinuity triggered by an encoder event due to sensor interruption, displacement or restart)
* Enabling signal alignment across multiple channels and signal types.

NOTE – The timestamp insertion into the bitstream can occur in both the encoder (signal input) and bitstream input sides.

**ts\_channel\_group\_parameter\_set\_id** specifies the value of cgps\_channel\_group\_parameter\_set\_id for the CGPS in use.

**ts\_channel\_group\_id** identifies the channel group to which the current timestamp belongs. When ts\_channel\_group\_id is not present, it is inferred to be equal to 0.

**ts\_type** indicates the timestamp use case as specified inTable 7‑3**.**

Table 7‑3 – Values of ts\_type

|  |  |
| --- | --- |
| ts\_type | Timing use case |
| 0 | Waveform acquisition |
| 1 | Encoding start |
| 2 | Waveform acquisition and encoding start |
| 3 | Discontinuity: last useful sample |
| 4 | Discontinuity: first useful sample |
| 5 | Encoding end |
| 6 (FEAT\_RBSP) | Feature set rbsp |
| 7 | reserved for future use |

**ts\_time\_idx** indicates the unique index of the timestamp packet related to feature set rbsp.

**ts\_time\_type** indicates the time type as specified in Table 7‑4.

Table 7‑4 – Values of ts\_time\_type

|  |  |
| --- | --- |
| ts\_time\_type | Timing scheme |
| 0 | TIME\_LONG |
| 1 | TIME\_SHORT |
| 2 | TIME\_UXT |
| 3 | TIME\_TAI |
| 4 | TIME\_UTC |
| 5-127 | reserved for future use |

**ts\_offset\_type\_flag** indicates the unit of ts\_time\_offset value. Shall be set to ‘0’ if the unit is miliseconds. Shall be set to ‘1’ if the unit is indicating the exact sample index. The desired floating-point time unit resolution in seconds shall be obtained using the underlying signal sampling frequency.

**ts\_time\_long** is counted in seconds and the count starts on January 1st, 2025 at 00:00:00 UTC.

**ts\_time\_offset** specifies an offset of time, added to ts\_time\_long or ts\_time\_short or ts\_time\_uxt, respectively, in unit signaled by ts\_offest\_type\_flag.

**ts\_time\_short** in seconds elapsed since last “ts\_time\_type = = TIME\_LONG”-update.

**ts\_time\_uxt** specifies the Unix time. It is counted in seconds and the count starts on January 1st, 1970 at 00:00:00 UTC, the Unix epoch.

**ts\_time\_tai** is specified according to ISO/IEC 23001-17.

**ts\_status\_bits** is specified according to the bits synchronization\_state, timestamp\_generation\_failure, timestamp\_is\_modified and reserved according to ISO/IEC 23001-17.

**ts\_time\_utc** specifies the UTC timing information yyyy-mm-ddThh:mm:ss[.xxx]Z, e.g., the Unix epoch is stored as 1970-01-01T00:00:00.000Z.

The time shall be set in a way that ts\_time\_[long, short, uxt] + ts\_time\_offset indicates the time. If ts\_offset\_type\_flag is set to ‘0’, the indicated *time* is (1000 \* ts\_time\_[…] + ts\_time\_offset) in miliseconds. The uniquely associated sample index shall be obtained by ( floor( 0.5 + *time* \* *sampling\_frequency* / 1000 ) ). If ts\_offset\_type\_flag is set to '1', the indicated *time* shall be calculated as (ts\_time\_[…] + ts\_time\_offset / *sampling\_frequency*) in seconds.

The time referring to the waveform indicates when the sample of following IF\_SPT or DF\_SPT with the same stream\_packet\_label has been recorded. Setting the stream\_packet\_label to ‘0’ shall indicate a timing information applied to all sub-streams.

In the absence of waveform acquisition/recording information in the bitstream, the waveform is assumed to start at time 00:00:00.000. The first timestamp of ts\_type = ‘0’ or ‘2’ points to the first sample of the waveform.

#### Segment metadata RBSP semantics

Segment metadata shall be used to obtain information on the coded data block sizes (IF\_SPT, DF\_SPT) and distortion measure per bitstream segment.

* By default, a segment refers to the whole coded bitstream
* A segment is also defined as a single or multiple of random access intervals in samples. A random access interval consists of a single or multiple of intra periods. An intra period is a sequence of one IF\_SPT followed by zero or more DF\_SPT blocks. Note a bitstream can be configured comprising only IF\_SPT blocks.

The segment metadata packet is inserted at the end of each segment.

The distortion measure information shall be used for, but not limited to, the following cases:

* Indicating or classifying the segment’s coding behavior, i.e., lossless, near lossless (small distortion) or lossy.
* Deriving other distortion measure metrics, e.g., percentage root mean square distortion (PRD), channel-normalized percentage root mean square distortion (CPRD).
* Enabling assessment of distortion at the decoder side without having access to the original signals. This use case is related to retrieval of lossy coded segments from a dataset by classifying and filtering of the segments in the context of further post-processing such as AI-based training.
* Transcoding (encoding of decoded bitstream) from lossless to lossy or tandem coding. The resulting distortion shall be updated accordingly.

**sm\_channel\_group\_parameter\_set\_id** specifies the value of cgps\_channel\_group\_parameter\_set\_id for the CGPS in use.

**sm\_channel\_group\_id** identifies the channel group to which the current segment metadata belongs. When sm\_channel\_group\_id is not present, it is inferred to be equal to 0.

**sm\_signal\_type** indicates the signal type as specified in Table 7‑13.

**sm\_segment\_stat\_flag** indicates whether an information on the block sizes within a segment is present or not.

**sm\_num\_blocks\_per\_segment** indicates the number of payload blocks carried in a segment.

**sm\_block\_size**[0] indicates the size/length of the first (n=0, IF\_SPT) coded data block in the segment. Subsequent block sizes (n>0) are encoded using the Golomb/Rice delta encoding method.

**sm\_delta\_GR\_param** specifies the parameter that controls the Golomb/Rice delta encoding of subsequent sm\_block\_size[n]. It uses the fixed-length (FL) binarization process having cMax = 15, see clause 9.4.3.9.

**sm\_abs\_delta** for a given iteration n, specifies the absolute value of the difference between the n-th and (n-1)-th sm\_block\_size values. It uses the un-truncated Rice (UTR) binarization process having cRiceParam = sm\_delta\_GR\_param, see clause 9.4.3.4.

**sm\_sign\_delta** specifies the sign of sm\_abs\_delta. It uses the fixed-length (FL) binarization process having cMax = 1, see clause 9.4.3.9.

**sm\_distortion\_measure\_flag** indicates whether the distortion measure metadata is present or not in the bitstream. This shall indicate the coded data coding mode, a lossless codec shall set this to ‘0’.

**sm\_num\_distortion\_measures** indicates the number of other distortion measures calculated for the segment.

**sm\_variance** indicates the signal variance measured per channel in dB unit, 10 \* log10 (sm\_variance).

**sm\_squared\_error** indicates the signal squared error measured per channel in dB unit, 10 \* log10 (sm\_squared\_error).

**sm\_distortion\_measure\_type** indicates other types of distortion measure calculated in a segment, e.g., maximum absolute error (MAE), maximum amplitude error (MAX), including it’s unit.

**sm\_distortion\_measure** indicates the distortion measure value.

#### Feature set RBSP semantics

**ft\_channel\_group\_parameter\_set\_id** specifies the value of cgps\_channel\_group\_parameter\_set\_id for the CGPS in use.

**ft\_channel\_group\_id** identifies the channel group to which the current feature set belongs. When ft\_channel\_group\_id is not present, it is inferred to be equal to 0.

**ft\_signal\_type** indicates the signal type as specified in Table 7‑13.

**ft\_sampling\_frequency** specifies the underlying signal sampling frequency.

**ft\_num\_features** the number of features available in the bitstream.

**ft\_feature\_annotation\_type** specifies the desired feature annotation type as indicated in Table 7‑5.

Table 7‑5 – Values of ft\_feature\_annotation\_type

|  |  |
| --- | --- |
| ft\_feature\_annotation\_type | Annotation type |
| 0 | Embedded annotation |
| 1 | Out-of-band annotation |
| 2 | Annotation channel RBSP |
| 3 | Pre-defined annotation |

**ft\_annotation\_str** specifies an arbitrary feature type annotation string.

**ft\_annotation\_uri** specifies the feature type annotation string in URI with syntax and semantics as specified in IETF Internet Standard 66.

**ft\_annotation\_channel\_waveform\_parameter\_set\_id** indicates the value of wps\_waveform\_parameter\_set\_id of the specified annotation\_channel WPS (ac\_waveform\_parameter\_set\_id).

**ft\_annotation\_channel\_id** indicates the annotation channel index of the specified annotation\_channel ID (ac\_annotation\_channel\_id). Together with ft\_annotation\_channel\_wps\_id, they shall point to the annotation stored in the annotation\_channel\_data of the specified annotation\_channel.

**ft\_feature\_type\_enum** indicates a certain type of features of the signal as indicated in the following tables (Table 7‑6, Table 7‑7, Table 7‑8) for different signal types.

Table 7‑6 – Values of ft\_feature\_type\_enum (for ft\_signal\_type ST\_ECG or ST\_PPG)

|  |  |
| --- | --- |
| ft\_feature\_type\_enum | Feature type |
| 0 | General |
| 1 | Abnormal Rythm |
| 2 | Abnormal Rate |
| 3-99 | /\* reserved for ITU use \*/ |
| All other values | /\* reserved for non-ITU use \*/ |

Table 7‑7 – Values of ft\_feature\_type\_enum (for ft\_signal\_type ST\_EEG)

|  |  |
| --- | --- |
| ft\_feature\_type\_enum | Feature type |
| 0 | General |
| 1 | Triphasic Waves |
| 2 | Interictal Epileptiform Discharges (IED) |
| 3 | Slowing/Diffuse Slowing/Focal Slowing |
| 4 | Electrocerebral inactivity (ECI) |
| 5 | Burst suppression pattern |
| 6 | Breach rhythm |
| 7-99 | /\* reserved for ITU use \*/ |
| All other values | /\* reserved for non-ITU use \*/ |

Table 7‑8 – Values of ft\_feature\_type\_enum (for ft\_signal\_type ST\_EMG)

|  |  |
| --- | --- |
| ft\_feature\_type\_enum | Feature type |
| 0 | General |
| 1-99 | /\* reserved for ITU use \*/ |
| All other values | /\* reserved for non-ITU use \*/ |

feat\_extract() function specifies the feature type value after processing the input syntax elements ft\_annotation\_str, ft\_annotation\_uri, ft\_annotation\_channel\_waveform\_parameter\_set\_id, ft\_annotation\_channel\_id and ft\_feature\_type\_enum.

**ft\_feature\_marking\_present\_flag** indicates the presence of a feature marking in the bitstream associated with the feature ft\_feature\_type

**ft\_feature\_start** indicates the timestamp index ts\_time\_idx of the start of a feature marking.

**ft\_feature\_length** indicates the timestamp index ts\_time\_idx denoting the end of a feature marking defining the feature length.

#### Synchronization RBSP semantics

**syncword** shall be equal to 0xDD.

#### User identifier RBSP semantics

The UUID specified in the user identifier RBSP data indicates a user identifier.

#### Stream identifier RBSP semantics

The UUID specified in the stream identifier RBSP data indicates a stream identifier.

#### Universally unique identifier semantics

**uuid\_segment\_start\_flag** identifies the start of a uuid segment, if set to ‘1’.

**uuid\_segment\_stop\_flag** identifies the end of a uuid\_segment, if set to ‘1’.

Note: If both uuid\_segment\_start\_flag and uuid\_segment\_stop\_flag are set to ‘1’ the uuid\_data-field contains the full uuid.

**uuid\_segment\_length\_minus1** plus 1 specifies the length of the partial uuid in number of bytes.

**uuid\_data** specifies a segment of a uuid or the full uuid.

#### Authentication start RBSP semantics

**aust\_id** indicates the combination of aust\_hash\_type, aust\_prov\_id and aust\_key\_id to which the related authentication information belongs to. This can be used to enable authentication of one authentication sequence with different authentication configurations.

**aust\_sequence\_id** indicates the authentication sequence the related authentication information belongs to.

**aust\_hash\_type** indicates the hashing algorithm as specified in Table 7‑9.

Table 7‑9 – Values of aust\_hash\_type

|  |  |
| --- | --- |
| aust\_hash\_type | Hashing algorithm |
| 0 | SHA-1 |
| 1 | SHA-224 |
| 2 | SHA-256 |
| 3 | SHA-384 |
| 4 | SHA-512 |
| All other values | /\* reserved for ITU use \*/ |

**aust\_key\_id** identifies the authentication key used to calculate the value of the signature (ausig\_sig\_partial, ausig\_sig\_complete) as specified in Table 7‑10. The values of this field are implementation dependent and are not defined in the present document. This value shall be set to 0 in case there is no key needed of the underlying hash-function.

Table 7‑10 – Values of aust\_key\_id

|  |  |
| --- | --- |
| aust\_key\_id | Hashing algorithm |
| 0 | No key. |
| All other values | /\* Authentication Provider key ID \*/ |

**aust\_prov\_id** identifies the provider of the authentication system, as specified in Table 7‑11. In case aust\_prov\_id equals to 1, there is no provider. This mode can be used to create the message digest only by using the method identified by aust\_hash\_type.

Table 7‑11 – Values of aust\_prov\_id

|  |  |
| --- | --- |
| aust\_prov\_id | Hashing algorithm |
| 0 | See authSourceURI. |
| 1 | Message Digest only |
| All other values | /\* Registration Authority \*/ |

**aust\_key\_source\_uri** contains a URI with syntax and semantics as specified in IETF Internet Standard 66.

**aust\_frame\_types\_present\_flag** indicates if authentication information for additional packet types is signaled.

**aust\_inclusion\_types\_flag** indicates the following. If set to 1, all packet types signaled in aust\_packet\_type[ ] syntax elements shall be included into the calculation of the authentication information. If set to 0, all packet types signaled in aust\_packet\_type[ ] syntax elements shall be excluded from the calculation of the authentication information.

**aust\_pactype\_length\_minus1** Plus 1 indicates the number of syntax elements aust\_packet\_type[ ] present.

**aust\_packet\_type**[ ] indicates the following. If aust\_inclusion\_types\_flag is equal to 1, all packet types signaled in aust\_packet\_type[ ] syntax elements shall be included into the calculation of the authentication information. If aust\_inclusion\_types\_flag is equal to 0, all packet types signaled in aust\_packet\_type[ ] syntax elements shall be excluded from the calculation of the authentication information.

**aust\_multi\_stream\_flag** indicates if authentication information for additional labels is signaled.

**aust\_inclusion\_labels\_flag** indicates the following. If set to 1, all sub-streams signaled in aust\_add\_packet\_label[ ] syntax elements shall be included into the calculation of the authentication information. If set to 0, all sub-streams signaled in aust\_add\_packet\_label[ ] syntax elements shall be excluded from the calculation of the authentication information.

**aust\_label\_list\_length\_minus1** indicates the number of syntax elements aust\_add\_packet\_label[ ] present

**aust\_add\_packet\_label**[ ] indicates the following. The value of aust\_add\_packet\_label[ ] indicates that the sub-stream with this packet label shall be included in (aust\_inclusion\_labels\_flag is set to 1) or excluded from (aust\_inclusion\_labels\_flag is set to 0) the calculation of the authentication information in addition to the sub-stream with the same stream\_packet\_label as assigned to the AUTH\_START\_SPT packet.

Note – stream\_packet\_label equal to 0 indicates that all sub-streams are included. In this case, aust\_inclusion\_labels\_flag should be set to 0, to signal exclusion of the labels indicated in aust\_add\_packet\_label[ ].

#### Authentication signature RBSP semantics

**ausig\_id** See aust\_id.

**ausig\_sequence\_id** See aust\_sequence\_id.

**ausig\_partial\_sig\_flag** indicates whether a partial or a complete signature is present.

**ausig\_segment\_start\_flag** indicates whether the first part of new signature is present in ausig\_sig\_partial.

**ausig\_segment\_stop\_flag** indicates whether the last part of new signature is present in ausig\_sig\_partial.

NOTE: If both ausig\_segment\_start\_flag and and ausig\_segment\_stop\_flag are equal to ‘1’, ausig\_sig\_partial contains a signature which is complete, but shorter than a full signature resulting from the related hashing algorithm. In this case, verification may happen comparing only a subset of the bits resulting from the hashing algorithm.

**ausig\_segment\_length\_minus1** indicates the number of bytes for the syntax element ausig\_sig\_partial.

**ausig\_sig\_partial** carries partial protection information.

**ausig\_length\_minus1** indicates the number of bytes for the syntax element ausig\_sig\_complete.

**ausig\_sig\_complete** carries complete protection information.

#### Auxiliary metadata RBSP semantics

An AM RBSP unit shall only occur as the first stream packet in the bitstream.

**am\_fourcc\_id\_last\_three\_bytes** must equal 0x415743.

**am\_header\_crc32** is the CRC calculated over the byte sequence starting with the byte containing the am\_reserved\_flag until the end of auxiliary\_metadata\_rbsp( ).

**am\_reserved\_flag** shall be ignored.

**am\_waveform\_type** specifies the waveform type according to Table 7‑12.

Table 7‑12 – Name association to am\_waveform\_type and type description

|  |  |  |
| --- | --- | --- |
| am\_waveform\_type | Name of am\_waveform\_type | Type of waveform |
| 0 | WT\_GENERIC | None, not signalled |
| 1 | WT\_EDF\_PLUS | EDF+, www.edfplus.info |
| 2 | WT\_BS2088 | BW64, ITU-R BS.2088-1 |
| 3 | WT\_RESERVED | reserved, astro- or geophysical signal |

**am\_length\_signal\_mode** equal to 1 indicates that syntax element am\_stream\_num\_samples\_per\_ch is present in the bitstream.

**am\_allow\_reconfig\_flag**

**am\_copyright\_flag**

**am\_original\_flag**

**am\_private\_flag**

**am\_stream\_max\_sampling\_rate\_minus1** plus 1 specifies the maximum sampling rate present in the bitstream.

**am\_stream\_max\_num\_channels\_minus1** plus 1 specifies the maximum number of channels in the bitstream.

**am\_stream\_num\_samples\_per\_ch** specifies the number of samples per channel present in the bitstream.

**am\_metadata\_reserved\_flag** shall be ignored.

**am\_metadata\_num\_bytes\_minus1** plus 1 specifies the number of metadata payload bytes present in the AM RBSP.

**am\_metadata\_payload\_bytes**[ i ] specifies the i-th metadata payload byte. The array am\_metadata\_payload\_bytes is a bitstream according to ITU-R BS.2088-1

**am\_num\_channels\_edf** is used to determine the number of syntax elements am\_edf\_header\_payload\_bytes present in the current AM RBSP as 256 \* ( am\_num\_channels\_edf + 1).

**am\_edf\_header\_payload\_bytes**[ i ] specifies the i-th byte of an EDF header structure.

**am\_signal\_type** indicates the present signal type as specified in Table 7‑13

Table 7‑13 – Name association to am\_signal\_type, sm\_signal\_type and ft\_signal\_type type description

|  |  |  |
| --- | --- | --- |
| am\_signal\_type | Name of am\_signal\_type | Signal type |
| 0 | ST\_ECG | Coded Electrocardiography (ECG) data |
| 1 | ST\_EEG | Coded Electroencephalography (EEG) data |
| 2 | ST\_EMG | Coded Electromyography (EMG) data |
| 3 | ST\_PPG | Coded Photoplethysmogram (PPG) data |
| All other values | ST\_RESERVED | /\* reserved \*/ |

**am\_extension\_present\_flag** indicates the presence of an extended configuration setting.

**am\_num\_channels** indicates the number of coded input channels.

**am\_codec\_mode** indicates the encoding mode.

**am\_mean\_per\_channel**[ i ] indicates the data sample mean for the i-th channel.

**am\_global\_gain** indicates the data global gain.

**am\_lpc\_order** indicates the data LPC order.

#### RBSP trailing bits semantics

**rbsp\_stop\_one\_bit** shall be equal to 1.

**rbsp\_alignment\_zero\_bit** shall be equal to 0.

#### Byte alignment semantics

**byte\_alignment\_bit\_equal\_to\_one** shall be equal to 1.

**byte\_alignment\_bit\_equal\_to\_zero** shall be equal to 0.

### Frame data semantics

#### General frame data semantics

**end\_of\_frame\_sequence\_flag** equal to 1 indicates that that the current frame sequence is terminated. When end\_of\_frame\_sequence\_flag is not present, it is inferred to be equal to 0.

**block\_split\_log2** specifies a parameter for calculating Log2BlockSize. When block\_split\_log2 is not present, it is inferred to be equal to 0.

**lpc\_huffman\_flag** equal to one indicates that Linear Predictive Coding (LPC) mode shall be used for all blocks at the current block starting position and that Huffman coding shall be used for the prediction residuals.

**end\_of\_truncated\_frame\_sequence\_flag** equal to 1 indicates that the current block is the last block of the frame sequence. When end\_of\_truncated\_frame\_sequence\_flag is not present, it is inferred to be equal to 0.

**num\_samples\_per\_channel\_to\_discard** specifies the number of samples per channel to be discarded at the end of the current block. Discarding of samples is only done if end\_of\_truncated\_frame\_sequence\_flag equals 1. The length of this syntax element is Log2BlockSize bits. The value of num\_samples\_per\_channel\_to\_discard shall not be equal to 0.

**end\_of\_frame\_one\_bit** equal to 1 indicates the end of a frame. When end\_of\_frame\_one\_bit is present, it shall be equal to 1. When end\_of\_frame\_one\_bit is not present, it is inferred to be equal to 0.

#### Lpc Huffman coding block semantics

**mean\_mode** is a two-bit code that determines how the mean for the block is recovered or transmitted as shown in Table 7‑14.

Table 7‑14 Meaing of the mean\_mode

|  |  |
| --- | --- |
| mean\_mode | Meaning |
| 0 | No mean is transmitted or computed at the decoder. |
| 1 | Mean value for all channels is transported in the bitstream. The mean values are quantized using the global gain paramter (cgps\_qp). |
| 2 | The mean value is computed at the decoder from the previous block of samples. |
| 3 | RESERVED |

**abs\_mean\_value\_single\_channel** specifies, in the case of a single channel, the sum of the mean value and the value (1<<(NumMeanBits-1))

**mean\_GR\_param** is a 4-bit parameter that controls the Golomb/Rice encoding of the mean values in each channel if more than 1 channel is present in a channel group.

**abs\_mean\_value\_multi\_channel** specifies the absolute value of the mean value of a given channel in the case of more than one channels. See clause 9.4.3.

**mean\_value\_sign\_multi\_channel** specifies the sign of the mean value of a given channel in the case of more than one channels.

**enable\_IC** enables the use of forward adaptive inter-channel prediction.

**ref\_channel\_IC** the index of the reference channel used to predict the current channel. The ref\_channel\_IC index is transmitted with ceil(log2(n)) bits.

**pred\_gain\_IC** the gain applied to the reference channel to predict the current channel.

**order\_LPC** specifies the order of the LPC prediction for each channel and LPC region.

**reflection\_coeff** LPC filter coefficients specified in reflection coefficient form.

**num\_regions** indicates the number of sub-regions of the signal that is transmitted. The number of sub-regions transmitted ranges from 0 to max\_num\_regions, where max\_num\_regions is dependent on the block length as shown in Table 7‑15. If cgps\_qp equals to 0, num\_regions is not transmitted and set to max\_num\_regions.

Table 7‑15 Max number of regions and number of bits to read num\_regions for a given block length

|  |  |  |
| --- | --- | --- |
| **Block Length** | **max\_num\_regions** | **Bits to transmit** |
| 32 | 7 | 3 |
| 64 | 15 | 4 |
| 128 | 31 | 5 |
| 256 | 63 | 6 |
| 512 | 63 | 6 |
| 1024 | 63 | 6 |
| 2048 | 63 | 6 |

**reg\_cb\_zero** is a5-bit number that indicates the index of the 0-codebook for the n-th channel.

**delta\_reg\_cb** specifiesthe delta between the current region codebook index and the previous region codebook index and is Huffman coded using the table in Annex A.1.

region\_length is the length of each sub-region which is dependant on the length of each block and the sub-region index as shown in Table 7‑16.

Table 7‑16 Region Length for a given Block Length

|  |  |
| --- | --- |
| **Block Length** | **region\_length[k]** |
| 32 | 4,4,4,4,4,4,8 |
| 64 | 4,4,4,4,4,4,4,4,4,4,4,4,4,4,4,8 |
| 128 | 4,4,4,4,4,4,4,4,4,4,4,4,4,4,4,4,4,4,4,4,4,4,4,4,4,4,4,4,4,4,8 |
| 256 | 4,4,4,4,4,4,4,4,4,4,4,4,4,4,4,4,4,4,4,4,4,4,4,4,4,4,4,4,4,4,4,4,4,4,4,4,4,4,4,4,4,4,4,4,  4,4,4,4,4,4,4,4,4,4,4,4,4,4,4,4,4,4,8 |
| 512 | 8,8,8,8,8,8,8,8,8,8,8,8,8,8,8,8,8,8,8,8,8,8,8,8,8,8,8,8,8,8,8,8,8,8,8,8,8,8,8,8,8,8,8,8,8  ,8,8,8,8,8,8,8,8,8,8,8,8,8,8,8,8,8,16 |
| 1024 | 16,16,16,16,16,16,16,16,16,16,16,16,16,16,16,16,16,16,16,16,16,16,16,16,16,16,16,16,  16,16,16,16,16,16,16,16,16,16,16,16,16,16,16,16,16,16,16,16,16,16,16,16,16,16,16,16,  16,16,16,16,16,16,32 |
| 2048 | 32,32,32,32,32,32,32,32,32,32,32,32,32,32,32,32,32,32,32,32,32,32,32,32,32,32,32,32,  32,32,32,32,32,32,32,32,32,32,32,32,32,32,32,32,32,32,32,32,32,32,32,32,32,32,32,32,  32,32,32,32,32,32,64 |

**huff\_array\_signed\_sz4** is a Huffman code that represents a four-dimensional array that specifies four signed residual values huff\_array\_signed\_sz4[idx] with 0 <= idx <4.

**huff\_array\_unsigned\_sz4** is a Huffman code that represents a four-dimensional array that specifies four unsigned residual values huff\_array\_signed\_sz4[idx] with 0 <= idx <4.

**huff\_coeff\_sign** specifies the sign bit for a residual value. When huff\_coeff\_sign is not present, it is inferred to be equal to 0.

**huff\_array\_signed\_sz2** is a Huffman code that represents a two-dimensional array that specifies two signed residual values huff\_array\_signed\_sz2[idx] with 0 <= idx <2.

**huff\_array\_unsigned\_sz2** is a Huffman code that represents a two-dimensional array that specifies two unsigned residual values huff\_array\_signed\_sz2[idx] with 0 <= idx <2.

**val\_gr\_lpc\_lms** specifies an unsigned residual value coded with Golomb/Rice coding.

**gr\_lpc\_lms\_sign\_flag** specifies the sign bit for a residual value coded with Golomb/Rice coding. When gr\_lpc\_lms\_sign\_flag is not present, it is inferred to be equal to 0.

TCoeffLpcLms is the time or frequency residual values.

#### Predictive transform coding block semantics

##### Predictive trafo block data semantics

**block\_matching\_or\_cross\_channel\_pred\_flag** equal to 1 indicates that the predicition is generated by invoking either the block-matching or the linear model prediction mode. When block\_matching\_or\_cross\_channel\_pred\_flag is not present, it is inferred to be 0.

**cross\_channel\_pred\_flag** equal to 1 indicates that the prediction is generated by invoking the cross channel prediction mode.

When cross\_channel\_pred\_flag is not present, it is inferred as follows:

– If cgps\_allow\_cross\_channel\_pred\_flag is equal to 1 and if block\_matching\_or\_cross\_channel\_pred\_flag is equal to 1, cross\_channel\_pred\_flag is inferred to be 1.

– Otherwise (cgps\_allow\_cross\_channel\_pred\_flag is equal to 0 or block\_matching\_or\_cross\_channel\_pred\_flag is equal to 0), the value of cross\_channel\_pred\_flag is inferred to be 0.

**block\_pred\_mode** specifies the block prediction mode according to Table 7‑17. When block\_pred\_mode is not present, it is inferred to be equal to BPM\_OFF.

Table 7‑17 – Name association to block\_pred\_mode and mode description

|  |  |  |
| --- | --- | --- |
| block\_pred\_mode | Name of block\_pred\_mode | Mode description |
| 0 | BPM\_DC | Average value prediction |
| 1 | BPM\_LF | Linear-function predictor |
| 2 | BPM\_OFF | No block prediction |

**block\_abs\_delta\_qp** specifies the absolute value of the current QP-value-difference associated with the current block of the current channel. When block\_abs\_delta\_qp is not present, it is inferred to be equal to 0.

**block\_delta\_qp\_sign\_flag** specifies the sign of the current QP-value-difference as follows:

– When block\_delta\_qp\_sign\_flag is equal to 0, blockDeltaQP has a positive sign.

– Otherwise (block\_delta\_qp\_sign\_flag), blockDeltaQP has a negative sign.

When block\_delta\_qp\_sign\_flag is not present, it is inferred to be 0.

The variable BlockDeltaQP is derived from the syntax elements block\_abs\_delta\_qp and block\_delta\_qp\_sign\_flag by setting BlockDeltaQP = block\_delta\_qp\_sign\_flag ? – block\_abs\_delta\_qp : block\_abs\_delta\_qp.

**block\_delta\_zlsb\_present\_flag** equal to 1 indicates that the current number CurrZeroLSB[ ch ] of zero least significant bits has to be increased or decreased by one.

**block\_delta\_zlsb\_sign\_flag** specifies the change of the value of CurrZeroLSB[ ch ] as follows:

* If block\_delta\_zlsb\_sign\_flag is equal to 1, the value of CurrZeroLSB[ ch ] is decreased by one.
* Otherwise ( block\_delta\_zlsb\_sign\_flag is not equal to 1 ) , the value of CurrZeroLSB[ ch ] is increased by one.

**transform\_present\_flag** equal to 1 indicates that the identity transform is not used on the current block.

**transform\_dst\_flag** equal to 1 indicates that the discrete sine transform is used on the current block.

The syntax elements transform\_present\_flag and transform\_dst\_flag determine the blockwise transform TransformMode for the current block. The possible values of TransformMode are delineated in Table 7‑18.

Table 7‑18 – Name association to TransformMode and mode description

|  |  |
| --- | --- |
| Name of transform\_mode | Mode description |
| TM\_OFF | Identity transform |
| TM\_DCT | Discrete cosine transform |
| TM\_DST | Discrete sine transform |

**lms\_flag** equal to 1 indicates that Least Mean Squares Prediction is used for DCT coefficients

**enable\_lms\_split** indicates that the DCT domain frequency and channel prediction is seperately controlled for the first half of the spectrum and the second half of the spectrum. If the spectrum is split (enable\_lms\_splitequals to 1), two additional control bits are sent for each half of the spectrum. If enable\_lms\_splitis 0 then the prediction runs across the entire spectrum.

**enable\_ar\_lms**[]enables the backward adaptive LMS predictor to run along frequency. If enable\_lms\_split is true there will be 2 enable\_ar\_lms[0..1] for each half of the signal.

**enable\_ic\_lms**[]enables the backward adaptive LMS predictor to predict across channels. If enable\_lms\_split is true there will be 2 enable\_ic\_lms[0..1] for each half of the signal.

##### Cross channel prediction data semantics

**cc\_pred\_offset\_only\_flag** equal to 1 indicates that the cross channel prediction mode is to be applied without a scaling factor.

**cc\_pred\_filter\_flag** equal to 1 indicates that the output of the cross channel prediction mode is to be filtered, where the set of filter coefficients is determined by the syntax element cc\_pred\_filter\_idx. When cc\_pred\_filter\_flag is not present, it is inferred to be 0.

**cc\_pred\_filter\_idx** specifies the index filterIdx to derive the array CCFiltCoeffs as specified in Table 7‑19 for filtering the output of the cross channel prediction.

Table 7‑19 – Name association to filterIdx

|  |  |
| --- | --- |
| filterIdx | filter coefficients |
| 0 | {-3, 0, 19, 32, 19, 0, -3, 0} |
| 1 | {-1, -4, 8, 29, 29, 8, -4, -1} |

When cc\_pred\_filter\_idx is not present, it is inferred to be 1:

**cc\_pred\_mult\_hyp\_flag** equal to 1 indicates that the cross channel prediction mode with two hypotheses is used. When cc\_pred\_mult\_hyp\_flag is not present, it is inferred to be 0.

**cc\_pred\_abs\_chd\_greater0\_flag**[ n ] equal to 1 indicates that the channel difference to the predicted input channel difference minus 1 for the n-th hypothesis of the cross channel prediction is not 0.

**cc\_pred\_abs\_chd\_minus1**[ n ] plus 1 specifies the absolute value of the channel difference to the predicted input channel difference minus 1 for the n-th hypothesis of the cross channel prediction.

**cc\_pred\_chd\_sign\_flag**[ n ] specifies the sign of the channel difference to the predicted input channel difference minus 1 for the n-th hypothesis of the cross channel prediction as follows:

– When cc\_pred\_chd\_sign\_flag[ n ] is equal to 0, the corresponding channel difference has a positive sign.

– When cc\_pred\_chd\_sign\_flag[ n ] is equal to 1, the corresponding channel difference has a negative sign.

When cc\_pred\_chd\_sign\_flag[ n ] is not present, it is inferred to be 0.

##### Block matching prediction data semantics

**bm\_pred\_mult\_hyp\_flag** equal to 1 indicates that the block matching prediction mode with two hypotheses is used. When bm\_pred\_mult\_hyp\_flag is not present, it is inferred to be 0.

**bm\_pred\_add\_offset\_flag** equal to 1 indicates that an offset, derived from previous reconstructed samples, is added to the block matching prediction.

**bm\_pred\_filter\_flag**[ n ]equal to 1 indicates that the reference samples used for the n-th hypothesis of the block matching prediction are to be filtered, where the set of filter coefficients is determined by the syntax element bm\_pred\_filter\_idx[ n ]. When bm\_pred\_filter\_flag[ n ] is not present, it is inferred to be 0.

**bm\_pred\_filter\_idx**[ n ]specifies the index filterIdx used to derive the array BMFiltCoeffs[ n ][ i ], with 0 <=i < 7, of filter coefficients according to Table 7‑19 for filtering the reference samples of the n-th hypothesis of the block matching prediction. When bm\_pred\_filter\_idx[ n ] is not present, it is inferred to be 1:

**bm\_pred\_off\_pred\_prev\_ch\_flag**[ n ] equal to 1 indicates that the value of offset minus block size for the n-th block matching prediction hypothesis is predicted from the value of offset minus block size of the n-th hypothesis of the previous channel. When bm\_pred\_off\_pred\_prev\_ch\_flag[n] is not present, it is inferred to be 0.

**bm\_pred\_abs\_offd\_greater0\_flag**[ n ] equal to 1 indicates that the offset difference to the predicted value of offset minus block size for the n-th hypothesis of the block matching prediction is not 0.

**bm\_pred\_abs\_offd\_minus1**[ n ] plus 1 specifies the absolute value of the offset difference to the predicted value of offset minus blocksize for the n-th hypothesis of the block matching prediction.

**bm\_pred\_offd\_sign\_flag**[ n ]specifies the sign of the offset difference to the predicted value of offset minus blocksize for the n-th hypothesis of the block matching prediction as follows:

– When bm\_pred\_offd\_sign\_flag[ n ] is equal to 0, the corresponding offset difference has a positive sign.

– Otherwise (bm\_pred\_offd\_sign\_flag[ n ]is not equal to 0), the corresponding offset difference has a negative sign.

When bm\_pred\_offd\_sign\_flag[ n ] is not present, it is inferred to be 0.

##### Sample pred mode data semantics

The sample pred mode data syntax specifes the mode SamplePredMode for the sample wise prediction on a block. The supported options for SamplePredMode and their name and meaning are delinated inTable 7‑20.

Table 7‑20 – Name association to SamplePredMode and mode description

|  |  |  |
| --- | --- | --- |
| SamplePredMode | Name of sample\_pred\_mode | Mode description |
| 0 | SPM\_SLOPE | Full-slope delta coding |
| 1 | SPM\_HALF\_SLOPE | Half-slope delta coding |
| 2 | SPM\_OFF | No sample prediction |
| 3 | SPM\_LPC | Linear predictive filtering |
| 4 | SPM\_DIFFS | Sample-wise delta coding |

**spred\_lpf\_or\_diff\_flag** equal to 1 specifies that either linear predictive filtering or sample-wise delta coding is to be used as a sample wise prediction mode.

**spred\_lpf\_flag** equal to 1 specifies that linear predictive filtering is to be used as a sample wise prediction mode. When spred\_lpf\_flag is not present, it is inferred to be 0.

**spred\_rem\_mode\_idx** specifies the sample wise prediction mode to be used among the first three options in Table 7‑20.

The variable SamplePredMode is derived as follows:

– When spred\_lpf\_or\_diff\_flag is equal to 1, the following applies:   
– If spred\_lpf\_flag is equal to 0, SamplePredMode is set to 4.  
– Otherwise (spred\_lpf\_flag is equal to 1), SamplePredMode is set to 3.

– Otherwise (spred\_lpf\_or\_diff\_flag is not equal to 0), SamplePredMode is set to spred\_rem\_mode\_idx.

##### Linear predictive filtering data semantics

The array LPFWeightsCurr[  ] represents the filter coefficients used for the linear linear predictive filtering on the current block.

**lpf\_prev\_ch\_flag** equal to 1 specifies that the samples from previous channels contribute to the input of the linear predictive filtering. When lpf\_prev\_ch\_flag is not present, it is inferred to be 0.

**lpf\_delta\_coding\_flag** equal to 1 specifies that the current filter coefficients for the linear predictive filtering process are to be reconstructed predictively by using the filter coefficients LPFWeightsNoPrevChPred[  ] as a prediction input. When lpf\_delta\_coding\_flag is not present, it is inferred to be 0.

**lpf\_num\_weights\_idx** determines the number of filter coefficients for the linear predictive filtering process.

**abs\_lpf\_weight\_greater0\_flag**[ n ] equal to 1 specifies that the current coded filter coefficient value is not 0.

**abs\_lpf\_weight\_minus1**[ n ] plus 1 specifies the absolute value of the current coded filter coefficient value.

**lpf\_weight\_sign\_flag**[ n ] specifies the sign of the current coded filter coefficient value as follows:

– When lpf\_weight\_sign\_flag[ n ] is equal to 0, the current coded filter coefficient value has a positive sign.

– When lpf\_weight\_sign\_flag[ n ] is equal to 1, the current coded filter coefficient value has a negative sign.

When lpf\_weight\_sign\_flag[ n ] is not present, it is inferred to be 0.

##### Quant res sample data semantics

The array QuantIndices[ k ] represents an array of quantization indices for the current block. The array index k specifies the location of the quantization index within the current block.

The variables NumTSkipGtxFlags, MaxTSkipRemPrefix, Log2SbbSize, and NumTCoeffGtxFlags are specified as follows:

NumTSkipGtxFlags = 4 (53)

MaxTSkipRemPrefix = 32 (54)

Log2SbbSize = 1 (55)

NumTCoeffGtxFlags = 20 (56)

The variable templateSum[ k ] is invoked by the process 9.4.4.2.3 for each array index k.

The array QStateTransTable is specified as follows:

– If cgps\_residual\_quant\_mode is equal to 0, QStateTransTable is given by:

QStateTransTable[ ][ ] = { { 0, 0 } } (57)

– Otherwise, if cgps\_residual\_quant\_mode is equal to 1, QStateTransTable is given by:

QStateTransTable[ ][ ] = { { 0, 1 }, { 2, 3 }, { 1, 0 }, { 3, 2 } } (58)

– Otherwise (cgps\_residual\_quant\_mode is equal to 2), QStateTransTable is given by:

QStateTransTable[ ][ ] = { { 0, 2 }, { 5, 7 }, { 1, 3 }, { 6, 4 }, { 2, 0 }, { 4, 6 }, { 3, 1 }, { 7, 5 } } (59)

**coeff\_bypass\_value**[ k ] represents, when the current block is coded in bypass mode, the quantization index at location k within the current block as an unsigned integer. The value of coeff\_bypass\_value[ k ] shall be in the range of 0 to (1 << IntBitDepth) – 1, inclusive.

**abs\_tskip\_coeff\_gt0\_flag**[ k ] specifies, when the current block is coded with a sample-wise prediction mode, whether the quantization index at location k within the current block is non-zero as follows:

– If abs\_tskip\_coeff\_gt0\_flag[ k ] is equal to 0, the quantization index at location k is set equal to 0.

– Otherwise (abs\_tskip\_coeff\_gt0\_flag[ k ] is equal to 1), the quantization index at location k has non-zero value.

**abs\_tskip\_coeff\_offset**[ k ] specifies, when the current block is coded with a sample-wise prediction mode, an offset, coded using truncated unary binarization, for the absolute value of the quantization index at location k. The value of abs\_tskip\_coeff\_offset[ k ] shall be in the range of 0 to NumTSkipGtxFlags, inclusive. When abs\_tskip\_coeff\_offset[ k ] is not present, it shall be inferred to be equal to 0.

**abs\_tskip\_coeff\_rem\_prefix**[ k ] specifies, when the current block is coded with a sample-wise prediction mode, a prefix for the remainder of the absolute quantization index at location k within the current block. The value of abs\_tskip\_coeff\_rem\_prefix[ k ] shall be in the range of 0 to MaxTSkipRemPrefix, inclusive. When abs\_tskip\_coeff\_rem\_prefix[ k ] is not present, it shall be inferred to be equal to 0.

**abs\_tskip\_coeff\_rem\_fl\_suffix**[ k ] specifies, when the current block is coded with a sample-wise prediction mode, a suffix, coded using a fixed-length binarization, for the remainder of the absolute quantization index at location k within the current block. The value of abs\_tskip\_coeff\_rem\_fl\_suffix[ k ] shall be in the range of 0 to (1 << RiceParameter) – 1, inclusive. When abs\_tskip\_coeff\_rem\_fl\_suffix[ k ] is not present, it shall be inferred to be equal to 0.

**abs\_tskip\_coeff\_rem\_eg0\_suffix**[ k ] specifies, when the current block is coded with a sample-wise prediction mode, a suffix, coded using an exponential Goslomb code of order zero, for the remainder of the absolute quantization index at location k within the current block. When abs\_tskip\_coeff\_rem\_eg0\_suffix[ k ] is not present, it shall be inferred to be equal to 0.

**tskip\_coeff\_sign\_flag**[ k ] specifies, when the current block is coded with a sample-wise prediction mode, the sign of the quantization index at location k as follows:

– If tskip\_coeff\_sign\_flag[ k ] is equal to 0, the quantization index at location k a non-negative value.

– Otherwise (tskip\_coeff\_sign\_flag[ k ] is equal to 1), the quantization index at location k has a negative value.

When tskip\_coeff\_sign\_flag[ k ] is not present, it shall be inferred to be equal to 0.

**last\_pos\_index\_gt0\_flag** specifies, when the current block is coded with a block-wise transform, whether the last non-zero quantization index within the current block is non-zero.

**last\_pos\_index\_rem** specifies, when the current block is coded with a block-wise transform, the remainder of the last non-zero quantization index within the current block. The value of last\_pos\_index\_rem shall be in the range of 0 to (1 << Log2BlockSize) – 1, inclusive. When last\_pos\_index\_rem is not present, it shall be inferred to be equal to 0.

**last\_pos\_index\_sign** specifies, when the current block is coded with a block-wise transform, the sign of the coded last significant scanning position for the current block. If last\_pos\_index\_sign is not present, it is inferred to be equal to 0.

**abs\_trafo\_coeff\_gt0\_flag**[ k ] specifies, when the current block is coded with a block-wise transform, whether the quantization index at location k within the current block is non-zero as follows:

– If abs\_trafo\_coeff\_gt0\_flag[ k ] is equal to 0, the quantization index at location k is set equal to 0.

– Otherwise (abs\_trafo\_coeff\_gt0\_flag[ k ] is equal to 1), the quantization index at location k has non-zero value.

When abs\_trafo\_coeff\_gt0\_flag[ k ] is not present, it is inferred as follows:

– If k is equal to last\_scan\_pos and k is greater than zero, the value of abs\_trafo\_coeff\_gt0\_flag[ k ] is inferred to be equal to 1.

– Otherwise (k is not equal to ( (last\_pos\_index\_gt0\_flag + last\_pos\_index\_rem)  <<  Log2SbbSize ) + last\_index\_offset or k is equal to 0), the value of abs\_trafo\_coeff\_gt0\_flag[ k ] is inferred to be equal to 0.

**abs\_trafo\_parity\_flag**[ k ] specifies, when the current block is coded with a block-wise transform and the variable templateSum is greater than 3, the parity of the current absolute quantization index.

**abs\_trafo\_coeff\_offset**[ k ] specifies, when the current block is coded with a block-wise transform, an offset, coded using truncated unary binarization, for the absolute value of the quantization index at location k. The value of abs\_trafo\_coeff\_offset[ k ] shall be in the range of 0 to NumTCoeffGtxFlags, inclusive. When abs\_trafo\_coeff\_offset[ k ] is not present, it shall be inferred to be equal to 0.

**abs\_trafo\_coeff\_remainder**[ k ] specifies, when the current block is coded with a block-wise transform, the remainder of the absolute quantization index at location k within the current block. When abs\_trafo\_coeff\_remainder[ k ] is not present, it shall be inferred to be equal to 0.

**trafo\_coeff\_sign\_flag**[ k ] specifies, when the current block is coded with a block-wise transform, the sign of the quantization index at location k as follows:

– If trafo\_coeff\_sign\_flag[ k ] is equal to 0, the quantization index at location k a non-negative value.

– Otherwise (trafo\_coeff\_sign\_flag[ k ] is equal to 1), the quantization index at location k has a negative value.

When trafo\_coeff\_sign\_flag[ k ] is not present, it shall be inferred to be equal to 0.

##### Mean value trafo block semantics

**mean\_value\_sig\_flag** equal to one specifies that the mean value on the current block is not zero. When mean\_value\_sig\_flag is not present, it is inferred to be zero.

**mean\_value\_abs\_rem**  specifies the absolute value minus one of the mean value on the current block.

**mean\_value\_sign\_flag** specifies the sign of the mean value on the current block.

### Annotation channel data semantics

**am\_annotation\_byte** specifies an annotation channel byte.

# Decoding process

## General decoding process

### General

Input to this process is a bitstream BitstreamToDecode. Output of this process are a list of decoded channels, each having an associated waveform parameter set identifyer and an associated channel index.

The decoding process is specified such that all decoders that conform to the specification will produce numerically identical decoded output channels when invoking the decoding process. Any decoding process that produces identical decoded channels conforms to the decoding process requirements of this Specification.

### Channel output index derivation process

Input of this process are:

* The syntax elements of a waveform parameter set according to clause 7.3.2.1,
* a channel group index chGrpIdx
* a channel index chIdxInChGroup in a channel group.

Output of this process is an output channel index outChIdx.

This index is derived as follows:

The variable chIdxBRd which specifies the channel index before reordering ( if applicable ) is set to ChannelGroupStartingPos[chGrpIdx] + chIdxInChGroup.

If wps\_channel\_reordering\_flag is equal to zero, chIdxBdR is set equal to outChIdx.

Otherwise ( wps\_channel\_reordering\_flag is not equal to zero ), the following process is invoked:

Set outChIdx = chIdxBRd.

Set i = 0

do

if ( outChIdx == wps\_swap\_frst\_idx[ i ])

outChIdx += wps\_swap\_scnd\_idx\_min\_frst\_idx\_min1[ i ] + 1

else if (outputChIx == wps\_swap\_frst\_idx[ i ] + wps\_swap\_scnd\_idx\_min\_frst\_idx\_min1[ i ] + 1 )

outChIdx = wps\_swap\_frst\_idx[ i ]

i = i + 1

while ( i <= wps\_num\_channel\_swaps\_minus1)

### Decoding process for independent frames (stream packets of type IF\_SPT)

The syntax elements of the last previously decoded waveform parameter set in the bitstream in decoding order that has the same waveform parameter set identifier as the current independent frame (waveform\_parameter\_set\_id == if\_waveform\_parameter\_set\_id) are inferred. It is a requirement of bitstream conformance that such a waveform parameter set exists. The set of syntax elements of this waveform parameter set shall be referred to as wpsCurr.

The variable wPId is set to if\_waveform\_parameter\_set\_id and the variable chGId is set to if\_channel\_group\_id.

The frame decoding process of clause 8.2 is invoked with the variable frameStartPos set to 0 and the variable frameNumChannels set to NumChannels[ if\_channel\_group\_id ].

The output of this process is assigned to the number of reconstructed samples numRecSmpls and the array of reconstructed sample values Rec[ wPId ][ chGId ][ c ][ i ] with 0 <= c < NumChannels[ if\_channel\_group\_id ] and 0 <= i < numRecSmpls.

The variable NumSpls[ wPId ][ chGId ] which specifies the number of decoded samples corresponding to the current waveform parameter set id and to the current channel group id is set to numRecSmpls.

For each c with 0 <= c < NumChannels[ if\_channel\_group\_id ], the following applies:

* The decoded output channel outCh[ c ] is specified as the channel of reconstructed sample values Rec[ wPId ][ chGId ][ c ][ i ] with 0 <= i < numRecSmpls.
* The waveform parameter set identifier associated to outCh[ c ] is set to wpId.
* The process of clause 8.1.2 is invoked with the set of waveform parameter set syntax elements set to wpsCurr, the variable chGrpIdx set to if\_channel\_group\_id and the variable chIdxInChGroup set to c. The output of this process is assigned to the output channel index outputIdx associated to outCh[ c ].

### Decoding process for dependent frames (stream packets of type DF\_SPT)

The syntax elements of the independent frame header of the last previously decoded independent frame in the bitstream in decoding order that has the same waveform parameterset id and the same channel group id as the current dependent frame ( if\_waveform\_parameter\_set\_id == df\_waveform\_parameter\_set\_id and if\_channel\_group\_id == df\_channel\_group\_id ) are inferred. It is a requirement of bitstream conformance that such an independent frame exists. The set of syntax elements of the last previously decoded waveform parameter set that has the same waveform parameter set identifier as the current dependent frame (waveform\_parameter\_set\_id == df\_waveform\_parameter\_set\_id) shall be referred to as wpsCurr.

The variable wPId is set to df\_waveform\_parameter\_set\_id and the variable chGId is set to df\_channel\_group\_id.

The frame decoding process of clause 8.2 is invoked with the variable frameStartPos set to NumSpls[ wPId ][ chGId ], the variable frameNumChannels set to NumChannels[ if\_channel\_group\_id ] and the input array sample values recSamples[ c ][ i ] set to Rec[ wPId ][ chGId ][ c ][ i ] for 0 <= c < NumChannels[ df\_channel\_group\_id ] and 0 < =i < NumSpls[ wPId ][ chGId ].

The output of this process is assigned to the number of currently reconstructed samples numRecSmpls and the reconstructed sample values rec [ c ][ i ] with 0 <= c < NumChannels[ df\_channel\_group\_id ] and numSpls[ wPId ][ chGId ] < = i < numSpls[ wPId ][ chGId ] + numRecSmpls.

The values rec[ c ][ i ] are assigned to the variables Rec[ wPId ][ chGId ][ c ][ i ] for 0 <= c < NumChannels[ df\_channel\_group\_id ] and numSpls[ wPId ][ chGId ] < = i < numSpls[ wPId ][ chGId ] + numRecSmpls.

The variable NumSpls[ wPId ][ chGId ] is set to NumSpls[ wPId ][ chGId ] + numRecSmpls.

For each c with 0 <= c < NumChannels[ df\_channel\_group\_id ], the following applies:

* The decoded output channel outCh[ c ] is specified as the channel of reconstructed sample values Rec[ wPId ][ chGId ][ c ][ i ] with numSpls[ wPId ][ chGId ]< = i < numSpls[ wPId ][ chGId ] + numRecSmpls.
* The waveform parameter set identifier associated to outCh[ c ] is set to wpId.
* The process of clause 8.1.2 is invoked with the set of waveform parameter set syntax elements set to wpsCurr, the variable chGrpIdx set to df\_channel\_group\_id and the variable chIdxInChGroup set to c to specify the output channel index outputIdx associated to outCh[ c ].

## Frame data decoding process

Input to this process are:

* a starting position startPos.
* a number of channels numCh
* if starPos is not equal to zero: An array of reconstructed sample values rec[ c ][ i ] with 0 <= c < numCh and  
  0 <= i < startPos.

Output of this process are the number of reconstructed samples numRecSmpls and the newly reconstructed sample values rec[ c ][ i ] with 0 <= c <numCh and startPos <= i < startPos + numRecSmpls.

The ordered steps in the the decoding process of this clause follow the corresponding orderd steps in the syntax of clause 7.3.3.1, where at each step, the associated syntax elements are inferred from clause 7.3.3.

The variable currLog2TSize is set to 4 and the variable currTSize is set to ( 1 << currLog2Tsize ).

The variable maxVal is set to ( 1 << ( BitDepthMax – 1 ) ) – 1 and the variable minVall is set to – maxVal- 1.

The variable currBlockPos is initialized to 0.

For each step in the enclosing while loop of clause 7.3.3.1, the following ordered steps apply:

* The variable blockSize is set equal to ( 1 << Log2BlockSize ).
* If lpc\_huffman\_flag is equal to 1, for each channel with channel index currCh, 0 <= currCh <numCh, the following ordered steps apply:
  1. The LPC-Huffman scaling process of clause 8.3 is applied. The output of this process is assigned to the reconstructed residual samples values resLmsLpc[i] with 0 <= i< blockSize
  2. The LPC-Huffman decoding process of clause 8.4 is applied. The output of this process is assigned to the reconstructed signal signal[currCh][i].
  3. For 0 <= i< blockSize, the value signal[currCh][i]. is assigned to the reconstructed sample values recNoMean[ currCh ][ i ]
  4. The mean correction process of clause 8.10 is invoked. For 0 <= i < blockSize , the output of this process is assigned to the reconstructed sample values rec[ currCh ] [i].
* Otherwise (lpc\_huffman\_flag is not equal to 1), for each channel with channel index currCh, 0 <= currCh <numCh, the following ordered steps apply:

1. The blockwise prediction decoding process of clause 8.5 is applied. The output of this process is assigned to the prediction sample values predCurr[ i ] with 0 <= i < blockSize and the extended left adjacent residual samples resiLeftCurr[ j ] with 0 <= j < currTSize.
2. If lms\_flag is equal to 1, the Backward Adaptive (LMS prediction) process of clause 8.7 is applied.
3. The scaling and inverse blockwise transform process from clause 8.6 is applied. The output of this process is assigned to the intermediate reconstructed residual sample values resImdCurr[ i ] with 0 <= i < blockSize.
4. The sample wise prediction decoding process of clause 0 is applied. The output of this process is assigned to the final residual sample values resCurr[ i ] with 0 <= i < blockSize.
5. For 0 <= i < blockSize, the value Clip3( minVal, maxVal, predCurr[ i ] + resCurr[ i ]) is assigned to the reconstructed sample values rec[ currCh ][ i ]

* The variable currBlockPos is incremented as follows:
  + If end\_of\_truncated\_frame\_sequence\_flag is equal to 1, the variable currBlockPos is set equal to currBlockPos + blockSize – num\_samples\_per\_channel\_to\_discard
  + Otherwise ( end\_of\_truncated\_frame\_sequence\_flag is not equal to 1 ), the variable currBlockPos is set equal to currBlockPos + blockSize.

The variable currBlockPos is set equal to numRecSmpls.

## LPC-Huffman scaling process

The variable global\_gain is set to cgps\_qp and the variable signal\_bit\_depth is set to BitDepthMax.

The following source code shows the steps inverse quantize a single residual value:

residual = InverseQuantize(quant\_residual,global\_gain){

accum = (int64\_t)quant\_residual \* inv\_quant\_scale[global\_gain];

accum += 1 << (inv\_quant\_shift[global\_gain]-1);

accum >>= inv\_quant\_shift[global\_gain];

residual = (int32\_t)accum;

return residual;

}

The values of inv\_quant\_scale[global\_gain] and inv\_quant\_shift[global\_gain] are provided in Table B 1.

## LPC Huffman decoding process

### Forward Adaptive Prediction

If lpc\_Huffman\_flag is equal to 1, then forward adaptive prediction is used. The forward adaptive prediction is combination of LPC coding and a simple inter-channel prediction mode. The first part of decoding the forward adaptive prediction is the LPC decoding which is specified in the following pseudo-code for the channel ch. In the following pseudo-code, the values order\_LPC[ch] and reflection\_coeff[ch][n] are derived from the bitstream (see clause 7.4.4.2). The residual[ch][n] is the residual signal read from the bitstream, while the signal[ch][n] is the reconstructed signal.

accuracy\_shift = 17;

round\_offset =(1<<23);

AArray[32] = {0};

AArrayTemp[32] = {0};

buffer[32] = {0};

buffer\_pointer = 0;

buffer\_mask =31;

for(n = 0; n <= order\_LPC[ch]; n ++){

// Update the direct form LPC at each step

for(k = 1; k <= n; k ++){

reflection\_coeff[ch][n] -= 128;

KValue = (reflection\_coeff[ch][n] << accuracy\_shift);

accum = (int64\_t)KValue \* AArray[n - k] + round\_offset;

accum >>= 24;

AArrayTemp[k] = piAArray[k] + (int32\_t)accum;

}

for(k = 1; k <= n; k ++){

AArray[k] = AArrayTemp[k];

}

// Calculate prediction

pointer = buffer\_pointer;

accum = round\_offfset;

for(k = 1; k <= n; k ++){

accum += (int64\_t)buffer[pointer] \* AArray[k];

pointer --;

pointer &= buffer\_mask;

}

accum >>= 24;

// Calculate Output Signal

signal[ch][n] = residual[ch][n] – (int32\_t)accum;

// Update buffer

buffer\_pointer ++;

buffer\_pointer &= buffer\_mask;

buffer[iBufferPointerState] = signal[ch][n];

}

for(n = order\_LPC[ch] + 1;n < block\_length;n++){

pointer = buffer\_pointer;

accum = round\_offfset;

for(k = 1; k <= n; k ++){

accum += (int64\_t)buffer[pointer] \* AArray[k];

pointer --;

pointer &= buffer\_mask;

}

accum >>= 24;

// Calculate Output Signal

Signal[ch][n] = residual[ch][n] – (int32\_t)accum;

// Update buffer

buffer\_pointer ++;

buffer\_pointer &= buffer\_mask;

buffer[iBufferPointerState] = signal[ch][n];

}

Following the inverse LPC prediction, the inverse inter-channel prediction can computed for channel ch based on the previously reconstructed channel indexed by the ref\_channel\_IC[ch] which is carried in the bitstream. The following pseudo-code specifies the inverse inter-channel prediction for channel ch.

if(enable\_IC[ch]){

for(n = 0; n < block\_length; n ++){

pred\_gain\_IC[ch] -= 128;  
 signal[ch][n] += (pred\_gain\_IC[ch] \* signal[ref\_channel\_IC[ch]][n] + 8) >> 4;

}

}

The forward adaptive prediction will only be used when the cgps\_qp is zero (lossless).

## Blockwise prediction decoding process

Input to this process are:

* the current channel index currCh,
* the current block position currBlockPos,
* the array of reconstructed samples of previous channels rec[ c ][ i ] with   
  max( currCh – ( DepChMask & currCh ), 0 ) <= c < currCh and with 0 <= i < currBlockPos + ( 1 << Log2BlockSize ).
* the array of reconstructed samples of the current channel rec[ currCh ][ i ] with 0 < = i < currBlockPos.
* the parameter currLog2TSize which determines the size of the adjacent left residual samples to be computed and the size of the template for the parameter computation of the cross-channel and the block-matching prediction.

Output to this process are the prediction sample values pred [ i ] with 0 <= i < ( 1 << Log2BlockSize ) and the extended residual sample values resiLeft[ j ] with 0 <= j < (1 << currLog2TSize ). These values are derived as follows:

* If block\_matching\_or\_cross\_channel\_pred\_flag is equal to 1, the following applies:
  + If cross\_channel\_pred\_flag is equal to 1, the cross channel prediction decoding process of clause 8.5.6 is invoked with chIdx set equal to currCh, blockPos set equal to currBlockPos, log2BlockSize set equal to Log2BlockSize, the reference sample values of previous channels ref[ c ][ i ] set equal to rec[ c ][ i ] for max( currCh – ( DepChMask & currCh ), 0 ) <= c < currCh and 0 <= i < currBlockPos + ( 1 << Log2BlockSize), the reference sample values of the current channel refCurr[ i ] set equal to rec[ currCh ][ i ] with 0 < = i < currBlockPos and log2TSize set equal to currLog2TSize.
  + Otherwise ( cross\_channel\_pred\_flag is not equal to 1 ), the block matching prediction decoding process of clause 8.5.7 is invoked with chIdx set equal to currCh, blockPos set equal to currBlockPos, log2BlockSize set equal to Log2BlockSize, the reference sample values ref[ i ] set equal to rec[ currCh ][ i ] with 0 < = i < currBlockPos and log2TSize set equal to currLog2TSize.
* Otherwise (block\_matching\_or\_cross\_channel\_pred flag is not equal to 1), the following applies:
  + If block\_pred\_mode is equal to BPM\_DC, the DC prediction decoding process of clause 8.5.4 is invoked with blockPos set equal to currBlockPos, log2BlockSize set equal to Log2BlockSize, the reference sample values ref[ i ] set equal to rec[ currCh ][ i ] with 0 < = i < currBlockPos and log2TSize set equal to currLog2TSize.
  + If block\_pred\_mode is equal to BPM\_LF, the line fitting decoding process of clause 8.5.5 is invoked with blockPos set equal to currBlockPos, log2BlockSize set equal to Log2BlockSize, the reference sample values ref[ i ] set equal to rec[ currCh ][ i ] with 0 < = i < currBlockPos and log2TSize set equal to currLog2TSize.
  + If block\_pred\_mode is equal to BPM\_OFF, the zero prediction decoding process of clause 8.5.3 is invoked with log2BlockSize set equal to Log2BlockSize and log2TSize set equal to currLog2TSize.

### Linear extrapolation process of an array to the right

Input to this process are:

* an input array size szArr >= 4,
* an input array of sample values p[ i ] with 0 <= i < szArr,
* an extrapolation size log2SzExt > 0

Output to this process are the array values extrapolated to the right p[ szArr + j ] with 0 <= j < (1 << log2SzExt) and an extrapolated mean value meanValExtr.

The variable szExt is set to 1 << log2SzExt.

The variable slope is set to 15\*( p[ szArr – 1 ] – p[ szArr –4 ] ) +5\*( p[ szArr – 2 ] – p[ szArr – 3 ] ).

The variable offset is set to ( ( p[ szArr – 4 ] + p[ szArr – 3 ] + p[ szArr – 2] + p[ szArr – 1 ] +2 ) << 7 ).

For 0 <= j < szExt, the extrapolated array values p[ szArr + j ] are defined as follows:

* One sets stepCurr = 25 + j\*10.
* One sets slopeCurr = slope \* ( 2\*szExt – j ).
* One sets p[ szArr + j ] = ( ( offset<<( log2SzExt +1 ) )+ slopeCurr\*stepCurr ) >> (log2SzExt + 10).

One sets meanValExtr = (offset + 20 \* slope ) >> 9.

### Linear extrapolation process of an array to the left

Input to this process are:

* an input array starting position startPos
* an input array size szArr with szArr – startPos >= 4,
* an input array of sample values p[ i ] with startPos <= i < szArr,
* an extrapolation size szExt > 0

Output to this process are the array values extrapolated to the left p[ startPos – 1– j ] with 0 < = j < szExt.

The mirrored input array sample values pMirror[ i ] with 0 <= i < szArr – startPos are defined as pMirror[ i ] = p[ szArr – 1– i ].

The extrapolation process to the right from clause 8.5.1 is invoked with the input array size szArr – startPos, the input array pMirror and the extensions size set to Ceil( Log2 ( szExt ) ) as input to obtain the array values pMirror[ szArr + j ] with 0 <= j < ( 1 << Ceil( Log2 ( szExt ) ) ).

For 0 <= j < szExt the value pMirror[ szArr + j ] is assigned to p[ startPos – 1 – j ].

### Zero prediction decoding process

Input to this process are:

* a variable log2BlockSize that determines the size of the current block,
* the parameter log2TSize which determines the size of the adjacent left residual samples to be computed.

This process specifies as an output the arrays pred[ i ] = 0 with 0 <= i < (1 <<log2BlockSize) and the array of adjacent left residual samples resiLeft [ j ] = 0 with 0 <= j < ( 1 << log2TSize ).

### DC prediction decoding process

Input to this process are:

* a variable blockPos specifying the position of the first sample of the current block,
* a variable log2BlockSize that determinesthe size of the current block,
* an array of reconstructed samples ref [ i ] with 0 < = i < blockPos.
* a parameter log2TSize which determines the size of the adjacent left residual samples to be computed.

Output of this process are the array of DC prediction sample values pred[ i ] with 0 <= i < (1 <<log2BlockSize) and the array of adjacent left residual samples resiLeft [ j ] with 0 <= j < ( 1 << log2TSize ).

The variable maxPredVal is set to ( 1 << ( BitDepthMax – 1 ) ) – 1.

The variable minPredVal is set to – maxPredVal – 1.

The variable blockSize is set to 1 << log2BlockSize.

* If blockPos < 4, the values pred[ i ] with 0 <= i < blockSize and the values resiLeft[ j ] with 0 <=. j < tSize are set to 0.
* Otherwise (blockPos > 4 ), the following applies:
  + The variable mean is set as   
    mean = Clip3(minPredVal, maxPredVal, .
  + One sets pred[ i ] = mean for all i with 0 <= i < blockSize.
  + If blockPos >= tSize, resiLeft[ j ] is set to ( ref[ – blockPos + j ] – mean ) for all j with 0 <=. j < tSize.
  + Otherwise ( blockPos < tSize ), resiLeft[ j ] is set to 0 for all j with 0 <= j < tSize.

### Line fitting prediction decoding process

Input to this process are:

* a variable blockPos specifying the position of the first sample of the current block,
* a variable log2BlockSize that determinesthe size of the current block,
* the array of reconstructed samples of the current channel ref[ i ] with 0 < = i < blockPos.
* the parameter log2TSize which determines the size of the adjacent left residual samples to be computed.

Output of this process are the array of line fitting prediction sample values pred[ i ] with 0 <= i < (1 << log2BlockSize) and the array of adjacent left residual samples resiLeft [ j ] with 0 <= j < ( 1 << log2TSize ).

The variable maxPredVal is set to ( 1 << ( BitDepthMax – 1 ) ) – 1.

The variable minPredVal is set to – maxPredVal – 1.

The variable blockSize is set to 1 << log2BlockSize.

The variable tSize is set to 1 << log2TSize.

* If blockPos < 4, the values pred[ i ] with 0 <= i < blockSize and the values resiLeft[ j ] with 0 <=. j < tSize are set to 0.
* Otherwise (blockPos > 4 ), the following applies:
  + The array q[ j ] with 0 <=j <4 is defined as q[ j ] = ref[ blockPos – 4 + j ].
  + The linear extrapolation process to the right from clause 8.5.1 is invoked with input the input array size 4, the input array q and the extension size log2BlockSize to obtain the array values q[ 4 + i ] with 0 <= i < blockSize and the extrapolated mean value meanValExtr.
  + One sets pred[ i ] = Clip3( minPredVal, maxPredVal, q[ 4+i ] ) for all 0 <=i <blockSize.
  + If blockPos >= tSize, resiLeft[ j ] is set to ( ref[ – blockPos + j ] – meanValExtr ) for all j with 0 <=. j < tSize.
  + Otherwise ( blockPos < tSize ), resiLeft[ j ] is set to 0 for all j with 0 < = j < tSize.

### Cross channel prediction decoding process

Input to this process are:

* a variable chIdx specifying the current channel,
* a variable blockPos specifying the position of the first sample of the current block,
* a variable log2BlockSize that determinesthe size of the current block,
* the array of reference samples of previous channels ref[ c ][ i ] with   
  max( chIdx – ( DepChMask & chIdx ), 0 ) <= c < chIdx and 0 <= i < blockPos + (1 << log2BlockSize).
* the array of reference samples of the current channel refCurr[ i ] with 0 < = i < blockPos.
* the parameter log2TSize which determines the size of the adjacent left residual samples to be computed and which determines tze size of the template used for parameter derivation.

Output of this process are the array of cross channel prediction sample values pred[ i ] with 0 <= i < (1 << log2BlockSize) and the array of adjacent left residual samples resiLeft [ j ] with 0 <= j < ( 1 << log2TSize ).

The variable maxPredVal is set to ( 1 << ( BitDepthMax – 1 ) ) – 1.

The variable minPredVal is set to – maxPredVal – 1.

The variable blockSize is set to 1 << log2BlockSize.

The variable firstPrevCh which indexes the first input channel is set to   
chIdx – 1 – CrossChannelPredInputChDistMinus1[ chIdx ][ 0 ].

If cc\_pred\_mult\_hyp\_flag is not equal to zero, the variable secondPrevCh, which indexes the second input channel, is set to chIdx – 1– CrossChannelPredInputChDistMinus1[ chIdx ][ 1 ].

The variable tSize is set to 1 << log2TSize.

The variable fPdL which specifies the length to the left for the prediction filters of clause 7.3.3.3.2 is set to 3.

The variable log2FPdR which which determines the length to the right for the prediction filters of clause 7.3.3.3.2 is set to 2.

The variable fPdR is set to 1 << log2FPdR.

The variable fSz which specifies the filter size for the filters of clause 7.3.3.3.2 is set to fPdL + fPdR.

* If blockPos < tSize, the following applies:
  + The intermediate cross channel prediction samples before filtering and extrapolation p[ i ] with 0 <= i < blockSize are defined as follows:
    - If cc\_pred\_mult\_hyp\_flag is equal to zero, one pust p[ i ] = ref[ firstPrevCh ][ blockPos + i ].
    - Otherwise ( cc\_pred\_mult\_hyp\_flag is not equal to zero), one set   
      p[ i ] = ( ref[ firstPrevCh ][ blockPos + i ] + ref[ secondPrevCh ][ blockPos + i ] + 1 ) >> 1.
  + If cc\_pred\_filter\_flag is equal to zero, the final cross channel prediction sample values pred[ i ] are set to Clip3(minPredVal, maxPredVal, p[ i ]) for 0 <= i < blockSize.
  + Otherwise ( cc\_pred\_filter\_flag is not equal to zero ) , the following applies:
    - If blockPos < fPdL, the extrapolation process to the left from clause 8.5.2 is applied with the input starting position 0, the input array p, the input array size blockSize and the extension size fPdL to obtain the sample values p[ –fPdL + i ] with 0 <= i < fPdL.
    - Otherwise ( blockPos >= fPdL) the following applies:
      * If cc\_pred\_mult\_hyp\_flag is equal to zero, for 0 <= i < fPdL the value ref[ firstPrevCh ][ blockPos –fPdL + i ] is assigned to p[ –fPdL + i ].
      * Otherwise ( cc\_pred\_mult\_hyp\_flag is not equal to zero ) , for 0 <= i < fPdL the value ( ref[ firstPrevCh ][ blockPos –fPdL + i ] + ref[ secondPrevCh ][ blockPos –fPdL + i ]+ 1 ) >>1 is assigned to p[ –fPdL + i ].
    - The extrapolation process to the right from clause 8.5.1 is applied with the input array p, the input array size blockSize and the extension size log2FPdR. The output of this process is assigned to the sample values p[ blockSize +i  ] with 0 <= i < fPdR.
    - The final cross channel prediction sample values pred[ i ] with 0 <= i < blockSize are set to Clip3( minPredVal, maxPredVal, )
  + The extended residual samples resiLeft[ i ] are set to 0 for 0 <=i < tSize.
* Otherwise (blockPos >= tSize), the following applies:

For 0 <= i < tSize, the previous reconstructed sample value currChTpl[ i ] in the current channel on the left template is set to refCurr[ blockPos – tSize + i ], with 0 <= i < tSize.

The array firstPrevChTpl[  ] of previous reconstructed sample values in the first input channel on the left template is defined as

firstPrevChTpl [ i ] = ref[ firstPrevCh ][ blockPos – tSize + i ], with 0 <= i < tSize.

If cc\_pred\_mult\_hyp\_flag is not equal to zero, the array secondPrevChTpl[  ] of previous reconstructed sample values in the second input channel on the left template is defined as

secondPrevChTpl [ i ] = ref[ secondPrevCh ][ blockPos – tSize + i ], with 0 <= i< tSize.

The intermediate cross channel prediction signal samples before filtering and extrapolation to the right p[ i ] with 0 <= i < blockSize + tSize +fPdL are defined as follows:

* If cc\_pred\_offset\_only\_flag is equal to one, the following applies:
  + The variable sum Diff is defined as follows:
    - If cc\_pred\_mult\_hyp\_flag is equal to zero, one sets   
      sumDiff =
    - Otherwise (cc\_pred\_mult\_hyp flag is not equal to zero), one sets   
      sumDiff =
  + The variable offset is defined as offset = (sumDiff + (1 << (log2TSize – 1 ) ) ) >> log2TSize
  + If cc\_pred\_mult\_hyp\_flag is equal to zero, the following applies:
    - If tSize + fPdL <= blockPos, for 0 <= i < blockSize + tSize +fPdL one sets:   
      p[ i ] = ref[ chIdxFirst ][ blockPos – tSize – fPdL + i ] + offset.
    - Otherwise ( tSize + fPdL > blockPos), the following applies:
      * For fPdL <= i <blockSize + tSize +fPdL one sets p[ i ] = ref[ chIdxFirst ][ blockPos – tSize – fPdL + i ] + offset.
      * The extrapolation process to the left fom clause 8.5.2 is invoked with the input starting position fPdL, the input array size blockSize + tSize, the input array p and the extension size fPdL to obtain the values p[ i ] with 0 <= i < fPdL.
  + Otherwise ( cc\_pred\_mult\_hyp\_flag is not equal to zero), the following applies:
    - If tSize + fPdL <= blockPos, for 0 <= i < blockSize + tSize +fPdL one sets:   
      p[ i ] = ( ( ref[ chIdxFirst ][ blockPos – tSize – fPdL + i ] + ref[ chIdxScnd ][ blockPos – tSize – fPdL + i ] +1 ) >> 1 )+ offset.
    - Otherwise ( tSize + fPdL > blockPos), the following applies:
      * For fPdL <= i <blockSize + tSize +fPdL one sets p[ i ] = ( ( ref[ chIdxFirst ][ blockPos – tSize – fPdL + i ] + ref[ chIdxScnd ][ blockPos – tSize – fPdL + i ] +1 ) >> 1 )+ offset.
      * The extrapolation process to the left fom clause 8.5.2 is invoked with the input starting position fPdL, the input array size blockSize + tSize, the input array p and the extension size fPdL to obtain the values p[ i ] with 0 <= i < fPdL.
* Otherwise ( cc\_pred\_offset\_only flag is not equal to one ), if cc\_pred\_mult\_hyp\_flag is equal to zero, the following applies:
  1. The symmetric 2x2 matrix A with the following entries A[ 0 ][ 0 ], A[ 0 ][ 1 ], A[ 1 ][ 0 ], A[ 1 ][ 1 ] is defined:
     + A[ 0 ][ 0 ] =
     + A[ 0 ][ 1 ]
     + A[ 1 ][ 1 ] = tSize
  2. The 2 dimensional vector b with the following entries band bs defined:
     + b[ 0 ]=
     + b[ 1 ]=
  3. The cross component precision ccShift is set to 16
  4. The process of clause 5.10.4 is invoked to obtain the 2 dimensional vector v with entries v[ 0 ] and v[ 1 ] which solves the equation Ax=b in precision ccShift according to that clause.
  5. The variable ccShiftOffst is set to ( (1 << ccShift) – 1 ).
  6. The following is applied:
     + If tSize + fPdL <= blockPos, for 0 <= i < blockSize + tSize +fPdL one sets:   
       p[ i ] = ( v[ 0 ]\*ref[ chIdxFirst ][ blockPos – tSize – fPdL + i ] + v[ 1 ] + ccShiftOffst) ) >> ccShift.
     + Otherwise ( tSize + fPdL > blockPos), the following applies:
       - For fPdL <= i <blockSize + tSize +fPdL one sets p[ i ] = (v[ 0 ]\*ref[ chIdxFirst ][ blockPos – tSize – fPdL + i ] + v[ 1 ] + ccShiftOffst) ) >> ccShift.
       - The extrapolation process to the left fom clause 8.5.2 is invoked with the input starting position fPdL, the input array size blockSize + tSize, the input array p and the extension size fPdL to obtain the values p[ i ] with 0 <= i < fPdL.
* Otherwise ( cc\_pred\_offset\_only flag is not equal to one and cgps\_cc\_pred\_mult\_hyp\_flag is equal to one ), the following applies:
  + The symmetric 3x3 matric A with the entries A[ k ][ l ] with 0 <= k < 3 and 0 <= l < 3 is defined as follows:
    - A[ 0 ][ 0 ] =
    - A[ 0 ][ 1 ] =
    - A[ 0 ][ 2 ] =
    - A[ 1 ][ 0 ] = A[ 0 ][ 1 ]
    - A[ 1 ][ 1 ] =
    - A[ 1 ][ 2 ] =
    - A[ 2 ][ 0 ] = A[ 0 ][ 2 ]
    - A[ 2 ][ 1 ] = A[1 ][ 2 ]
    - A[ 2 ][ 2 ] = tSize
  + The 3 dimensional vector b with the following entries b[ 0 ], b[ 1 ] and b[ 2 ] is defined as follows:
    - b[ 0 ] =
    - b[ 1 ] =
    - b[ 2 ] =
  + The cross component precision ccShift is set to 16.
  + The process of clause 5.10.4 which solves the equation Ax=b in precision ccShift is invoked to obtain the 3 dimensional vector v with entries v[ 0 ], v[ 1 ] and v[ 2 ].
  + The following is applied:
    - If tSize + fPdL <= blockPos, for 0 <= i < blockSize + tSize +fPdL one sets   
      p[ i ] = (v[ 0 ]\*ref[ chIdxFirst ][ blockPos – tSize – fPdL + i ] + v[ 1 ]\* ref[ chIdxSecond ][ blockPos – tSize – fPdL + i ] + v[ 2 ]+ccShiftOffst) >> ccShift.
    - Otherwise (tSize + fPdL > blockPos), the following applies:
      * For fPdL <= i < blockSize + tSize +fPdL, one sets   
        p[ i ] = (v[ 0 ]\*ref[ chIdxFirst ][ blockPos – tSize – fPdL + i ] + v[ 1 ]\* ref[ chIdxSecond ][ blockPos – tSize – fPdL + i ] + v[ 2 ]+ccShiftOffst) >> ccShift
      * The extrapolation process to the left fom clause 8.4.2 is invoked with the input starting position fPdL, the input array size blockSize + tSize, the input array p and the extension size fPdL to obtain the values p[ i ] with 0 <= i < fPdL.
  + If cc\_pred\_filter\_flag is equal to zero, the following applies:
    - For 0 <= i < blockSize one sets pred[ i ] = Clip3( minPredVal, maxPredVal, p[ tSize +fPdL + i ] ).
    - For 0 <=i < tSize one sets   
      resiLeft[ i ] = currChTpl[ i ] – Clip3( minPredVal, maxPredVal, p[ fPdL +i ] ).
  + Otherwise (cc\_pred\_filter\_flag is not equal to zero), the following applies:
    - The extrapolation process to the right from clause 8.5.1 is invoked with input array size   
      fPdL + tSize +blockSize, input array p and extrapolation size log2FPdR to obtain the values p[ fPdL +tSize + blockSize + k ] with 0 <= k < fPdR.
    - For 0 <= i < blockSize one sets pred[ i ] = Clip3( minPredVal, maxPredVal, ).
    - For 0 <= j < tSize one sets resiLeft[ i ] = currChTpl[ i ] – Clip3( minPredVal, maxPredVal, ).

### Block matching prediction decoding process

Input to this process are:

* a variable chIdx specifying the current channel,
* a variable blockPos specifying the position of the first sample of the current block,
* a variable log2BlockSize which determines the size of the current block,
* the array of reconstructed samples of the current channel ref[ i ] with 0 < = i < blockPos.
* the parameter log2TSize which determines the size of the adjacent left residual samples to be computed.

Output of this process are the array of block matching prediction sample values pred[ i ] with 0 <= i < (1 <<log2BlockSize) and the array of adjacent left residual samples resiLeft [ j ] with 0 <= j < ( 1 << log2TSize ).

The variable maxPredVal is set to ( 1 << ( BitDepthMax – 1 ) ) – 1.

The variable minPredVal is set to – maxPredVal – 1.

The variable blockSize is set to 1 << log2BlockSize

The variable tSize is set to 1 << log2TSize.

If blockPos < blockSize, one sets pred[ i ] = 0 for all i with 0 <= i < blockSize and resiLef[ j ] = 0 for all j with 0 <= j < tSize.

Otherwise (blockPos >= blockSize), the following applies:

The variable fPdL which specifies the padding length to the left for the prediction filters of clause 7.3.3.3.2 is set to 3.

The variable log2FPdR which which determines the length to the right for the prediction filters of clause 7.3.3.3.2 is set to 2.

The variable fPdR is set to 1 << log2FPdR.

The variable fSz which specifies the filter size for the filters of clause 7.3.3.3.2 is set as fSz = fPdL + fPdR.

The variable maxBMOffMinusBS is set to min( ( 1 << 16) – 1, (1 << ( Log2MaxBlockSize + 6 ) ).

The variables offsetMinusBSFirst and blockOffsetFirst are derived as follows:

offsetMinusBSFirst =   
min(maxBMOffMinusBS, BlockMatchingPredOffsetMinusBlocksSize[ chIdx ][ 0 ])

blockOffsetFirst = min ( blockPos, blockSize + offsetMinusBSFirst ).

If bm\_pred\_mult\_hyp\_flag is equal to 1, the variables offsetMinusBSScnd and blockOffsetScnd are derived as follows:

offsetMinusBSScnd =   
min ( maxBMOffMinusBS, BlockMatchingPredOffsetMinusBlocksSize[ currCh ][ 1 ] ).

blockOffsetScnd =min( blockPos, blockSize + offsetMinusBSScnd).

If blockOffsetFirst < blockSize + fPdR or if bm\_pred\_mult\_hyp\_flag is equal to 1 and blockOffsetScnd < blockSize + fPdR , the exptrapolation process to the right from clause 8.5.1is invoked with input array size blockPos, input array ref and extension size log2FPdR to obtain the reference sample values ref[ i ] with blockPos <= i < blockPos + fPdR.

The variable minPos is set to max( 0, blockPos – maxBMOffMinusBS – blockSize ).

If blockPos – blockOffsetFirst –fPdL < minPos or if bm\_pred\_mult\_hyp\_flag is equal to 1 and   
blockPos – blockOffsetScnd –fPdL < minPos, the extrapolation process to the left from clause 8.5.2 is invoked with input starting position minPos, input array size blockPos, input array ref and extension size fPdL to obtain the reference sample values ref [ minPos – fPdL + i  ] with 0 <= i < fPdL.

The intermediate prediction sample values of the first hypothesis pFirst[ i ] with 0 <= i < blockSize are derived as follows:

* If bm\_pred\_filter\_flag[ 0 ] is equal to 0, one puts   
  pFirst[ i ] = ref[ blockPos – blockOffsetFirst +  i ].
* Otherwise ( bm\_pred\_filter\_flag[ 0 ] is not equal to 0 ), one puts   
  pFirst[ i ] =

If bm\_pred\_mult\_hyp\_flag is equal to 1, the intermediate prediction values of the second hypothesis pScnd[ i ] with 0 <= i < blockSize are derived as follows:

* If bm\_pred\_filter\_flag[ 1 ] is equal to 0, one puts pScnd[ i ] = ref[ currCh ][ blockPos– blockOffsetScnd +  i ].
* Otherwise ( bm\_pred\_filter\_flag[ 1 ] is not equal to 0 ), one puts   
  pScnd[ i ]   
  =

The extended first left prediction sample values pFirstLeftExt[ i ] with 0 <= i < tSize are derived as follows:

* If bm\_pred\_filter\_flag[ 0 ] is equal to 0, the following applies:
  + If blockPos – blockOffsetFirst –tSize < minPos – fPdL, one sets pFirstLeftExt[ i ] = 0.
  + Otherwise (blockPos – blockOffsetFirst– tSize >= minPos – fPdL ), one sets   
    pFirstLeftExt[ i ] = ref[ blockPos –tSize – blockOffsetFirst + i ] .
* Otherwise ( bm\_pred\_filter\_flag[ 0 ] is not equal to 0), the following applies:
  + If blockPos – blockOffsetFirst – tSize < minPos, one sets pFirstLeftExt[ i ] = 0.
  + Otherwise (blockPos – blockOffsetFirst – tSize >= minPos), one sets   
    pFirstLeftExt[ i ] = 6.

If bm\_pred\_mult\_hyp\_flag is equal to 1, the extended second left prediction sample values pScndLeftExt[ i ] with 0 <= i < tSize are derived as follows:

* If bm\_pred\_filter\_flag[ 1 ] is equal to 0, the following applies:
  + If blockPos – blockOffsetScnd – tSize < minPos – fPdL, one sets pScndLeftExt[ i ] = 0.
  + Otherwise (blockPos – blockOffsetScnd– tSize >= minPos – fPdL), one sets   
    pScndLeftExt[ i ] = ref[ blockPos –tSize – blockOffsetScnd + i ] .
* Otherwise ( bm\_pred\_filter\_flag[ 1 ] is not equal to 0), the following applies:
  + If blockPos – blockOffsetScnd – tSize < minPos, one sets pScndLeftExt[ i ] = 0.
  + Otherwise (blockPos – blockOffsetScnd – tSize >= minPos), one sets   
    pScndLeftExt[ i ] = 6.

The variable diffTpl is derived as follows:

* If bm\_pred\_add\_offset\_flag is equal to zero, one sets diffTpl = 0
* Otherwise if blockPos < tSize, one sets diffTpl = 0.
* Otherwise (bm\_pred\_add\_offset\_flag is not equal to zero and blockPos >= tSize), the following applies:
  + If bm\_pred\_mult\_hyp\_flag is equal to 0, one sets   
    diffTpl = .
  + Otherwise (bm\_pred\_mult\_hyp\_flag is not equal to 0), one set   
    diffTpl =

The variable offsetAdd is derived as offsetAd = ( diffTpl + ( 1 << ( log2TSize – 1 ) )) >> log2TSize.

The final block matching prediction sample values pred[ i ] with 0 <= i < blockSize are derived as follows:

* If bm\_pred\_mult\_hyp\_flag is equal to 0, one sets pred[ i ] = Clip3( minPredVal, maxPredVal, pFirst[ i ] + offsetAd ).
* Oterwise (bm\_pred\_mult\_hyp\_flag is not equal to 0), one sets   
  pred[ i ] = Clip3( minPredVal, maxPredVal, ((pFirst[ i ] + pSecond[ i ] + 1 ) >> 1 ) + offsetAd).

The final adjacent left residual sample values resiLeft[ i ] with 0 <= i < tSize are derived as follows:

* If blockPos < tSize, one sets reiLeft[ i  = 0
* Otherwise ( blockPos >= tSize ), the following applies:
  + If bm\_pred\_mult\_hyp\_flag is equal to 0, one sets   
    resiLeft[ i ] = ref[blockPos tSize + i] – Clip3( minPredVal, maxPredVal,pFirst [ i ] + offsetAd).
  + Otherwise (bm\_pred\_mult\_hyp\_flag is not equal to 0), one sets   
    resiLeft[ i ] = ref[blockPos tSize + i] – Clip3(minPredVal, maxPredVal, ((pFirst [ i ] + pSecond [ i ] + 1 ) >> 1 ) + offsetAd.

## Blockwise scaling and inverse transformation decoding process

This process specifies the computation of the reconstructed residual sample values res[ i ] with 0 <= i < blockSize.

The following steps are applied:

* The process of Clause 8.6.1 is invoked. The output of this process is assigned to the residual transform coefficients tCoeff [ i ] with 0 <= i < Log2BlockSize.
* The process of Clause 8.6.2 is invoked with the variable blockSize set to ( 1 << Log2BlockSize ) and the residual transform coefficients tCoeffCurr[ i ] set to tCoeff[ i ] for 0 <= i < ( 1 << Log2BlockSize ). The output sample values of this process are assigned to the intermediate residual values resImd[ i ] with 0 <= i < ( 1 << Log2BlockSize ).

### Scaling process for transform coefficient levels

Output of this process are the intermediate reconstructed residual transform coefficients tCoeff[ i ] with 0 <= i < (1 << Log2BlockSize).

The variable leftShiftTrigTrafo is set to be equal to 32 – BitDepthMax – dct\_headroom[ Log2BlockSize ].

The variable maxCoeffVal is set to be equal to (1<<31) – 1 and the variable minCoeffVal is set to be equal to – maxCoeffCal – 1.

The values of the variables qScale and qShift are determined as follows:

qScale = inv\_quant\_scale[ CurrBlockQP[ch] & 31 ]

qShift = 29 – ( CurrBlockQP[ch] >> 5 )

if( qShift < 0 ) {

qScale <<= –qShift

qScale = min( qScale, ( 1 << 31 ) – 1 )

qShift = 0

}

downShift = qShift – 8

if( downShift > 0 ) {

addRound = 1 << (downShift – 1 )

qScale = ( qScale + addRound ) >> downShift

qShift = 8

}

The reconstructed residual transform coefficients tCoeff[ i ] with 0 <= i < ( 1 << Log2BlockSize ) are derived as follows:

* If transform\_present\_flag is equal is not equal to 1, the following applies:
  + If qShift > 0,  
     addRound = 1 << ( qShift – 1 )  
     tCoeff[ i ] = QuantIndices[ i ] \* qScale +  
     ( QuantIndices[ i ] < 0 ? addRound – 1 : addRound ) >> qShift  
     tCoeff[ i ] = Clip3( minCoeffVal, maxCoeffVal, tCoeff[ i ] )
  + Otherwise, (qShift <= 0),  
     tCoeff[ i ] = Clip3( minCoeffVal, maxCoeffVal, tCoeff[ i ] \* ( qScale << ( –qShift ) ) )
  + Otherwise (transform\_present\_flag is equal to 1) the following applies:
  + The variable qShift is modified to qShift – leftShiftTrigTrafo + 1
  + The variable tCoeff [ i ] is determined by the following pseudo-code process:  
     if( qShift > 0 ) {  
     offset = 1 << ( qShift – 1 )  
     nextState = 0  
     for( i = last\_scan\_pos, i >= 0 , i = i – 1 ) {  
     if( QuantIndices[ i ] != 0 ) {  
     valCurr = ( Abs( QuantIndices[ i ] ) << 1) – ( nextState & 1 ) ) \* qScale )  
     valCurr = ( valCurr + offset ) >> qShift  
     tCoeff[ i ] = QuantIndices[ i ] < 0 ? Max( minCoeffVal, –valCurr ) :  
     Min( maxCoeffVal, valCurr )  
     }  
     else  
     {  
     tCoeff[ i ] = 0  
     }  
     nextState = QStateTransTabel[ nextState ][ QuantIndices[ i ] & 1 ]  
     }  
     } else {  
     nextState = 0  
     for( i = last\_scan\_pos, i >= 0 , i = i – 1 ) {  
     if( QuantIndices[ i ] != 0 ) {  
     offsetCurr = ( QuantIndices[ i ] < 0 ) ? nextState & 1 : – ( nextState & 1 )  
     valCurr =(QuantIndices[ i ] << 1) + offsetCurr ) \* qScale   
     tCoeff[ i ] = Clip3( minCoeffVal, maxCoeffVal, valCurr )  
     }  
     else  
     {  
     tCoeff[ i ] = 0  
     }  
     nextState = QStateTransTabel[ nextState ][ QuantIndices[ i ] & 1 ]  
     }  
     }

### Inverse transformation process

Input to this process are a block size bSizeCurr and reconstructed transform coefficients tCoeffCurr[ i ] with 0 <= i < bSizeCurr. Output of this process are the intermediate residual sample values resImdCurr[ i ] with 0 <= i < bSizeCurr.

The following is applied

* If transform\_present\_flag is not equal to 1, the values tCoeffCurr[ i ] are assigned to the residual samples resImd[ i ].
* Otherwise ( transform\_present\_flag is equal to 1), the following applies:
  + If transform\_dst\_flag is equal to 1, a DST-II transform process of Clause 8.8 is applied where the values tCoeffCurr[ i ] are assigned to the input of this process. The output of this process is assigned to the residual sample values resImd[ i ].
  + Otherwise ( transform\_dst\_flag is not equal to 1), the DCT-II transform process of Clause 8.8 is invoked, where the values tCoeffCurr[ i ] are assigned to the input of this process. The output of this process is assigned to the residual sample values resImd[ i ].

## Backward Adaptive Prediction

The backward adaptive prediction is based on a normalized least means squared (NLMS) prediction algorithm in the DCT domain and allows for both inter-channel and intra-channel prediction. If the NLMS is running the DCT domain the predictor runs downward in frequency if the NLMS is running in the time domain then the prediction is forward in time. The following psuedo-code specifies the NLMS inverse prediction for channel ch. The signal\_bit\_depth is needed from clause 8.3.

start = block\_length-1;

stop = -1;

inc\_dec=-1;

if(enable\_ic\_lms==1){

start\_ch = ch-32;

start\_ch =(start\_ch>0) ? start\_ch : 0;

stop\_ch = ch;

}

else{

start\_ch = 0;

stop\_ch = 0;

}

if(enable\_ar\_lms==1){

// Set lms\_order based on cgps\_lms\_order see clause 7.4.3.2

if(cgps\_lms\_order > 0){

lms\_order = (cgps\_lms\_order << log2\_block\_length)>>11;

lms\_order = (lms\_order > 4) ? lms\_order : 4;

}

else{  
 default\_lms\_order[] = {4,4,4,4,4,4,4,4,4,10,20,40};

lms\_order = default\_lms\_order[log2\_block\_length];

}

}

else{

lms\_order = 0;

}

IC\_pred\_lms\_coeff[32] = {0};

AR\_pred\_lms\_coeff[64] = {0};

buffer[64] = {0};

buffer\_pointer=0;

buffer\_mask = 63;

energy\_shift = signal\_bit\_depth – 24;

energy\_shift = (energy\_shift > 0) ? energy\_shift : 0;

buffer\_energy = 0;

done = 0;

n = start;

while(done == 0){

Coeff\_max = (1<<(19+5))-1;

Coeff\_min = 1-(1<<(19+5));

energy = 0;

accum = 0;

// Compute inter-channel prediction

for(k = start\_channel; k < stop\_channel; k ++){

accum += (int64\_t)signal[k][n] \* IC\_pred\_lms\_coeff [k];

energy += (int64\_t)(signal[k][n] >> energy\_shift);

}

//compute intra-channel predition

pointer = buffer\_pointer - 1;

iBufferPointer2 &= buffer\_mask;

for(k = 0; k < lms\_order; k ++){

accum += (int64\_t) AR\_pred\_lms\_coeff[k] \* buffer[pointer];

pointer --;

pointer &= buffer\_mask;

}

energy += buffer\_energy;

accum = (accum + (1 << (19 – 1))) >> 19;

accum = (accum < INT32\_MAX)? accum : INT32\_MAX;

accum = (accum > INT32\_MIN)? accum : INT32\_MIN;

prediction = (int32\_t)accum;

if(global\_gain > 0){

residual = InverseQuantize(residual[ch][n],global\_gain); //see clause 8.3

}

else{  
 residual = residual[ch][n];

}

//Don’t predict DC value enable\_lms\_split==0

if(n == 0 && enable\_lms\_split==0){

signal[ch][n] = residual[ch][n];

}

else{

signal[ch][n] = residual[ch][n] + prediction;

}

//compute update gain

for(accum = energy, log2\_energy = 0; accum > 0; accum >>= 1, log2\_energy ++);

log2\_energy += (energy\_shift << 1);

log2\_energy >>= 1;

round\_offset= (log2\_energy > 0) ? (1 << (log2\_energy - 1)) : 0;

gain = (int32\_t)(((((int64\_t)residual << 19) >> log2\_energy) + 2) >> 2);

gain = (gain > -(1<<17)) ? gain : -(1<<17);

gain = (gain < (1<<17)) ? gain : (1<<17);

// update inter-channel prediction coeff

for(k = start\_channel; k < stop\_channel; k ++){

accum = (int64\_t)gain \* signal[k][n];

accum += round\_offset;

accum >> log2\_energy;

IC\_pred\_lms\_coeff [k] += (int32\_t)accum;

IC\_pred\_lms\_coeff [k] = (IC\_pred\_lms\_coeff [k] > Coeff\_min) ? IC\_pred\_lms\_coeff [k]: Coeff\_min;

IC\_pred\_lms\_coeff [k] = (IC\_pred\_lms\_coeff [k] < Coeff\_max) ? IC\_pred\_lms\_coeff [k]: Coeff\_max;

}

//update intra-channel prediction coeff

pointer = buffer\_pointer - 1;

iBufferPointer2 &= buffer\_mask;

for(k = 0; k < lms\_order; k ++){

accum += (int64\_t)gain\* buffer[pointer];

accum += round\_offset;

accum >> log2\_energy;

AR\_pred\_lms\_coeff[k] += (int32\_t)accum;

AR\_pred\_lms\_coeff[k] = (AR\_pred\_lms\_coeff[k] > Coeff\_min) ? AR\_pred\_lms\_coeff[k]: Coeff\_min;

AR\_pred\_lms\_coeff[k] = (AR\_pred\_lms\_coeff[k] < Coeff\_max) ? AR\_pred\_lms\_coeff[k]:Coeff\_max;

pointer --;

pointer &= buffer\_mask;

}

//update buffer energy

pointer = buffer\_pointer -pred\_order;

pointer &= buffer\_mask;

buffer\_energy -= (int64\_t)(buffer[pointer]\* buffer[pointer]) >> energy\_shift;

buffer\_energy += (int64\_t)signal[ch][n] \* signal[ch][n] >> energy\_shift;

//update buffer

buffer[buffer\_pointer] = signal[ch][n];

buffer\_pointer ++;

buffer\_pointer &= buffer\_mask;

n += inc\_dec;

if(n == stop)

done ++;

}

If enable\_lms\_split is 1 then above psuedo-code is repeated twice for each half oft he signal. Hence the block\_length is half the actual block\_length. If the LMS predictor is operating in the DCT domain (enable\_DCT==1) and the enable\_lms\_split==0 then the DC value is not predicted. If enable\_lms\_split==1with enable\_DCT==1 then the DC value is predicted.

## IntDCT and intIDCT

The IntDCT and its inverse intIDCT are integer invertible approximations of the DCT type 2 and it’s inverse IDCT type 2 (DCT type 3). The IntDCT can support power of 2 transform lengths ranging from 16 to 2048.

In the following clauses, the DCT and IDCT will be derived from a Discrete Fourier Transform (DFT). The IntDCT and intIDCT approximations will then be explained using a similar derivation from the DFT but using lifting techniques to ensure the transforms are integer invertible.

### Derivation of the DCT and IDCT from an DFT

The forward DCT type 2 is defined by:

The inverse DCT type 2, IDCT, also known as a DCT type 3 is defined by

The DCT type 2 and its inverse can be derived from an DFT as described in [1]. The DCT derivation from a DFT can be summarized in the following steps:

Given a real sequence

1. Reorder the input to create a sequence
2. Compute a real only DFT of length () of the sequence to derive
3. Multiply by
4. The final DCT, is then given by:

The inverse DCT type 2 can similarly be derived from a DFT using the following steps:

1. Compute using lifting factorization
2. Compute a real only IDFT of length () of to derive
3. Retrieve from by reversing the shuffling in step 1 of the forward transform

The forward IntDCT and its inverse intIDCT use the same derivation but employ lifting factorization to ensure integer invertibility.

### Lifting factorization for Givens rotations

Givens rotations are central to trigonometric transforms like the DCT and the DFT. The Givens rotation can be approximated using lifting using the following factorization of the rotation matrix:

The integer approximation can be achieved by applying a rounding function prior to each addition. The 3-step lifting structure is illustrated in Figure 1. In Figure 1 the [] symbols are the rounding functions; the terms A and B are and respectively.



Figure 1 – 3-step lifting scheme to implement an integer approximation of a Given rotation.

The lifting-based approximation of the Givens rotation shown in Figure 1 can be exactly inverted by simply reversing the flow and replacing additions with subtractions.

The pseudo-code to realize the integer approximation of the Givens rotation sued the following definitions:

INT\_DCT2\_MAX\_BITS = 31

INT\_DCT2\_ROUND\_OFFSET = 1073741824

The following pseudo-code is used to implement the forward Givens rotation approximation:

RotateLift(const int iA,

const int iB,

int \*piX1,

int \*piX2)

{

INT64 iAccum;

iAccum = (INT64)iA \* (\*piX2);

\*piX1 += (int)((iAccum + INT\_DCT2\_ROUND\_OFFSET) >> INT\_DCT2\_MAX\_BITS);

iAccum = (INT64)iB \* (\*piX1);

\*piX2 += (int)((iAccum + INT\_DCT2\_ROUND\_OFFSET) >> INT\_DCT2\_MAX\_BITS);

iAccum = (INT64)iA \* (\*piX2);

\*piX1 += (int)((iAccum + INT\_DCT2\_ROUND\_OFFSET) >> INT\_DCT2\_MAX\_BITS);

}

Where, iA and iB are the lifting coefficients shown in Figure 1, and piX1 and piX2 are pointers to the integer components of a 2d vector that will be rotated.

The following pseudo-code is used to implement the inverse Givens rotation:

RotateInverseLift(const int iA,

const int iB,

int \*piX1,

int \*piX2)

{

INT64 iAccum;

iAccum = (INT64)iA \* (\*piX2);

\*piX1 -= (int)((iAccum + INT\_DCT2\_ROUND\_OFFSET) >> INT\_DCT2\_MAX\_BITS);

iAccum = (INT64)iB \* (\*piX1);

\*piX2 -= (int)((iAccum + INT\_DCT2\_ROUND\_OFFSET) >> INT\_DCT2\_MAX\_BITS);

iAccum = (INT64)iA \* (\*piX2);

\*piX1 -= (int)((iAccum + INT\_DCT2\_ROUND\_OFFSET) >> INT\_DCT2\_MAX\_BITS);

}

### Forward IntDCT

The forward integer invertible approximation of the DCT (IntDCT) uses the same steps to derive the transform as outlined in clause 8.8.1. However, the multiplication by the complex exponential (rotation) is replaced with the lifting approximation shown in clause 8.8.2.

As the underlying real only DFT approximation (see clause 8.8.9) requires additional steps for a single channel there are 2 separate implementations of the IntDCT, a 2-channel version and a single channel version. The following pseudo-code shows the forward inDCT for 2 channels. The pseudo-code uses a structure (IntDCT2Config) to contain scratch memory and pre-computed lifting coefficients. The IntDCT2Config will be detailed in clause 8.8.10.

void IntDualDCT2(IntDCT2Config \*psIntDCT2Config,

int \*piData1,

int \*piData2)

{

int n;

int iLength;

int iHalfLength;

int \*piReal1;

int \*piImag1;

int \*piReal2;

int \*piImag2;

int \*piA;

int \*piB;

iLength = psIntDCT2Config->iDCTLength;

iHalfLength = iLength >> 1;

piReal1 = psIntDCT2Config->piReal1;

piImag1 = psIntDCT2Config->piImag1;

piReal2 = psIntDCT2Config->piReal2;

piImag2 = psIntDCT2Config->piImag2;

piA = psIntDCT2Config->piA4;

piB = psIntDCT2Config->piB4;

// Shuffle

for(n = 0; n < iHalfLength; n ++){

piReal1[n] = piData1[2 \* n];

piImag1[n] = 0;

piReal1[iHalfLength + n] = piData1[iLength - 2 \* n - 1];

piImag1[iHalfLength + n] = 0;

piReal2[n] = piData2[2 \* n];

piImag2[n] = 0;

piReal2[iHalfLength + n] = piData2[iLength - 2 \* n - 1];

piImag2[iHalfLength + n] = 0;

}

LiftDualRealFFT(iLength,piReal1,piImag1,piReal2,piImag2,psIntDCT2Config);

for(n = 1; n < iHalfLength; n ++){

RotateLift(piA[n],piB[n],&piReal1[n],&piImag1[n]);

RotateLift(piA[n],piB[n],&piReal2[n],&piImag2[n]);

}

for(n = 0; n < iHalfLength + 1; n ++){

piData1[n] = piReal1[n];

piData2[n] = piReal2[n];

}

for(n = iHalfLength + 1; n < iLength; n ++){

piData1[n] = -piImag1[iLength - n];

piData2[n] = -piImag2[iLength - n];

}

}

The following pseudo-code is the IntDCT for a single channel:

void IntDCT2(IntDCT2Config \*psIntDCT2Config,

int \*piData)

{

int n;

int iLength;

int iHalfLength;

int \*piReal;

int \*piImag;

int \*piA;

int \*piB;

iLength = psIntDCT2Config->iDCTLength;

iHalfLength = iLength >> 1;

piReal = psIntDCT2Config->piReal1;

piImag = psIntDCT2Config->piImag1;

piA = psIntDCT2Config->piA4;

piB = psIntDCT2Config->piB4;

// Shuffle

for(n = 0; n < iHalfLength; n ++){

piReal[n] = piData[2 \* n];

piImag[n] = 0;

piReal[iHalfLength + n] = piData[iLength - 2 \* n - 1];

piImag[iHalfLength + n] = 0;

}

LiftRealFFT(iLength,piReal,piImag,psIntDCT2Config);

for(n = 1; n < iHalfLength; n ++){

RotateLift(piA[n],piB[n],&piReal[n],&piImag[n]);

}

for(n = 0; n < iHalfLength + 1; n ++){

piData[n] = piReal[n];

}

for(n = iHalfLength + 1; n < iLength; n ++){

piData[n] = -piImag[iLength - n];

}

}

### Inverse IntDCT (IntIDCT)

As with the forward IntDCT described in clause 8.8.3, the IntIDCT has 2 versions, a dual channel version and a single channel version. The following pseudo-code implements the IntIDCT for 2 channels:

void IntDualIDCT2(IntDCT2Config \*psIntDCT2Config,

int \*piData1,

int \*piData2)

{

int n;

int iLength;

int iHalfLength;

int \*piReal1;

int \*piImag1;

int \*piReal2;

int \*piImag2;

int \*piA;

int \*piB;

iLength = psIntDCT2Config->iDCTLength;

iHalfLength = iLength >> 1;

piReal1 = psIntDCT2Config->piReal1;

piImag1 = psIntDCT2Config->piImag1;

piReal2 = psIntDCT2Config->piReal2;

piImag2 = psIntDCT2Config->piImag2;

piA = psIntDCT2Config->piA4;

piB = psIntDCT2Config->piB4;

piReal1[0] = piData1[0];

piReal1[iHalfLength] = piData1[iHalfLength];

piReal2[0] = piData2[0];

piReal2[iHalfLength] = piData2[iHalfLength];

for(n = 1; n < iHalfLength; n ++){

piReal1[n] = piData1[n];

piImag1[n] = -piData1[iLength - n];

piReal2[n] = piData2[n];

piImag2[n] = -piData2[iLength - n];

}

for(n = 1; n < iHalfLength; n ++){

RotateInverseLift(piA[n],piB[n],&piReal1[n],&piImag1[n]);

RotateInverseLift(piA[n],piB[n],&piReal2[n],&piImag2[n]);

}

LiftDualRealIFFT(iLength,piReal1,piImag1,piReal2,piImag2,psIntDCT2Config);

for(n = 0; n < iHalfLength; n ++){

piData1[2 \* n] = piReal1[n];

piData1[iLength - 2 \* n - 1] = piReal1[iHalfLength + n];

piData2[2 \* n] = piReal2[n];

piData2[iLength - 2 \* n - 1] = piReal2[iHalfLength + n];

}

}

The following pseudo-code implements the IntIDCT for a single channel:

void IntIDCT2(IntDCT2Config \*psIntDCT2Config,

int \*piData)

{

int n;

int iLength;

int iHalfLength;

int \*piReal;

int \*piImag;

int \*piA;

int \*piB;

iLength = psIntDCT2Config->iDCTLength;

iHalfLength = iLength >> 1;

piReal = psIntDCT2Config->piReal1;

piImag = psIntDCT2Config->piImag1;

piA = psIntDCT2Config->piA4;

piB = psIntDCT2Config->piB4;

piReal[0] = piData[0];

piReal[iHalfLength] = piData[iHalfLength];

for(n = 1; n < iHalfLength; n ++){

piReal[n] = piData[n];

piImag[n] = -piData[iLength - n];

}

for(n = 1; n < iHalfLength; n ++){

RotateInverseLift(piA[n],piB[n],&piReal[n],&piImag[n]);

}

LiftRealIFFT(iLength,piReal,piImag,psIntDCT2Config);

for(n = 0; n < iHalfLength; n ++){

piData[2 \* n] = piReal[n];

piData[iLength - 2 \* n - 1] = piReal[iHalfLength + n];

}

}

### Forward IntDST

The IntDST is an integer invertible approximation of the DST type 2 and is defined by:

The IntDST can be derived in the same way as the IntDCT with minor changes to the reordering of the input in step 1 of clause 8.8.1 and the ordering of the output in step 4 of clause 8.8.1. Specifically, the reordering procedure in step 1 is redefined by

The output is then reversed relative to step 4 in clause 8.8.1, therefore, the output of the IntDST, is then given by:

The following pseudo-code implements the forward IntDST for dual channel signals:

void IntDualDST2(IntDCT2Config \*psIntDCT2Config,

int \*piData1,

int \*piData2)

{

int n;

int iLength;

int iHalfLength;

int \*piReal1;

int \*piImag1;

int \*piReal2;

int \*piImag2;

int \*piA;

int \*piB;

iLength = psIntDCT2Config->iDCTLength;

iHalfLength = iLength >> 1;

piReal1 = psIntDCT2Config->piReal1;

piImag1 = psIntDCT2Config->piImag1;

piReal2 = psIntDCT2Config->piReal2;

piImag2 = psIntDCT2Config->piImag2;

piA = psIntDCT2Config->piA4;

piB = psIntDCT2Config->piB4;

// Shuffle

for(n = 0; n < iHalfLength; n ++){

piReal1[n] = piData1[2 \* n];

piImag1[n] = 0;

piReal1[iHalfLength + n] = -piData1[iLength - 2 \* n - 1];

piImag1[iHalfLength + n] = 0;

piReal2[n] = piData2[2 \* n];

piImag2[n] = 0;

piReal2[iHalfLength + n] = -piData2[iLength - 2 \* n - 1];

piImag2[iHalfLength + n] = 0;

}

LiftDualRealFFT(iLength,piReal1,piImag1,piReal2,piImag2,psIntDCT2Config);

for(n = 1; n < iHalfLength; n ++){

RotateLift(piA[n],piB[n],&piReal1[n],&piImag1[n]);

RotateLift(piA[n],piB[n],&piReal2[n],&piImag2[n]);

}

for(n = 0; n < iHalfLength - 1; n ++){

piData1[n] = -piImag1[n + 1];

piData2[n] = -piImag2[n + 1];

}

for(n = iHalfLength - 1; n < iLength; n ++){

piData1[n] = piReal1[iLength - n - 1];

piData2[n] = piReal2[iLength - n - 1];

}

}

The following pseudo-code implements the IntDST for a single channel signal:

void IntDST2(IntDCT2Config \*psIntDCT2Config,

int \*piData)

{

int n;

int iLength;

int iHalfLength;

int \*piReal;

int \*piImag;

int \*piA;

int \*piB;

iLength = psIntDCT2Config->iDCTLength;

iHalfLength = iLength >> 1;

piReal = psIntDCT2Config->piReal1;

piImag = psIntDCT2Config->piImag1;

piA = psIntDCT2Config->piA4;

piB = psIntDCT2Config->piB4;

// Shuffle

for(n = 0; n < iHalfLength; n ++){

piReal[n] = piData[2 \* n];

piImag[n] = 0;

piReal[iHalfLength + n] = -piData[iLength - 2 \* n - 1];

piImag[iHalfLength + n] = 0;

}

LiftRealFFT(iLength,piReal,piImag,psIntDCT2Config);

for(n = 1; n < iHalfLength; n ++){

RotateLift(piA[n],piB[n],&piReal[n],&piImag[n]);

}

for(n = 0; n < iHalfLength - 1; n ++){

piData[n] = -piImag[n + 1];

}

for(n = iHalfLength - 1; n < iLength; n ++){

piData[n] = piReal[iLength - n - 1];

}

}

### Inverse IntDST (IntIDST)

As with the forward IntDST, the inverse is minor modification to the IntIDCT. Specifically, a reordering of the input and phase flip on every-other sample of the output. The following pseudo-code implements the inverse IntDST (IntIDST) for a dual channel signal:

void IntDualIDST2(IntDCT2Config \*psIntDCT2Config,

int \*piData1,

int \*piData2)

{

int n;

int iLength;

int iHalfLength;

int \*piReal1;

int \*piImag1;

int \*piReal2;

int \*piImag2;

int \*piA;

int \*piB;

iLength = psIntDCT2Config->iDCTLength;

iHalfLength = iLength >> 1;

piReal1 = psIntDCT2Config->piReal1;

piImag1 = psIntDCT2Config->piImag1;

piReal2 = psIntDCT2Config->piReal2;

piImag2 = psIntDCT2Config->piImag2;

piA = psIntDCT2Config->piA4;

piB = psIntDCT2Config->piB4;

piReal1[0] = piData1[iLength - 1];

piReal1[iHalfLength] = piData1[iHalfLength - 1];

piReal2[0] = piData2[iLength - 1];

piReal2[iHalfLength] = piData2[iHalfLength - 1];

for(n = 1; n < iHalfLength; n ++){

piReal1[n] = piData1[iLength - n - 1];

piImag1[n] = -piData1[n - 1];

piReal2[n] = piData2[iLength - n - 1];

piImag2[n] = -piData2[n - 1];

}

for(n = 1; n < iHalfLength; n ++){

RotateInverseLift(piA[n],piB[n],&piReal1[n],&piImag1[n]);

RotateInverseLift(piA[n],piB[n],&piReal2[n],&piImag2[n]);

}

LiftDualRealIFFT(iLength,piReal1,piImag1,piReal2,piImag2,psIntDCT2Config);

for(n = 0; n < iHalfLength; n ++){

piData1[2 \* n] = piReal1[n];

piData1[iLength - 2 \* n - 1] = -piReal1[iHalfLength + n];

piData2[2 \* n] = piReal2[n];

piData2[iLength - 2 \* n - 1] = -piReal2[iHalfLength + n];

}

}

The following pseudo-code implements the inverse IntDST (IntIDST) for a single channel signal:

void IntIDST2(IntDCT2Config \*psIntDCT2Config,

int \*piData)

{

int n;

int iLength;

int iHalfLength;

int \*piReal;

int \*piImag;

int \*piA;

int \*piB;

iLength = psIntDCT2Config->iDCTLength;

iHalfLength = iLength >> 1;

piReal = psIntDCT2Config->piReal1;

piImag = psIntDCT2Config->piImag1;

piA = psIntDCT2Config->piA4;

piB = psIntDCT2Config->piB4;

piReal[0] = piData[iLength - 1];

piReal[iHalfLength] = piData[iHalfLength - 1];

for(n = 1; n < iHalfLength; n ++){

piReal[n] = piData[iLength - n - 1];

piImag[n] = -piData[n - 1];

}

for(n = 1; n < iHalfLength; n ++){

RotateInverseLift(piA[n],piB[n],&piReal[n],&piImag[n]);

}

LiftRealIFFT(iLength,piReal,piImag,psIntDCT2Config);

for(n = 0; n < iHalfLength; n ++){

piData[2 \* n] = piReal[n];

piData[iLength - 2 \* n - 1] = -piReal[iHalfLength + n];

}

}

### Multi-dimensional lifting to perform dual integer invertible DFTs

In [2] the following matrix decomposition for any invertible matrix *A* is shown:

Where, is a square *n* by *n* matrix,

is a *n* by *n* identity matrix, and

0 is a *n* by *n* matrix of zeros

As all the operations are permutations and additions, then this factorization can be used to perform matrix operations using lifting. Specifically, the matrix *A* can be an orthonormal DFT, where the orthonormal DFT is defined by:

Then the inverse orthonormal DFT can be computed by simply conjugating the input prior to the DFT and then conjugating the output of the DFT. Therefore, it can be shown that 2 orthonormal integer-invertible DFTs can be computed using the multi-dimension lifting factorization using non-integer-invertible DFTs. The flow graph for computing 2 normalized integer invertible DFTs from non-integer invertible DFTs is shown in Figure 2.

Figure 2

Figure 2

Figure 2

Figure 2

Figure 2

Figure 2

Figure 2

Figure 2

Figure 2



Figure 2 – Signal flow diagram for computing 2 integer invertible DFTs.

The following pseudo-code implements the dual forward orthonormal DFTs. The pseudo-code uses a structure (FPRadix2FFTConfig) to maintain precomputed coefficients for the fixed-point DFT (see clause 8.8.10).

static void FFTLift(const int iLength,

int \*piReal1,

int \*piImag1,

int \*piReal2,

int \*piImag2,

int \*piScratchReal,

int \*piScratchImag,

FPRadix2FFTConfig \*psFPRadix2FFTConfig)

{

int n;

//conj

for(n = 0; n < iLength; n ++){

piImag2[n] = -piImag2[n];

}

for(n = 0; n < iLength; n ++){

int iSwap;

iSwap = piReal1[n];

piReal1[n] = piReal2[n];

piReal2[n] = iSwap;

iSwap = piImag1[n];

piImag1[n] = piImag2[n]; //in conj

piImag2[n] = iSwap;

piScratchReal[n] = piReal1[n];

piScratchImag[n] = -piImag1[n]; //conj inv(A)

}

// Fixed-point FFT

FPRadix2FFT(psFPRadix2FFTConfig, piScratchReal, piScratchImag);

for(n = 0; n < iLength; n ++){

piReal2[n] += piScratchReal[n];

piImag2[n] -= piScratchImag[n]; //conj inv(A)

piScratchReal[n] = piReal2[n];

piScratchImag[n] = piImag2[n];

}

// Fixed-point FFT

FPRadix2FFT(psFPRadix2FFTConfig, piScratchReal, piScratchImag);

for(n = 0; n < iLength; n ++){

piReal1[n] -= piScratchReal[n];

piImag1[n] -= piScratchImag[n];

piScratchReal[n] = piReal1[n];

piScratchImag[n] = -piImag1[n]; //conj inv(A)

}

// Fixed-point FFT

FPRadix2FFT(psFPRadix2FFTConfig, piScratchReal, piScratchImag);

for(n = 0; n < iLength; n ++){

piReal2[n] += piScratchReal[n];

piImag2[n] -= piScratchImag[n]; //conj inv(A)

piReal1[n] = -piReal1[n];

piImag1[n] = -piImag1[n];

}

// conj

for(n = 0; n < iLength; n ++){

piImag2[n] = -piImag2[n];

}

}

The following pseudo-code implements the dual inverse orthonormal DFTs:

static void IFFTLift(const int iLength,

int \*piReal1,

int \*piImag1,

int \*piReal2,

int \*piImag2,

int \*piScratchReal,

int \*piScratchImag,

FPRadix2FFTConfig \*psFPRadix2FFTConfig)

{

int n;

//Conj

for(n = 0; n < iLength; n ++){

piImag2[n] = -piImag2[n];

}

for(n = 0; n < iLength; n ++){

piReal1[n] = -piReal1[n];

piImag1[n] = -piImag1[n];

piScratchReal[n] = piReal1[n];

piScratchImag[n] = -piImag1[n]; //conj inv(A)

}

FPRadix2FFT(psFPRadix2FFTConfig, piScratchReal, piScratchImag);

for(n = 0; n < iLength; n ++){

piReal2[n] -= piScratchReal[n];

piImag2[n] += piScratchImag[n]; //conj inv(A)

piScratchReal[n] = piReal2[n];

piScratchImag[n] = piImag2[n];

}

FPRadix2FFT(psFPRadix2FFTConfig, piScratchReal, piScratchImag);

for(n = 0; n < iLength; n ++){

piReal1[n] += piScratchReal[n];

piImag1[n] += piScratchImag[n];

piScratchReal[n] = piReal1[n];

piScratchImag[n] = -piImag1[n]; //conj inv(A)

}

FPRadix2FFT(psFPRadix2FFTConfig, piScratchReal, piScratchImag);

for(n = 0; n < iLength; n ++){

int iSwap;

piReal2[n] -= piScratchReal[n];

piImag2[n] += piScratchImag[n]; //conj inv(A)

iSwap = piReal1[n];

piReal1[n] = piReal2[n];

piReal2[n] = iSwap;

iSwap = piImag1[n];

piImag1[n] = piImag2[n];

piImag2[n] = iSwap;

}

//Conj

for(n = 0; n < iLength; n ++){

piImag2[n] = -piImag2[n];

}

}

While the multi-dimensional lifting can use any DFT implementation it must be deterministic. The following pseudo-code provides the fixed-point FFT used:

void FPRadix2FFT(FPRadix2FFTConfig \*psFPRadix2FFTConfig,

int \*piReal,

int \*piImag)

{

int iFFTLength;

int iHalfFFTLength;

int iSkip;

int iFFTCounter;

int iCounter1;

int iCounter2;

int iOffset;

int \*piTwiddleReal;

int \*piTwiddleImag;

int iNorm;

int iMaxAbsValue;

int iCeilLog2MaxAbsValue;

int iShift;

int iRoundOffset;

iFFTLength = psFPRadix2FFTConfig->iFFTLength;

iHalfFFTLength = iFFTLength >> 1;

piTwiddleReal = psFPRadix2FFTConfig->piTwiddleReal;

piTwiddleImag = psFPRadix2FFTConfig->piTwiddleImag;

iNorm = psFPRadix2FFTConfig->iNorm;

iMaxAbsValue = 0;

for(iCounter1 = 0; iCounter1 < iFFTLength; iCounter1 ++){

iMaxAbsValue |= abs(piReal[iCounter1]);

iMaxAbsValue |= abs(piImag[iCounter1]);

}

for(iCeilLog2MaxAbsValue = 0; iMaxAbsValue > 0; iMaxAbsValue >>= 1){

iCeilLog2MaxAbsValue ++;

}

iShift = INT\_DCT2\_MAX\_BITS - iCeilLog2MaxAbsValue - psFPRadix2FFTConfig->iMinFFTMSB;

iShift = (iShift < 15) ? iShift : 15;

if(iShift > 0){

iRoundOffset = 1 << (iShift - 1);

}

else{

iShift = 0;

iRoundOffset = 0;

}

/\* Normalize output 1/sqrt(iFFTLength) \*/

for(iCounter1 = 0; iCounter1 < iFFTLength; iCounter1 ++){

INT64 iAccum;

piReal[iCounter1] <<= iShift;

piImag[iCounter1] <<= iShift;

iAccum = (INT64)piReal[iCounter1] \* iNorm;

piReal[iCounter1] = (int)((iAccum + INT\_DCT2\_ROUND\_OFFSET) >> INT\_DCT2\_MAX\_BITS);

iAccum = (INT64)piImag[iCounter1] \* iNorm;

piImag[iCounter1] = (int)((iAccum + INT\_DCT2\_ROUND\_OFFSET) >> INT\_DCT2\_MAX\_BITS);

}

iFFTCounter = 1;

for(iSkip = iHalfFFTLength; iSkip > 0;iSkip >>= 1){

iOffset = 0;

for(iCounter1 = 0;iCounter1 < iFFTCounter; iCounter1 ++){

int offset1;

int offset2;

int twiddle\_offset;

offset1 = iOffset;

offset2 = offset1 + iSkip;

twiddle\_offset = 0;

for(iCounter2 = 0; iCounter2 < iSkip; iCounter2 ++){

int iTemp;

iTemp = piReal[offset1];

piReal[offset1] += piReal[offset2];

piReal[offset2] = iTemp - piReal[offset2];

iTemp = piImag[offset1];

piImag[offset1] += piImag[offset2];

piImag[offset2] = iTemp - piImag[offset2];

if(iCounter2){

INT64 iAccum;

iTemp = piReal[offset2];

iAccum = (INT64)piReal[offset2] \* piTwiddleReal[twiddle\_offset] -

(INT64)piImag[offset2] \* piTwiddleImag[twiddle\_offset];

piReal[offset2] = (int)((iAccum + INT\_DCT2\_ROUND\_OFFSET) >> INT\_DCT2\_MAX\_BITS);

iAccum = (INT64)iTemp \* piTwiddleImag[twiddle\_offset] +

(INT64)piImag[offset2] \* piTwiddleReal[twiddle\_offset];

piImag[offset2] = (int)((iAccum + INT\_DCT2\_ROUND\_OFFSET) >> INT\_DCT2\_MAX\_BITS);

}

offset1 ++;

offset2 ++;

twiddle\_offset += iFFTCounter;

}

iOffset += (iSkip << 1);

}

iFFTCounter <<= 1;

}

/\*Reorder Data \*/

iCounter1 = 0;

for(iCounter2 = 0; iCounter2 < (iFFTLength - 1); iCounter2 ++){

int iCounter3;

if(iCounter2 < iCounter1){

int iTemp;

iTemp = piReal[iCounter2];

piReal[iCounter2] = piReal[iCounter1];

piReal[iCounter1] = iTemp;

iTemp = piImag[iCounter2];

piImag[iCounter2] = piImag[iCounter1];

piImag[iCounter1] = iTemp;

}

iCounter3 = iHalfFFTLength;

while(iCounter3 <= iCounter1){

iCounter1 -= iCounter3;

iCounter3 = iCounter3 >> 1;

}

iCounter1 = iCounter1 + iCounter3;

}

if(iShift > 0){

for(iCounter1 = 0; iCounter1 < iFFTLength; iCounter1 ++){

piReal[iCounter1] += iRoundOffset;

piReal[iCounter1] >>= iShift;

piImag[iCounter1] += iRoundOffset;

piImag[iCounter1] >>= iShift;

}

}

}

### Single integer invertible DFT from 2 integer invertible DFTs

For 2 channel signals the integer invertible DFTs in the previous clause can be applied to both channels, however, for single channel signals the 2 DFTs need to be combined. The well-known decimation in time technique can be used to combine 2 N/2-point DFTs requiring a complex rotation and 2-point DFT. Both the complex rotation and the 2-point DFT can be approximated using lifting steps. Combining 2 N/2-point DFTs adds additional lifting steps and therefore, reduces accuracy. Hence, for 2 channels the additional lifting steps are avoided. The following pseudo-code computes a single N-point integer invertible DFT from 2 N/2-point DFTs.

static void LiftSplitFFT(const int iLength,

int \*piReal,

int \*piImag,

IntDCT2Config \*psIntDCT2Config)

{

int n;

int k;

int iHalfLength;

int \*piScratchReal;

int \*piScratchImag;

int \*piA1;

int \*piB1;

int iA2;

int iB2;

iHalfLength = (iLength >> 1);

piScratchReal = psIntDCT2Config->piScratchReal;

piScratchImag = psIntDCT2Config->piScratchImag;

piA1 = psIntDCT2Config->piA1;

piB1 = psIntDCT2Config->piB1;

iA2 = psIntDCT2Config->iA2;

iB2 = psIntDCT2Config->iB2;

for(n = 0,k = 0; n < iHalfLength; n ++,k += 2){

piScratchReal[n] = piReal[k];

piScratchImag[n] = piImag[k];

piScratchReal[n + iHalfLength] = piReal[k + 1];

piScratchImag[n + iHalfLength] = piImag[k + 1];

}

FFTLift(iHalfLength,

piScratchReal,

piScratchImag,

&piScratchReal[iHalfLength],

&piScratchImag[iHalfLength],

piReal,

piImag,

psIntDCT2Config->psFPRadix2FFTConfig);

for(n = 0;n < iHalfLength; n ++){

int iReal1;

int iImag1;

int iReal2;

int iImag2;

iReal2 = -piScratchImag[n + iHalfLength];

iImag2 = piScratchReal[n + iHalfLength];

RotateLift(piA1[n],piB1[n],&iReal2,&iImag2);

iReal1 = piScratchReal[n];

iImag1 = piScratchImag[n];

RotateLift(iA2,iB2,&iReal1,&iReal2);

RotateLift(iA2,iB2,&iImag1,&iImag2);

piReal[n] = iReal1;

piImag[n] = iImag1;

piReal[iHalfLength + n] = iReal2;

piImag[iHalfLength + n] = iImag2;

}

}

The following pseudo-code implements a single N-point integer invertible DFT from 2 N/2-point IDFTs:

static void LiftSplitIFFT(const int iLength,

int \*piReal,

int \*piImag,

IntDCT2Config \*psIntDCT2Config)

{

int n;

int k;

int iHalfLength;

int \*piScratchReal;

int \*piScratchImag;

int \*piA1;

int \*piB1;

int iA2;

int iB2;

iHalfLength = (iLength >> 1);

piScratchReal = psIntDCT2Config->piScratchReal;

piScratchImag = psIntDCT2Config->piScratchImag;

piA1 = psIntDCT2Config->piA1;

piB1 = psIntDCT2Config->piB1;

iA2 = psIntDCT2Config->iA2;

iB2 = psIntDCT2Config->iB2;

for(n = 0;n < iHalfLength; n ++){

int iReal1;

int iImag1;

int iReal2;

int iImag2;

iReal1 = piReal[n];

iImag1 = piImag[n];

iReal2 = piReal[iHalfLength + n];

iImag2 = piImag[iHalfLength + n];

RotateInverseLift(iA2,iB2,&iReal1,&iReal2);

RotateInverseLift(iA2,iB2,&iImag1,&iImag2);

RotateInverseLift(piA1[n],piB1[n],&iReal2,&iImag2);

piScratchReal[n] = iReal1;

piScratchImag[n] = iImag1;

piScratchReal[iHalfLength + n] = iImag2;

piScratchImag[iHalfLength + n] = -iReal2;

}

IFFTLift(iHalfLength,

piScratchReal,

piScratchImag,

&piScratchReal[iHalfLength],

&piScratchImag[iHalfLength],

piReal,

piImag,

psIntDCT2Config->psFPRadix2FFTConfig);

for(n = 0,k = 0; n < iHalfLength; n ++,k += 2){

piReal[k] = piScratchReal[n];

piImag[k] = piScratchImag[n];

piReal[k + 1] = piScratchReal[iHalfLength + n];

piImag[k + 1] = piScratchImag[iHalfLength + n];

}

}

### DFT for real sequences

The appendix of [1] demonstrates the computation of a DFT for a real sequence with N samples using a N/2-point DFT. The following steps are required for computing a DFT for a real sequence:

Given a real sequence ,

1. Create a complex signal with real part are the even samples of and the imaginary part are the odd samples of :
2. Compute the -point DFT of
3. Compute from sing the following expressions:

The above equations can be mapped to Given rotations (with additional sign flips) and therefore factorized into lifting steps.

As previously described, there is an advantage of computing the integer invertible DFT on 2 channels when available. Therefore, there are 2 versions of the real integer invertible DFT, a dual channel version and single channel version. The following pseudo-code implements the forward real DFT for dual channel signals:

void LiftDualRealFFT(const int iLength,

int \*piReal1,

int \*piImag1,

int \*piReal2,

int \*piImag2,

IntDCT2Config \*psIntDCT2Config)

{

int n;

int k;

int iHalfLength;

int iQuarterLength;

int iA1;

int iB1;

int \*piA2;

int \*piB2;

int iA3;

int iB3;

int \*piScratchReal;

int \*piScratchImag;

iHalfLength = (iLength >> 1);

iQuarterLength = (iHalfLength >> 1);

iA1 = -psIntDCT2Config->iA2;

iB1 = -psIntDCT2Config->iB2;

piA2 = psIntDCT2Config->piA3;

piB2 = psIntDCT2Config->piB3;

iA3 = psIntDCT2Config->iA2;

iB3 = psIntDCT2Config->iB2;

piScratchReal = psIntDCT2Config->piScratchReal;

piScratchImag = psIntDCT2Config->piScratchImag;

for(n = 0,k = 0; n < iHalfLength; n ++,k += 2){

piReal1[n] = piReal1[k];

piImag1[n] = piReal1[k + 1];

piReal2[n] = piReal2[k];

piImag2[n] = piReal2[k + 1];

}

FFTLift( iHalfLength,

piReal1,

piImag1,

piReal2,

piImag2,

piScratchReal,

piScratchImag,

psIntDCT2Config->psFPRadix2FFTConfigDual);

for(n = 1; n < iQuarterLength; n ++){

int iReal1;

int iImag1;

int iReal2;

int iImag2;

iReal1 = piReal1[n];

iImag1 = piImag1[n];

iReal2 = piReal1[iHalfLength - n];

iImag2 = -piImag1[iHalfLength - n];

RotateLift(iA1,iB1,&iReal1,&iReal2);

RotateLift(iA1,iB1,&iImag1,&iImag2);

RotateLift(piA2[n],piB2[n],&iReal2,&iImag2);

RotateLift(iA1,iB1,&iReal1,&iReal2);

RotateLift(iA1,iB1,&iImag1,&iImag2);

piReal1[n] = iReal1;

piImag1[n] = iImag1;

piReal1[iHalfLength - n] = -iReal2;

piImag1[iHalfLength - n] = iImag2;

/\* ---- \*/

iReal1 = piReal2[n];

iImag1 = piImag2[n];

iReal2 = piReal2[iHalfLength - n];

iImag2 = -piImag2[iHalfLength - n];

RotateLift(iA1,iB1,&iReal1,&iReal2);

RotateLift(iA1,iB1,&iImag1,&iImag2);

RotateLift(piA2[n],piB2[n],&iReal2,&iImag2);

RotateLift(iA1,iB1,&iReal1,&iReal2);

RotateLift(iA1,iB1,&iImag1,&iImag2);

piReal2[n] = iReal1;

piImag2[n] = iImag1;

piReal2[iHalfLength - n] = -iReal2;

piImag2[iHalfLength - n] = iImag2;

}

piImag1[iQuarterLength] = -piImag1[iQuarterLength];

piImag2[iQuarterLength] = -piImag2[iQuarterLength];

piImag1[0] = -piImag1[0];

RotateLift(iA3,iB3,&piReal1[0],&piImag1[0]);

piImag2[0] = -piImag2[0];

RotateLift(iA3,iB3,&piReal2[0],&piImag2[0]);

piReal1[iHalfLength] = piImag1[0];

piImag1[iHalfLength] = 0;

piImag1[0] = 0;

piReal2[iHalfLength] = piImag2[0];

piImag2[iHalfLength] = 0;

piImag2[0] = 0;

}

The following pseudo-code implements the forward integer invertible real DFT for a single channel:

void LiftRealFFT(const int iLength,

int \*piReal,

int \*piImag,

IntDCT2Config \*psIntDCT2Config)

{

int n;

int k;

int iHalfLength;

int iQuarterLength;

int iA1;

int iB1;

int \*piA2;

int \*piB2;

int iA3;

int iB3;

iHalfLength = (iLength >> 1);

iQuarterLength = (iHalfLength >> 1);

iA1 = -psIntDCT2Config->iA2;

iB1 = -psIntDCT2Config->iB2;

piA2 = psIntDCT2Config->piA3;

piB2 = psIntDCT2Config->piB3;

iA3 = psIntDCT2Config->iA2;

iB3 = psIntDCT2Config->iB2;

for(n = 0,k = 0; n < iHalfLength; n ++,k += 2){

piReal[n] = piReal[k];

piImag[n] = piReal[k + 1];

}

LiftSplitFFT(iHalfLength,

piReal,

piImag,

psIntDCT2Config);

for(n = 1; n < iQuarterLength; n ++){

int iReal1;

int iImag1;

int iReal2;

int iImag2;

iReal1 = piReal[n];

iImag1 = piImag[n];

iReal2 = piReal[iHalfLength - n];

iImag2 = -piImag[iHalfLength - n];

RotateLift(iA1,iB1,&iReal1,&iReal2);

RotateLift(iA1,iB1,&iImag1,&iImag2);

RotateLift(piA2[n], piB2[n], &iReal2, &iImag2);

RotateLift(iA1,iB1,&iReal1,&iReal2);

RotateLift(iA1,iB1,&iImag1,&iImag2);

piReal[n] = iReal1;

piImag[n] = iImag1;

piReal[iHalfLength - n] = -iReal2;

piImag[iHalfLength - n] = iImag2;

}

piImag[iQuarterLength] = -piImag[iQuarterLength];

piImag[0] = -piImag[0];

RotateLift(iA3,iB3,&piReal[0],&piImag[0]);

piReal[iHalfLength] = piImag[0];

piImag[iHalfLength] = 0;

piImag[0] = 0;

}

The following pseudo-code implements the inverse integer invertible real DFT for a dual channel:

void LiftDualRealIFFT(const int iLength,

int \*piReal1,

int \*piImag1,

int \*piReal2,

int \*piImag2,

IntDCT2Config \*psIntDCT2Config)

{

int n;

int k;

int iHalfLength;

int iQuarterLength;

int iA1;

int iB1;

int \*piA2;

int \*piB2;

int iA3;

int iB3;

int \*piScratchReal;

int \*piScratchImag;

iHalfLength = (iLength >> 1);

iQuarterLength = (iHalfLength >> 1);

iA1 = psIntDCT2Config->iA2;

iB1 = psIntDCT2Config->iB2;

piA2 = psIntDCT2Config->piA3;

piB2 = psIntDCT2Config->piB3;

iA3 = -psIntDCT2Config->iA2;

iB3 = -psIntDCT2Config->iB2;

piScratchReal = psIntDCT2Config->piScratchReal;

piScratchImag = psIntDCT2Config->piScratchImag;

for(n = 1; n < iQuarterLength; n ++){

int iReal1;

int iImag1;

int iReal2;

int iImag2;

iReal1 = piReal1[n];

iImag1 = piImag1[n];

iReal2 = piReal1[iHalfLength - n];

iImag2 = -piImag1[iHalfLength - n];

RotateInverseLift(iA1,iB1,&iReal1,&iReal2);

RotateInverseLift(iA1,iB1,&iImag1,&iImag2);

RotateInverseLift(piA2[n], piB2[n], &iReal2, &iImag2);

RotateInverseLift(iA1,iB1,&iReal1,&iReal2);

RotateInverseLift(iA1,iB1,&iImag1,&iImag2);

piReal1[n] = iReal1;

piImag1[n] = iImag1;

piReal1[iHalfLength - n] = -iReal2;

piImag1[iHalfLength - n] = iImag2;

/\* --- \*/

iReal1 = piReal2[n];

iImag1 = piImag2[n];

iReal2 = piReal2[iHalfLength - n];

iImag2 = -piImag2[iHalfLength - n];

RotateInverseLift(iA1,iB1,&iReal1,&iReal2);

RotateInverseLift(iA1,iB1,&iImag1,&iImag2);

RotateInverseLift(piA2[n], piB2[n], &iReal2, &iImag2);

RotateInverseLift(iA1,iB1,&iReal1,&iReal2);

RotateInverseLift(iA1,iB1,&iImag1,&iImag2);

piReal2[n] = iReal1;

piImag2[n] = iImag1;

piReal2[iHalfLength - n] = -iReal2;

piImag2[iHalfLength - n] = iImag2;

}

piImag1[iQuarterLength] = -piImag1[iQuarterLength];

piImag1[0] = -piReal1[iHalfLength];

RotateInverseLift(iA3,iB3,&piReal1[0],&piImag1[0]);

piImag2[iQuarterLength] = -piImag2[iQuarterLength];

piImag2[0] = -piReal2[iHalfLength];

RotateInverseLift(iA3,iB3,&piReal2[0],&piImag2[0]);

IFFTLift(iHalfLength,

piReal1,

piImag1,

piReal2,

piImag2,

piScratchReal,

piScratchImag,

psIntDCT2Config->psFPRadix2FFTConfigDual);

for(n = 0; n < iHalfLength; n ++){

piImag1[iHalfLength + n] = piReal1[n];

piImag2[iHalfLength + n] = piReal2[n];

}

for(n = 0,k = 0; n < iHalfLength; n ++, k += 2){

piReal1[k] = piImag1[iHalfLength + n];

piReal1[k + 1] = piImag1[n];

piImag1[iHalfLength + n] = 0;

piImag1[n] = 0;

piReal2[k] = piImag2[iHalfLength + n];

piReal2[k + 1] = piImag2[n];

piImag2[iHalfLength + n] = 0;

piImag2[n] = 0;

}

}

The following pseudo-code implements the inverse integer invertible real DFT for a single channel:

void LiftRealIFFT(const int iLength,

int \*piReal,

int \*piImag,

IntDCT2Config \*psIntDCT2Config)

{

int n;

int k;

int iHalfLength;

int iQuarterLength;

int iA1;

int iB1;

int \*piA2;

int \*piB2;

int iA3;

int iB3;

iHalfLength = (iLength >> 1);

iQuarterLength = (iHalfLength >> 1);

iA1 = psIntDCT2Config->iA2;

iB1 = psIntDCT2Config->iB2;

piA2 = psIntDCT2Config->piA3;

piB2 = psIntDCT2Config->piB3;

iA3 = -psIntDCT2Config->iA2;

iB3 = -psIntDCT2Config->iB2;

for(n = 1; n < iQuarterLength; n ++){

int iReal1;

int iImag1;

int iReal2;

int iImag2;

iReal1 = piReal[n];

iImag1 = piImag[n];

iReal2 = piReal[iHalfLength - n];

iImag2 = -piImag[iHalfLength - n];

RotateInverseLift(iA1,iB1,&iReal1,&iReal2);

RotateInverseLift(iA1,iB1,&iImag1,&iImag2);

RotateInverseLift(piA2[n], piB2[n], &iReal2, &iImag2);

RotateInverseLift(iA1,iB1,&iReal1,&iReal2);

RotateInverseLift(iA1,iB1,&iImag1,&iImag2);

piReal[n] = iReal1;

piImag[n] = iImag1;

piReal[iHalfLength - n] = -iReal2;

piImag[iHalfLength - n] = iImag2;

}

piImag[iQuarterLength] = -piImag[iQuarterLength];

piImag[0] = -piReal[iHalfLength];

RotateInverseLift(iA3,iB3,&piReal[0],&piImag[0]);

LiftSplitIFFT(iHalfLength,

piReal,

piImag,

psIntDCT2Config);

for(n = 0; n < iHalfLength; n ++){

piImag[iHalfLength + n] = piReal[n];

}

for(n = 0,k = 0; n < iHalfLength; n ++, k += 2){

piReal[k] = piImag[iHalfLength + n];

piReal[k + 1] = piImag[n];

piImag[iHalfLength + n] = 0;

piImag[n] = 0;

}

}

### Precomputed rotations and lifting coefficients:

The pseudo-code in the previous clauses use 2 structures to encapsulate scratch memory, predefined lifting coefficients, and predefined twiddle factors. The first structure is for the fixed-point FFT (FPRadix2FFTConfig), which is defined as follows:

typedef struct FP\_RADIX\_2\_FFT\_CONFIG{

int iFFTLength;

int iNorm;

int iLog2FFTLength;

int iMinFFTMSB;

const int \*piTwiddleReal;

const int \*piTwiddleImag;

}FPRadix2FFTConfig;

The following pseudo-code creates the FPRadix2FFTConfig structure for a given FFT length, where c\_aiTwiddleReal\_\*[] and c\_aiTwiddleImag\_\*[] are defined in Annex C:

FPRadix2FFTConfig\* CreateFPRadix2FFTConfig(const int iFFTLength)

{

FPRadix2FFTConfig \*psFPRadix2FFTConfig;

psFPRadix2FFTConfig = (FPRadix2FFTConfig\*)malloc(sizeof(FPRadix2FFTConfig));

if(psFPRadix2FFTConfig){

psFPRadix2FFTConfig->iFFTLength = iFFTLength;

switch(iFFTLength){

case 4:

psFPRadix2FFTConfig->iLog2FFTLength = 2;

psFPRadix2FFTConfig->iMinFFTMSB = 1;

psFPRadix2FFTConfig->iNorm = 1073741824;

psFPRadix2FFTConfig->piTwiddleReal = c\_aiTwiddleReal\_4;

psFPRadix2FFTConfig->piTwiddleImag = c\_aiTwiddleImag\_4;

break;

case 8:

psFPRadix2FFTConfig->iLog2FFTLength = 3;

psFPRadix2FFTConfig->iMinFFTMSB = 2;

psFPRadix2FFTConfig->iNorm = 759250125;

psFPRadix2FFTConfig->piTwiddleReal = c\_aiTwiddleReal\_8;

psFPRadix2FFTConfig->piTwiddleImag = c\_aiTwiddleImag\_8;

break;

case 16:

psFPRadix2FFTConfig->iLog2FFTLength = 4;

psFPRadix2FFTConfig->iMinFFTMSB = 2;

psFPRadix2FFTConfig->iNorm = 536870912;

psFPRadix2FFTConfig->piTwiddleReal = c\_aiTwiddleReal\_16;

psFPRadix2FFTConfig->piTwiddleImag = c\_aiTwiddleImag\_16;

break;

case 32:

psFPRadix2FFTConfig->iLog2FFTLength = 5;

psFPRadix2FFTConfig->iMinFFTMSB = 3;

psFPRadix2FFTConfig->iNorm = 379625062;

psFPRadix2FFTConfig->piTwiddleReal = c\_aiTwiddleReal\_32;

psFPRadix2FFTConfig->piTwiddleImag = c\_aiTwiddleImag\_32;

break;

case 64:

psFPRadix2FFTConfig->iLog2FFTLength = 6;

psFPRadix2FFTConfig->iMinFFTMSB = 3;

psFPRadix2FFTConfig->iNorm = 268435456;

psFPRadix2FFTConfig->piTwiddleReal = c\_aiTwiddleReal\_64;

psFPRadix2FFTConfig->piTwiddleImag = c\_aiTwiddleImag\_64;

break;

case 128:

psFPRadix2FFTConfig->iLog2FFTLength = 7;

psFPRadix2FFTConfig->iMinFFTMSB = 4;

psFPRadix2FFTConfig->iNorm = 189812531;

psFPRadix2FFTConfig->piTwiddleReal = c\_aiTwiddleReal\_128;

psFPRadix2FFTConfig->piTwiddleImag = c\_aiTwiddleImag\_128;

break;

case 256:

psFPRadix2FFTConfig->iLog2FFTLength = 8;

psFPRadix2FFTConfig->iMinFFTMSB = 4;

psFPRadix2FFTConfig->iNorm = 134217728;

psFPRadix2FFTConfig->piTwiddleReal = c\_aiTwiddleReal\_256;

psFPRadix2FFTConfig->piTwiddleImag = c\_aiTwiddleImag\_256;

break;

case 512:

psFPRadix2FFTConfig->iLog2FFTLength = 9;

psFPRadix2FFTConfig->iMinFFTMSB = 5;

psFPRadix2FFTConfig->iNorm = 94906266;

psFPRadix2FFTConfig->piTwiddleReal = c\_aiTwiddleReal\_512;

psFPRadix2FFTConfig->piTwiddleImag = c\_aiTwiddleImag\_512;

break;

case 1024:

psFPRadix2FFTConfig->iLog2FFTLength = 10;

psFPRadix2FFTConfig->iMinFFTMSB = 5;

psFPRadix2FFTConfig->iNorm = 67108864;

psFPRadix2FFTConfig->piTwiddleReal = c\_aiTwiddleReal\_1024;

psFPRadix2FFTConfig->piTwiddleImag = c\_aiTwiddleImag\_1024;

break;

default:

printf("Error unsuported FFT length %d\n",iFFTLength);

}

}

return psFPRadix2FFTConfig;

}

The second structure (IntDCT2Config) is for the IntDCT/IntIDCT and IntDST/IntIDST. The structure IntDCT2Config is defined as follows:

**typedef** **struct** INT\_DCT2\_CONFIG{

**int** iDCTLength;

**const** **int** \*piA1;

**const** **int** \*piB1;

**int** iA2;

**int** iB2;

**const** **int** \*piA3;

**const** **int** \*piB3;

**const** **int** \*piA4;

**const** **int** \*piB4;

**int** \*piReal1;

**int** \*piImag1;

**int** \*piReal2;

**int** \*piImag2;

**int** \*piScratchReal;

**int** \*piScratchImag;

FPRadix2FFTConfig \*psFPRadix2FFTConfigDual;

FPRadix2FFTConfig \*psFPRadix2FFTConfig;

}IntDCT2Config;

The following pseudo-code creates the IntDCT2Config structure for a given DCT length, where c\_aiA\*\_\* and c\_aiB\*\_\* are defined in Annex C:

IntDCT2Config\* CreateIntDCT2Config(const int iDCTLength)

{

IntDCT2Config \*psIntDCT2Config;

psIntDCT2Config = (IntDCT2Config\*)malloc(sizeof(IntDCT2Config));

if(psIntDCT2Config){

int iHalfDCTLength;

int iQuarterDCTLength;

iHalfDCTLength = iDCTLength >> 1;

iQuarterDCTLength = iHalfDCTLength >> 1;

psIntDCT2Config->iDCTLength = iDCTLength;

/\* Allocate scratch memory \*/

psIntDCT2Config->piReal1 = (int\*)malloc(sizeof(int) \* iDCTLength);

psIntDCT2Config->piImag1 = (int\*)malloc(sizeof(int) \* iDCTLength);

psIntDCT2Config->piReal2 = (int\*)malloc(sizeof(int) \* iDCTLength);

psIntDCT2Config->piImag2 = (int\*)malloc(sizeof(int) \* iDCTLength);

psIntDCT2Config->piScratchReal = (int\*)malloc(sizeof(int) \* iDCTLength);

psIntDCT2Config->piScratchImag = (int\*)malloc(sizeof(int) \* iDCTLength);

psIntDCT2Config->iA2 = -889516852;

psIntDCT2Config->iB2 = 1518500249;

switch(iDCTLength){

case 16:

psIntDCT2Config->piA1 = c\_aiA1\_16;

psIntDCT2Config->piB1 = c\_aiB1\_16;

psIntDCT2Config->piA3 = c\_aiA3\_16;

psIntDCT2Config->piB3 = c\_aiB3\_16;

psIntDCT2Config->piA4 = c\_aiA4\_16;

psIntDCT2Config->piB4 = c\_aiB4\_16;

break;

case 32:

psIntDCT2Config->piA1 = c\_aiA1\_32;

psIntDCT2Config->piB1 = c\_aiB1\_32;

psIntDCT2Config->piA3 = c\_aiA3\_32;

psIntDCT2Config->piB3 = c\_aiB3\_32;

psIntDCT2Config->piA4 = c\_aiA4\_32;

psIntDCT2Config->piB4 = c\_aiB4\_32;

break;

case 64:

psIntDCT2Config->piA1 = c\_aiA1\_64;

psIntDCT2Config->piB1 = c\_aiB1\_64;

psIntDCT2Config->piA3 = c\_aiA3\_64;

psIntDCT2Config->piB3 = c\_aiB3\_64;

psIntDCT2Config->piA4 = c\_aiA4\_64;

psIntDCT2Config->piB4 = c\_aiB4\_64;

break;

case 128:

psIntDCT2Config->piA1 = c\_aiA1\_128;

psIntDCT2Config->piB1 = c\_aiB1\_128;

psIntDCT2Config->piA3 = c\_aiA3\_128;

psIntDCT2Config->piB3 = c\_aiB3\_128;

psIntDCT2Config->piA4 = c\_aiA4\_128;

psIntDCT2Config->piB4 = c\_aiB4\_128;

break;

case 256:

psIntDCT2Config->piA1 = c\_aiA1\_256;

psIntDCT2Config->piB1 = c\_aiB1\_256;

psIntDCT2Config->piA3 = c\_aiA3\_256;

psIntDCT2Config->piB3 = c\_aiB3\_256;

psIntDCT2Config->piA4 = c\_aiA4\_256;

psIntDCT2Config->piB4 = c\_aiB4\_256;

break;

case 512:

psIntDCT2Config->piA1 = c\_aiA1\_512;

psIntDCT2Config->piB1 = c\_aiB1\_512;

psIntDCT2Config->piA3 = c\_aiA3\_512;

psIntDCT2Config->piB3 = c\_aiB3\_512;

psIntDCT2Config->piA4 = c\_aiA4\_512;

psIntDCT2Config->piB4 = c\_aiB4\_512;

break;

case 1024:

psIntDCT2Config->piA1 = c\_aiA1\_1024;

psIntDCT2Config->piB1 = c\_aiB1\_1024;

psIntDCT2Config->piA3 = c\_aiA3\_1024;

psIntDCT2Config->piB3 = c\_aiB3\_1024;

psIntDCT2Config->piA4 = c\_aiA4\_1024;

psIntDCT2Config->piB4 = c\_aiB4\_1024;

break;

case 2048:

psIntDCT2Config->piA1 = c\_aiA1\_2048;

psIntDCT2Config->piB1 = c\_aiB1\_2048;

psIntDCT2Config->piA3 = c\_aiA3\_2048;

psIntDCT2Config->piB3 = c\_aiB3\_2048;

psIntDCT2Config->piA4 = c\_aiA4\_2048;

psIntDCT2Config->piB4 = c\_aiB4\_2048;

break;

default:

printf("Error: Unsupported DCT length %d\n",iDCTLength);

}

psIntDCT2Config->psFPRadix2FFTConfigDual = CreateFPRadix2FFTConfig(iHalfDCTLength);

psIntDCT2Config->psFPRadix2FFTConfig = CreateFPRadix2FFTConfig(iQuarterDCTLength);

}

return psIntDCT2Config;

}

## Inverse DCT transformation process for multiple channels

To take advantage of the reduced lifting steps by processing 2 channels simultaneously, for signals with 2 or more channels, the channels are grouped into pairs in the order that the channels appear in the signal. If the signal contains an odd number of channels, the last remaining channel uses the single channel processing. After the inverse transform, if the global\_gain > 0, then the signal needs to be right shifted (see clause 8.3 for calculation of dct\_shift).

The following pseudo-code shows the inverse DCT and shifting required to produce time domain signals.

if(enable\_DCT==1){

for(p = 0, n = 0; p < (numChannels>>1); p ++, n += 2){

IntDualIDCT2(psIntDCT2Config, signal[n], signal[n+1])

}

if(numChannels & 0x1){

IntIDCT2(psIntDCT2Config, signal[numChannels-1])

}

if(global\_gain > 0){

for(n = 0; n < numChannels; n ++){

for(k = 0; k < block\_length;k++){

signal[n][k] += (1<<(dct\_shift-1)); //see clause 8.3 for calculation of dct\_shift

signal[n][k] >> dct\_shift;

}

}

}

}

## Mean value correction process

The final step to reproduce the signal waveform is to replace any DC bias in the original signal as specified in the following pseudo-code:

for(k = 0; k < block\_length; k ++){

signal[ch][k] += MeanValueTrafoBlock;

}

## Sample wise prediction decoding process

### Overview

Input to this process are:

* the current channel index currCh,
* the current block position currBlockPos,
* the array of reconstructed samples of previous channels rec[ c ][ i ] with   
  max( currCh – ( DepChMask & currCh ), 0 ) <= c < currCh and with 0 <= i < currBlockPos + ( 1 << Log2BlockSize ),
* the array of reconstructed samples of the current channel rec[ currCh ][ i ] with 0 <= i < currBlockPos,
* the value maxTemplateSize,
* the array of left residual values resiLeftCurr[ j ] with 0 <= j < maxTemplateSize,
* the array of reconstructed intermediate residual sample values resImdCurr[ i ] with 0 <= i <   
  ( 1 << Log2BlockSize ).

Output to this process are the residual sample values res[ i ] with 0 <= i < ( 1 << Log2BlockSize ). These values are derived as follows:

* If SamplePredMoed is equal SPM\_OFF, for 0 <= i < ( 1 << Log2BlockSize ) one sets res[ i ] = resImdCurr[ i ].
* If SamplePredMode is equal to SPM\_DIFFS, the process of clause 8.11.2 is invoked with blockSize set to   
  (1 << Log2BlockSize), resiLeftVal set to resiLeftCurr[ maxTemplateSize – 1 ] and resImd set to resImdCurr .
* If SamplePredMode is equal to SPM\_SLOPE, the process of clause 8.11.3 is invoked with blockSize set to   
  (1 << Log2BlockSize), resiLeftValFirst set to resiLeftCurr[ maxTemplateSize – 1 ], resiLeftValSecond set to resiLeftCurr[ maxTemplateSize – 2 ] and resImd set to resImdCurr .
* If SamplePredMode is equal to SPM\_HALF\_SLOPE, the process of clause 8.11.4 is invoked with blockSize set to (1 << Log2BlockSize), resiLeftValFirst set to resiLeftCurr[ maxTemplateSize – 1 ], resiLeftValSecond set to resiLeftCurr[ maxTemplateSize – 2 ] and resImd set to resImdCurr .
* If SamplePredMode is equal to SPM\_LPC, the following applies:
  + The variable fltrSzCurrCh is set to 1 << (lpf\_num\_weights\_idx+1).
  + If lpc\_use\_prev\_ch\_flag is equal 1, the following applies:
    - The process from clause 8.11.6 is invoked with fSCurrCh set to fltrSzCurrCh and numPrevCh set to min( 3, currCh & DepChMask ) to obtain the filter weights for the current channel wghtCurrCh[ k ] with 0 <= k < fSCurrCh and the filter weights for the previous channel wghtPrevCh[ k ] with 0 <= k <= numPrevCh.
    - The process from clause 8.11.8 is invoked with blockSize set to (1 << Log2BlockSize), fSCurrCh set to fltrSzCurrCh, numPrevCh set to min( 3, currCh & DepChMask ), wCurrCh set to wghtCurrCh, wPrevCh set to wghtPrevCh, refPrev[ c ][ l ] set to rec[ currCh – 1 – c ][ l ], where 0 <= c < min( 3, currCh & DepChMask ) and 0 <= l < ( 1 << Log2BlockSize), resiLeft[ k ] set to resiLeftCurr[ maxTemplateSize – fltrSzCurrCh + k ] for 0 <= k < fltrSzCurrCh and resImd set to resImdCurr.
  + Otherwise (lpc\_use\_prev\_ch\_flag is not equal to 1), the following applies:
    - The process from clause 8.11.5 is invoked with fltrSz set to fltrSzCurrCh   
      to obtain the filter weights for the current channel wghtCurr[ k ] with 0 <= k < fSCurrCh.
    - The process from clause 8.11.7 is invoked with blockSize set to (1 << Log2BlockSize), fltrSz set to fltrSzCurrCh, w set to wghtCurr, resiLeft[ k ] set to resiLeftCurr[ maxTemplateSize – fltrSzCurrCh + k ] for 0 <= k < fltrSzCurrCh and resImd set to resImdCurr.

### Sample wise one tap prediction decoding process

Input to this process are:

* a variable blockSize which determines the size of the current block,
* an adjacent left residual value resiLeftVal
* an array of intermediate reconstructed residual samples resImd[ j ] with 0 <= j < blockSize.

Output of this process are the reconstructed residual samples res[ i ] with 0 <= i < blockSize.

The variable maxPredVal is set to ( 1 << ( BitDepthMax – 1 ) ) – 1.

The variable minPredVal is set to – maxPredVal – 1.

The array of input values q[ k ] with 0 <= k < blockSize + 1 is initialized with 0.

One sets q[ 0 ] = resiLeftVal

The following process is invoked:

Set j = 1

do

q[ j ] = q[ j – 1 ] + resImd[ j – 1  ]

j = j+1

while( j < blockSize + 1)

For 0 <= i < blockSize one sets res[ i ] =Clip3( minResVal, maxResVal, q[ 1 + i ] ).

### Sample wise full slope prediction decoding process

Input to this process are:

* a variable blockSize which determines the size of the current block,
* a directly adjacent left residual value resiLeftValFirst
* a penultimately adjacent left residual value resiLeftValSecond
* an array of intermediate reconstructed residual samples resImd[ j ] with 0 <= j < blockSize.

Output of this process are the reconstructed residual samples res[ i ] with 0 <= i < blockSize.

The variable maxPredVal is set to ( 1 << ( BitDepthMax – 1 ) ) – 1.

The variable minPredVal is set to – maxPredVal – 1.

The array of input values q[ k ] with 0 <= k < blockSize + 2 is initialized with 0.

One sets q[ 0 ] = resiLeftValSecond and q[ 1 ] = resiLeftValFirst.

The following process is invoked:

Set j = 2.

do

q[ j ] = ( (q[ j – 1 ] – q[ j – 2 ] ) <<1 ) + resImd[ j – 2 ].

j = j+1

while( j < blockSize + 2)

For 0 <= i < blockSize one sets res[ i ] =Clip3( minResVal, maxResVal, q[ 2 + i ] ).

### Sample wise half slope prediction decoding process

Input to this process are:

* a variable blockSize which determines the size of the current block,
* a directly adjacent left residual value resiLeftValFirst
* a penultimately adjacent left residual value resiLeftValSecond
* an array of intermediate reconstructed residual samples resImd[ j ] with 0 <= j < blockSize.

Output of this process are the reconstructed residual samples res[ i ] with 0 <= i < blockSize.

The variable maxPredVal is set to ( 1 << ( BitDepthMax – 1 ) ) – 1.

The variable minPredVal is set to – maxPredVal – 1.

The array of input values q[ k ] with 0 <= k < blockSize + 2 is initialized with 0.

One sets q[ 0 ] = resiLeftValSecond and q[ 1 ] = resiLeftValFirst.

The following process is invoked:

Set j = 2.

do

q[ j ] = q[ j – 1 ] + ( ( q[ j – 1 ] – q[ j – 2 ] +1) >> 1 ) + resImd[ j – 2 ].

j = j+1

while( j < blockSize + 2 )

For 0 <= i < blockSize one sets res[ i ] =Clip3( minResVal, maxResVal, q[ 2 + i ] ).

### Filter coefficient decoding process for single channel linear predictive filtering

Input to this process is a filter size fltrSz.

Output of this process are the reconstructed filter coefficients w[ k ] with 0 < =k < fltrSz.

The variable weightPrec is set to 14.

The intermediate temporal coefficient values tempImdCoeff[ k ] with 0 <= k < fltrSz are defined as

tempImdCoeff[ k ] =( 64 – Abs( LPFWeightsCurr[ k ] ) ) << 1.

The temporal coefficient values tempCoeff[ k ] with 0 <= k < fltrSz are defined as

tempCoeff[ k ] =( ( 1 << 14 ) – tempImdCoeff[ k ]\* tempImdCoeff[ k ] )\*

( lpf\_weight\_sign\_flag[ k ] > 0 ? – 1: 1 )

The following process is invoked:

Set i = 0

do

a[ i ] = tempCoeff[ i ]

set j = 0

do

b [ j ] = a[ j ] – tempCoeff[ i ]\*a[ i – j – 1 ]

while( j < i)

set j = 0

do

a[ j ] = b[ j ]

while ( j < i )

while( i < fltrSz )

### Filter coefficient decoding process for multi channel linear predictive filtering

Input to this process are:

* a variable fSCurrCh which specifies the number of prediction filter coefficients for the current channel,
* a variable numPrevCh which specifiec the number of previous channels.

Output of this process are the filter coeffcients for the current channel wCurrCh[ k ] with 0 <= k < fSCurrCh and the filter coefficients for the previous channel wPrevCh[ c ] with 0 <= c <= numPrevCh.

For 0 <= k < fSCurrCh, one sets wCurrCh[ k ] = LPFWeightsCurr[ fsCurrCh + numPrevCh – k ].

For 0 <= c <= numPrevCh, one sets wPrevCh[ c ] = LPFWeightsCurr[ numPrevCh – c ].

### Single channel linear predictive filtering prediction decoding process

Input to this process are:

* a variable blockSize which specifies the size of the current block,
* a variable fltrSz which specifies the number of prediction filter coefficients,
* an array of prediction filter coefficients w[ k ] with 0 <= k < fltrSz,
* an array of left adjacent residual samples resiLeft[ j ] with 0 <= j <fltrSz,
* an array of intermediate reconstructed residual samples resImd[ j ] with 0 <= j < blockSize.

Output of this process are the reconstructed residual samples res[ i ] with 0 <= i < blockSize.

The variable maxResVal is set to ( 1 << ( BitDepthMax – 1 ) ) – 1.

The variable minResVal is set to – maxPredVal – 1.

The array of input values q[ k ] with 0 <= k < blockSize + fltrSz is initialized with 0.

For 0 <= j < fltrSz one sets q[ j ] = resiLeft[ j ].

One sets leftShiftFltr = 14.

One sets offsetLeftShift = 1 << ( leftShiftFltr – 1 ).

The following process is invoked:

Set j = fltrSz.

do

q[ j ] = ( ( ( ) + offsetLeftShift) ) >>leftShiftFltr )+ resImd[ j – fltrSz ].

j = j+1

while( j < blockSize + fltrSz)

For 0 <= i < blockSize one sets res[ i ] =Clip3( minResVal, maxResVal, q[ fltrSz + i ] ).

### Multi channel linear predictive filtering prediction decoding process

Input to this process are:

* a variable blockSize which specifies the size of the current block,
* a variable fSCurrCh which specifies the number of prediction filter coefficients for the current channel,
* a variable numPrevCh, 0 < numPrevCh <= 3 which specifies the number of previous channels,
* an array of prediction filter coefficients for the current channel wCurrCh [ k ] with 0 <= k < fSCurrCh,
* an array of prediction filter coefficients for the previous channel wPrevCh[ c ] with 0 <= c <= numPrevCh,
* an arry of reconstructed sample values of previous channels refPrev[ c ][ l ], where 0 <= c < numPrevCh and   
  0 <= l < blockSize.
* an array of left adjacent residual samples resiLeft[ j ] with 0 <= j < fSCurrCh,
* an array of intermediate reconstructed residual samples resImd[ j ] with 0 <= j < blockSize.

Output of this process are the reconstructed residual samples res[ i ] with 0 <= i < blockSize.

The variable maxResVal is set to ( 1 << ( BitDepthMax – 1 ) ) – 1.

The variable minResVal is set to – maxResVal – 1.

The array of input values q[ k ] with 0 <= k < blockSize + fltrSz is initialized with 0.

For 0 <= j < fSCurrCh one sets q[ j ] = resiLeft[ j ].

One sets leftShiftFltr = 14.

One sets offsetLeftShift = 1 << ( leftShiftFltr – 1 ).

The following process is invoked:

Set j = fSCurrCh.

do

q[ j ] = ( ( ( )

+ + wPrevCh[ numPrevCh ])

+offsetLeftShift )>> leftShiftFltr) + resImd[ j – fSCurrCh ].

j = j+1

while( j < blockSize + fSCurrCh )

For 0 <= i < blockSize one sets res[ i ] =Clip3 ( minResVal, maxResVal, q[ fSCurrCh + i ] ).

# Parsing process

## General

Inputs to this process are bits from the RBSP.

Outputs of this process are syntax element values.

This process is invoked when the descriptor of a syntax element in the syntax tables is equal to ue(v), se(v), or ae(v) (see clause 9.4).

## Parsing process for escaped values

This process is invoked when the descriptor of a syntax element in the syntax tables is equal to ev(k,m,n).

Inputs to this process are bits from the RBSP and the variables k, m, n.

Outputs of this process are syntax element values.

Syntax elements coded as ev(k,m,n) are escaped-coded values that are coded with k bits, k + m bits, or k + m + n bits. The parsing process for escaped values is specified as follows:

val = read\_bits( k )  
if( val = = (1  <<  k) – 1 ) { (60)  
 addVal = read\_bits( m )  
 val += addVal  
 if( addVal = = (1  <<  m)  – 1 ) {  
 addVal = read\_bits( n )  
 val += addVal  
 }  
}

where the value returned from read\_bits( ) is interpreted as a binary representation of an unsigned integer with most significant bit written first.

The value of a syntax element coded as ev(k,m,n) is set equal to val.

## Parsing process for k-th order Exp-Golomb codes

### General

This process is invoked when the descriptor of a syntax element in the syntax tables is equal to ue(v) or se(v).

Inputs to this process are bits from the RBSP.

Outputs of this process are syntax element values.

Syntax elements coded as ue(v) or se(v) are Exp-Golomb-coded with order k equal to 0. The parsing process for these syntax elements begins with reading the bits starting at the current location in the bitstream up to and including the first non-zero bit, and counting the number of leading bits that are equal to 0. This process is specified as follows:

leadingZeroBits = −1  
for( b = 0; !b; leadingZeroBits++ ) (61)  
 b = read\_bits( 1 )

The variable codeNum is then assigned as follows:

codeNum = ( 2leadingZeroBits − 1 ) \* 2k + read\_bits( leadingZeroBits + k ) (62)

where the value returned from read\_bits( leadingZeroBits ) is interpreted as a binary representation of an unsigned integer with most significant bit written first.

Table 9‑1 illustrates the structure of the 0-th order Exp-Golomb code by separating the bit string into "prefix" and "suffix" bits. The "prefix" bits are those bits that are parsed for the computation of leadingZeroBits, and are shown as either 0 or 1 in the bit string column of Table 9‑1. The "suffix" bits are those bits that are parsed in the computation of codeNum and are shown as xi in Table 9‑1, with i in the range of 0 to leadingZeroBits − 1, inclusive. Each xi is equal to either 0 or 1.

Table 9‑1 – Bit strings with "prefix" and "suffix" bits and assignment to codeNum ranges (informative)

|  |  |
| --- | --- |
| **Bit string form** | **Range of codeNum** |
| 1 | 0 |
| 0 1 x0 | 1..2 |
| 0 0 1 x1 x0 | 3..6 |
| 0 0 0 1 x2 x1 x0 | 7..14 |
| 0 0 0 0 1 x3 x2 x1 x0 | 15..30 |
| 0 0 0 0 0 1 x4 x3 x2 x1 x0 | 31..62 |
| ... | ... |

Table 9‑2 illustrates explicitly the assignment of bit strings to codeNum values.

Table 9‑2 – Exp-Golomb bit strings and codeNum in explicit form and used as ue(v) (informative)

|  |  |
| --- | --- |
| **Bit string** | **codeNum** |
| 1 | 0 |
| 0 1 0 | 1 |
| 0 1 1 | 2 |
| 0 0 1 0 0 | 3 |
| 0 0 1 0 1 | 4 |
| 0 0 1 1 0 | 5 |
| 0 0 1 1 1 | 6 |
| 0 0 0 1 0 0 0 | 7 |
| 0 0 0 1 0 0 1 | 8 |
| 0 0 0 1 0 1 0 | 9 |
| ... | ... |

Depending on the descriptor, the value of a syntax element is derived as follows:

* If the syntax element is coded as ue(v), the value of the syntax element is equal to codeNum.
* Otherwise (the syntax element is coded as se(v)), the value of the syntax element is derived by invoking the mapping process for signed Exp-Golomb codes as specified in clause 9.3.2 with codeNum as input.

### Mapping process for signed Exp-Golomb codes

Input to this process is codeNum as specified in clause 9.3.1.

Output of this process is a value of a syntax element coded as se(v).

The syntax element is assigned to the codeNum by ordering the syntax element by its absolute value in increasing order and representing the positive value for a given absolute value with the lower codeNum. Table 9‑3 provides the assignment rule.

Table 9‑3 – Assignment of syntax element to codeNum for signed Exp-Golomb coded syntax elements se(v)

|  |  |
| --- | --- |
| **codeNum** | **syntax element value** |
| 0 | 0 |
| 1 | 1 |
| 2 | −1 |
| 3 | 2 |
| 4 | −2 |
| 5 | 3 |
| 6 | −3 |
| k | (−1)k + 1 \* Ceil( k ÷ 2 ) |

## CABAC parsing process for frame data

### General

Inputs to this process are a request for a value of a syntax element and values of prior parsed syntax elements.

Output of this process is the value of the syntax element.

The initialization process as specified in clause 9.4.2 is invoked when starting the parsing of the general frame data syntax specified in clause 7.3.3.1.

The parsing of syntax elements proceeds as follows:

For each requested value of a syntax element a binarization is derived as specified in clause 9.4.3.

The binarization for the syntax element and the sequence of parsed bins determines the decoding process flow as described in clause 9.4.4.

### Initialization process

#### General

Outputs of this process are initialized CABAC internal variables.

The context variables of the arithmetic decoding engine are initialized as follows:

– The initialization process for context variables is invoked as specified in clause 9.4.2.2.

The decoding engine registers ivlCurrRange and ivlOffset both in 16 bit register precision are initialized by invoking the initialization process for the arithmetic decoding engine as specified in clause 9.4.2.3.

#### Initialization process for context variables

Outputs of this process are the initialized CABAC context variables indexed by ctxTable and ctxIdx.

For each context variable, the three variables pBinCount, pStateIdx0 and pStateIdx1 are initialized as follows:

* Variable pBinCount is set to 63.
* Table 9‑5 to Table 9‑6 contain the values of the 12 bit variable initValue used in the initialization of context variables that are assigned to all syntax elements in clauses 7.3.3.1 through 7.3.3, except end\_of\_frame\_sequence\_flag, end\_of\_truncated\_frame\_sequence\_flag, num\_samples\_per\_channel\_to\_discard, and end\_of\_frame\_one\_bit.
* From the 12 bit table entry initValue, the two 2 bit variables qpPosProb0 and log2qpRange and the two 4 bit variables probStart and probEnd are derived as follows:

qpPosProb0 = ( 2 << ( initValue & 3 ) ) − 2  
log2qpRange = ( ( initValue >> 2 ) & 3 ) + 3  
probStart = ( ( initValue >> 4 ) & 15 ) \* 8  
probEnd = ( ( initValue >> 8 ) & 15 ) \* 8 (63)

* The variables slopeMul and valAdd, used in the initialization of context variables, are derived from probStart, probEnd and log2qpRange as follows:

slopeMul = probEnd − probStart  
valAdd = ( ( 1 << log2qpRange ) >> 1 (64)

* The two values assigned to pStateIdx0 and pStateIdx1 for the initialization are derived from cpgs\_indep\_init\_block\_qp. Given the variables m and n, the initialization is specified as follows:

currQP = ( cgps\_qp >> 1 ) − qpPosProb0  
preCtxState = ( currQP \* slopeMul + ( probStart << log2qpRange ) + add ) >> log2qpRange (65)

* The two values assigned to pStateIdx0 and pStateIdx1 for the initialization are derived as follows:

pStateIdx0 = Clip3( 32, 992, preCtxState << 3 ) − 512  
pStateIdx1 = Clip3( 256, 7936, preCtxState << 6 ) − 4096 (66)

NOTE – The variables pStateIdx0 and pStateIdx1 correspond to the probability state indices as further described in clause 9.4.4.3.

Table 9‑4 lists the range of ctxIdx values for which initialization is needed for each of the three initialization types, specified by the variable initType. It also lists the table number that includes the values of initValue needed for the initialization for each value of ctxIdx. The derivation of initType depends on the value of the cgps\_ctx\_init\_flag syntax element and on the value of the if\_ctx\_init\_mode syntax element. The variable initType is derived as follows:

if( !cgps\_ctx\_init\_flag )  
 initType = 0  
else if( if\_ctx\_init\_mode == 0 )  
 initType = 1 (67)  
else  
 initType = 2

| Table 9‑4 – Association of ctxIdx and syntax elements for each initializationType in the initialization process | | | | | |
| --- | --- | --- | --- | --- | --- |
| **Syntax structure** | **Syntax element** | **ctxTable** | **initType** | | |
| **0** | **1** | **2** |
| frame\_data( ) | block\_split\_log2 | Table XX | 0..8 | 9..17 | 18..26 |
| prediction\_trafo\_data\_block( ) | block\_matching\_or\_cross\_channel\_ pred\_flag | Table XX | 0 |  |  |
| cross\_channel\_pred\_flag | Table XX | 0 |  |  |
| block\_pred\_mode | Table XX | 0 |  |  |
| block\_abs\_delta\_qp | Table XX | 0..7 |  |  |
| block\_delta\_zlsb\_present\_flag | Table XX | 0 |  |  |
| transform\_present\_flag | Table XX | 0 |  |  |
| lms\_flag | Table XX | 0..1 |  |  |
| enable\_lms\_split | Table XX | 0 |  |  |
| enable\_ar\_lms[ ] | Table XX | 0 |  |  |
| enable\_ic\_lms[ ] | Table XX | 0 |  |  |
| cross\_channel\_ prediction\_data( ) | cc\_pred\_offset\_only\_flag | Table XX | 0 |  |  |
| cc\_pred\_filter\_flag | Table XX | 0 |  |  |
| cc\_pred\_filter\_idx | Table XX | 0 |  |  |
| cc\_pred\_mult\_hyp\_flag | Table XX | 0 |  |  |
| cc\_pred\_abs\_chd\_greater0\_flag[ ] | Table XX | 0 |  |  |
| cc\_pred\_abs\_chd\_minus1[ ] | Table XX | 0..15 |  |  |
| block\_matching\_ prediction\_data( ) | bm\_pred\_mult\_hyp\_flag | Table XX | 0 |  |  |
| bm\_pred\_add\_offset\_flag | Table XX | 0 |  |  |
| bm\_pred\_filter\_flag[ ] | Table XX | 0 |  |  |
| bm\_pred\_filter\_idx[ ] | Table XX | 0 |  |  |
| bm\_pred\_off\_pred\_prev\_ch\_flag[ ] | Table XX | 0 |  |  |
| bm\_pred\_abs\_offd\_greater0\_flag[ ] | Table XX | 0 |  |  |
| bm\_pred\_abs\_offd\_minus1[ ] | Table XX | 0..15 |  |  |
| sample\_pred\_ mode( ) | spred\_lpf\_or\_diff\_flag | Table XX | 0 |  |  |
| spred\_lpf\_flag | Table XX | 0. |  |  |
| spred\_rem\_mode\_idx | Table XX | 0. |  |  |
| linear\_predictive\_ filtering\_data( ) | lpf\_prev\_ch\_flag | Table XX | 0 |  |  |
| lpf\_delta\_coding\_flag | Table XX | 0 |  |  |
| lpf\_num\_weights\_idx | Table XX | 0..9 |  |  |
| abs\_lpf\_weight\_greater0\_flag[ ] | Table XX | 0 |  |  |
| abs\_lpf\_weight\_minus1[ ] | Table XX | 0 |  |  |
| quant\_res\_sample\_ data( ) | abs\_tskip\_coeff\_gt0\_flag[ ] | Table XXX | 0 |  |  |
| abs\_tskip\_coeff\_offset[ ] | Table XXX | 0..3 |  |  |
| abs\_tskip\_coeff\_rem\_prefix[ ] | Table XXX | 0..7 |  |  |
| abs\_tskip\_coeff\_rem\_eg0\_suffix[ ] | Table XXX | 0..30 |  |  |
| last\_pos\_index\_gt0\_flag | Table XXX | 0 |  |  |
| last\_pos\_index\_rem | Table XXX | 0..14 |  |  |
| abs\_trafo\_coeff\_gt0\_flag[ ] | Table XXX | 0..53 |  |  |
| abs\_trafo\_parity\_flag[ ] | Table XXX | 0 |  |  |
| abs\_trafo\_coeff\_offset[ ] | Table XXX | 0..8 |  |  |
| abs\_trafo\_coeff\_remainder[ ] | Table XXX | 0..30 | 31..61 | 62..92 |
| mean\_value\_trafo\_block( ) | mean\_value\_sig\_flag | Table XXX | 0 |  |  |

Table 9‑5 – Specification of initValue for ctxIdx of block\_split\_log2

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Initialization variable** | **ctxIdx of block\_split\_log2** | | | | | | | | | | | | | | | |
| **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** |
| **initValue** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | **16** | **17** | **18** | **19** | **20** | **21** | **22** | **23** | **24** | **25** | **26** |  |  |  |  |  |
| **initValue** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

Add init tables later.

Table 9‑6 – Specification of initValue for ctxIdx of abs\_trafo\_coeff\_remainder

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Initialization variable** | **ctxIdx of abs\_trafo\_coeff\_remainder** | | | | | | | | | | | | | | | | | |
| **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** | **16** | **17** |
| **initValue** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

#### Initialization process for the arithmetic decoding engine

Outputs of this process are the initialized decoding engine registers ivlCurrRange and ivlOffset both in 16 bit register precision.

The status of the arithmetic decoding engine is represented by the variables ivlCurrRange and ivlOffset. In the initialization procedure of the arithmetic decoding process, ivlCurrRange is set equal to 510 and ivlOffset is set equal to the value returned from read\_bits( 9 ) interpreted as a 9 bit binary representation of an unsigned integer with the most significant bit written first.

The bitstream shall not contain data that result in a value of ivlOffset being equal to 510 or 511.

NOTE – The description of the arithmetic decoding engine in this Specification utilizes the 16-bit register precision. However, a minimum register precision of 9 bits is required for storing the values of the variables ivlCurrRange and ivlOffset after invocation of the arithmetic decoding process (DecodeBin) as specified in clause 9.4.4.3. The arithmetic decoding process for a binary decision (DecodeDecision) as specified in clause 9.4.4.3.2 and the decoding process for a binary decision before termination (DecodeTerminate) as specified in clause 9.4.4.3.5 require a minimum register precision of 9 bits for the variables ivlCurrRange and ivlOffset. The bypass decoding process for binary decisions (DecodeBypass) as specified in clause 9.4.4.3.4 requires a minimum register precision of 10 bits for the variable ivlOffset and a minimum register precision of 9 bits for the variable ivlCurrRange.

### Binarization process

#### General

Input to this process is a request for a syntax element.

Output of this process is the binarization of the syntax element.

Table 9‑7 specifies the type of binarization process associated with each syntax element and corresponding inputs.

The specification of the truncated Rice (TR) binarization process, the un-truncated Rice binarization process (UTR), the truncated binary (TB) binarization process, the k-th order Exp-Golomb (EGk) binarization process, the limited k-th order Exp-Golomb (LEGk) binarization process, and the fixed-length (FL) binarization process are given in clauses 9.4.3.2 through 9.4.3.9, respectively.

| Table 9‑7 – Syntax elements and associated binarizations | | | |
| --- | --- | --- | --- |
| **Syntax structure** | **Syntax element** | **Binarization** | |
| **Process** | **Input parameters** |
| frame\_data( ) | end\_of\_frame\_sequence\_flag | FL | cMax = 1 |
| end\_of\_truncated\_frame\_sequence\_ flag | FL | cMax = 1 |
| end\_of\_frame\_one\_bit | FL | cMax = 1 |
| block\_split\_log2 | TR | cMax = MaxSplitDepth, cRiceParam = 0 |
| lpc\_huffman\_coding\_block( ) | mean\_mode | FL | cMax = 3 |
| abs\_mean\_value\_single\_channel | FL | cMax = ( 1 << NumMeanBits ) – 1 |
| mean\_GR\_param | FL | cMax = 15 |
| abs\_mean\_value\_multi\_channel | UTR | cRiceParam = mean\_GR\_param |
| mean\_value\_sign\_multi\_channel | FL | cMax = 1 |
| enable\_IC[n] | FL | cMax = 1 |
| ref\_channel\_IC[n] | FL | cMax = n-1 |
| pred\_gain\_IC[n] | FL | cMax = 255 |
| order\_LPC[n] | FL | cMax = 31 |
| reflection\_coeff[n][k] | FL | cMax = 255 |
| num\_regions | 9.4.3.2 | Log2BlockSize |
| reg\_cb\_zero | FL | cMax=31 |
| delta\_reg\_cb | Table A.1 |  |
| huff\_array\_signed\_sz4 | 9.4.3.2 | RegCBIdx[k] |
| huff\_array\_unsigned\_sz4 | 9.4.3.2 | RegCBIdx[k] |
| huff\_coeff\_sign | FL | cMax = 1 |
| huff\_array\_signed\_sz2 | 9.4.3.2 | RegCBIdx[k] |
| huff\_array\_unsigned\_sz2 | 9.4.3.2 | RegCBIdx[k] |
| val\_gr\_lpc\_lms | UTR | cRiceParam = RegCBIdx[k] – 9 |
| gr\_lpc\_lms\_sign\_flag | FL | cMax = 1 |
| prediction\_trafo\_data\_block ( ) |  |  |  |
| block\_matching\_or\_cross\_channel\_ pred\_flag | FL | cMax = 1 |
| cross\_channel\_pred\_flag | FL | cMax = 1 |
| block\_pred\_mode | FL | cMax =2 |
| block\_abs\_delta\_qp | LEG0 | maxPreExtLen = cgps\_max\_abs\_delta\_qp\_idx |
| block\_delta\_qp\_sign\_flag | FL | cMax = 1 |
| block\_delta\_zlsb\_present\_flag | FL | cMax = 1 |
| block\_delta\_zlsb\_sign\_flag | FL | cMax = 1 |
| transform\_present\_flag | FL | cMax = 1 |
| transform\_dst\_flag | FL | cMax = 1 |
| lms\_flag | FL | cMax = 1 |
| enable\_lms\_split | FL | cMax = 1 |
| enable\_ar\_lms[ ] | FL | cMax = 1 |
| enable\_ic\_lms[ ] | FL | cMax = 1 |
| cross\_channel\_ prediction\_data( ) | cc\_pred\_offset\_only\_flag | FL | cMax = 1 |
| cc\_pred\_filter\_flag | FL | cMax = 1 |
| cc\_pred\_filter\_idx | FL | cMax = 1 |
| cc\_pred\_mult\_hyp\_flag | FL | cMax = 1 |
| cc\_pred\_abs\_chd\_greater0\_flag[ ] | FL | cMax = 1 |
| cc\_pred\_abs\_chd\_minus1[ ] | LEG0 | maxPreExtLen = 15 |
| cc\_pred\_chd\_sign\_flag[ ] | FL | cMax = 1 |
| block\_matching\_ prediction\_data( ) | bm\_pred\_mult\_hyp\_flag | FL | cMax = 1 |
| bm\_pred\_add\_offset\_flag | FL | cMax = 1 |
| bm\_pred\_filter\_flag[ ] | FL | cMax = 1 |
| bm\_pred\_filter\_idx[ ] | FL | cMax = 1 |
| bm\_pred\_off\_pred\_prev\_ch\_flag[ ] | FL | cMax = 1 |
| bm\_pred\_abs\_offd\_greater0\_flag[ ] | FL | cMax = 1 |
| bm\_pred\_abs\_offd\_minus1[ ] | LEG0 | maxPreExtLen = 15 |
| bm\_pred\_offd\_sign\_flag[ ] | FL | cMax = 1 |
| sample\_pred\_mode( ) | spred\_lpf\_or\_diff\_flag | FL | cMax = 1 |
| spred\_lpf\_flag | FL | cMax = 1 |
| spred\_rem\_mode\_idx | FL | cMax = 2 |
| linear\_predictive\_ filtering\_data( ) | lpf\_prev\_ch\_flag | FL | cMax = 1 |
| lpf\_delta\_coding\_flag | FL | cMax = 1 |
| lpf\_num\_weights\_idx | TR | cMax = 6, cRiceParam = 1 |
| abs\_lpf\_weight\_greater0\_flag[ ] | FL | cMax = 1 |
| abs\_lpf\_weight\_minus1[ ] | 9.4.3.10 | lpf\_prev\_ch\_flag, lpf\_delta\_coding\_flag , filter coefficient index i, number of filter weights LPFNumWeightsCurr |
| lpf\_weight\_sign\_flag[ ] | FL | cMax = 1 |
| quant\_res\_sample\_ data( ) | coeff\_bypass\_value[ ] | FL | cMax = ( 1  <<  IntBitDepth ) – 1 |
| abs\_tskip\_coeff\_gt0\_flag[ ] | FL | cMax = 1 |
| abs\_tskip\_coeff\_offset[ ] | TR | cMax = NumTSkipGtxFlags, cRiceParam = 0 |
| abs\_tskip\_coeff\_rem\_prefix[ ] | TR | cMax = MaxTSkipRemPrefix, cRiceParam = 0 |
| abs\_tskip\_coeff\_rem\_fl\_suffix[ ] | FL | cMax = TSkipRiceParameter |
| abs\_tskip\_coeff\_rem\_eg0\_suffix[ ] | EG0 | - |
| tskip\_coeff\_sign\_flag[ ] | FL | cMax = 1 |
| last\_pos\_index\_gt0\_flag | FL | cMax = 1 |
| last\_pos\_index\_rem | LEG0 | maxPreExtLen = Log2BlockSize – Log2SbbSize – 1 |
| last\_pos\_index\_sign | FL | cMax = 1 |
| abs\_trafo\_coeff\_gt0\_flag[ ] | FL | cMax = 1 |
| abs\_trafo\_parity\_flag[ ] | FL | cMax = 1 |
| abs\_trafo\_coeff\_offset[ ] | TR | cMax = NumTCoeffGtxFlags, cRiceParam = 0 |
| abs\_trafo\_coeff\_remainder[ ] | EG0 | - |
| trafo\_coeff\_sign\_flag[ ] | FL | cMax = 1 |
| mean\_value\_trafo\_block | mean\_value\_sig\_flag | FL | cMax = 1 |
| mean\_value\_abs\_rem | EG0 | - |
| mean\_value\_sign\_flag | FL | cMax = 1 |

#### Binarization process for num\_regions

Input to this process is a request for a binarization of the syntax element num\_regions and then number Log2BlockSize. Output to this process is the bin-string for num\_regions.

The varialbe max\_num\_regions is derived according to Table 7‑13 Max number of regions and number of bits to read num\_regions for a given block length for Block Length = (1<<Log2BlockSize). The binarization of num\_regions is specified by invoking the fixed length binarization process as specified in Clause 9.4.3.9 with cMax = max\_num\_regions as input.

#### Huffman binarization process

Input to this process is a request for Huffman binarization and a region codebook index RegCBIdx which lies between 1 and 10, inclusively.

If RegCBIdx lies between 1 and 4, inclusively, the output of this process is the binarization associating each 4-dimensional array whose range of entries is determined by the corresponding Huffman Table Index accoring to Table 9‑8 below with a corresponding bin string.

If RegCBIdx lies between 5 and 10, inclusively, the output of this process is the binarization associating each 2-dimensional array whose range of entries is determined by the corresponding Huffman Table Index accorindg to Table 9‑8 below with a corresponding bin string.

Table 9‑8 Residual Codebook Parameters

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **RegCBIdx** | **Codebook Type** | **Golomb/Rice Parameter** | **Unsigned Codebook** | **Codebook Dimension** | **Largest Absolute Value** | **Huffman Table Index** |
| 0 | N/A | N/A | N/A | 0 | 0 | N/A |
| 1 | Huffman | N/A | 0 | 4 | 1 | Table A. 2 |
| 2 | Huffman | N/A | 0 | 4 | 1 | Table A. 3 |
| 3 | Huffman | N/A | 1 | 4 | 2 | Table A. 4 |
| 4 | Huffman | N/A | 1 | 4 | 2 | Table A. 5 |
| 5 | Huffman | N/A | 0 | 2 | 4 | Table A. 6 |
| 6 | Huffman | N/A | 0 | 2 | 4 | Table A. 7 |
| 7 | Huffman | N/A | 1 | 2 | 7 | Table A. 8 |
| 8 | Huffman | N/A | 1 | 2 | 7 | Table A. 9 |
| 9 | Huffman | N/A | 1 | 2 | 12 | Table A. 10Table A. 9 |
| 10 | Huffman | N/A | 1 | 2 | 12 | Table A. 11 |

#### Untruncated Rice binarization process

Input to this process is a request for a Untruncated Rice (UTR) binarization and cRiceParam > 0.

Output of this process is the UTR binarization associating each value symbolVal with a corresponding bin string.

A UTR bin string is a concatenation of a prefix bin string and, when present, a suffix bin string.

For the derivation of the prefix bin string, the following applies:

* The prefix value of symbolVal, prefixVal, is derived as follows:

prefixVal = symbolVal  >>  cRiceParam (68)

* The prefix of the TR bin string is specified as follows:
* The prefix bin string is a bit string of length prefixVal + 1 indexed by binIdx. The bins for binIdx less than prefixVal are equal to 1. The bin with binIdx equal to prefixVal is equal to 0. Table 9‑9 illustrates the bin strings of this unary binarization for prefixVal.

The suffix of the TR bin string is present and it is derived as follows:

* The suffix value suffixVal is derived as follows:

suffixVal = symbolVal − ( prefixVal  <<  cRiceParam ) (69)

* The suffix of the UTR bin string is specified by invoking the fixed-length (FL) binarization process as specified in clause 9.4.3.9 for suffixVal with a cMax value equal to ( 1  <<  cRiceParam ) − 1.

#### Truncated Rice binarization process

Input to this process is a request for a truncated Rice (TR) binarization, cMax and cRiceParam.

Output of this process is the TR binarization associating each value symbolVal with a corresponding bin string.

A TR bin string is a concatenation of a prefix bin string and, when present, a suffix bin string.

For the derivation of the prefix bin string, the following applies:

* The prefix value of symbolVal, prefixVal, is derived as follows:

prefixVal = symbolVal  >>  cRiceParam (70)

* The prefix of the TR bin string is specified as follows:
* If prefixVal is less than cMax  >>  cRiceParam, the prefix bin string is a bit string of length prefixVal + 1 indexed by binIdx. The bins for binIdx less than prefixVal are equal to 1. The bin with binIdx equal to prefixVal is equal to 0. Table 9‑9 illustrates the bin strings of this unary binarization for prefixVal.
* Otherwise, the bin string is a bit string of length cMax  >>  cRiceParam with all bins being equal to 1.

Table 9‑9 – Bin string of the unary binarization (informative)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **prefixVal** | **Bin string** | | | | | |
| 0 | 0 |  |  |  |  |  |
| 1 | 1 | 0 |  |  |  |  |
| 2 | 1 | 1 | 0 |  |  |  |
| 3 | 1 | 1 | 1 | 0 |  |  |
| 4 | 1 | 1 | 1 | 1 | 0 |  |
| 5 | 1 | 1 | 1 | 1 | 1 | 0 |
| ... |  |  |  |  |  |  |
| binIdx | 0 | 1 | 2 | 3 | 4 | 5 |

When cMax is greater than symbolVal and cRiceParam is greater than 0, the suffix of the TR bin string is present and it is derived as follows:

* The suffix value suffixVal is derived as follows:

suffixVal = symbolVal − ( prefixVal  <<  cRiceParam ) (71)

* The suffix of the TR bin string is specified by invoking the fixed-length (FL) binarization process as specified in clause 9.4.3.9 for suffixVal with a cMax value equal to ( 1  <<  cRiceParam ) − 1.

NOTE – For the input parameter cRiceParam = 0, the TR binarization is exactly a truncated unary binarization and it is always invoked with a cMax value equal to the largest possible value of the syntax element being decoded.

#### Truncated binary (TB) binarization process

Input to this process is a request for a TB binarization for a syntax element with value synVal and cMax. Output of this process is the TB binarization of the syntax element.The bin string of the TB binarization process of a syntax element synVal is specified as follows:

n = cMax + 1  
k = Floor( Log2( n ) ) (72)  
u = ( 1  <<  ( k + 1 ) ) − n

* If synVal is less than u, the TB bin string is derived by invoking the FL binarization process specified in clause 9.4.3.9 for synVal with a cMax value equal to ( 1  <<  k ) − 1.
* Otherwise (synVal is greater than or equal to u), the TB bin string is derived by invoking the FL binarization process specified in clause 9.4.3.9 for ( synVal + u ) with a cMax value equal to ( 1  <<  ( k + 1 ) ) − 1.

#### k-th order Exp-Golomb binarization process

Inputs to this process is a request for a k-th order Exp-Golomb (EGk) binarization.

Output of this process is the EGk binarization associating each value symbolVal with a corresponding bin string.

The bin string of the EGk binarization process for each value symbolVal is specified as follows, where each call of the function put( X ), with X being equal to 0 or 1, adds the binary value X at the end of the bin string:

absV = Abs( symbolVal )  
stopLoop = 0  
do  
 if( absV >= ( 1 << k ) ) {  
 put( 1 )  
 absV = absV − ( 1 << k )  
 k++  
 } else {  
 put( 0 ) (73)  
 while( k− − )  
 put( ( absV >> k ) & 1 )  
 stopLoop = 1  
 }  
while( !stopLoop )

NOTE – The specification for the k-th order Exp-Golomb (EGk) code uses 1s and 0s in reverse meaning for the unary part of the Exp-Golomb code of k-th order as specified in clause 9.3.

#### Limited k-th order Exp-Golomb binarization process

Inputs to this process is a request for a limited k-th order Exp-Golomb (EGk) binarization, the order k, the variables maxPreExtLen and truncSuffixLen.

Output of this process is the limited EGk binarization associating each value symbolVal with a corresponding bin string.

When truncSuffixLen is not specified as input to this process, the value of truncSuffixLen is inferred to be equal to maxPreExtLen + k.

The bin string of the limited EGk binarization process for each value symbolVal is specified as follows, where each call of the function put( X ), with X being equal to 0 or 1, adds the binary value X at the end of the bin string:

codeValue = symbolVal >> k  
preExtLen = 0  
while( ( preExtLen < maxPreExtLen ) && ( codeValue > ( ( 2 << preExtLen ) − 2 ) ) ) {  
 preExtLen++  
 put( 1 )  
}  
if( preExtLen = = maxPreExtLen ) (74)  
 escapeLength = truncSuffixLen  
else {  
 escapeLength = preExtLen + k  
 put( 0 )   
}  
symbolVal = symbolVal − ( ( ( 1 << preExtLen ) − 1 ) << k )  
while( ( escapeLength− − ) > 0 )  
 put( ( symbolVal >> escapeLength ) & 1 )

#### Fixed-length binarization process

Inputs to this process are a request for a fixed-length (FL) binarization and cMax.

Output of this process is the FL binarization associating each value symbolVal with a corresponding bin string.

FL binarization is constructed by using the fixedLength‑bit unsigned integer bin string of the symbol value symbolVal, where fixedLength = Ceil( Log2( cMax + 1 ) ). The indexing of bins for the FL binarization is such that the binIdx = 0 relates to the most significant bit with increasing values of binIdx towards the least significant bit.

#### Binarization process for abs\_lpf\_weight\_minus1

Input to this process is a request for the binarization of abs\_lpf\_weight\_minus1[ ], the number of

filter coefficients LPFNumWeightsCurr, the filter coefficient index i and the syntax elements lpf\_prev\_ch\_flag, lpf\_delta\_coding\_flag.

Output of this process is a binarization of abs\_lpf\_weight\_minus1[ i ].

The variable shiftStartVal is derived as follows:

* If lpf\_prev\_ch\_flag is equal to 0, shiftStartVal is set equal to 6.
* Otherwise ( lpf\_prev\_ch\_flag is not equal to 0 ), shiftStartVal is set equal to 13.

The variable cMax is derived as follows:

* If lpf\_prev\_ch\_flag is not equal to 0, cMax is set equal to 1<<17.
* Otherwise ( lpf\_prev\_ch\_flag is equal to 0 ), the following applies:
  + If lpf\_delta\_coding\_flag is equal to 0, cMax is set equal to 64.
  + Otherwise (lpf\_delta\_coding\_flag is not equal to 0), cMax is set equal to 128.

The variable rightShift is derived as follows:

* If lpf\_prev\_ch\_flag is equal to 0, rightShift is set equal to 2.
* Otherwise ( lpf\_prev\_ch\_flag is not equal to 0), rightShift is set to 4.

The variable cRiceParam is derived as

cRiceParam = max (2, shftStartVal - ((i + 3) >> rightShift))-1.

The binarization of abs\_lpf\_weight\_minus1[ i ] is specified by invoking the TR binarization process as specified in clause 9.4.3.2 with the variables cMax and cRiceParam as inputs.

### Decoding process flow

#### General

Inputs to this process are all bin strings of the binarization of the requested syntax element as specified in clause 9.4.3.

Output of this process is the value of the syntax element.

This process specifies how each bin of a bin string is parsed for each syntax element. After parsing each bin, the resulting bin string is compared to all bin strings of the binarization of the syntax element and the following applies:

– If the bin string is equal to one of the bin strings, the corresponding value of the syntax element is the output.

– Otherwise (the bin string is not equal to one of the bin strings), the next bit is parsed.

While parsing each bin, the variable binIdx is incremented by 1 starting with binIdx being set equal to 0 for the first bin.

The parsing of each bin is specified by the following two ordered steps:

1. The derivation process for ctxTable, ctxIdx, and bypassFlag as specified in clause 9.4.4.2 is invoked with binIdx as input and ctxTable, ctxIdx and bypassFlag as outputs.

2. The arithmetic decoding process as specified in clause 9.4.4.3 is invoked with ctxTable, ctxIdx and bypassFlag as inputs and the value of the bin as output.

#### Derivation process for ctxTable, ctxIdx and bypassFlag

##### General

Input to this process is the position of the current bin within the bin string, binIdx.

Outputs of this process are ctxTable, ctxIdx and bypassFlag.

The values of ctxTable, ctxIdx and bypassFlag are derived as follows based on the entries for binIdx of the corresponding syntax element in Table 9‑10:

* If the entry in Table 9‑10 is not equal to any of "bypass", "terminate" and "na", the values of binIdx are decoded by invoking the DecodeDecision process as specified in clause 9.4.4.3.2 and the following applies:
* ctxTable is specified in Table 9‑4
* The variable ctxInc is specified by the corresponding entry in Table 9‑10 and when more than one value is listed in Table 9‑10 for a binIdx, the assignment process for ctxInc for that binIdx is further specified in the clauses given in parenthesis.
* The variable ctxIdxOffset set equal to the smallest value of ctxIdx is specified in Table 9‑4 for the current value of initType and the current syntax element.
* ctxIdx is set equal to the sum of ctxInc and ctxIdxOffset.
* bypassFlag is set equal to 0.
* Otherwise, if the entry in Table 9‑10 is equal to "bypass", the values of binIdx are decoded by invoking the DecodeBypass process as specified in clause 9.4.4.3.4 and the following applies:
* ctxTable is set equal to 0.
* ctxIdx is set equal to 0.
* bypassFlag is set equal to 1.
* Otherwise, if the entry in Table 9‑10 is equal to "terminate", the values of binIdx are decoded by invoking the DecodeTerminate process as specified in clause 9.4.4.3.5 and the following applies:
* ctxTable is set equal to 0.
* ctxIdx is set equal to 0.
* bypassFlag is set equal to 0.
* Otherwise (the entry in Table 9‑10 is equal to "na"), the values of binIdx do not occur for the corresponding syntax element.

| Table 9‑10 – Assignment of ctxInc to syntax elements with context coded bins | | | | | | |
| --- | --- | --- | --- | --- | --- | --- |
| **Syntax element** | **binIdx** | | | | | |
| **0** | **1** | **2** | **3** | **4** | **>= 5** |
| end\_of\_frame\_sequence\_flag | terminate | na | na | na | na | na |
| block\_split\_log2 | min( binIdx, 8 ) | | | | | |
| mean\_mode | bypass | bypass | bypass | bypass | bypass | bypass |
| abs\_mean\_value\_single\_channel | bypass | bypass | bypass | bypass | bypass | bypass |
| mean\_GR\_param | bypass | bypass | bypass | bypass | bypass | bypass |
| abs\_mean\_value\_multi\_channel | bypass | bypass | bypass | bypass | bypass | bypass |
| mean\_value\_sign\_multi\_channel | bypass | na | na | na | na | na |
| enable\_IC[n] | bypass | na | na | na | na | na |
| ref\_channel\_IC[n] | bypass | bypass | bypass | bypass | bypass | bypass |
| pred\_gain\_IC[n] | bypass | bypass | bypass | bypass | bypass | bypass |
| order\_LPC[n] | bypass | bypass | bypass | bypass | bypass | bypass |
| reflection\_coeff[n][k] | bypass | bypass | bypass | bypass | bypass | bypass |
| num\_regions[n] | bypass | bypass | bypass | bypass | bypass | bypass |
| reg\_cb\_zero | bypass | bypass | bypass | bypass | bypass | bypass |
| delta\_reg\_cb | bypass | bypass | bypass | bypass | bypass | bypass |
| huff\_array\_signed\_sz4 | bypass | bypass | bypass | bypass | bypass | bypass |
| huff\_array\_unsigned\_sz4 | bypass | bypass | bypass | bypass | bypass | bypass |
| huff\_coeff\_sign | bypass | na | na | na | na | na |
| huff\_array\_signed\_sz2 | bypass | bypass | bypass | bypass | bypass | bypass |
| huff\_array\_unsigned\_sz2 | bypass | bypass | bypass | bypass | bypass | bypass |
| val\_gr\_lpc\_lms | bypass | bypass | bypass | bypass | bypass | bypass |
| gr\_lpc\_lms\_sign\_flag | bypass | na | na | na | na | na |
| block\_matching\_or\_cross\_channel\_ pred\_flag | 0 | na | na | na | na | na |
| cross\_channel\_pred\_flag | 0 | na | na | na | na | na |
| block\_pred\_mode | 0 | bypass | na | na | na | na |
| block\_abs\_delta\_qp | min( binIdx, 7 ) | | | | | |
| block\_delta\_qp\_sign\_flag | bypass | na | na | na | na | na |
| block\_delta\_zlsb\_present\_flag | 0 | na | na | na | na | na |
| block\_delta\_zlsb\_sign\_flag | bypass | na | na | na | na | na |
| transform\_present\_flag | 0 | na | na | na | na | na |
| transform\_dst\_flag | bypass | na | na | na | na | na |
| lms\_flag | 0..1  (clause 9.4.4.2.2) | na | na | na | na | na |
| enable\_lms\_split | 0 | na | na | na | na | na |
| enable\_ar\_lms[ ] | 0 | na | na | na | na | na |
| enable\_ic\_lms[ ] | 0 | na | na | na | na | na |
| end\_of\_truncated\_frame\_sequence\_ flag | terminate | na | na | na | na | na |
| end\_of\_frame\_one\_bit | terminate | na | na | na | na | na |
| cc\_pred\_offset\_only\_flag | 0 | na | na | na | na | na |
| cc\_pred\_filter\_flag | 0 | na | na | na | na | na |
| cc\_pred\_filter\_idx | 0 | na | na | na | na | na |
| cc\_pred\_mult\_hyp\_flag | 0 | na | na | na | na | na |
| cc\_pred\_abs\_chd\_greater0\_flag[ ] | 0 | na | na | na | na | na |
| cc\_pred\_abs\_chd\_minus1[ ] (if the bin with binIdx is part of the prefix code of the limited EG0 binarization) | min( binIdx, 15 ) | | | | | |
| cc\_pred\_abs\_chd\_minus1[ ] (if the bin with binIdx is part of the fixed-length suffix code of the limited EG0 binarization) | bypass | bypass | bypass | bypass | bypass | bypass |
| cc\_pred\_chd\_sign\_flag[ ] | bypass | na | na | na | na | na |
| bm\_pred\_mult\_hyp\_flag | 0 | na | na | na | na | na |
| bm\_pred\_add\_offset\_flag | 0 | nan | nan | nan | nan | nan |
| bm\_pred\_filter\_flag[ ] | 0 | na | na | na | na | na |
| bm\_pred\_filter\_idx[ ] | 0 | na | na | na | na | na |
| bm\_pred\_off\_pred\_prev\_ch\_flag[ ] | 0 | na | na | na | na | na |
| bm\_pred\_abs\_offd\_greater0\_flag[ ] | 0 | na | na | na | na | na |
| bm\_pred\_abs\_offd\_minus1[ ] (if the bin with binIdx is part of the prefix code of the limited EG0 binarization) | min( binIdx, 15 ) | | | | | |
| bm\_pred\_abs\_offd\_minus1[ ] (if the bin with binIdx is part of the fixed-length suffix code of the limited EG0 binarization) | bypass | bypass | bypass | bypass | bypass | bypass |
| bm\_pred\_offd\_sign\_flag[ ] | na | na | na | na | na | na |
| spred\_lpf\_or\_diff\_flag | 0 | Na | na | na | na | na |
| spred\_lpf\_flag | 0 | Na | na | na | na | na |
| spred\_rem\_mode\_idx | 0 | bypass | na | na | na | na |
| lpf\_prev\_ch\_flag | 0 | na | na | na | na | na |
| lpf\_delta\_coding\_flag | 0 | na | na | na | na | na |
| lpf\_num\_weights\_idx | 0 | 1 if bin at index 0 is equal to 1, otherwise bypass | bypass | bypass | na | na |
| abs\_lpf\_weight\_greater0\_flag[ ] | 0 | na | na | na | na | na |
| abs\_lpf\_weight\_minus1[ ] (if the bin with binIdx is part of the fixed length suffix code of the Truncated Rice binarization) | min( binIdx, 9 ) | | | | | |
| abs\_lpf\_weight\_minus1[ ] (if the bin with binIdx is part of the fixed length suffix code of the Truncated Rice binarization) | bypass | bypass | bypass | bypass | bypass | bypass |
| lpf\_weight\_sign\_flag[ ] | bypass | na | na | na | na | na |
| coeff\_bypass\_value[ ] | bypass | bypass | bypass | bypass | bypass | bypass |
| abs\_tskip\_coeff\_gt0\_flag[ ] | 0 | na | na | na | na | na |
| abs\_tskip\_coeff\_offset[ ] | Min( binIdx, NumTSkipGtxFlags ) | | | | | |
| abs\_tskip\_coeff\_rem\_prefix[ ] | Min( binIdx, MaxTSkipRemPrefix ) | | | | | |
| abs\_tskip\_coeff\_rem\_fl\_suffix[ ] | bypass | bypass | bypass | bypass | bypass | bypass |
| abs\_tskip\_coeff\_rem\_eg0\_suffix[ ] (if the bin with binIdx is part of the unary prefix code of the EG0 binarization) | Min( binIdx, 30 ) | | | | | |
| abs\_tskip\_coeff\_rem\_eg0\_suffix[ ] (if the bin with binIdx is part of the fixed-length suffiox code of the EG0 binarization) | bypass | bypass | bypass | bypass | bypass | bypass |
| tskip\_coeff\_sign\_flag[ ] | bypass | na | na | na | na | na |
| last\_pos\_index\_gt0\_flag | 0 | na | na | na | na | Na |
| last\_pos\_index\_rem (if the bin with binIdx is part of the unary prefix code of the limited EG0 binarization)s | Min( binIdx, 14 ) | | | | | |
| last\_pos\_index\_sign | bypass | | | | | |
| abs\_trafo\_coeff\_gt0\_flag[ ] | 0..53 (clause 9.4.4.2.3) | na | na | na | na | na |
| abs\_trafo\_parity\_flag | 0 | na | na | na | na | na |
| abs\_trafo\_coeff\_offset[ ] | 0..8 (clause 9.4.4.2.4) | | | | | |
| abs\_trafo\_coeff\_remainder[ ] (if the bin with binIdx is part of the unary prefix code of the EG0 binarization) | Min( binIdx, 30 ) | | | | | |
| abs\_trafo\_coeff\_remainder[ ] (if the bin with binIdx is part of the fixed-length suffiox code of the EG0 binarization) | bypass | bypass | bypass | bypass | bypass | bypass |
| trafo\_coeff\_sign\_flag[ ] | bypass | na | na | na | na | na |
| mean\_value\_sig\_flag | 0 | na | na | na | na | na |
| mean\_value\_abs\_rem | bypass | bypass | bypass | bypass | bypass | bypass |
| mean\_value\_sign\_flag | bypass | na | na | na | na | na |

##### Derivation process of ctxInc for the syntax element lms\_flag

Output of this process is the variable ctxInc.

If block\_matching\_or\_cross\_channel\_pred\_flag is equal to 1 and cross\_channel\_pred\_flag is equal to 0, ctxInc is set equal to 0. Otherwise ( block\_matching\_or\_cross\_channel\_pred\_flag is equal to 0 or cross\_channel\_pred\_flag is equal to 1), ctxInc is set equal to 1.

##### Derivation process of ctxInc for the syntax element abs\_trafo\_coeff\_gt0\_flag

Inputs to this process is the location k of the current quantization index.

Output of this process is the variable ctxInc.

The variable templateClass is derived as specified by the following pseudo-code:

templateSum = 0 (75)  
for( n = k + 1; n < Min( NumQuantIndices – 1, k + 4 ; n = n + 1 )  
 templateSum += Abs( QuantIndices[ n ] )  
templateClass = Min( 2, templateSum )

The variable posClass is derived as specified by the following pseudo-code:

posThresholds[ ] = { 0, 1, 2, 3, 7, 11, 15, 23 } (76)  
posClass = 0  
for( n = 0; n < 8 ; n = n + 1 )  
 if( k > posThresholds[ n ] )  
 posClass += 1

The variable ctxInc is derived by

ctxInc = 27 \* ( QState & 1 ) + 3 \* posClass + templateClass (77)

##### Derivation process of ctxInc for the syntax element abs\_trafo\_coeff\_offset

Inputs is the location k of the current quantization index.

Output of this process is the variable ctxInc.

The variable posClass is derived as specified by the following pseudo-code:

posThresholds[ ] = { 0, 1, 2, 3, 7, 11, 15, 23 } (78)  
posClass = 0  
for( n = 0; n < 8 ; n = n + 1 )  
 if( k > posThresholds[ n ] )  
 posClass += 1

The variable ctxInc is set equal to posClass.

#### Arithmetic decoding process

##### General

Inputs to this process are ctxTable, ctxIdx, and bypassFlag, as derived in clause 9.4.4.2, and the state variables ivlCurrRange and ivlOffset of the arithmetic decoding engine.

Output of this process is the value of the bin.

Figure 3 illustrates the whole arithmetic decoding process for a single bin. For decoding the value of a bin, the context index table ctxTable, the ctxIdx and the bypassFlag are passed to the arithmetic decoding process DecodeBin( ctxTable, ctxIdx, bypassFlag ), which is specified as follows:

– If bypassFlag is equal to 1, DecodeBypass( ) as specified in clause 9.4.4.3.4 is invoked.

– Otherwise, if bypassFlag is equal to 0, ctxTable is equal to 0, and ctxIdx is equal to 0, DecodeTerminate( ) as specified in clause 9.4.4.3.5 is invoked.

– Otherwise (bypassFlag is equal to 0 and ctxTable is not equal to 0), DecodeDecision( ctxTable, ctxIdx ) as specified in clause 9.4.4.3.2 is invoked.

Diagram

Description automatically generated

Figure 3 – Flowchart of the arithmetic decoding process for a single bin (informative)

NOTE – Arithmetic coding is based on the principle of recursive interval subdivision. Given a probability estimation p( 0 ) and p( 1 ) = 1 − p( 0 ) of a binary decision ( 0, 1 ), an initially given code sub-interval with the range ivlCurrRange would be subdivided into two sub-intervals having range p( 0 ) \* ivlCurrRange and ivlCurrRange − p( 0 ) \* ivlCurrRange, respectively. Depending on the decision, which has been observed, the corresponding sub-interval would be chosen as the new code interval, and a binary code string pointing into that interval would represent the sequence of observed binary decisions. It is useful to distinguish between the most probable symbol(MPS) and the least probable symbol(LPS), so that the binary decisions have to be identified as either MPS or LPS, rather than 0 or 1. Given this terminology, each context is specified by the probability pLPS of the LPS and the value of MPS (valMps), which is either 0 or 1. The arithmetic core engine in this Specification has the following two distinct properties:

– The range ivlCurrRange representing the state of the coding engine and the probability estimate are quantized to reduced-precision values to allow for a reduced-precision multiplication to determine the product ivlCurrRange and the probability estimate.

– For syntax elements or parts thereof for which an approximately uniform probability distribution is assumed to be given a separate simplified encoding and decoding bypass process is used.

##### Arithmetic decoding process for a binary decision

###### General

Inputs to this process are the variables ctxTable, ctxIdx, ivlCurrRange, and ivlOffset.

Outputs of this process are the decoded value binVal, and the updated variables ivlCurrRange and ivlOffset.

1. The value of the variable ivlLpsRange is derived as follows:

– Given the current value of ivlCurrRange, the variable qRangeIdx is derived as follows:

qRangeIdx = ( ivlCurrRange − 256 ) >> 5 (79)

– Given qRangeIdx, pStateIdx0 and pStateIdx1 associated with ctxTable and ctxIdx, valMps and ivlLpsRange are derived as follows:

rangeTabLps[ ][ ] =  
{  
 { 128, 142, 156, 171, 185, 199, 213, 228 }, { 112, 125, 137, 150, 162, 175, 187, 200 },  
 { 97, 108, 119, 130, 141, 152, 163, 174 }, { 84, 93, 103, 112, 121, 131, 140, 150 },  
 { 74, 82, 90, 99, 107, 115, 123, 132 }, { 65, 72, 79, 87, 94, 101, 108, 116 },  
 { 57, 63, 70, 76, 82, 89, 95, 102 }, { 50, 56, 61, 67, 73, 78, 84, 90 },  
 { 45, 50, 55, 60, 65, 70, 75, 80 }, { 39, 43, 48, 52, 56, 61, 65, 70 },  
 { 34, 38, 42, 46, 50, 54, 58, 62 }, { 30, 33, 37, 40, 43, 47, 50, 54 },  
 { 27, 30, 33, 36, 39, 42, 45, 48 }, { 23, 26, 28, 31, 34, 36, 39, 42 },  
 { 20, 22, 24, 27, 29, 31, 33, 36 }, { 18, 20, 22, 24, 26, 28, 30, 32 },  
 { 15, 17, 19, 21, 22, 24, 26, 28 }, { 14, 16, 17, 19, 21, 22, 24, 26 },  
 { 12, 13, 15, 16, 17, 19, 20, 22 }, { 11, 12, 13, 15, 16, 17, 18, 20 },  
 { 10, 11, 12, 13, 14, 15, 16, 18 }, { 9, 10, 11, 12, 13, 14, 15, 16 },  
 { 7, 8, 9, 10, 11, 12, 13, 14 }, { 7, 8, 9, 10, 11, 12, 13, 14 },  
 { 5, 6, 6, 7, 8, 8, 9, 10 }, { 5, 6, 6, 7, 8, 8, 9, 10 },  
 { 4, 5, 5, 6, 6, 7, 7, 8 }, { 4, 5, 5, 6, 6, 7, 7, 8 },  
 { 3, 3, 4, 4, 4, 5, 5, 6 }, { 3, 3, 4, 4, 4, 5, 5, 6 },  
 { 2, 2, 2, 3, 3, 3, 3, 4 }, { 2, 2, 2, 3, 3, 3, 3, 4 }  
}  
pState = ( pStateIdx1 + 8 \* pStateIdx0 ) >> 8  
valMps = pState >= 0 ? 1 : 0  
ivlLpsRange = rangeTabLps[ Abs( pState ) ][ qRangeIdx ] (80)

1. The variable ivlCurrRange is set equal to ivlCurrRange − ivlLpsRange and the following applies:

– If ivlOffset is greater than or equal to ivlCurrRange, the variable binVal is set equal to 1 − valMps, ivlOffset is decremented by ivlCurrRange, and ivlCurrRange is set equal to ivlLpsRange.

– Otherwise, the variable binVal is set equal to valMps.

Given the value of binVal, the state transition isperformed as specified in clause 9.4.4.3.2.2. Depending on the current value of ivlCurrRange, renormalization is performed as specified in clause 9.4.4.3.3.

###### State transition process

Inputs to this process are the current pBinCount, pStateIdx0, and pStateIdx1, and the decoded value binVal.

Outputs of this process are the updated pBinCount , pStateIdx0, and pStateIdx1 of the context variable associated with ctxTable and ctxIdx.

Depending on the decoded value binVal, the update of the three variables pBinCount, pStateIdx0, and pStateIdx1 associated with ctxTable and ctxIdx is derived as follows:

transitionTable[ ] =  
{  
 157, 143, 129, 115, 101, 87, 73, 59, 45, 35, 29, 23, 17, 13, 9, 5,  
 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 0  
}  
signVal = 2 \* binVal − 1  
if( pBinCount > 0) {  
 pStateIdx0 += signVal \* ( transitionTable[ 16 + ( ( signVal \* pStateIdx0 ) >> 5 ) ] << 1 )  
 pStateIdx1 = pStateIdx0 << 3  
 pBinCount− −  
} else {

pStateIdx0 += signVal \* transitionTable[ 16 + ( ( signVal \* pStateIdx0 ) >> 5 ) ]  
 pStateIdx1 += signVal \* transitionTable[ 16 + ( ( signVal \* pStateIdx1 ) >> 8 ) ]  
}

##### Renormalization process in the arithmetic decoding engine

Inputs to this process are bits from slice data and the variables ivlCurrRange and ivlOffset.

Outputs of this process are the updated variables ivlCurrRange and ivlOffset.

A flowchart of the renormalization is shown in Figure 4. The current value of ivlCurrRange is first compared to 256 and further steps are specified as follows:

– If ivlCurrRange is greater than or equal to 256, no renormalization is needed and the RenormD process is finished;

– Otherwise (ivlCurrRange is less than 256), the renormalization loop is entered. Within this loop, the value of ivlCurrRange is doubled, i.e., left-shifted by 1 and a single bit is shifted into ivlOffset by using read\_bits( 1 ).

The bitstream shall not contain data that result in a value of ivlOffset being greater than or equal to ivlCurrRange upon completion of this process.

A close up of text on a black background

Description automatically generated

Figure 4 – Flowchart of renormalization

##### Bypass decoding process for binary decisions

Inputs to this process are bits from slice data and the variables ivlCurrRange and ivlOffset.

Outputs of this process are the updated variable ivlOffset and the decoded value binVal.

The bypass decoding process is invoked when bypassFlag is equal to 1. Figure 5 shows a flowchart of the corresponding process.

First, the value of ivlOffset is doubled, i.e., left-shifted by 1 and a single bit is shifted into ivlOffset by using read\_bits( 1 ). Then, the value of ivlOffset is compared to the value of ivlCurrRange and further steps are specified as follows:

– If ivlOffset is greater than or equal to ivlCurrRange, the variable binVal is set equal to 1 and ivlOffset is decremented by ivlCurrRange.

– Otherwise (ivlOffset is less than ivlCurrRange), the variable binVal is set equal to 0*.*

The bitstream shall not contain data that result in a value of ivlOffset being greater than or equal to ivlCurrRange upon completion of this process.

A close up of a logo

Description automatically generated

Figure 5 – Flowchart of bypass decoding process

##### Decoding process for binary decisions before termination

Inputs to this process are bits from slice data and the variables ivlCurrRange and ivlOffset.

Outputs of this process are the updated variables ivlCurrRange and ivlOffset, and the decoded value binVal.

This decoding process applies to decoding of end\_of\_frame\_sequence\_flag, end\_of\_truncated\_frame\_sequence\_flag, and end\_of\_frame\_one\_bit corresponding to ctxTable equal to 0 and ctxIdx equal to 0. Figure 6 shows the flowchart of the corresponding decoding process, which is specified as follows:

First, the value of ivlCurrRange is decremented by 2. Then, the value of ivlOffset is compared to the value of ivlCurrRange and further steps are specified as follows:

– If ivlOffset is greater than or equal to ivlCurrRange, the variable binVal is set equal to 1, no renormalization is carried out, and CABAC decoding is terminated. The last bit inserted in register ivlOffset is equal to 1. When decoding end\_of\_slice\_one\_bit, this last bit inserted in register ivlOffset is interpreted as rbsp\_stop\_one\_bit. When decoding end\_of\_tile\_one\_bit or end\_of\_subset\_one\_bit, this last bit inserted in register ivlOffset is interpreted as byte\_alignment\_bit\_equal\_to\_one.

– Otherwise (ivlOffset is less than ivlCurrRange), the variable binVal is set equal to 0 and renormalization is performed as specified in clause 9.4.4.3.3.

NOTE – This procedure could also be implemented using DecodeDecision( ctxTable, ctxIdx, bypassFlag ) with ctxTable = 0, ctxIdx = 0 and bypassFlag = 0. In the case where the decoded value is equal to 1, 7 more bits would be read by DecodeDecision( ctxTable, ctxIdx, bypassFlag ) and a decoding process would have to adjust its bitstream pointer accordingly to properly decode following syntax elements.

A screenshot of a cell phone

Description automatically generated

Figure 6 – Flowchart of decoding a decision before termination

1. Huffman Codebook Tables for LMS LPC Coding Block

Table A. 1 - Region Codebook Selection Delta Huffman Codebook

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Index** | **Length** | **Codeword** | **Index** | **Length** | **Codeword** |
| 0 | 16 | 0x0000 | 23 | 4 | 0x0001 |
| 1 | 16 | 0x0001 | 24 | 3 | 0x0003 |
| 2 | 16 | 0x0002 | 25 | 7 | 0x0001 |
| 3 | 16 | 0x0003 | 26 | 6 | 0x0003 |
| 4 | 16 | 0x0004 | 27 | 9 | 0x0002 |
| 5 | 16 | 0x0005 | 28 | 9 | 0x0003 |
| 6 | 16 | 0x0006 | 29 | 13 | 0x0004 |
| 7 | 16 | 0x0007 | 30 | 13 | 0x0005 |
| 8 | 16 | 0x0008 | 31 | 16 | 0x000E |
| 9 | 16 | 0x0009 | 32 | 16 | 0x000F |
| 10 | 16 | 0x000A | 33 | 16 | 0x0010 |
| 11 | 16 | 0x000B | 34 | 16 | 0x0011 |
| 12 | 16 | 0x000C | 35 | 16 | 0x0012 |
| 13 | 16 | 0x000D | 36 | 16 | 0x0013 |
| 14 | 14 | 0x0007 | 37 | 16 | 0x0014 |
| 15 | 12 | 0x0003 | 38 | 16 | 0x0015 |
| 16 | 10 | 0x0001 | 39 | 16 | 0x0016 |
| 17 | 9 | 0x0001 | 40 | 16 | 0x0017 |
| 18 | 6 | 0x0001 | 41 | 16 | 0x0018 |
| 19 | 6 | 0x0002 | 42 | 16 | 0x0019 |
| 20 | 3 | 0x0001 | 43 | 16 | 0x001A |
| 21 | 3 | 0x0002 | 44 | 16 | 0x001B |
| 22 | 1 | 0x0001 | 45 | 0 | 0x0009 |

Table A. 2 - Residual Huffman Codebook 1

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Index | Length | Codeword | w | x | y | z |
| 0 | 9 | 0x000B | -1 | -1 | -1 | -1 |
| 1 | 9 | 0x000C | -1 | -1 | -1 | 0 |
| 2 | 12 | 0x0000 | -1 | -1 | -1 | 1 |
| 3 | 10 | 0x0004 | -1 | -1 | 0 | -1 |
| 4 | 7 | 0x0008 | -1 | -1 | 0 | 0 |
| 5 | 10 | 0x0005 | -1 | -1 | 0 | 1 |
| 6 | 12 | 0x0001 | -1 | -1 | 1 | -1 |
| 7 | 10 | 0x0006 | -1 | -1 | 1 | 0 |
| 8 | 11 | 0x0004 | -1 | -1 | 1 | 1 |
| 9 | 10 | 0x0007 | -1 | 0 | -1 | -1 |
| 10 | 7 | 0x0009 | -1 | 0 | -1 | 0 |
| 11 | 10 | 0x0008 | -1 | 0 | -1 | 1 |
| 12 | 7 | 0x000A | -1 | 0 | 0 | -1 |
| 13 | 5 | 0x0008 | -1 | 0 | 0 | 0 |
| 14 | 7 | 0x000B | -1 | 0 | 0 | 1 |
| 15 | 9 | 0x000D | -1 | 0 | 1 | -1 |
| 16 | 7 | 0x000C | -1 | 0 | 1 | 0 |
| 17 | 10 | 0x0009 | -1 | 0 | 1 | 1 |
| 18 | 11 | 0x0005 | -1 | 1 | -1 | -1 |
| 19 | 8 | 0x000D | -1 | 1 | -1 | 0 |
| 20 | 9 | 0x000E | -1 | 1 | -1 | 1 |
| 21 | 9 | 0x000F | -1 | 1 | 0 | -1 |
| 22 | 7 | 0x000D | -1 | 1 | 0 | 0 |
| 23 | 9 | 0x0010 | -1 | 1 | 0 | 1 |
| 24 | 11 | 0x0006 | -1 | 1 | 1 | -1 |
| 25 | 10 | 0x000A | -1 | 1 | 1 | 0 |
| 26 | 12 | 0x0002 | -1 | 1 | 1 | 1 |
| 27 | 9 | 0x0011 | 0 | -1 | -1 | -1 |
| 28 | 7 | 0x000E | 0 | -1 | -1 | 0 |
| 29 | 10 | 0x000B | 0 | -1 | -1 | 1 |
| 30 | 7 | 0x000F | 0 | -1 | 0 | -1 |
| 31 | 5 | 0x0009 | 0 | -1 | 0 | 0 |
| 32 | 7 | 0x0010 | 0 | -1 | 0 | 1 |
| 33 | 9 | 0x0012 | 0 | -1 | 1 | -1 |
| 34 | 7 | 0x0011 | 0 | -1 | 1 | 0 |
| 35 | 10 | 0x000C | 0 | -1 | 1 | 1 |
| 36 | 7 | 0x0012 | 0 | 0 | -1 | -1 |
| 37 | 5 | 0x000A | 0 | 0 | -1 | 0 |
| 38 | 7 | 0x0013 | 0 | 0 | -1 | 1 |
| 39 | 5 | 0x000B | 0 | 0 | 0 | -1 |
| 40 | 1 | 0x0001 | 0 | 0 | 0 | 0 |
| 41 | 5 | 0x000C | 0 | 0 | 0 | 1 |
| 42 | 7 | 0x0014 | 0 | 0 | 1 | -1 |
| 43 | 5 | 0x000D | 0 | 0 | 1 | 0 |
| 44 | 7 | 0x0015 | 0 | 0 | 1 | 1 |
| 45 | 10 | 0x000D | 0 | 1 | -1 | -1 |
| 46 | 7 | 0x0016 | 0 | 1 | -1 | 0 |
| 47 | 8 | 0x000E | 0 | 1 | -1 | 1 |
| 48 | 7 | 0x0017 | 0 | 1 | 0 | -1 |
| 49 | 5 | 0x000E | 0 | 1 | 0 | 0 |
| 50 | 7 | 0x0018 | 0 | 1 | 0 | 1 |
| 51 | 10 | 0x000E | 0 | 1 | 1 | -1 |
| 52 | 7 | 0x0019 | 0 | 1 | 1 | 0 |
| 53 | 9 | 0x0013 | 0 | 1 | 1 | 1 |
| 54 | 12 | 0x0003 | 1 | -1 | -1 | -1 |
| 55 | 10 | 0x000F | 1 | -1 | -1 | 0 |
| 56 | 11 | 0x0007 | 1 | -1 | -1 | 1 |
| 57 | 9 | 0x0014 | 1 | -1 | 0 | -1 |
| 58 | 7 | 0x001A | 1 | -1 | 0 | 0 |
| 59 | 10 | 0x0010 | 1 | -1 | 0 | 1 |
| 60 | 9 | 0x0015 | 1 | -1 | 1 | -1 |
| 61 | 8 | 0x000F | 1 | -1 | 1 | 0 |
| 62 | 12 | 0x0004 | 1 | -1 | 1 | 1 |
| 63 | 10 | 0x0011 | 1 | 0 | -1 | -1 |
| 64 | 7 | 0x001B | 1 | 0 | -1 | 0 |
| 65 | 9 | 0x0016 | 1 | 0 | -1 | 1 |
| 66 | 7 | 0x001C | 1 | 0 | 0 | -1 |
| 67 | 5 | 0x000F | 1 | 0 | 0 | 0 |
| 68 | 7 | 0x001D | 1 | 0 | 0 | 1 |
| 69 | 9 | 0x0017 | 1 | 0 | 1 | -1 |
| 70 | 7 | 0x001E | 1 | 0 | 1 | 0 |
| 71 | 10 | 0x0012 | 1 | 0 | 1 | 1 |
| 72 | 12 | 0x0005 | 1 | 1 | -1 | -1 |
| 73 | 10 | 0x0013 | 1 | 1 | -1 | 0 |
| 74 | 12 | 0x0006 | 1 | 1 | -1 | 1 |
| 75 | 10 | 0x0014 | 1 | 1 | 0 | -1 |
| 76 | 7 | 0x001F | 1 | 1 | 0 | 0 |
| 77 | 10 | 0x0015 | 1 | 1 | 0 | 1 |
| 78 | 12 | 0x0007 | 1 | 1 | 1 | -1 |
| 79 | 9 | 0x0018 | 1 | 1 | 1 | 0 |
| 80 | 9 | 0x0019 | 1 | 1 | 1 | 1 |

Table A. 3 - Residual Huffman Codebook 2

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Index** | **Length** | **Codeword** | **w** | **x** | **y** | **z** |
| 0 | 8 | 0x0006 | -1 | -1 | -1 | -1 |
| 1 | 7 | 0x000E | -1 | -1 | -1 | 0 |
| 2 | 9 | 0x0000 | -1 | -1 | -1 | 1 |
| 3 | 8 | 0x0007 | -1 | -1 | 0 | -1 |
| 4 | 6 | 0x000E | -1 | -1 | 0 | 0 |
| 5 | 8 | 0x0008 | -1 | -1 | 0 | 1 |
| 6 | 9 | 0x0001 | -1 | -1 | 1 | -1 |
| 7 | 8 | 0x0009 | -1 | -1 | 1 | 0 |
| 8 | 9 | 0x0002 | -1 | -1 | 1 | 1 |
| 9 | 8 | 0x000A | -1 | 0 | -1 | -1 |
| 10 | 6 | 0x000F | -1 | 0 | -1 | 0 |
| 11 | 7 | 0x000F | -1 | 0 | -1 | 1 |
| 12 | 6 | 0x0010 | -1 | 0 | 0 | -1 |
| 13 | 5 | 0x0013 | -1 | 0 | 0 | 0 |
| 14 | 6 | 0x0011 | -1 | 0 | 0 | 1 |
| 15 | 7 | 0x0010 | -1 | 0 | 1 | -1 |
| 16 | 6 | 0x0012 | -1 | 0 | 1 | 0 |
| 17 | 8 | 0x000B | -1 | 0 | 1 | 1 |
| 18 | 9 | 0x0003 | -1 | 1 | -1 | -1 |
| 19 | 7 | 0x0011 | -1 | 1 | -1 | 0 |
| 20 | 7 | 0x0012 | -1 | 1 | -1 | 1 |
| 21 | 7 | 0x0013 | -1 | 1 | 0 | -1 |
| 22 | 6 | 0x0013 | -1 | 1 | 0 | 0 |
| 23 | 7 | 0x0014 | -1 | 1 | 0 | 1 |
| 24 | 9 | 0x0004 | -1 | 1 | 1 | -1 |
| 25 | 8 | 0x000C | -1 | 1 | 1 | 0 |
| 26 | 9 | 0x0005 | -1 | 1 | 1 | 1 |
| 27 | 8 | 0x000D | 0 | -1 | -1 | -1 |
| 28 | 6 | 0x0014 | 0 | -1 | -1 | 0 |
| 29 | 8 | 0x000E | 0 | -1 | -1 | 1 |
| 30 | 6 | 0x0015 | 0 | -1 | 0 | -1 |
| 31 | 5 | 0x0014 | 0 | -1 | 0 | 0 |
| 32 | 6 | 0x0016 | 0 | -1 | 0 | 1 |
| 33 | 7 | 0x0015 | 0 | -1 | 1 | -1 |
| 34 | 6 | 0x0017 | 0 | -1 | 1 | 0 |
| 35 | 8 | 0x000F | 0 | -1 | 1 | 1 |
| 36 | 6 | 0x0018 | 0 | 0 | -1 | -1 |
| 37 | 5 | 0x0015 | 0 | 0 | -1 | 0 |
| 38 | 6 | 0x0019 | 0 | 0 | -1 | 1 |
| 39 | 5 | 0x0016 | 0 | 0 | 0 | -1 |
| 40 | 3 | 0x0007 | 0 | 0 | 0 | 0 |
| 41 | 5 | 0x0017 | 0 | 0 | 0 | 1 |
| 42 | 6 | 0x001A | 0 | 0 | 1 | -1 |
| 43 | 5 | 0x0018 | 0 | 0 | 1 | 0 |
| 44 | 6 | 0x001B | 0 | 0 | 1 | 1 |
| 45 | 8 | 0x0010 | 0 | 1 | -1 | -1 |
| 46 | 6 | 0x001C | 0 | 1 | -1 | 0 |
| 47 | 7 | 0x0016 | 0 | 1 | -1 | 1 |
| 48 | 6 | 0x001D | 0 | 1 | 0 | -1 |
| 49 | 5 | 0x0019 | 0 | 1 | 0 | 0 |
| 50 | 6 | 0x001E | 0 | 1 | 0 | 1 |
| 51 | 8 | 0x0011 | 0 | 1 | 1 | -1 |
| 52 | 6 | 0x001F | 0 | 1 | 1 | 0 |
| 53 | 8 | 0x0012 | 0 | 1 | 1 | 1 |
| 54 | 9 | 0x0006 | 1 | -1 | -1 | -1 |
| 55 | 8 | 0x0013 | 1 | -1 | -1 | 0 |
| 56 | 9 | 0x0007 | 1 | -1 | -1 | 1 |
| 57 | 8 | 0x0014 | 1 | -1 | 0 | -1 |
| 58 | 6 | 0x0020 | 1 | -1 | 0 | 0 |
| 59 | 7 | 0x0017 | 1 | -1 | 0 | 1 |
| 60 | 7 | 0x0018 | 1 | -1 | 1 | -1 |
| 61 | 7 | 0x0019 | 1 | -1 | 1 | 0 |
| 62 | 9 | 0x0008 | 1 | -1 | 1 | 1 |
| 63 | 8 | 0x0015 | 1 | 0 | -1 | -1 |
| 64 | 6 | 0x0021 | 1 | 0 | -1 | 0 |
| 65 | 7 | 0x001A | 1 | 0 | -1 | 1 |
| 66 | 6 | 0x0022 | 1 | 0 | 0 | -1 |
| 67 | 4 | 0x000D | 1 | 0 | 0 | 0 |
| 68 | 6 | 0x0023 | 1 | 0 | 0 | 1 |
| 69 | 8 | 0x0016 | 1 | 0 | 1 | -1 |
| 70 | 6 | 0x0024 | 1 | 0 | 1 | 0 |
| 71 | 8 | 0x0017 | 1 | 0 | 1 | 1 |
| 72 | 9 | 0x0009 | 1 | 1 | -1 | -1 |
| 73 | 8 | 0x0018 | 1 | 1 | -1 | 0 |
| 74 | 9 | 0x000A | 1 | 1 | -1 | 1 |
| 75 | 8 | 0x0019 | 1 | 1 | 0 | -1 |
| 76 | 6 | 0x0025 | 1 | 1 | 0 | 0 |
| 77 | 8 | 0x001A | 1 | 1 | 0 | 1 |
| 78 | 9 | 0x000B | 1 | 1 | 1 | -1 |
| 79 | 7 | 0x001B | 1 | 1 | 1 | 0 |
| 80 | 8 | 0x001B | 1 | 1 | 1 | 1 |
|  |  |  |  |  |  |  |

Table A. 4 - Residual Huffman Codebook 3

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Index** | **Length** | **Codeword** | **w** | **x** | **y** | **z** |
| 0 | 1 | 0x0001 | 0 | 0 | 0 | 0 |
| 1 | 4 | 0x0004 | 0 | 0 | 0 | 1 |
| 2 | 9 | 0x000D | 0 | 0 | 0 | 2 |
| 3 | 4 | 0x0005 | 0 | 0 | 1 | 0 |
| 4 | 5 | 0x0005 | 0 | 0 | 1 | 1 |
| 5 | 9 | 0x000E | 0 | 0 | 1 | 2 |
| 6 | 10 | 0x000A | 0 | 0 | 2 | 0 |
| 7 | 10 | 0x000B | 0 | 0 | 2 | 1 |
| 8 | 12 | 0x0005 | 0 | 0 | 2 | 2 |
| 9 | 4 | 0x0006 | 0 | 1 | 0 | 0 |
| 10 | 6 | 0x0004 | 0 | 1 | 0 | 1 |
| 11 | 10 | 0x000C | 0 | 1 | 0 | 2 |
| 12 | 5 | 0x0006 | 0 | 1 | 1 | 0 |
| 13 | 6 | 0x0005 | 0 | 1 | 1 | 1 |
| 14 | 9 | 0x000F | 0 | 1 | 1 | 2 |
| 15 | 10 | 0x000D | 0 | 1 | 2 | 0 |
| 16 | 9 | 0x0010 | 0 | 1 | 2 | 1 |
| 17 | 11 | 0x0007 | 0 | 1 | 2 | 2 |
| 18 | 10 | 0x000E | 0 | 2 | 0 | 0 |
| 19 | 11 | 0x0008 | 0 | 2 | 0 | 1 |
| 20 | 14 | 0x0002 | 0 | 2 | 0 | 2 |
| 21 | 10 | 0x000F | 0 | 2 | 1 | 0 |
| 22 | 10 | 0x0010 | 0 | 2 | 1 | 1 |
| 23 | 12 | 0x0006 | 0 | 2 | 1 | 2 |
| 24 | 12 | 0x0007 | 0 | 2 | 2 | 0 |
| 25 | 11 | 0x0009 | 0 | 2 | 2 | 1 |
| 26 | 13 | 0x0004 | 0 | 2 | 2 | 2 |
| 27 | 4 | 0x0007 | 1 | 0 | 0 | 0 |
| 28 | 6 | 0x0006 | 1 | 0 | 0 | 1 |
| 29 | 11 | 0x000A | 1 | 0 | 0 | 2 |
| 30 | 6 | 0x0007 | 1 | 0 | 1 | 0 |
| 31 | 7 | 0x0006 | 1 | 0 | 1 | 1 |
| 32 | 10 | 0x0011 | 1 | 0 | 1 | 2 |
| 33 | 11 | 0x000B | 1 | 0 | 2 | 0 |
| 34 | 10 | 0x0012 | 1 | 0 | 2 | 1 |
| 35 | 12 | 0x0008 | 1 | 0 | 2 | 2 |
| 36 | 5 | 0x0007 | 1 | 1 | 0 | 0 |
| 37 | 7 | 0x0007 | 1 | 1 | 0 | 1 |
| 38 | 11 | 0x000C | 1 | 1 | 0 | 2 |
| 39 | 6 | 0x0008 | 1 | 1 | 1 | 0 |
| 40 | 6 | 0x0009 | 1 | 1 | 1 | 1 |
| 41 | 10 | 0x0013 | 1 | 1 | 1 | 2 |
| 42 | 10 | 0x0014 | 1 | 1 | 2 | 0 |
| 43 | 9 | 0x0011 | 1 | 1 | 2 | 1 |
| 44 | 11 | 0x000D | 1 | 1 | 2 | 2 |
| 45 | 9 | 0x0012 | 1 | 2 | 0 | 0 |
| 46 | 10 | 0x0015 | 1 | 2 | 0 | 1 |
| 47 | 13 | 0x0005 | 1 | 2 | 0 | 2 |
| 48 | 9 | 0x0013 | 1 | 2 | 1 | 0 |
| 49 | 9 | 0x0014 | 1 | 2 | 1 | 1 |
| 50 | 12 | 0x0009 | 1 | 2 | 1 | 2 |
| 51 | 11 | 0x000E | 1 | 2 | 2 | 0 |
| 52 | 11 | 0x000F | 1 | 2 | 2 | 1 |
| 53 | 12 | 0x000A | 1 | 2 | 2 | 2 |
| 54 | 9 | 0x0015 | 2 | 0 | 0 | 0 |
| 55 | 10 | 0x0016 | 2 | 0 | 0 | 1 |
| 56 | 15 | 0x0000 | 2 | 0 | 0 | 2 |
| 57 | 10 | 0x0017 | 2 | 0 | 1 | 0 |
| 58 | 11 | 0x0010 | 2 | 0 | 1 | 1 |
| 59 | 15 | 0x0001 | 2 | 0 | 1 | 2 |
| 60 | 14 | 0x0003 | 2 | 0 | 2 | 0 |
| 61 | 13 | 0x0006 | 2 | 0 | 2 | 1 |
| 62 | 15 | 0x0002 | 2 | 0 | 2 | 2 |
| 63 | 9 | 0x0016 | 2 | 1 | 0 | 0 |
| 64 | 10 | 0x0018 | 2 | 1 | 0 | 1 |
| 65 | 14 | 0x0004 | 2 | 1 | 0 | 2 |
| 66 | 9 | 0x0017 | 2 | 1 | 1 | 0 |
| 67 | 10 | 0x0019 | 2 | 1 | 1 | 1 |
| 68 | 13 | 0x0007 | 2 | 1 | 1 | 2 |
| 69 | 13 | 0x0008 | 2 | 1 | 2 | 0 |
| 70 | 12 | 0x000B | 2 | 1 | 2 | 1 |
| 71 | 14 | 0x0005 | 2 | 1 | 2 | 2 |
| 72 | 11 | 0x0011 | 2 | 2 | 0 | 0 |
| 73 | 12 | 0x000C | 2 | 2 | 0 | 1 |
| 74 | 15 | 0x0003 | 2 | 2 | 0 | 2 |
| 75 | 11 | 0x0012 | 2 | 2 | 1 | 0 |
| 76 | 11 | 0x0013 | 2 | 2 | 1 | 1 |
| 77 | 14 | 0x0006 | 2 | 2 | 1 | 2 |
| 78 | 13 | 0x0009 | 2 | 2 | 2 | 0 |
| 79 | 12 | 0x000D | 2 | 2 | 2 | 1 |
| 80 | 14 | 0x0007 | 2 | 2 | 2 | 2 |
|  |  |  |  |  |  |  |

Table A. 5 - Residual Huffman Codebook 4

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Index** | **Length** | **Codeword** | **w** | **x** | **y** | **z** |
| 0 | 4 | 0x0005 | 0 | 0 | 0 | 0 |
| 1 | 4 | 0x0006 | 0 | 0 | 0 | 1 |
| 2 | 9 | 0x000A | 0 | 0 | 0 | 2 |
| 3 | 5 | 0x0005 | 0 | 0 | 1 | 0 |
| 4 | 4 | 0x0007 | 0 | 0 | 1 | 1 |
| 5 | 8 | 0x000A | 0 | 0 | 1 | 2 |
| 6 | 9 | 0x000B | 0 | 0 | 2 | 0 |
| 7 | 8 | 0x000B | 0 | 0 | 2 | 1 |
| 8 | 11 | 0x0002 | 0 | 0 | 2 | 2 |
| 9 | 4 | 0x0008 | 0 | 1 | 0 | 0 |
| 10 | 5 | 0x0006 | 0 | 1 | 0 | 1 |
| 11 | 8 | 0x000C | 0 | 1 | 0 | 2 |
| 12 | 5 | 0x0007 | 0 | 1 | 1 | 0 |
| 13 | 4 | 0x0009 | 0 | 1 | 1 | 1 |
| 14 | 8 | 0x000D | 0 | 1 | 1 | 2 |
| 15 | 8 | 0x000E | 0 | 1 | 2 | 0 |
| 16 | 8 | 0x000F | 0 | 1 | 2 | 1 |
| 17 | 10 | 0x0007 | 0 | 1 | 2 | 2 |
| 18 | 9 | 0x000C | 0 | 2 | 0 | 0 |
| 19 | 9 | 0x000D | 0 | 2 | 0 | 1 |
| 20 | 11 | 0x0003 | 0 | 2 | 0 | 2 |
| 21 | 8 | 0x0010 | 0 | 2 | 1 | 0 |
| 22 | 8 | 0x0011 | 0 | 2 | 1 | 1 |
| 23 | 10 | 0x0008 | 0 | 2 | 1 | 2 |
| 24 | 11 | 0x0004 | 0 | 2 | 2 | 0 |
| 25 | 10 | 0x0009 | 0 | 2 | 2 | 1 |
| 26 | 12 | 0x0000 | 0 | 2 | 2 | 2 |
| 27 | 4 | 0x000A | 1 | 0 | 0 | 0 |
| 28 | 5 | 0x0008 | 1 | 0 | 0 | 1 |
| 29 | 8 | 0x0012 | 1 | 0 | 0 | 2 |
| 30 | 5 | 0x0009 | 1 | 0 | 1 | 0 |
| 31 | 4 | 0x000B | 1 | 0 | 1 | 1 |
| 32 | 8 | 0x0013 | 1 | 0 | 1 | 2 |
| 33 | 9 | 0x000E | 1 | 0 | 2 | 0 |
| 34 | 8 | 0x0014 | 1 | 0 | 2 | 1 |
| 35 | 10 | 0x000A | 1 | 0 | 2 | 2 |
| 36 | 4 | 0x000C | 1 | 1 | 0 | 0 |
| 37 | 4 | 0x000D | 1 | 1 | 0 | 1 |
| 38 | 8 | 0x0015 | 1 | 1 | 0 | 2 |
| 39 | 4 | 0x000E | 1 | 1 | 1 | 0 |
| 40 | 4 | 0x000F | 1 | 1 | 1 | 1 |
| 41 | 7 | 0x0010 | 1 | 1 | 1 | 2 |
| 42 | 8 | 0x0016 | 1 | 1 | 2 | 0 |
| 43 | 7 | 0x0011 | 1 | 1 | 2 | 1 |
| 44 | 9 | 0x000F | 1 | 1 | 2 | 2 |
| 45 | 8 | 0x0017 | 1 | 2 | 0 | 0 |
| 46 | 8 | 0x0018 | 1 | 2 | 0 | 1 |
| 47 | 11 | 0x0005 | 1 | 2 | 0 | 2 |
| 48 | 8 | 0x0019 | 1 | 2 | 1 | 0 |
| 49 | 7 | 0x0012 | 1 | 2 | 1 | 1 |
| 50 | 10 | 0x000B | 1 | 2 | 1 | 2 |
| 51 | 10 | 0x000C | 1 | 2 | 2 | 0 |
| 52 | 9 | 0x0010 | 1 | 2 | 2 | 1 |
| 53 | 10 | 0x000D | 1 | 2 | 2 | 2 |
| 54 | 9 | 0x0011 | 2 | 0 | 0 | 0 |
| 55 | 8 | 0x001A | 2 | 0 | 0 | 1 |
| 56 | 11 | 0x0006 | 2 | 0 | 0 | 2 |
| 57 | 8 | 0x001B | 2 | 0 | 1 | 0 |
| 58 | 8 | 0x001C | 2 | 0 | 1 | 1 |
| 59 | 11 | 0x0007 | 2 | 0 | 1 | 2 |
| 60 | 11 | 0x0008 | 2 | 0 | 2 | 0 |
| 61 | 10 | 0x000E | 2 | 0 | 2 | 1 |
| 62 | 12 | 0x0001 | 2 | 0 | 2 | 2 |
| 63 | 8 | 0x001D | 2 | 1 | 0 | 0 |
| 64 | 8 | 0x001E | 2 | 1 | 0 | 1 |
| 65 | 11 | 0x0009 | 2 | 1 | 0 | 2 |
| 66 | 8 | 0x001F | 2 | 1 | 1 | 0 |
| 67 | 7 | 0x0013 | 2 | 1 | 1 | 1 |
| 68 | 10 | 0x000F | 2 | 1 | 1 | 2 |
| 69 | 10 | 0x0010 | 2 | 1 | 2 | 0 |
| 70 | 9 | 0x0012 | 2 | 1 | 2 | 1 |
| 71 | 11 | 0x000A | 2 | 1 | 2 | 2 |
| 72 | 11 | 0x000B | 2 | 2 | 0 | 0 |
| 73 | 10 | 0x0011 | 2 | 2 | 0 | 1 |
| 74 | 12 | 0x0002 | 2 | 2 | 0 | 2 |
| 75 | 10 | 0x0012 | 2 | 2 | 1 | 0 |
| 76 | 9 | 0x0013 | 2 | 2 | 1 | 1 |
| 77 | 11 | 0x000C | 2 | 2 | 1 | 2 |
| 78 | 12 | 0x0003 | 2 | 2 | 2 | 0 |
| 79 | 10 | 0x0013 | 2 | 2 | 2 | 1 |
| 80 | 11 | 0x000D | 2 | 2 | 2 | 2 |
|  |  |  |  |  |  |  |

Table A. 6 - Residual Huffman Codebook 5

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Index** | **Length** | **Codeword** | **x** | **y** |
| 0 | 14 | 0x0000 | -4 | -4 |
| 1 | 13 | 0x0002 | -4 | -3 |
| 2 | 12 | 0x0005 | -4 | -2 |
| 3 | 12 | 0x0006 | -4 | -1 |
| 4 | 11 | 0x000B | -4 | 0 |
| 5 | 11 | 0x000C | -4 | 1 |
| 6 | 12 | 0x0007 | -4 | 2 |
| 7 | 13 | 0x0003 | -4 | 3 |
| 8 | 14 | 0x0001 | -4 | 4 |
| 9 | 13 | 0x0004 | -3 | -4 |
| 10 | 12 | 0x0008 | -3 | -3 |
| 11 | 10 | 0x0009 | -3 | -2 |
| 12 | 9 | 0x0009 | -3 | -1 |
| 13 | 9 | 0x000A | -3 | 0 |
| 14 | 9 | 0x000B | -3 | 1 |
| 15 | 10 | 0x000A | -3 | 2 |
| 16 | 11 | 0x000D | -3 | 3 |
| 17 | 13 | 0x0005 | -3 | 4 |
| 18 | 13 | 0x0006 | -2 | -4 |
| 19 | 10 | 0x000B | -2 | -3 |
| 20 | 9 | 0x000C | -2 | -2 |
| 21 | 8 | 0x000C | -2 | -1 |
| 22 | 7 | 0x0008 | -2 | 0 |
| 23 | 7 | 0x0009 | -2 | 1 |
| 24 | 9 | 0x000D | -2 | 2 |
| 25 | 10 | 0x000C | -2 | 3 |
| 26 | 12 | 0x0009 | -2 | 4 |
| 27 | 12 | 0x000A | -1 | -4 |
| 28 | 9 | 0x000E | -1 | -3 |
| 29 | 8 | 0x000D | -1 | -2 |
| 30 | 5 | 0x0004 | -1 | -1 |
| 31 | 4 | 0x0004 | -1 | 0 |
| 32 | 5 | 0x0005 | -1 | 1 |
| 33 | 7 | 0x000A | -1 | 2 |
| 34 | 9 | 0x000F | -1 | 3 |
| 35 | 12 | 0x000B | -1 | 4 |
| 36 | 12 | 0x000C | 0 | -4 |
| 37 | 9 | 0x0010 | 0 | -3 |
| 38 | 7 | 0x000B | 0 | -2 |
| 39 | 4 | 0x0005 | 0 | -1 |
| 40 | 1 | 0x0001 | 0 | 0 |
| 41 | 4 | 0x0006 | 0 | 1 |
| 42 | 7 | 0x000C | 0 | 2 |
| 43 | 9 | 0x0011 | 0 | 3 |
| 44 | 12 | 0x000D | 0 | 4 |
| 45 | 11 | 0x000E | 1 | -4 |
| 46 | 9 | 0x0012 | 1 | -3 |
| 47 | 7 | 0x000D | 1 | -2 |
| 48 | 5 | 0x0006 | 1 | -1 |
| 49 | 4 | 0x0007 | 1 | 0 |
| 50 | 5 | 0x0007 | 1 | 1 |
| 51 | 8 | 0x000E | 1 | 2 |
| 52 | 9 | 0x0013 | 1 | 3 |
| 53 | 12 | 0x000E | 1 | 4 |
| 54 | 12 | 0x000F | 2 | -4 |
| 55 | 10 | 0x000D | 2 | -3 |
| 56 | 9 | 0x0014 | 2 | -2 |
| 57 | 7 | 0x000E | 2 | -1 |
| 58 | 7 | 0x000F | 2 | 0 |
| 59 | 8 | 0x000F | 2 | 1 |
| 60 | 9 | 0x0015 | 2 | 2 |
| 61 | 10 | 0x000E | 2 | 3 |
| 62 | 12 | 0x0010 | 2 | 4 |
| 63 | 13 | 0x0007 | 3 | -4 |
| 64 | 11 | 0x000F | 3 | -3 |
| 65 | 10 | 0x000F | 3 | -2 |
| 66 | 9 | 0x0016 | 3 | -1 |
| 67 | 9 | 0x0017 | 3 | 0 |
| 68 | 10 | 0x0010 | 3 | 1 |
| 69 | 10 | 0x0011 | 3 | 2 |
| 70 | 12 | 0x0011 | 3 | 3 |
| 71 | 13 | 0x0008 | 3 | 4 |
| 72 | 14 | 0x0002 | 4 | -4 |
| 73 | 12 | 0x0012 | 4 | -3 |
| 74 | 12 | 0x0013 | 4 | -2 |
| 75 | 12 | 0x0014 | 4 | -1 |
| 76 | 11 | 0x0010 | 4 | 0 |
| 77 | 11 | 0x0011 | 4 | 1 |
| 78 | 12 | 0x0015 | 4 | 2 |
| 79 | 13 | 0x0009 | 4 | 3 |
| 80 | 14 | 0x0003 | 4 | 4 |
|  |  |  |  |  |

Table A. 7 - Residual Huffman Codebook 6

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Index** | **Length** | **Codeword** | **x** | **y** |
| 0 | 12 | 0x0000 | -4 | -4 |
| 1 | 11 | 0x0002 | -4 | -3 |
| 2 | 10 | 0x0006 | -4 | -2 |
| 3 | 10 | 0x0007 | -4 | -1 |
| 4 | 10 | 0x0008 | -4 | 0 |
| 5 | 10 | 0x0009 | -4 | 1 |
| 6 | 10 | 0x000A | -4 | 2 |
| 7 | 11 | 0x0003 | -4 | 3 |
| 8 | 12 | 0x0001 | -4 | 4 |
| 9 | 11 | 0x0004 | -3 | -4 |
| 10 | 9 | 0x000C | -3 | -3 |
| 11 | 8 | 0x0008 | -3 | -2 |
| 12 | 8 | 0x0009 | -3 | -1 |
| 13 | 8 | 0x000A | -3 | 0 |
| 14 | 8 | 0x000B | -3 | 1 |
| 15 | 8 | 0x000C | -3 | 2 |
| 16 | 9 | 0x000D | -3 | 3 |
| 17 | 11 | 0x0005 | -3 | 4 |
| 18 | 10 | 0x000B | -2 | -4 |
| 19 | 8 | 0x000D | -2 | -3 |
| 20 | 6 | 0x0007 | -2 | -2 |
| 21 | 6 | 0x0008 | -2 | -1 |
| 22 | 6 | 0x0009 | -2 | 0 |
| 23 | 5 | 0x0009 | -2 | 1 |
| 24 | 6 | 0x000A | -2 | 2 |
| 25 | 8 | 0x000E | -2 | 3 |
| 26 | 10 | 0x000C | -2 | 4 |
| 27 | 10 | 0x000D | -1 | -4 |
| 28 | 8 | 0x000F | -1 | -3 |
| 29 | 6 | 0x000B | -1 | -2 |
| 30 | 4 | 0x0007 | -1 | -1 |
| 31 | 4 | 0x0008 | -1 | 0 |
| 32 | 4 | 0x0009 | -1 | 1 |
| 33 | 5 | 0x000A | -1 | 2 |
| 34 | 8 | 0x0010 | -1 | 3 |
| 35 | 10 | 0x000E | -1 | 4 |
| 36 | 10 | 0x000F | 0 | -4 |
| 37 | 8 | 0x0011 | 0 | -3 |
| 38 | 6 | 0x000C | 0 | -2 |
| 39 | 4 | 0x000A | 0 | -1 |
| 40 | 4 | 0x000B | 0 | 0 |
| 41 | 4 | 0x000C | 0 | 1 |
| 42 | 6 | 0x000D | 0 | 2 |
| 43 | 8 | 0x0012 | 0 | 3 |
| 44 | 10 | 0x0010 | 0 | 4 |
| 45 | 10 | 0x0011 | 1 | -4 |
| 46 | 8 | 0x0013 | 1 | -3 |
| 47 | 5 | 0x000B | 1 | -2 |
| 48 | 4 | 0x000D | 1 | -1 |
| 49 | 4 | 0x000E | 1 | 0 |
| 50 | 4 | 0x000F | 1 | 1 |
| 51 | 6 | 0x000E | 1 | 2 |
| 52 | 8 | 0x0014 | 1 | 3 |
| 53 | 10 | 0x0012 | 1 | 4 |
| 54 | 10 | 0x0013 | 2 | -4 |
| 55 | 8 | 0x0015 | 2 | -3 |
| 56 | 6 | 0x000F | 2 | -2 |
| 57 | 5 | 0x000C | 2 | -1 |
| 58 | 6 | 0x0010 | 2 | 0 |
| 59 | 5 | 0x000D | 2 | 1 |
| 60 | 6 | 0x0011 | 2 | 2 |
| 61 | 8 | 0x0016 | 2 | 3 |
| 62 | 11 | 0x0006 | 2 | 4 |
| 63 | 11 | 0x0007 | 3 | -4 |
| 64 | 9 | 0x000E | 3 | -3 |
| 65 | 8 | 0x0017 | 3 | -2 |
| 66 | 8 | 0x0018 | 3 | -1 |
| 67 | 8 | 0x0019 | 3 | 0 |
| 68 | 8 | 0x001A | 3 | 1 |
| 69 | 8 | 0x001B | 3 | 2 |
| 70 | 9 | 0x000F | 3 | 3 |
| 71 | 11 | 0x0008 | 3 | 4 |
| 72 | 12 | 0x0002 | 4 | -4 |
| 73 | 11 | 0x0009 | 4 | -3 |
| 74 | 10 | 0x0014 | 4 | -2 |
| 75 | 10 | 0x0015 | 4 | -1 |
| 76 | 11 | 0x000A | 4 | 0 |
| 77 | 10 | 0x0016 | 4 | 1 |
| 78 | 10 | 0x0017 | 4 | 2 |
| 79 | 11 | 0x000B | 4 | 3 |
| 80 | 12 | 0x0003 | 4 | 4 |
|  |  |  |  |  |

Table A. 8 - Residual Huffman Codebook 7

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Index** | **Length** | **Codeword** | **x** | **y** |
| 0 | 1 | 0x0001 | 0 | 0 |
| 1 | 3 | 0x0002 | 0 | 1 |
| 2 | 6 | 0x0007 | 0 | 2 |
| 3 | 8 | 0x000B | 0 | 3 |
| 4 | 9 | 0x000A | 0 | 4 |
| 5 | 9 | 0x000B | 0 | 5 |
| 6 | 10 | 0x0006 | 0 | 6 |
| 7 | 11 | 0x0004 | 0 | 7 |
| 8 | 3 | 0x0003 | 1 | 0 |
| 9 | 4 | 0x0003 | 1 | 1 |
| 10 | 6 | 0x0008 | 1 | 2 |
| 11 | 7 | 0x000B | 1 | 3 |
| 12 | 8 | 0x000C | 1 | 4 |
| 13 | 8 | 0x000D | 1 | 5 |
| 14 | 9 | 0x000C | 1 | 6 |
| 15 | 10 | 0x0007 | 1 | 7 |
| 16 | 6 | 0x0009 | 2 | 0 |
| 17 | 5 | 0x0005 | 2 | 1 |
| 18 | 7 | 0x000C | 2 | 2 |
| 19 | 8 | 0x000E | 2 | 3 |
| 20 | 8 | 0x000F | 2 | 4 |
| 21 | 9 | 0x000D | 2 | 5 |
| 22 | 10 | 0x0008 | 2 | 6 |
| 23 | 11 | 0x0005 | 2 | 7 |
| 24 | 8 | 0x0010 | 3 | 0 |
| 25 | 7 | 0x000D | 3 | 1 |
| 26 | 8 | 0x0011 | 3 | 2 |
| 27 | 8 | 0x0012 | 3 | 3 |
| 28 | 9 | 0x000E | 3 | 4 |
| 29 | 9 | 0x000F | 3 | 5 |
| 30 | 10 | 0x0009 | 3 | 6 |
| 31 | 11 | 0x0006 | 3 | 7 |
| 32 | 9 | 0x0010 | 4 | 0 |
| 33 | 8 | 0x0013 | 4 | 1 |
| 34 | 8 | 0x0014 | 4 | 2 |
| 35 | 9 | 0x0011 | 4 | 3 |
| 36 | 10 | 0x000A | 4 | 4 |
| 37 | 10 | 0x000B | 4 | 5 |
| 38 | 10 | 0x000C | 4 | 6 |
| 39 | 11 | 0x0007 | 4 | 7 |
| 40 | 9 | 0x0012 | 5 | 0 |
| 41 | 8 | 0x0015 | 5 | 1 |
| 42 | 9 | 0x0013 | 5 | 2 |
| 43 | 9 | 0x0014 | 5 | 3 |
| 44 | 10 | 0x000D | 5 | 4 |
| 45 | 10 | 0x000E | 5 | 5 |
| 46 | 11 | 0x0008 | 5 | 6 |
| 47 | 12 | 0x0000 | 5 | 7 |
| 48 | 10 | 0x000F | 6 | 0 |
| 49 | 9 | 0x0015 | 6 | 1 |
| 50 | 10 | 0x0010 | 6 | 2 |
| 51 | 10 | 0x0011 | 6 | 3 |
| 52 | 10 | 0x0012 | 6 | 4 |
| 53 | 11 | 0x0009 | 6 | 5 |
| 54 | 12 | 0x0001 | 6 | 6 |
| 55 | 12 | 0x0002 | 6 | 7 |
| 56 | 12 | 0x0003 | 7 | 0 |
| 57 | 10 | 0x0013 | 7 | 1 |
| 58 | 11 | 0x000A | 7 | 2 |
| 59 | 11 | 0x000B | 7 | 3 |
| 60 | 12 | 0x0004 | 7 | 4 |
| 61 | 12 | 0x0005 | 7 | 5 |
| 62 | 12 | 0x0006 | 7 | 6 |
| 63 | 12 | 0x0007 | 7 | 7 |
|  |  |  |  |  |

Table A. 9 - Residual Huffman Codebook 8

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Index** | **Length** | **Codeword** | **x** | **y** |
| 0 | 4 | 0x0008 | 0 | 0 |
| 1 | 4 | 0x0009 | 0 | 1 |
| 2 | 5 | 0x0009 | 0 | 2 |
| 3 | 6 | 0x000A | 0 | 3 |
| 4 | 7 | 0x0009 | 0 | 4 |
| 5 | 8 | 0x0008 | 0 | 5 |
| 6 | 9 | 0x0004 | 0 | 6 |
| 7 | 10 | 0x0001 | 0 | 7 |
| 8 | 4 | 0x000A | 1 | 0 |
| 9 | 3 | 0x0007 | 1 | 1 |
| 10 | 4 | 0x000B | 1 | 2 |
| 11 | 5 | 0x000A | 1 | 3 |
| 12 | 6 | 0x000B | 1 | 4 |
| 13 | 7 | 0x000A | 1 | 5 |
| 14 | 8 | 0x0009 | 1 | 6 |
| 15 | 9 | 0x0005 | 1 | 7 |
| 16 | 5 | 0x000B | 2 | 0 |
| 17 | 4 | 0x000C | 2 | 1 |
| 18 | 4 | 0x000D | 2 | 2 |
| 19 | 5 | 0x000C | 2 | 3 |
| 20 | 6 | 0x000C | 2 | 4 |
| 21 | 7 | 0x000B | 2 | 5 |
| 22 | 8 | 0x000A | 2 | 6 |
| 23 | 9 | 0x0006 | 2 | 7 |
| 24 | 6 | 0x000D | 3 | 0 |
| 25 | 5 | 0x000D | 3 | 1 |
| 26 | 5 | 0x000E | 3 | 2 |
| 27 | 5 | 0x000F | 3 | 3 |
| 28 | 6 | 0x000E | 3 | 4 |
| 29 | 7 | 0x000C | 3 | 5 |
| 30 | 8 | 0x000B | 3 | 6 |
| 31 | 9 | 0x0007 | 3 | 7 |
| 32 | 7 | 0x000D | 4 | 0 |
| 33 | 6 | 0x000F | 4 | 1 |
| 34 | 6 | 0x0010 | 4 | 2 |
| 35 | 6 | 0x0011 | 4 | 3 |
| 36 | 7 | 0x000E | 4 | 4 |
| 37 | 7 | 0x000F | 4 | 5 |
| 38 | 9 | 0x0008 | 4 | 6 |
| 39 | 10 | 0x0002 | 4 | 7 |
| 40 | 8 | 0x000C | 5 | 0 |
| 41 | 7 | 0x0010 | 5 | 1 |
| 42 | 7 | 0x0011 | 5 | 2 |
| 43 | 7 | 0x0012 | 5 | 3 |
| 44 | 7 | 0x0013 | 5 | 4 |
| 45 | 8 | 0x000D | 5 | 5 |
| 46 | 9 | 0x0009 | 5 | 6 |
| 47 | 10 | 0x0003 | 5 | 7 |
| 48 | 9 | 0x000A | 6 | 0 |
| 49 | 8 | 0x000E | 6 | 1 |
| 50 | 8 | 0x000F | 6 | 2 |
| 51 | 8 | 0x0010 | 6 | 3 |
| 52 | 8 | 0x0011 | 6 | 4 |
| 53 | 9 | 0x000B | 6 | 5 |
| 54 | 9 | 0x000C | 6 | 6 |
| 55 | 10 | 0x0004 | 6 | 7 |
| 56 | 11 | 0x0000 | 7 | 0 |
| 57 | 9 | 0x000D | 7 | 1 |
| 58 | 9 | 0x000E | 7 | 2 |
| 59 | 9 | 0x000F | 7 | 3 |
| 60 | 10 | 0x0005 | 7 | 4 |
| 61 | 10 | 0x0006 | 7 | 5 |
| 62 | 10 | 0x0007 | 7 | 6 |
| 63 | 11 | 0x0001 | 7 | 7 |
|  |  |  |  |  |

Table A. 10 - Residual Huffman Codebook 9

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Index** | **Length** | **Codeword** | **x** | **y** |
| 0 | 1 | 0x0001 | 0 | 0 |
| 1 | 3 | 0x0002 | 0 | 1 |
| 2 | 6 | 0x0008 | 0 | 2 |
| 3 | 8 | 0x0014 | 0 | 3 |
| 4 | 9 | 0x001B | 0 | 4 |
| 5 | 10 | 0x0020 | 0 | 5 |
| 6 | 10 | 0x0021 | 0 | 6 |
| 7 | 11 | 0x001E | 0 | 7 |
| 8 | 11 | 0x001F | 0 | 8 |
| 9 | 12 | 0x0011 | 0 | 9 |
| 10 | 12 | 0x0012 | 0 | 10 |
| 11 | 12 | 0x0013 | 0 | 11 |
| 12 | 13 | 0x0006 | 0 | 12 |
| 13 | 3 | 0x0003 | 1 | 0 |
| 14 | 4 | 0x0003 | 1 | 1 |
| 15 | 6 | 0x0009 | 1 | 2 |
| 16 | 7 | 0x000D | 1 | 3 |
| 17 | 8 | 0x0015 | 1 | 4 |
| 18 | 9 | 0x001C | 1 | 5 |
| 19 | 9 | 0x001D | 1 | 6 |
| 20 | 10 | 0x0022 | 1 | 7 |
| 21 | 10 | 0x0023 | 1 | 8 |
| 22 | 11 | 0x0020 | 1 | 9 |
| 23 | 11 | 0x0021 | 1 | 10 |
| 24 | 11 | 0x0022 | 1 | 11 |
| 25 | 12 | 0x0014 | 1 | 12 |
| 26 | 6 | 0x000A | 2 | 0 |
| 27 | 6 | 0x000B | 2 | 1 |
| 28 | 7 | 0x000E | 2 | 2 |
| 29 | 8 | 0x0016 | 2 | 3 |
| 30 | 9 | 0x001E | 2 | 4 |
| 31 | 9 | 0x001F | 2 | 5 |
| 32 | 10 | 0x0024 | 2 | 6 |
| 33 | 10 | 0x0025 | 2 | 7 |
| 34 | 10 | 0x0026 | 2 | 8 |
| 35 | 11 | 0x0023 | 2 | 9 |
| 36 | 11 | 0x0024 | 2 | 10 |
| 37 | 12 | 0x0015 | 2 | 11 |
| 38 | 12 | 0x0016 | 2 | 12 |
| 39 | 8 | 0x0017 | 3 | 0 |
| 40 | 7 | 0x000F | 3 | 1 |
| 41 | 8 | 0x0018 | 3 | 2 |
| 42 | 9 | 0x0020 | 3 | 3 |
| 43 | 9 | 0x0021 | 3 | 4 |
| 44 | 10 | 0x0027 | 3 | 5 |
| 45 | 10 | 0x0028 | 3 | 6 |
| 46 | 11 | 0x0025 | 3 | 7 |
| 47 | 11 | 0x0026 | 3 | 8 |
| 48 | 11 | 0x0027 | 3 | 9 |
| 49 | 12 | 0x0017 | 3 | 10 |
| 50 | 12 | 0x0018 | 3 | 11 |
| 51 | 12 | 0x0019 | 3 | 12 |
| 52 | 9 | 0x0022 | 4 | 0 |
| 53 | 8 | 0x0019 | 4 | 1 |
| 54 | 9 | 0x0023 | 4 | 2 |
| 55 | 9 | 0x0024 | 4 | 3 |
| 56 | 10 | 0x0029 | 4 | 4 |
| 57 | 10 | 0x002A | 4 | 5 |
| 58 | 11 | 0x0028 | 4 | 6 |
| 59 | 11 | 0x0029 | 4 | 7 |
| 60 | 11 | 0x002A | 4 | 8 |
| 61 | 12 | 0x001A | 4 | 9 |
| 62 | 12 | 0x001B | 4 | 10 |
| 63 | 12 | 0x001C | 4 | 11 |
| 64 | 13 | 0x0007 | 4 | 12 |
| 65 | 10 | 0x002B | 5 | 0 |
| 66 | 9 | 0x0025 | 5 | 1 |
| 67 | 9 | 0x0026 | 5 | 2 |
| 68 | 10 | 0x002C | 5 | 3 |
| 69 | 10 | 0x002D | 5 | 4 |
| 70 | 10 | 0x002E | 5 | 5 |
| 71 | 11 | 0x002B | 5 | 6 |
| 72 | 11 | 0x002C | 5 | 7 |
| 73 | 11 | 0x002D | 5 | 8 |
| 74 | 12 | 0x001D | 5 | 9 |
| 75 | 12 | 0x001E | 5 | 10 |
| 76 | 12 | 0x001F | 5 | 11 |
| 77 | 13 | 0x0008 | 5 | 12 |
| 78 | 10 | 0x002F | 6 | 0 |
| 79 | 9 | 0x0027 | 6 | 1 |
| 80 | 10 | 0x0030 | 6 | 2 |
| 81 | 10 | 0x0031 | 6 | 3 |
| 82 | 11 | 0x002E | 6 | 4 |
| 83 | 11 | 0x002F | 6 | 5 |
| 84 | 11 | 0x0030 | 6 | 6 |
| 85 | 12 | 0x0020 | 6 | 7 |
| 86 | 12 | 0x0021 | 6 | 8 |
| 87 | 12 | 0x0022 | 6 | 9 |
| 88 | 12 | 0x0023 | 6 | 10 |
| 89 | 13 | 0x0009 | 6 | 11 |
| 90 | 13 | 0x000A | 6 | 12 |
| 91 | 11 | 0x0031 | 7 | 0 |
| 92 | 10 | 0x0032 | 7 | 1 |
| 93 | 10 | 0x0033 | 7 | 2 |
| 94 | 11 | 0x0032 | 7 | 3 |
| 95 | 11 | 0x0033 | 7 | 4 |
| 96 | 12 | 0x0024 | 7 | 5 |
| 97 | 12 | 0x0025 | 7 | 6 |
| 98 | 12 | 0x0026 | 7 | 7 |
| 99 | 12 | 0x0027 | 7 | 8 |
| 100 | 12 | 0x0028 | 7 | 9 |
| 101 | 13 | 0x000B | 7 | 10 |
| 102 | 13 | 0x000C | 7 | 11 |
| 103 | 13 | 0x000D | 7 | 12 |
| 104 | 11 | 0x0034 | 8 | 0 |
| 105 | 10 | 0x0034 | 8 | 1 |
| 106 | 10 | 0x0035 | 8 | 2 |
| 107 | 11 | 0x0035 | 8 | 3 |
| 108 | 11 | 0x0036 | 8 | 4 |
| 109 | 11 | 0x0037 | 8 | 5 |
| 110 | 12 | 0x0029 | 8 | 6 |
| 111 | 12 | 0x002A | 8 | 7 |
| 112 | 12 | 0x002B | 8 | 8 |
| 113 | 13 | 0x000E | 8 | 9 |
| 114 | 13 | 0x000F | 8 | 10 |
| 115 | 13 | 0x0010 | 8 | 11 |
| 116 | 14 | 0x0000 | 8 | 12 |
| 117 | 12 | 0x002C | 9 | 0 |
| 118 | 11 | 0x0038 | 9 | 1 |
| 119 | 11 | 0x0039 | 9 | 2 |
| 120 | 11 | 0x003A | 9 | 3 |
| 121 | 11 | 0x003B | 9 | 4 |
| 122 | 12 | 0x002D | 9 | 5 |
| 123 | 12 | 0x002E | 9 | 6 |
| 124 | 12 | 0x002F | 9 | 7 |
| 125 | 13 | 0x0011 | 9 | 8 |
| 126 | 13 | 0x0012 | 9 | 9 |
| 127 | 13 | 0x0013 | 9 | 10 |
| 128 | 14 | 0x0001 | 9 | 11 |
| 129 | 14 | 0x0002 | 9 | 12 |
| 130 | 12 | 0x0030 | 10 | 0 |
| 131 | 11 | 0x003C | 10 | 1 |
| 132 | 11 | 0x003D | 10 | 2 |
| 133 | 12 | 0x0031 | 10 | 3 |
| 134 | 12 | 0x0032 | 10 | 4 |
| 135 | 12 | 0x0033 | 10 | 5 |
| 136 | 12 | 0x0034 | 10 | 6 |
| 137 | 13 | 0x0014 | 10 | 7 |
| 138 | 13 | 0x0015 | 10 | 8 |
| 139 | 13 | 0x0016 | 10 | 9 |
| 140 | 13 | 0x0017 | 10 | 10 |
| 141 | 14 | 0x0003 | 10 | 11 |
| 142 | 14 | 0x0004 | 10 | 12 |
| 143 | 12 | 0x0035 | 11 | 0 |
| 144 | 11 | 0x003E | 11 | 1 |
| 145 | 11 | 0x003F | 11 | 2 |
| 146 | 12 | 0x0036 | 11 | 3 |
| 147 | 12 | 0x0037 | 11 | 4 |
| 148 | 12 | 0x0038 | 11 | 5 |
| 149 | 13 | 0x0018 | 11 | 6 |
| 150 | 13 | 0x0019 | 11 | 7 |
| 151 | 13 | 0x001A | 11 | 8 |
| 152 | 13 | 0x001B | 11 | 9 |
| 153 | 13 | 0x001C | 11 | 10 |
| 154 | 14 | 0x0005 | 11 | 11 |
| 155 | 14 | 0x0006 | 11 | 12 |
| 156 | 13 | 0x001D | 12 | 0 |
| 157 | 12 | 0x0039 | 12 | 1 |
| 158 | 12 | 0x003A | 12 | 2 |
| 159 | 12 | 0x003B | 12 | 3 |
| 160 | 13 | 0x001E | 12 | 4 |
| 161 | 13 | 0x001F | 12 | 5 |
| 162 | 13 | 0x0020 | 12 | 6 |
| 163 | 13 | 0x0021 | 12 | 7 |
| 164 | 14 | 0x0007 | 12 | 8 |
| 165 | 14 | 0x0008 | 12 | 9 |
| 166 | 14 | 0x0009 | 12 | 10 |
| 167 | 14 | 0x000A | 12 | 11 |
| 168 | 14 | 0x000B | 12 | 12 |
|  |  |  |  |  |

Table A. 11 - Residual Huffman Codebook 10

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Index** | **Length** | **Codeword** | **x** | **y** |
| 0 | 6 | 0x0014 | 0 | 0 |
| 1 | 5 | 0x0011 | 0 | 1 |
| 2 | 6 | 0x0015 | 0 | 2 |
| 3 | 6 | 0x0016 | 0 | 3 |
| 4 | 7 | 0x0017 | 0 | 4 |
| 5 | 8 | 0x001A | 0 | 5 |
| 6 | 9 | 0x001D | 0 | 6 |
| 7 | 10 | 0x0011 | 0 | 7 |
| 8 | 10 | 0x0012 | 0 | 8 |
| 9 | 11 | 0x0007 | 0 | 9 |
| 10 | 11 | 0x0008 | 0 | 10 |
| 11 | 12 | 0x0002 | 0 | 11 |
| 12 | 12 | 0x0003 | 0 | 12 |
| 13 | 5 | 0x0012 | 1 | 0 |
| 14 | 4 | 0x000C | 1 | 1 |
| 15 | 4 | 0x000D | 1 | 2 |
| 16 | 5 | 0x0013 | 1 | 3 |
| 17 | 6 | 0x0017 | 1 | 4 |
| 18 | 7 | 0x0018 | 1 | 5 |
| 19 | 7 | 0x0019 | 1 | 6 |
| 20 | 8 | 0x001B | 1 | 7 |
| 21 | 9 | 0x001E | 1 | 8 |
| 22 | 10 | 0x0013 | 1 | 9 |
| 23 | 10 | 0x0014 | 1 | 10 |
| 24 | 10 | 0x0015 | 1 | 11 |
| 25 | 11 | 0x0009 | 1 | 12 |
| 26 | 6 | 0x0018 | 2 | 0 |
| 27 | 4 | 0x000E | 2 | 1 |
| 28 | 4 | 0x000F | 2 | 2 |
| 29 | 5 | 0x0014 | 2 | 3 |
| 30 | 6 | 0x0019 | 2 | 4 |
| 31 | 6 | 0x001A | 2 | 5 |
| 32 | 7 | 0x001A | 2 | 6 |
| 33 | 8 | 0x001C | 2 | 7 |
| 34 | 9 | 0x001F | 2 | 8 |
| 35 | 9 | 0x0020 | 2 | 9 |
| 36 | 10 | 0x0016 | 2 | 10 |
| 37 | 10 | 0x0017 | 2 | 11 |
| 38 | 11 | 0x000A | 2 | 12 |
| 39 | 6 | 0x001B | 3 | 0 |
| 40 | 5 | 0x0015 | 3 | 1 |
| 41 | 5 | 0x0016 | 3 | 2 |
| 42 | 5 | 0x0017 | 3 | 3 |
| 43 | 6 | 0x001C | 3 | 4 |
| 44 | 7 | 0x001B | 3 | 5 |
| 45 | 7 | 0x001C | 3 | 6 |
| 46 | 8 | 0x001D | 3 | 7 |
| 47 | 8 | 0x001E | 3 | 8 |
| 48 | 9 | 0x0021 | 3 | 9 |
| 49 | 10 | 0x0018 | 3 | 10 |
| 50 | 10 | 0x0019 | 3 | 11 |
| 51 | 11 | 0x000B | 3 | 12 |
| 52 | 7 | 0x001D | 4 | 0 |
| 53 | 6 | 0x001D | 4 | 1 |
| 54 | 6 | 0x001E | 4 | 2 |
| 55 | 6 | 0x001F | 4 | 3 |
| 56 | 6 | 0x0020 | 4 | 4 |
| 57 | 7 | 0x001E | 4 | 5 |
| 58 | 7 | 0x001F | 4 | 6 |
| 59 | 8 | 0x001F | 4 | 7 |
| 60 | 9 | 0x0022 | 4 | 8 |
| 61 | 9 | 0x0023 | 4 | 9 |
| 62 | 10 | 0x001A | 4 | 10 |
| 63 | 10 | 0x001B | 4 | 11 |
| 64 | 11 | 0x000C | 4 | 12 |
| 65 | 8 | 0x0020 | 5 | 0 |
| 66 | 7 | 0x0020 | 5 | 1 |
| 67 | 6 | 0x0021 | 5 | 2 |
| 68 | 7 | 0x0021 | 5 | 3 |
| 69 | 7 | 0x0022 | 5 | 4 |
| 70 | 7 | 0x0023 | 5 | 5 |
| 71 | 8 | 0x0021 | 5 | 6 |
| 72 | 8 | 0x0022 | 5 | 7 |
| 73 | 9 | 0x0024 | 5 | 8 |
| 74 | 9 | 0x0025 | 5 | 9 |
| 75 | 10 | 0x001C | 5 | 10 |
| 76 | 10 | 0x001D | 5 | 11 |
| 77 | 11 | 0x000D | 5 | 12 |
| 78 | 9 | 0x0026 | 6 | 0 |
| 79 | 7 | 0x0024 | 6 | 1 |
| 80 | 7 | 0x0025 | 6 | 2 |
| 81 | 7 | 0x0026 | 6 | 3 |
| 82 | 7 | 0x0027 | 6 | 4 |
| 83 | 8 | 0x0023 | 6 | 5 |
| 84 | 8 | 0x0024 | 6 | 6 |
| 85 | 9 | 0x0027 | 6 | 7 |
| 86 | 9 | 0x0028 | 6 | 8 |
| 87 | 10 | 0x001E | 6 | 9 |
| 88 | 10 | 0x001F | 6 | 10 |
| 89 | 10 | 0x0020 | 6 | 11 |
| 90 | 12 | 0x0004 | 6 | 12 |
| 91 | 10 | 0x0021 | 7 | 0 |
| 92 | 8 | 0x0025 | 7 | 1 |
| 93 | 8 | 0x0026 | 7 | 2 |
| 94 | 8 | 0x0027 | 7 | 3 |
| 95 | 8 | 0x0028 | 7 | 4 |
| 96 | 8 | 0x0029 | 7 | 5 |
| 97 | 9 | 0x0029 | 7 | 6 |
| 98 | 9 | 0x002A | 7 | 7 |
| 99 | 9 | 0x002B | 7 | 8 |
| 100 | 10 | 0x0022 | 7 | 9 |
| 101 | 10 | 0x0023 | 7 | 10 |
| 102 | 11 | 0x000E | 7 | 11 |
| 103 | 12 | 0x0005 | 7 | 12 |
| 104 | 10 | 0x0024 | 8 | 0 |
| 105 | 8 | 0x002A | 8 | 1 |
| 106 | 8 | 0x002B | 8 | 2 |
| 107 | 8 | 0x002C | 8 | 3 |
| 108 | 8 | 0x002D | 8 | 4 |
| 109 | 9 | 0x002C | 8 | 5 |
| 110 | 9 | 0x002D | 8 | 6 |
| 111 | 9 | 0x002E | 8 | 7 |
| 112 | 10 | 0x0025 | 8 | 8 |
| 113 | 10 | 0x0026 | 8 | 9 |
| 114 | 10 | 0x0027 | 8 | 10 |
| 115 | 11 | 0x000F | 8 | 11 |
| 116 | 12 | 0x0006 | 8 | 12 |
| 117 | 11 | 0x0010 | 9 | 0 |
| 118 | 9 | 0x002F | 9 | 1 |
| 119 | 9 | 0x0030 | 9 | 2 |
| 120 | 9 | 0x0031 | 9 | 3 |
| 121 | 9 | 0x0032 | 9 | 4 |
| 122 | 9 | 0x0033 | 9 | 5 |
| 123 | 10 | 0x0028 | 9 | 6 |
| 124 | 10 | 0x0029 | 9 | 7 |
| 125 | 10 | 0x002A | 9 | 8 |
| 126 | 10 | 0x002B | 9 | 9 |
| 127 | 11 | 0x0011 | 9 | 10 |
| 128 | 11 | 0x0012 | 9 | 11 |
| 129 | 13 | 0x0000 | 9 | 12 |
| 130 | 11 | 0x0013 | 10 | 0 |
| 131 | 10 | 0x002C | 10 | 1 |
| 132 | 10 | 0x002D | 10 | 2 |
| 133 | 10 | 0x002E | 10 | 3 |
| 134 | 10 | 0x002F | 10 | 4 |
| 135 | 10 | 0x0030 | 10 | 5 |
| 136 | 10 | 0x0031 | 10 | 6 |
| 137 | 10 | 0x0032 | 10 | 7 |
| 138 | 11 | 0x0014 | 10 | 8 |
| 139 | 11 | 0x0015 | 10 | 9 |
| 140 | 11 | 0x0016 | 10 | 10 |
| 141 | 11 | 0x0017 | 10 | 11 |
| 142 | 13 | 0x0001 | 10 | 12 |
| 143 | 12 | 0x0007 | 11 | 0 |
| 144 | 10 | 0x0033 | 11 | 1 |
| 145 | 10 | 0x0034 | 11 | 2 |
| 146 | 10 | 0x0035 | 11 | 3 |
| 147 | 10 | 0x0036 | 11 | 4 |
| 148 | 10 | 0x0037 | 11 | 5 |
| 149 | 10 | 0x0038 | 11 | 6 |
| 150 | 10 | 0x0039 | 11 | 7 |
| 151 | 11 | 0x0018 | 11 | 8 |
| 152 | 11 | 0x0019 | 11 | 9 |
| 153 | 11 | 0x001A | 11 | 10 |
| 154 | 12 | 0x0008 | 11 | 11 |
| 155 | 12 | 0x0009 | 11 | 12 |
| 156 | 12 | 0x000A | 12 | 0 |
| 157 | 11 | 0x001B | 12 | 1 |
| 158 | 11 | 0x001C | 12 | 2 |
| 159 | 11 | 0x001D | 12 | 3 |
| 160 | 11 | 0x001E | 12 | 4 |
| 161 | 11 | 0x001F | 12 | 5 |
| 162 | 11 | 0x0020 | 12 | 6 |
| 163 | 11 | 0x0021 | 12 | 7 |
| 164 | 12 | 0x000B | 12 | 8 |
| 165 | 12 | 0x000C | 12 | 9 |
| 166 | 13 | 0x0002 | 12 | 10 |
| 167 | 12 | 0x000D | 12 | 11 |
| 168 | 13 | 0x0003 | 12 | 12 |
|  |  |  |  |  |

1. Inverse Quantization Tables

Table B 1 Inverse Quantization Scale and Shift Parameters

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| global\_gain | inv\_quant\_scale | inv\_quant\_shift | global\_gain | inv\_quant\_scale | inv\_quant\_shift |
| 0 | 0x40000000 | 30 | 512 | 0x40000000 | 14 |
| 1 | 0x20B361A6 | 29 | 513 | 0x20B361A6 | 13 |
| 2 | 0x216AB0DA | 29 | 514 | 0x216AB0DA | 13 |
| 3 | 0x222603A0 | 29 | 515 | 0x222603A0 | 13 |
| 4 | 0x22E57079 | 29 | 516 | 0x22E57079 | 13 |
| 5 | 0x23A90E63 | 29 | 517 | 0x23A90E63 | 13 |
| 6 | 0x2470F4DD | 29 | 518 | 0x2470F4DD | 13 |
| 7 | 0x253D3BEA | 29 | 519 | 0x253D3BEA | 13 |
| 8 | 0x260DFC14 | 29 | 520 | 0x260DFC14 | 13 |
| 9 | 0x26E34E6E | 29 | 521 | 0x26E34E6E | 13 |
| 10 | 0x27BD4C98 | 29 | 522 | 0x27BD4C98 | 13 |
| 11 | 0x289C10C1 | 29 | 523 | 0x289C10C1 | 13 |
| 12 | 0x297FB5AA | 29 | 524 | 0x297FB5AA | 13 |
| 13 | 0x2A6856AD | 29 | 525 | 0x2A6856AD | 13 |
| 14 | 0x2B560FBB | 29 | 526 | 0x2B560FBB | 13 |
| 15 | 0x2C48FD60 | 29 | 527 | 0x2C48FD60 | 13 |
| 16 | 0x2D413CCD | 29 | 528 | 0x2D413CCD | 13 |
| 17 | 0x2E3EEBD2 | 29 | 529 | 0x2E3EEBD2 | 13 |
| 18 | 0x2F4228E8 | 29 | 530 | 0x2F4228E8 | 13 |
| 19 | 0x304B1333 | 29 | 531 | 0x304B1333 | 13 |
| 20 | 0x3159CA84 | 29 | 532 | 0x3159CA84 | 13 |
| 21 | 0x326E6F62 | 29 | 533 | 0x326E6F62 | 13 |
| 22 | 0x33892305 | 29 | 534 | 0x33892305 | 13 |
| 23 | 0x34AA0764 | 29 | 535 | 0x34AA0764 | 13 |
| 24 | 0x35D13F33 | 29 | 536 | 0x35D13F33 | 13 |
| 25 | 0x36FEEDE6 | 29 | 537 | 0x36FEEDE6 | 13 |
| 26 | 0x383337BB | 29 | 538 | 0x383337BB | 13 |
| 27 | 0x396E41BA | 29 | 539 | 0x396E41BA | 13 |
| 28 | 0x3AB031BA | 29 | 540 | 0x3AB031BA | 13 |
| 29 | 0x3BF92E67 | 29 | 541 | 0x3BF92E67 | 13 |
| 30 | 0x3D495F45 | 29 | 542 | 0x3D495F45 | 13 |
| 31 | 0x3EA0ECB7 | 29 | 543 | 0x3EA0ECB7 | 13 |
| 32 | 0x40000000 | 29 | 544 | 0x40000000 | 13 |
| 33 | 0x20B361A6 | 28 | 545 | 0x20B361A6 | 12 |
| 34 | 0x216AB0DA | 28 | 546 | 0x216AB0DA | 12 |
| 35 | 0x222603A0 | 28 | 547 | 0x222603A0 | 12 |
| 36 | 0x22E57079 | 28 | 548 | 0x22E57079 | 12 |
| 37 | 0x23A90E63 | 28 | 549 | 0x23A90E63 | 12 |
| 38 | 0x2470F4DD | 28 | 550 | 0x2470F4DD | 12 |
| 39 | 0x253D3BEA | 28 | 551 | 0x253D3BEA | 12 |
| 40 | 0x260DFC14 | 28 | 552 | 0x260DFC14 | 12 |
| 41 | 0x26E34E6E | 28 | 553 | 0x26E34E6E | 12 |
| 42 | 0x27BD4C98 | 28 | 554 | 0x27BD4C98 | 12 |
| 43 | 0x289C10C1 | 28 | 555 | 0x289C10C1 | 12 |
| 44 | 0x297FB5AA | 28 | 556 | 0x297FB5AA | 12 |
| 45 | 0x2A6856AD | 28 | 557 | 0x2A6856AD | 12 |
| 46 | 0x2B560FBB | 28 | 558 | 0x2B560FBB | 12 |
| 47 | 0x2C48FD60 | 28 | 559 | 0x2C48FD60 | 12 |
| 48 | 0x2D413CCD | 28 | 560 | 0x2D413CCD | 12 |
| 49 | 0x2E3EEBD2 | 28 | 561 | 0x2E3EEBD2 | 12 |
| 50 | 0x2F4228E8 | 28 | 562 | 0x2F4228E8 | 12 |
| 51 | 0x304B1333 | 28 | 563 | 0x304B1333 | 12 |
| 52 | 0x3159CA84 | 28 | 564 | 0x3159CA84 | 12 |
| 53 | 0x326E6F62 | 28 | 565 | 0x326E6F62 | 12 |
| 54 | 0x33892305 | 28 | 566 | 0x33892305 | 12 |
| 55 | 0x34AA0764 | 28 | 567 | 0x34AA0764 | 12 |
| 56 | 0x35D13F33 | 28 | 568 | 0x35D13F33 | 12 |
| 57 | 0x36FEEDE6 | 28 | 569 | 0x36FEEDE6 | 12 |
| 58 | 0x383337BB | 28 | 570 | 0x383337BB | 12 |
| 59 | 0x396E41BA | 28 | 571 | 0x396E41BA | 12 |
| 60 | 0x3AB031BA | 28 | 572 | 0x3AB031BA | 12 |
| 61 | 0x3BF92E67 | 28 | 573 | 0x3BF92E67 | 12 |
| 62 | 0x3D495F45 | 28 | 574 | 0x3D495F45 | 12 |
| 63 | 0x3EA0ECB7 | 28 | 575 | 0x3EA0ECB7 | 12 |
| 64 | 0x40000000 | 28 | 576 | 0x40000000 | 12 |
| 65 | 0x20B361A6 | 27 | 577 | 0x20B361A6 | 11 |
| 66 | 0x216AB0DA | 27 | 578 | 0x216AB0DA | 11 |
| 67 | 0x222603A0 | 27 | 579 | 0x222603A0 | 11 |
| 68 | 0x22E57079 | 27 | 580 | 0x22E57079 | 11 |
| 69 | 0x23A90E63 | 27 | 581 | 0x23A90E63 | 11 |
| 70 | 0x2470F4DD | 27 | 582 | 0x2470F4DD | 11 |
| 71 | 0x253D3BEA | 27 | 583 | 0x253D3BEA | 11 |
| 72 | 0x260DFC14 | 27 | 584 | 0x260DFC14 | 11 |
| 73 | 0x26E34E6E | 27 | 585 | 0x26E34E6E | 11 |
| 74 | 0x27BD4C98 | 27 | 586 | 0x27BD4C98 | 11 |
| 75 | 0x289C10C1 | 27 | 587 | 0x289C10C1 | 11 |
| 76 | 0x297FB5AA | 27 | 588 | 0x297FB5AA | 11 |
| 77 | 0x2A6856AD | 27 | 589 | 0x2A6856AD | 11 |
| 78 | 0x2B560FBB | 27 | 590 | 0x2B560FBB | 11 |
| 79 | 0x2C48FD60 | 27 | 591 | 0x2C48FD60 | 11 |
| 80 | 0x2D413CCD | 27 | 592 | 0x2D413CCD | 11 |
| 81 | 0x2E3EEBD2 | 27 | 593 | 0x2E3EEBD2 | 11 |
| 82 | 0x2F4228E8 | 27 | 594 | 0x2F4228E8 | 11 |
| 83 | 0x304B1333 | 27 | 595 | 0x304B1333 | 11 |
| 84 | 0x3159CA84 | 27 | 596 | 0x3159CA84 | 11 |
| 85 | 0x326E6F62 | 27 | 597 | 0x326E6F62 | 11 |
| 86 | 0x33892305 | 27 | 598 | 0x33892305 | 11 |
| 87 | 0x34AA0764 | 27 | 599 | 0x34AA0764 | 11 |
| 88 | 0x35D13F33 | 27 | 600 | 0x35D13F33 | 11 |
| 89 | 0x36FEEDE6 | 27 | 601 | 0x36FEEDE6 | 11 |
| 90 | 0x383337BB | 27 | 602 | 0x383337BB | 11 |
| 91 | 0x396E41BA | 27 | 603 | 0x396E41BA | 11 |
| 92 | 0x3AB031BA | 27 | 604 | 0x3AB031BA | 11 |
| 93 | 0x3BF92E67 | 27 | 605 | 0x3BF92E67 | 11 |
| 94 | 0x3D495F45 | 27 | 606 | 0x3D495F45 | 11 |
| 95 | 0x3EA0ECB7 | 27 | 607 | 0x3EA0ECB7 | 11 |
| 96 | 0x40000000 | 27 | 608 | 0x40000000 | 11 |
| 97 | 0x20B361A6 | 26 | 609 | 0x20B361A6 | 10 |
| 98 | 0x216AB0DA | 26 | 610 | 0x216AB0DA | 10 |
| 99 | 0x222603A0 | 26 | 611 | 0x222603A0 | 10 |
| 100 | 0x22E57079 | 26 | 612 | 0x22E57079 | 10 |
| 101 | 0x23A90E63 | 26 | 613 | 0x23A90E63 | 10 |
| 102 | 0x2470F4DD | 26 | 614 | 0x2470F4DD | 10 |
| 103 | 0x253D3BEA | 26 | 615 | 0x253D3BEA | 10 |
| 104 | 0x260DFC14 | 26 | 616 | 0x260DFC14 | 10 |
| 105 | 0x26E34E6E | 26 | 617 | 0x26E34E6E | 10 |
| 106 | 0x27BD4C98 | 26 | 618 | 0x27BD4C98 | 10 |
| 107 | 0x289C10C1 | 26 | 619 | 0x289C10C1 | 10 |
| 108 | 0x297FB5AA | 26 | 620 | 0x297FB5AA | 10 |
| 109 | 0x2A6856AD | 26 | 621 | 0x2A6856AD | 10 |
| 110 | 0x2B560FBB | 26 | 622 | 0x2B560FBB | 10 |
| 111 | 0x2C48FD60 | 26 | 623 | 0x2C48FD60 | 10 |
| 112 | 0x2D413CCD | 26 | 624 | 0x2D413CCD | 10 |
| 113 | 0x2E3EEBD2 | 26 | 625 | 0x2E3EEBD2 | 10 |
| 114 | 0x2F4228E8 | 26 | 626 | 0x2F4228E8 | 10 |
| 115 | 0x304B1333 | 26 | 627 | 0x304B1333 | 10 |
| 116 | 0x3159CA84 | 26 | 628 | 0x3159CA84 | 10 |
| 117 | 0x326E6F62 | 26 | 629 | 0x326E6F62 | 10 |
| 118 | 0x33892305 | 26 | 630 | 0x33892305 | 10 |
| 119 | 0x34AA0764 | 26 | 631 | 0x34AA0764 | 10 |
| 120 | 0x35D13F33 | 26 | 632 | 0x35D13F33 | 10 |
| 121 | 0x36FEEDE6 | 26 | 633 | 0x36FEEDE6 | 10 |
| 122 | 0x383337BB | 26 | 634 | 0x383337BB | 10 |
| 123 | 0x396E41BA | 26 | 635 | 0x396E41BA | 10 |
| 124 | 0x3AB031BA | 26 | 636 | 0x3AB031BA | 10 |
| 125 | 0x3BF92E67 | 26 | 637 | 0x3BF92E67 | 10 |
| 126 | 0x3D495F45 | 26 | 638 | 0x3D495F45 | 10 |
| 127 | 0x3EA0ECB7 | 26 | 639 | 0x3EA0ECB7 | 10 |
| 128 | 0x40000000 | 26 | 640 | 0x40000000 | 10 |
| 129 | 0x20B361A6 | 25 | 641 | 0x20B361A6 | 9 |
| 130 | 0x216AB0DA | 25 | 642 | 0x216AB0DA | 9 |
| 131 | 0x222603A0 | 25 | 643 | 0x222603A0 | 9 |
| 132 | 0x22E57079 | 25 | 644 | 0x22E57079 | 9 |
| 133 | 0x23A90E63 | 25 | 645 | 0x23A90E63 | 9 |
| 134 | 0x2470F4DD | 25 | 646 | 0x2470F4DD | 9 |
| 135 | 0x253D3BEA | 25 | 647 | 0x253D3BEA | 9 |
| 136 | 0x260DFC14 | 25 | 648 | 0x260DFC14 | 9 |
| 137 | 0x26E34E6E | 25 | 649 | 0x26E34E6E | 9 |
| 138 | 0x27BD4C98 | 25 | 650 | 0x27BD4C98 | 9 |
| 139 | 0x289C10C1 | 25 | 651 | 0x289C10C1 | 9 |
| 140 | 0x297FB5AA | 25 | 652 | 0x297FB5AA | 9 |
| 141 | 0x2A6856AD | 25 | 653 | 0x2A6856AD | 9 |
| 142 | 0x2B560FBB | 25 | 654 | 0x2B560FBB | 9 |
| 143 | 0x2C48FD60 | 25 | 655 | 0x2C48FD60 | 9 |
| 144 | 0x2D413CCD | 25 | 656 | 0x2D413CCD | 9 |
| 145 | 0x2E3EEBD2 | 25 | 657 | 0x2E3EEBD2 | 9 |
| 146 | 0x2F4228E8 | 25 | 658 | 0x2F4228E8 | 9 |
| 147 | 0x304B1333 | 25 | 659 | 0x304B1333 | 9 |
| 148 | 0x3159CA84 | 25 | 660 | 0x3159CA84 | 9 |
| 149 | 0x326E6F62 | 25 | 661 | 0x326E6F62 | 9 |
| 150 | 0x33892305 | 25 | 662 | 0x33892305 | 9 |
| 151 | 0x34AA0764 | 25 | 663 | 0x34AA0764 | 9 |
| 152 | 0x35D13F33 | 25 | 664 | 0x35D13F33 | 9 |
| 153 | 0x36FEEDE6 | 25 | 665 | 0x36FEEDE6 | 9 |
| 154 | 0x383337BB | 25 | 666 | 0x383337BB | 9 |
| 155 | 0x396E41BA | 25 | 667 | 0x396E41BA | 9 |
| 156 | 0x3AB031BA | 25 | 668 | 0x3AB031BA | 9 |
| 157 | 0x3BF92E67 | 25 | 669 | 0x3BF92E67 | 9 |
| 158 | 0x3D495F45 | 25 | 670 | 0x3D495F45 | 9 |
| 159 | 0x3EA0ECB7 | 25 | 671 | 0x3EA0ECB7 | 9 |
| 160 | 0x40000000 | 25 | 672 | 0x40000000 | 9 |
| 161 | 0x20B361A6 | 24 | 673 | 0x20B361A6 | 8 |
| 162 | 0x216AB0DA | 24 | 674 | 0x216AB0DA | 8 |
| 163 | 0x222603A0 | 24 | 675 | 0x222603A0 | 8 |
| 164 | 0x22E57079 | 24 | 676 | 0x22E57079 | 8 |
| 165 | 0x23A90E63 | 24 | 677 | 0x23A90E63 | 8 |
| 166 | 0x2470F4DD | 24 | 678 | 0x2470F4DD | 8 |
| 167 | 0x253D3BEA | 24 | 679 | 0x253D3BEA | 8 |
| 168 | 0x260DFC14 | 24 | 680 | 0x260DFC14 | 8 |
| 169 | 0x26E34E6E | 24 | 681 | 0x26E34E6E | 8 |
| 170 | 0x27BD4C98 | 24 | 682 | 0x27BD4C98 | 8 |
| 171 | 0x289C10C1 | 24 | 683 | 0x289C10C1 | 8 |
| 172 | 0x297FB5AA | 24 | 684 | 0x297FB5AA | 8 |
| 173 | 0x2A6856AD | 24 | 685 | 0x2A6856AD | 8 |
| 174 | 0x2B560FBB | 24 | 686 | 0x2B560FBB | 8 |
| 175 | 0x2C48FD60 | 24 | 687 | 0x2C48FD60 | 8 |
| 176 | 0x2D413CCD | 24 | 688 | 0x2D413CCD | 8 |
| 177 | 0x2E3EEBD2 | 24 | 689 | 0x2E3EEBD2 | 8 |
| 178 | 0x2F4228E8 | 24 | 690 | 0x2F4228E8 | 8 |
| 179 | 0x304B1333 | 24 | 691 | 0x304B1333 | 8 |
| 180 | 0x3159CA84 | 24 | 692 | 0x3159CA84 | 8 |
| 181 | 0x326E6F62 | 24 | 693 | 0x326E6F62 | 8 |
| 182 | 0x33892305 | 24 | 694 | 0x33892305 | 8 |
| 183 | 0x34AA0764 | 24 | 695 | 0x34AA0764 | 8 |
| 184 | 0x35D13F33 | 24 | 696 | 0x35D13F33 | 8 |
| 185 | 0x36FEEDE6 | 24 | 697 | 0x36FEEDE6 | 8 |
| 186 | 0x383337BB | 24 | 698 | 0x383337BB | 8 |
| 187 | 0x396E41BA | 24 | 699 | 0x396E41BA | 8 |
| 188 | 0x3AB031BA | 24 | 700 | 0x3AB031BA | 8 |
| 189 | 0x3BF92E67 | 24 | 701 | 0x3BF92E67 | 8 |
| 190 | 0x3D495F45 | 24 | 702 | 0x3D495F45 | 8 |
| 191 | 0x3EA0ECB7 | 24 | 703 | 0x3EA0ECB7 | 8 |
| 192 | 0x40000000 | 24 | 704 | 0x40000000 | 8 |
| 193 | 0x20B361A6 | 23 | 705 | 0x20B361A6 | 7 |
| 194 | 0x216AB0DA | 23 | 706 | 0x216AB0DA | 7 |
| 195 | 0x222603A0 | 23 | 707 | 0x222603A0 | 7 |
| 196 | 0x22E57079 | 23 | 708 | 0x22E57079 | 7 |
| 197 | 0x23A90E63 | 23 | 709 | 0x23A90E63 | 7 |
| 198 | 0x2470F4DD | 23 | 710 | 0x2470F4DD | 7 |
| 199 | 0x253D3BEA | 23 | 711 | 0x253D3BEA | 7 |
| 200 | 0x260DFC14 | 23 | 712 | 0x260DFC14 | 7 |
| 201 | 0x26E34E6E | 23 | 713 | 0x26E34E6E | 7 |
| 202 | 0x27BD4C98 | 23 | 714 | 0x27BD4C98 | 7 |
| 203 | 0x289C10C1 | 23 | 715 | 0x289C10C1 | 7 |
| 204 | 0x297FB5AA | 23 | 716 | 0x297FB5AA | 7 |
| 205 | 0x2A6856AD | 23 | 717 | 0x2A6856AD | 7 |
| 206 | 0x2B560FBB | 23 | 718 | 0x2B560FBB | 7 |
| 207 | 0x2C48FD60 | 23 | 719 | 0x2C48FD60 | 7 |
| 208 | 0x2D413CCD | 23 | 720 | 0x2D413CCD | 7 |
| 209 | 0x2E3EEBD2 | 23 | 721 | 0x2E3EEBD2 | 7 |
| 210 | 0x2F4228E8 | 23 | 722 | 0x2F4228E8 | 7 |
| 211 | 0x304B1333 | 23 | 723 | 0x304B1333 | 7 |
| 212 | 0x3159CA84 | 23 | 724 | 0x3159CA84 | 7 |
| 213 | 0x326E6F62 | 23 | 725 | 0x326E6F62 | 7 |
| 214 | 0x33892305 | 23 | 726 | 0x33892305 | 7 |
| 215 | 0x34AA0764 | 23 | 727 | 0x34AA0764 | 7 |
| 216 | 0x35D13F33 | 23 | 728 | 0x35D13F33 | 7 |
| 217 | 0x36FEEDE6 | 23 | 729 | 0x36FEEDE6 | 7 |
| 218 | 0x383337BB | 23 | 730 | 0x383337BB | 7 |
| 219 | 0x396E41BA | 23 | 731 | 0x396E41BA | 7 |
| 220 | 0x3AB031BA | 23 | 732 | 0x3AB031BA | 7 |
| 221 | 0x3BF92E67 | 23 | 733 | 0x3BF92E67 | 7 |
| 222 | 0x3D495F45 | 23 | 734 | 0x3D495F45 | 7 |
| 223 | 0x3EA0ECB7 | 23 | 735 | 0x3EA0ECB7 | 7 |
| 224 | 0x40000000 | 23 | 736 | 0x40000000 | 7 |
| 225 | 0x20B361A6 | 22 | 737 | 0x20B361A6 | 6 |
| 226 | 0x216AB0DA | 22 | 738 | 0x216AB0DA | 6 |
| 227 | 0x222603A0 | 22 | 739 | 0x222603A0 | 6 |
| 228 | 0x22E57079 | 22 | 740 | 0x22E57079 | 6 |
| 229 | 0x23A90E63 | 22 | 741 | 0x23A90E63 | 6 |
| 230 | 0x2470F4DD | 22 | 742 | 0x2470F4DD | 6 |
| 231 | 0x253D3BEA | 22 | 743 | 0x253D3BEA | 6 |
| 232 | 0x260DFC14 | 22 | 744 | 0x260DFC14 | 6 |
| 233 | 0x26E34E6E | 22 | 745 | 0x26E34E6E | 6 |
| 234 | 0x27BD4C98 | 22 | 746 | 0x27BD4C98 | 6 |
| 235 | 0x289C10C1 | 22 | 747 | 0x289C10C1 | 6 |
| 236 | 0x297FB5AA | 22 | 748 | 0x297FB5AA | 6 |
| 237 | 0x2A6856AD | 22 | 749 | 0x2A6856AD | 6 |
| 238 | 0x2B560FBB | 22 | 750 | 0x2B560FBB | 6 |
| 239 | 0x2C48FD60 | 22 | 751 | 0x2C48FD60 | 6 |
| 240 | 0x2D413CCD | 22 | 752 | 0x2D413CCD | 6 |
| 241 | 0x2E3EEBD2 | 22 | 753 | 0x2E3EEBD2 | 6 |
| 242 | 0x2F4228E8 | 22 | 754 | 0x2F4228E8 | 6 |
| 243 | 0x304B1333 | 22 | 755 | 0x304B1333 | 6 |
| 244 | 0x3159CA84 | 22 | 756 | 0x3159CA84 | 6 |
| 245 | 0x326E6F62 | 22 | 757 | 0x326E6F62 | 6 |
| 246 | 0x33892305 | 22 | 758 | 0x33892305 | 6 |
| 247 | 0x34AA0764 | 22 | 759 | 0x34AA0764 | 6 |
| 248 | 0x35D13F33 | 22 | 760 | 0x35D13F33 | 6 |
| 249 | 0x36FEEDE6 | 22 | 761 | 0x36FEEDE6 | 6 |
| 250 | 0x383337BB | 22 | 762 | 0x383337BB | 6 |
| 251 | 0x396E41BA | 22 | 763 | 0x396E41BA | 6 |
| 252 | 0x3AB031BA | 22 | 764 | 0x3AB031BA | 6 |
| 253 | 0x3BF92E67 | 22 | 765 | 0x3BF92E67 | 6 |
| 254 | 0x3D495F45 | 22 | 766 | 0x3D495F45 | 6 |
| 255 | 0x3EA0ECB7 | 22 | 767 | 0x3EA0ECB7 | 6 |
| 256 | 0x40000000 | 22 | 768 | 0x40000000 | 6 |
| 257 | 0x20B361A6 | 21 | 769 | 0x20B361A6 | 5 |
| 258 | 0x216AB0DA | 21 | 770 | 0x216AB0DA | 5 |
| 259 | 0x222603A0 | 21 | 771 | 0x222603A0 | 5 |
| 260 | 0x22E57079 | 21 | 772 | 0x22E57079 | 5 |
| 261 | 0x23A90E63 | 21 | 773 | 0x23A90E63 | 5 |
| 262 | 0x2470F4DD | 21 | 774 | 0x2470F4DD | 5 |
| 263 | 0x253D3BEA | 21 | 775 | 0x253D3BEA | 5 |
| 264 | 0x260DFC14 | 21 | 776 | 0x260DFC14 | 5 |
| 265 | 0x26E34E6E | 21 | 777 | 0x26E34E6E | 5 |
| 266 | 0x27BD4C98 | 21 | 778 | 0x27BD4C98 | 5 |
| 267 | 0x289C10C1 | 21 | 779 | 0x289C10C1 | 5 |
| 268 | 0x297FB5AA | 21 | 780 | 0x297FB5AA | 5 |
| 269 | 0x2A6856AD | 21 | 781 | 0x2A6856AD | 5 |
| 270 | 0x2B560FBB | 21 | 782 | 0x2B560FBB | 5 |
| 271 | 0x2C48FD60 | 21 | 783 | 0x2C48FD60 | 5 |
| 272 | 0x2D413CCD | 21 | 784 | 0x2D413CCD | 5 |
| 273 | 0x2E3EEBD2 | 21 | 785 | 0x2E3EEBD2 | 5 |
| 274 | 0x2F4228E8 | 21 | 786 | 0x2F4228E8 | 5 |
| 275 | 0x304B1333 | 21 | 787 | 0x304B1333 | 5 |
| 276 | 0x3159CA84 | 21 | 788 | 0x3159CA84 | 5 |
| 277 | 0x326E6F62 | 21 | 789 | 0x326E6F62 | 5 |
| 278 | 0x33892305 | 21 | 790 | 0x33892305 | 5 |
| 279 | 0x34AA0764 | 21 | 791 | 0x34AA0764 | 5 |
| 280 | 0x35D13F33 | 21 | 792 | 0x35D13F33 | 5 |
| 281 | 0x36FEEDE6 | 21 | 793 | 0x36FEEDE6 | 5 |
| 282 | 0x383337BB | 21 | 794 | 0x383337BB | 5 |
| 283 | 0x396E41BA | 21 | 795 | 0x396E41BA | 5 |
| 284 | 0x3AB031BA | 21 | 796 | 0x3AB031BA | 5 |
| 285 | 0x3BF92E67 | 21 | 797 | 0x3BF92E67 | 5 |
| 286 | 0x3D495F45 | 21 | 798 | 0x3D495F45 | 5 |
| 287 | 0x3EA0ECB7 | 21 | 799 | 0x3EA0ECB7 | 5 |
| 288 | 0x40000000 | 21 | 800 | 0x40000000 | 5 |
| 289 | 0x20B361A6 | 20 | 801 | 0x20B361A6 | 4 |
| 290 | 0x216AB0DA | 20 | 802 | 0x216AB0DA | 4 |
| 291 | 0x222603A0 | 20 | 803 | 0x222603A0 | 4 |
| 292 | 0x22E57079 | 20 | 804 | 0x22E57079 | 4 |
| 293 | 0x23A90E63 | 20 | 805 | 0x23A90E63 | 4 |
| 294 | 0x2470F4DD | 20 | 806 | 0x2470F4DD | 4 |
| 295 | 0x253D3BEA | 20 | 807 | 0x253D3BEA | 4 |
| 296 | 0x260DFC14 | 20 | 808 | 0x260DFC14 | 4 |
| 297 | 0x26E34E6E | 20 | 809 | 0x26E34E6E | 4 |
| 298 | 0x27BD4C98 | 20 | 810 | 0x27BD4C98 | 4 |
| 299 | 0x289C10C1 | 20 | 811 | 0x289C10C1 | 4 |
| 300 | 0x297FB5AA | 20 | 812 | 0x297FB5AA | 4 |
| 301 | 0x2A6856AD | 20 | 813 | 0x2A6856AD | 4 |
| 302 | 0x2B560FBB | 20 | 814 | 0x2B560FBB | 4 |
| 303 | 0x2C48FD60 | 20 | 815 | 0x2C48FD60 | 4 |
| 304 | 0x2D413CCD | 20 | 816 | 0x2D413CCD | 4 |
| 305 | 0x2E3EEBD2 | 20 | 817 | 0x2E3EEBD2 | 4 |
| 306 | 0x2F4228E8 | 20 | 818 | 0x2F4228E8 | 4 |
| 307 | 0x304B1333 | 20 | 819 | 0x304B1333 | 4 |
| 308 | 0x3159CA84 | 20 | 820 | 0x3159CA84 | 4 |
| 309 | 0x326E6F62 | 20 | 821 | 0x326E6F62 | 4 |
| 310 | 0x33892305 | 20 | 822 | 0x33892305 | 4 |
| 311 | 0x34AA0764 | 20 | 823 | 0x34AA0764 | 4 |
| 312 | 0x35D13F33 | 20 | 824 | 0x35D13F33 | 4 |
| 313 | 0x36FEEDE6 | 20 | 825 | 0x36FEEDE6 | 4 |
| 314 | 0x383337BB | 20 | 826 | 0x383337BB | 4 |
| 315 | 0x396E41BA | 20 | 827 | 0x396E41BA | 4 |
| 316 | 0x3AB031BA | 20 | 828 | 0x3AB031BA | 4 |
| 317 | 0x3BF92E67 | 20 | 829 | 0x3BF92E67 | 4 |
| 318 | 0x3D495F45 | 20 | 830 | 0x3D495F45 | 4 |
| 319 | 0x3EA0ECB7 | 20 | 831 | 0x3EA0ECB7 | 4 |
| 320 | 0x40000000 | 20 | 832 | 0x40000000 | 4 |
| 321 | 0x20B361A6 | 19 | 833 | 0x20B361A6 | 3 |
| 322 | 0x216AB0DA | 19 | 834 | 0x216AB0DA | 3 |
| 323 | 0x222603A0 | 19 | 835 | 0x222603A0 | 3 |
| 324 | 0x22E57079 | 19 | 836 | 0x22E57079 | 3 |
| 325 | 0x23A90E63 | 19 | 837 | 0x23A90E63 | 3 |
| 326 | 0x2470F4DD | 19 | 838 | 0x2470F4DD | 3 |
| 327 | 0x253D3BEA | 19 | 839 | 0x253D3BEA | 3 |
| 328 | 0x260DFC14 | 19 | 840 | 0x260DFC14 | 3 |
| 329 | 0x26E34E6E | 19 | 841 | 0x26E34E6E | 3 |
| 330 | 0x27BD4C98 | 19 | 842 | 0x27BD4C98 | 3 |
| 331 | 0x289C10C1 | 19 | 843 | 0x289C10C1 | 3 |
| 332 | 0x297FB5AA | 19 | 844 | 0x297FB5AA | 3 |
| 333 | 0x2A6856AD | 19 | 845 | 0x2A6856AD | 3 |
| 334 | 0x2B560FBB | 19 | 846 | 0x2B560FBB | 3 |
| 335 | 0x2C48FD60 | 19 | 847 | 0x2C48FD60 | 3 |
| 336 | 0x2D413CCD | 19 | 848 | 0x2D413CCD | 3 |
| 337 | 0x2E3EEBD2 | 19 | 849 | 0x2E3EEBD2 | 3 |
| 338 | 0x2F4228E8 | 19 | 850 | 0x2F4228E8 | 3 |
| 339 | 0x304B1333 | 19 | 851 | 0x304B1333 | 3 |
| 340 | 0x3159CA84 | 19 | 852 | 0x3159CA84 | 3 |
| 341 | 0x326E6F62 | 19 | 853 | 0x326E6F62 | 3 |
| 342 | 0x33892305 | 19 | 854 | 0x33892305 | 3 |
| 343 | 0x34AA0764 | 19 | 855 | 0x34AA0764 | 3 |
| 344 | 0x35D13F33 | 19 | 856 | 0x35D13F33 | 3 |
| 345 | 0x36FEEDE6 | 19 | 857 | 0x36FEEDE6 | 3 |
| 346 | 0x383337BB | 19 | 858 | 0x383337BB | 3 |
| 347 | 0x396E41BA | 19 | 859 | 0x396E41BA | 3 |
| 348 | 0x3AB031BA | 19 | 860 | 0x3AB031BA | 3 |
| 349 | 0x3BF92E67 | 19 | 861 | 0x3BF92E67 | 3 |
| 350 | 0x3D495F45 | 19 | 862 | 0x3D495F45 | 3 |
| 351 | 0x3EA0ECB7 | 19 | 863 | 0x3EA0ECB7 | 3 |
| 352 | 0x40000000 | 19 | 864 | 0x40000000 | 3 |
| 353 | 0x20B361A6 | 18 | 865 | 0x20B361A6 | 2 |
| 354 | 0x216AB0DA | 18 | 866 | 0x216AB0DA | 2 |
| 355 | 0x222603A0 | 18 | 867 | 0x222603A0 | 2 |
| 356 | 0x22E57079 | 18 | 868 | 0x22E57079 | 2 |
| 357 | 0x23A90E63 | 18 | 869 | 0x23A90E63 | 2 |
| 358 | 0x2470F4DD | 18 | 870 | 0x2470F4DD | 2 |
| 359 | 0x253D3BEA | 18 | 871 | 0x253D3BEA | 2 |
| 360 | 0x260DFC14 | 18 | 872 | 0x260DFC14 | 2 |
| 361 | 0x26E34E6E | 18 | 873 | 0x26E34E6E | 2 |
| 362 | 0x27BD4C98 | 18 | 874 | 0x27BD4C98 | 2 |
| 363 | 0x289C10C1 | 18 | 875 | 0x289C10C1 | 2 |
| 364 | 0x297FB5AA | 18 | 876 | 0x297FB5AA | 2 |
| 365 | 0x2A6856AD | 18 | 877 | 0x2A6856AD | 2 |
| 366 | 0x2B560FBB | 18 | 878 | 0x2B560FBB | 2 |
| 367 | 0x2C48FD60 | 18 | 879 | 0x2C48FD60 | 2 |
| 368 | 0x2D413CCD | 18 | 880 | 0x2D413CCD | 2 |
| 369 | 0x2E3EEBD2 | 18 | 881 | 0x2E3EEBD2 | 2 |
| 370 | 0x2F4228E8 | 18 | 882 | 0x2F4228E8 | 2 |
| 371 | 0x304B1333 | 18 | 883 | 0x304B1333 | 2 |
| 372 | 0x3159CA84 | 18 | 884 | 0x3159CA84 | 2 |
| 373 | 0x326E6F62 | 18 | 885 | 0x326E6F62 | 2 |
| 374 | 0x33892305 | 18 | 886 | 0x33892305 | 2 |
| 375 | 0x34AA0764 | 18 | 887 | 0x34AA0764 | 2 |
| 376 | 0x35D13F33 | 18 | 888 | 0x35D13F33 | 2 |
| 377 | 0x36FEEDE6 | 18 | 889 | 0x36FEEDE6 | 2 |
| 378 | 0x383337BB | 18 | 890 | 0x383337BB | 2 |
| 379 | 0x396E41BA | 18 | 891 | 0x396E41BA | 2 |
| 380 | 0x3AB031BA | 18 | 892 | 0x3AB031BA | 2 |
| 381 | 0x3BF92E67 | 18 | 893 | 0x3BF92E67 | 2 |
| 382 | 0x3D495F45 | 18 | 894 | 0x3D495F45 | 2 |
| 383 | 0x3EA0ECB7 | 18 | 895 | 0x3EA0ECB7 | 2 |
| 384 | 0x40000000 | 18 | 896 | 0x40000000 | 2 |
| 385 | 0x20B361A6 | 17 | 897 | 0x20B361A6 | 1 |
| 386 | 0x216AB0DA | 17 | 898 | 0x216AB0DA | 1 |
| 387 | 0x222603A0 | 17 | 899 | 0x222603A0 | 1 |
| 388 | 0x22E57079 | 17 | 900 | 0x22E57079 | 1 |
| 389 | 0x23A90E63 | 17 | 901 | 0x23A90E63 | 1 |
| 390 | 0x2470F4DD | 17 | 902 | 0x2470F4DD | 1 |
| 391 | 0x253D3BEA | 17 | 903 | 0x253D3BEA | 1 |
| 392 | 0x260DFC14 | 17 | 904 | 0x260DFC14 | 1 |
| 393 | 0x26E34E6E | 17 | 905 | 0x26E34E6E | 1 |
| 394 | 0x27BD4C98 | 17 | 906 | 0x27BD4C98 | 1 |
| 395 | 0x289C10C1 | 17 | 907 | 0x289C10C1 | 1 |
| 396 | 0x297FB5AA | 17 | 908 | 0x297FB5AA | 1 |
| 397 | 0x2A6856AD | 17 | 909 | 0x2A6856AD | 1 |
| 398 | 0x2B560FBB | 17 | 910 | 0x2B560FBB | 1 |
| 399 | 0x2C48FD60 | 17 | 911 | 0x2C48FD60 | 1 |
| 400 | 0x2D413CCD | 17 | 912 | 0x2D413CCD | 1 |
| 401 | 0x2E3EEBD2 | 17 | 913 | 0x2E3EEBD2 | 1 |
| 402 | 0x2F4228E8 | 17 | 914 | 0x2F4228E8 | 1 |
| 403 | 0x304B1333 | 17 | 915 | 0x304B1333 | 1 |
| 404 | 0x3159CA84 | 17 | 916 | 0x3159CA84 | 1 |
| 405 | 0x326E6F62 | 17 | 917 | 0x326E6F62 | 1 |
| 406 | 0x33892305 | 17 | 918 | 0x33892305 | 1 |
| 407 | 0x34AA0764 | 17 | 919 | 0x34AA0764 | 1 |
| 408 | 0x35D13F33 | 17 | 920 | 0x35D13F33 | 1 |
| 409 | 0x36FEEDE6 | 17 | 921 | 0x36FEEDE6 | 1 |
| 410 | 0x383337BB | 17 | 922 | 0x383337BB | 1 |
| 411 | 0x396E41BA | 17 | 923 | 0x396E41BA | 1 |
| 412 | 0x3AB031BA | 17 | 924 | 0x3AB031BA | 1 |
| 413 | 0x3BF92E67 | 17 | 925 | 0x3BF92E67 | 1 |
| 414 | 0x3D495F45 | 17 | 926 | 0x3D495F45 | 1 |
| 415 | 0x3EA0ECB7 | 17 | 927 | 0x3EA0ECB7 | 1 |
| 416 | 0x40000000 | 17 | 928 | 0x40000000 | 1 |
| 417 | 0x20B361A6 | 16 | 929 | 0x20B361A6 | 0 |
| 418 | 0x216AB0DA | 16 | 930 | 0x216AB0DA | 0 |
| 419 | 0x222603A0 | 16 | 931 | 0x222603A0 | 0 |
| 420 | 0x22E57079 | 16 | 932 | 0x22E57079 | 0 |
| 421 | 0x23A90E63 | 16 | 933 | 0x23A90E63 | 0 |
| 422 | 0x2470F4DD | 16 | 934 | 0x2470F4DD | 0 |
| 423 | 0x253D3BEA | 16 | 935 | 0x253D3BEA | 0 |
| 424 | 0x260DFC14 | 16 | 936 | 0x260DFC14 | 0 |
| 425 | 0x26E34E6E | 16 | 937 | 0x26E34E6E | 0 |
| 426 | 0x27BD4C98 | 16 | 938 | 0x27BD4C98 | 0 |
| 427 | 0x289C10C1 | 16 | 939 | 0x289C10C1 | 0 |
| 428 | 0x297FB5AA | 16 | 940 | 0x297FB5AA | 0 |
| 429 | 0x2A6856AD | 16 | 941 | 0x2A6856AD | 0 |
| 430 | 0x2B560FBB | 16 | 942 | 0x2B560FBB | 0 |
| 431 | 0x2C48FD60 | 16 | 943 | 0x2C48FD60 | 0 |
| 432 | 0x2D413CCD | 16 | 944 | 0x2D413CCD | 0 |
| 433 | 0x2E3EEBD2 | 16 | 945 | 0x2E3EEBD2 | 0 |
| 434 | 0x2F4228E8 | 16 | 946 | 0x2F4228E8 | 0 |
| 435 | 0x304B1333 | 16 | 947 | 0x304B1333 | 0 |
| 436 | 0x3159CA84 | 16 | 948 | 0x3159CA84 | 0 |
| 437 | 0x326E6F62 | 16 | 949 | 0x326E6F62 | 0 |
| 438 | 0x33892305 | 16 | 950 | 0x33892305 | 0 |
| 439 | 0x34AA0764 | 16 | 951 | 0x34AA0764 | 0 |
| 440 | 0x35D13F33 | 16 | 952 | 0x35D13F33 | 0 |
| 441 | 0x36FEEDE6 | 16 | 953 | 0x36FEEDE6 | 0 |
| 442 | 0x383337BB | 16 | 954 | 0x383337BB | 0 |
| 443 | 0x396E41BA | 16 | 955 | 0x396E41BA | 0 |
| 444 | 0x3AB031BA | 16 | 956 | 0x3AB031BA | 0 |
| 445 | 0x3BF92E67 | 16 | 957 | 0x3BF92E67 | 0 |
| 446 | 0x3D495F45 | 16 | 958 | 0x3D495F45 | 0 |
| 447 | 0x3EA0ECB7 | 16 | 959 | 0x3EA0ECB7 | 0 |
| 448 | 0x40000000 | 16 | 960 | 0x40000000 | 0 |
| 449 | 0x20B361A6 | 15 | 961 | 0x4166C34C | 0 |
| 450 | 0x216AB0DA | 15 | 962 | 0x42D561B4 | 0 |
| 451 | 0x222603A0 | 15 | 963 | 0x444C0740 | 0 |
| 452 | 0x22E57079 | 15 | 964 | 0x45CAE0F2 | 0 |
| 453 | 0x23A90E63 | 15 | 965 | 0x47521CC6 | 0 |
| 454 | 0x2470F4DD | 15 | 966 | 0x48E1E9BA | 0 |
| 455 | 0x253D3BEA | 15 | 967 | 0x4A7A77D4 | 0 |
| 456 | 0x260DFC14 | 15 | 968 | 0x4C1BF829 | 0 |
| 457 | 0x26E34E6E | 15 | 969 | 0x4DC69CDD | 0 |
| 458 | 0x27BD4C98 | 15 | 970 | 0x4F7A9930 | 0 |
| 459 | 0x289C10C1 | 15 | 971 | 0x51382182 | 0 |
| 460 | 0x297FB5AA | 15 | 972 | 0x52FF6B55 | 0 |
| 461 | 0x2A6856AD | 15 | 973 | 0x54D0AD5A | 0 |
| 462 | 0x2B560FBB | 15 | 974 | 0x56AC1F75 | 0 |
| 463 | 0x2C48FD60 | 15 | 975 | 0x5891FAC1 | 0 |
| 464 | 0x2D413CCD | 15 | 976 | 0x5A82799A | 0 |
| 465 | 0x2E3EEBD2 | 15 | 977 | 0x5C7DD7A4 | 0 |
| 466 | 0x2F4228E8 | 15 | 978 | 0x5E8451D0 | 0 |
| 467 | 0x304B1333 | 15 | 979 | 0x60962665 | 0 |
| 468 | 0x3159CA84 | 15 | 980 | 0x62B39509 | 0 |
| 469 | 0x326E6F62 | 15 | 981 | 0x64DCDEC3 | 0 |
| 470 | 0x33892305 | 15 | 982 | 0x6712460B | 0 |
| 471 | 0x34AA0764 | 15 | 983 | 0x69540EC9 | 0 |
| 472 | 0x35D13F33 | 15 | 984 | 0x6BA27E65 | 0 |
| 473 | 0x36FEEDE6 | 15 | 985 | 0x6DFDDBCC | 0 |
| 474 | 0x383337BB | 15 | 986 | 0x70666F76 | 0 |
| 475 | 0x396E41BA | 15 | 987 | 0x72DC8374 | 0 |
| 476 | 0x3AB031BA | 15 | 988 | 0x75606374 | 0 |
| 477 | 0x3BF92E67 | 15 | 989 | 0x77F25CCE | 0 |
| 478 | 0x3D495F45 | 15 | 990 | 0x7A92BE8B | 0 |
| 479 | 0x3EA0ECB7 | 15 | 991 | 0x7D41D96E | 0 |
| 480 | 0x40000000 | 15 | 992 | 0x7FFFFFFF | 0 |
| 481 | 0x20B361A6 | 14 | 993 | 0x7FFFFFFF | 0 |
| 482 | 0x216AB0DA | 14 | 994 | 0x7FFFFFFF | 0 |
| 483 | 0x222603A0 | 14 | 995 | 0x7FFFFFFF | 0 |
| 484 | 0x22E57079 | 14 | 996 | 0x7FFFFFFF | 0 |
| 485 | 0x23A90E63 | 14 | 997 | 0x7FFFFFFF | 0 |
| 486 | 0x2470F4DD | 14 | 998 | 0x7FFFFFFF | 0 |
| 487 | 0x253D3BEA | 14 | 999 | 0x7FFFFFFF | 0 |
| 488 | 0x260DFC14 | 14 | 1000 | 0x7FFFFFFF | 0 |
| 489 | 0x26E34E6E | 14 | 1001 | 0x7FFFFFFF | 0 |
| 490 | 0x27BD4C98 | 14 | 1002 | 0x7FFFFFFF | 0 |
| 491 | 0x289C10C1 | 14 | 1003 | 0x7FFFFFFF | 0 |
| 492 | 0x297FB5AA | 14 | 1004 | 0x7FFFFFFF | 0 |
| 493 | 0x2A6856AD | 14 | 1005 | 0x7FFFFFFF | 0 |
| 494 | 0x2B560FBB | 14 | 1006 | 0x7FFFFFFF | 0 |
| 495 | 0x2C48FD60 | 14 | 1007 | 0x7FFFFFFF | 0 |
| 496 | 0x2D413CCD | 14 | 1008 | 0x7FFFFFFF | 0 |
| 497 | 0x2E3EEBD2 | 14 | 1009 | 0x7FFFFFFF | 0 |
| 498 | 0x2F4228E8 | 14 | 1010 | 0x7FFFFFFF | 0 |
| 499 | 0x304B1333 | 14 | 1011 | 0x7FFFFFFF | 0 |
| 500 | 0x3159CA84 | 14 | 1012 | 0x7FFFFFFF | 0 |
| 501 | 0x326E6F62 | 14 | 1013 | 0x7FFFFFFF | 0 |
| 502 | 0x33892305 | 14 | 1014 | 0x7FFFFFFF | 0 |
| 503 | 0x34AA0764 | 14 | 1015 | 0x7FFFFFFF | 0 |
| 504 | 0x35D13F33 | 14 | 1016 | 0x7FFFFFFF | 0 |
| 505 | 0x36FEEDE6 | 14 | 1017 | 0x7FFFFFFF | 0 |
| 506 | 0x383337BB | 14 | 1018 | 0x7FFFFFFF | 0 |
| 507 | 0x396E41BA | 14 | 1019 | 0x7FFFFFFF | 0 |
| 508 | 0x3AB031BA | 14 | 1020 | 0x7FFFFFFF | 0 |
| 509 | 0x3BF92E67 | 14 | 1021 | 0x7FFFFFFF | 0 |
| 510 | 0x3D495F45 | 14 | 1022 | 0x7FFFFFFF | 0 |
| 511 | 0x3EA0ECB7 | 14 | 1023 | 0x7FFFFFFF | 0 |

1. Predfined Coefficients for Integer Invertible DCT

const int c\_aiA1\_16[4] = {

-2147483647,-889516852,0,889516852,

};

const int c\_aiB1\_16[4] = {

2147483647,1518500249,0,-1518500249,

};

const int c\_aiA3\_16[4] = {

-2147483647,-1434902698,-889516852,-427161056,

};

const int c\_aiB3\_16[4] = {

2147483647,1984016188,1518500249,821806413,

};

const int c\_aiA4\_16[8] = {

0,105499107,211508678,318549108,427161056,537916651,651432042,768381935,

};

const int c\_aiB4\_16[8] = {

0,-210490206,-418953276,-623381597,-821806413,-1012316784,-1193077990,-1362349204,

};

const int c\_aiA1\_32[8] = {

-2147483647,-1434902698,-889516852,-427161056,0,427161056,889516852,1434902698,

};

const int c\_aiB1\_32[8] = {

2147483647,1984016188,1518500249,821806413,0,-821806413,-1518500249,-1984016188,

};

const int c\_aiA3\_32[8] = {

-2147483647,-1762394283,-1434902698,-1147853924,-889516852,-651432042,-427161056,-211508678,

};

const int c\_aiB3\_32[8] = {

2147483647,2106220351,1984016188,1785567395,1518500249,1193077990,821806413,418953276,

};

const int c\_aiA4\_32[16] = {

0,52717765,105499107,158407910,211508678,264866845,318549108,372623761,

427161056,482233579,537916651,594288762,651432042,709432771,768381935,828375853,

};

const int c\_aiB4\_32[16] = {

0,-105372028,-210490206,-315101294,-418953276,-521795963,-623381597,-723465451,

-821806413,-918167571,-1012316784,-1104027236,-1193077990,-1279254515,-1362349204,-1442161874,

};

const int c\_aiA1\_64[16] = {

-2147483647,-1762394283,-1434902698,-1147853924,-889516852,-651432042,-427161056,-211508678,

0,211508678,427161056,651432042,889516852,1147853924,1434902698,1762394283,

};

const int c\_aiB1\_64[16] = {

2147483647,2106220351,1984016188,1785567395,1518500249,1193077990,821806413,418953276,

0,-418953276,-821806413,-1193077990,-1518500249,-1785567395,-1984016188,-2106220351,

};

const int c\_aiA3\_64[16] = {

-2147483647,-1946365724,-1762394283,-1592682420,-1434902698,-1287152163,-1147853924,-1015684122,

-889516852,-768381935,-651432042,-537916651,-427161056,-318549108,-211508678,-105499107,

};

const int c\_aiB3\_64[16] = {

2147483647,2137142926,2106220351,2055013722,1984016188,1893911493,1785567395,1660027308,

1518500249,1362349204,1193077990,1012316784,821806413,623381597,418953276,210490206,

};

const int c\_aiA4\_64[32] = {

0,26354912,52717765,79096506,105499107,131933563,158407910,184930235,

211508678,238151452,264866845,291663238,318549108,345533045,372623761,399830101,

427161056,454625776,482233579,509993970,537916651,566011534,594288762,622758717,

651432042,680319656,709432771,738782911,768381935,798242054,828375853,858796317,

};

const int c\_aiB4\_64[32] = {

0,-52701887,-105372028,-157978697,-210490206,-262874923,-315101294,-367137860,

-418953276,-470516330,-521795963,-572761285,-623381597,-673626408,-723465451,-772868706,

-821806413,-870249095,-918167571,-965532978,-1012316784,-1058490807,-1104027236,-1148898640,

-1193077990,-1236538675,-1279254515,-1321199780,-1362349204,-1402677999,-1442161874,-1480777044,

};

const int c\_aiA1\_128[32] = {

-2147483647,-1946365724,-1762394283,-1592682420,-1434902698,-1287152163,-1147853924,-1015684122,

-889516852,-768381935,-651432042,-537916651,-427161056,-318549108,-211508678,-105499107,

0,105499107,211508678,318549108,427161056,537916651,651432042,768381935,

889516852,1015684122,1147853924,1287152163,1434902698,1592682420,1762394283,1946365724,

};

const int c\_aiB1\_128[32] = {

2147483647,2137142926,2106220351,2055013722,1984016188,1893911493,1785567395,1660027308,

1518500249,1362349204,1193077990,1012316784,821806413,623381597,418953276,210490206,

0,-210490206,-418953276,-623381597,-821806413,-1012316784,-1193077990,-1362349204,

-1518500249,-1660027308,-1785567395,-1893911493,-1984016188,-2055013722,-2106220351,-2137142926,

};

const int c\_aiA3\_128[32] = {

-2147483647,-2044574398,-1946365724,-1852432133,-1762394283,-1675912687,-1592682420,-1512428625,

-1434902698,-1359879022,-1287152163,-1216534460,-1147853924,-1080952429,-1015684122,-951914032,

-889516852,-828375853,-768381935,-709432771,-651432042,-594288762,-537916651,-482233579,

-427161056,-372623761,-318549108,-264866845,-211508678,-158407910,-105499107,-52717765,

};

const int c\_aiB3\_128[32] = {

2147483647,2144896909,2137142926,2124240379,2106220351,2083126253,2055013722,2021950483,

1984016188,1941302224,1893911493,1841958164,1785567395,1724875039,1660027308,1591180425,

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};

const int c\_aiA4\_128[64] = {

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318549108,332028276,345533045,359064506,372623761,386211919,399830101,413479434,

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537916651,551941939,566011534,580126712,594288762,608498990,622758717,637069283,

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-418953276,-444768293,-470516330,-496193509,-521795963,-547319836,-572761285,-598116478,

-623381597,-648552837,-673626408,-698598533,-723465451,-748223418,-772868706,-797397602,

-821806413,-846091463,-870249095,-894275670,-918167571,-941921200,-965532978,-988999351,

-1012316784,-1035481765,-1058490807,-1081340445,-1104027236,-1126547765,-1148898640,-1171076495,

-1193077990,-1214899812,-1236538675,-1257991319,-1279254515,-1300325059,-1321199780,-1341875532,

-1362349204,-1382617710,-1402677999,-1422527050,-1442161874,-1461579513,-1480777044,-1499751575,

};

const int c\_aiA1\_256[64] = {

-2147483647,-2044574398,-1946365724,-1852432133,-1762394283,-1675912687,-1592682420,-1512428625,

-1434902698,-1359879022,-1287152163,-1216534460,-1147853924,-1080952429,-1015684122,-951914032,

-889516852,-828375853,-768381935,-709432771,-651432042,-594288762,-537916651,-482233579,

-427161056,-372623761,-318549108,-264866845,-211508678,-158407910,-105499107,-52717765,

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-1518500249,-1591180425,-1660027308,-1724875039,-1785567395,-1841958164,-1893911493,-1941302224,

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};

const int c\_aiA3\_256[64] = {

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-1762394283,-1718728765,-1675912687,-1633908973,-1592682420,-1552199576,-1512428625,-1473339283,

-1434902698,-1397091361,-1359879022,-1323240610,-1287152163,-1251590761,-1216534460,-1181962234,

-1147853924,-1114190182,-1080952429,-1048122803,-1015684122,-983619845,-951914032,-920551313,

-889516852,-858796317,-828375853,-798242054,-768381935,-738782911,-709432771,-680319656,

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-427161056,-399830101,-372623761,-345533045,-318549108,-291663238,-264866845,-238151452,

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821806413,772868706,723465451,673626408,623381597,572761285,521795963,470516330,

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};

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};

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-723465451,-735858287,-748223418,-760560379,-772868706,-785147934,-797397602,-809617248,

-821806413,-833964637,-846091463,-858186434,-870249095,-882278991,-894275670,-906238681,

-918167571,-930061894,-941921200,-953745043,-965532978,-977284561,-988999351,-1000676905,

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-1279254515,-1289814068,-1300325059,-1310787095,-1321199780,-1331562722,-1341875532,-1352137822,

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};

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-1147853924,-1114190182,-1080952429,-1048122803,-1015684122,-983619845,-951914032,-920551313,

-889516852,-858796317,-828375853,-798242054,-768381935,-738782911,-709432771,-680319656,

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};

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};

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-1193077990,-1194447152,-1195815611,-1197183367,-1198550419,-1199916765,-1201282406,-1202647340,

-1204011566,-1205375085,-1206737894,-1208099993,-1209461381,-1210822058,-1212182023,-1213541275,

-1214899812,-1216257635,-1217614743,-1218971134,-1220326808,-1221681764,-1223036002,-1224389520,

-1225742318,-1227094395,-1228445749,-1229796382,-1231146290,-1232495475,-1233843934,-1235191668,

-1236538675,-1237884954,-1239230506,-1240575328,-1241919421,-1243262783,-1244605413,-1245947312,

-1247288477,-1248628909,-1249968606,-1251307568,-1252645793,-1253983282,-1255320033,-1256656046,

-1257991319,-1259325853,-1260659645,-1261992696,-1263325005,-1264656570,-1265987391,-1267317468,

-1268646799,-1269975384,-1271303222,-1272630311,-1273956652,-1275282244,-1276607086,-1277931176,

-1279254515,-1280577101,-1281898934,-1283220013,-1284540337,-1285859905,-1287178717,-1288496771,

-1289814068,-1291130605,-1292446384,-1293761402,-1295075658,-1296389153,-1297701886,-1299013855,

-1300325059,-1301635499,-1302945173,-1304254081,-1305562221,-1306869594,-1308176197,-1309482031,

-1310787095,-1312091387,-1313394908,-1314697656,-1315999631,-1317300831,-1318601257,-1319900907,

-1321199780,-1322497876,-1323795194,-1325091734,-1326387493,-1327682473,-1328976672,-1330270088,

-1331562722,-1332854573,-1334145640,-1335435922,-1336725418,-1338014128,-1339302051,-1340589186,

-1341875532,-1343161089,-1344445856,-1345729832,-1347013016,-1348295408,-1349577007,-1350857812,

-1352137822,-1353417036,-1354695455,-1355973076,-1357249900,-1358525925,-1359801152,-1361075578,

-1362349204,-1363622028,-1364894050,-1366165269,-1367435684,-1368705295,-1369974101,-1371242101,

-1372509294,-1373775680,-1375041257,-1376306026,-1377569985,-1378833134,-1380095471,-1381356997,

-1382617710,-1383877609,-1385136695,-1386394966,-1387652421,-1388909060,-1390164882,-1391419886,

-1392674071,-1393927437,-1395179983,-1396431709,-1397682613,-1398932694,-1400181953,-1401430388,

-1402677999,-1403924784,-1405170744,-1406415877,-1407660183,-1408903660,-1410146309,-1411388128,

-1412629117,-1413869275,-1415108601,-1416347094,-1417584755,-1418821581,-1420057573,-1421292730,

-1422527050,-1423760533,-1424993179,-1426224987,-1427455956,-1428686085,-1429915373,-1431143820,

-1432371426,-1433598188,-1434824108,-1436049183,-1437273414,-1438496799,-1439719338,-1440941029,

-1442161874,-1443381869,-1444601016,-1445819313,-1447036759,-1448253354,-1449469097,-1450683988,

-1451898025,-1453111208,-1454323536,-1455535008,-1456745625,-1457955384,-1459164286,-1460372329,

-1461579513,-1462785837,-1463991301,-1465195904,-1466399644,-1467602522,-1468804537,-1470005688,

-1471205973,-1472405394,-1473603948,-1474801635,-1475998455,-1477194406,-1478389489,-1479583701,

-1480777044,-1481969515,-1483161114,-1484351841,-1485541695,-1486730675,-1487918780,-1489106010,

-1490292364,-1491477841,-1492662441,-1493846162,-1495029005,-1496210969,-1497392052,-1498572254,

-1499751575,-1500930014,-1502107569,-1503284241,-1504460029,-1505634931,-1506808948,-1507982078,

-1509154322,-1510325677,-1511496144,-1512665722,-1513834410,-1515002207,-1516169113,-1517335128,

};

const int c\_aiTwiddleReal\_4[2] = {

2147483647,0,

};

const int c\_aiTwiddleImag\_4[2] = {

0,-2147483647,

};

const int c\_aiTwiddleReal\_8[4] = {

2147483647,1518500249,0,-1518500249,

};

const int c\_aiTwiddleImag\_8[4] = {

0,-1518500249,-2147483647,-1518500249,

};

const int c\_aiTwiddleReal\_16[8] = {

2147483647,1984016188,1518500249,821806413,0,-821806413,-1518500249,-1984016188,

};

const int c\_aiTwiddleImag\_16[8] = {

0,-821806413,-1518500249,-1984016188,-2147483647,-1984016188,-1518500249,-821806413,

};

const int c\_aiTwiddleReal\_32[16] = {

2147483647,2106220351,1984016188,1785567395,1518500249,1193077990,821806413,418953276,

0,-418953276,-821806413,-1193077990,-1518500249,-1785567395,-1984016188,-2106220351,

};

const int c\_aiTwiddleImag\_32[16] = {

0,-418953276,-821806413,-1193077990,-1518500249,-1785567395,-1984016188,-2106220351,

-2147483647,-2106220351,-1984016188,-1785567395,-1518500249,-1193077990,-821806413,-418953276,

};

const int c\_aiTwiddleReal\_64[32] = {

2147483647,2137142926,2106220351,2055013722,1984016188,1893911493,1785567395,1660027308,

1518500249,1362349204,1193077990,1012316784,821806413,623381597,418953276,210490206,

0,-210490206,-418953276,-623381597,-821806413,-1012316784,-1193077990,-1362349204,

-1518500249,-1660027308,-1785567395,-1893911493,-1984016188,-2055013722,-2106220351,-2137142926,

};

const int c\_aiTwiddleImag\_64[32] = {

0,-210490206,-418953276,-623381597,-821806413,-1012316784,-1193077990,-1362349204,

-1518500249,-1660027308,-1785567395,-1893911493,-1984016188,-2055013722,-2106220351,-2137142926,

-2147483647,-2137142926,-2106220351,-2055013722,-1984016188,-1893911493,-1785567395,-1660027308,

-1518500249,-1362349204,-1193077990,-1012316784,-821806413,-623381597,-418953276,-210490206,

};

const int c\_aiTwiddleReal\_128[64] = {

2147483647,2144896909,2137142926,2124240379,2106220351,2083126253,2055013722,2021950483,

1984016188,1941302224,1893911493,1841958164,1785567395,1724875039,1660027308,1591180425,

1518500249,1442161874,1362349204,1279254515,1193077990,1104027236,1012316784,918167571,

821806413,723465451,623381597,521795963,418953276,315101294,210490206,105372028,

0,-105372028,-210490206,-315101294,-418953276,-521795963,-623381597,-723465451,

-821806413,-918167571,-1012316784,-1104027236,-1193077990,-1279254515,-1362349204,-1442161874,

-1518500249,-1591180425,-1660027308,-1724875039,-1785567395,-1841958164,-1893911493,-1941302224,

-1984016188,-2021950483,-2055013722,-2083126253,-2106220351,-2124240379,-2137142926,-2144896909,

};

const int c\_aiTwiddleImag\_128[64] = {

0,-105372028,-210490206,-315101294,-418953276,-521795963,-623381597,-723465451,

-821806413,-918167571,-1012316784,-1104027236,-1193077990,-1279254515,-1362349204,-1442161874,

-1518500249,-1591180425,-1660027308,-1724875039,-1785567395,-1841958164,-1893911493,-1941302224,

-1984016188,-2021950483,-2055013722,-2083126253,-2106220351,-2124240379,-2137142926,-2144896909,

-2147483647,-2144896909,-2137142926,-2124240379,-2106220351,-2083126253,-2055013722,-2021950483,

-1984016188,-1941302224,-1893911493,-1841958164,-1785567395,-1724875039,-1660027308,-1591180425,

-1518500249,-1442161874,-1362349204,-1279254515,-1193077990,-1104027236,-1012316784,-918167571,

-821806413,-723465451,-623381597,-521795963,-418953276,-315101294,-210490206,-105372028,

};

const int c\_aiTwiddleReal\_256[128] = {

2147483647,2146836865,2144896909,2141664947,2137142926,2131333571,2124240379,2115867625,

2106220351,2095304369,2083126253,2069693341,2055013722,2039096240,2021950483,2003586778,

1984016188,1963250500,1941302224,1918184580,1893911493,1868497585,1841958164,1814309215,

1785567395,1755750016,1724875039,1692961061,1660027308,1626093615,1591180425,1555308767,

1518500249,1480777044,1442161874,1402677999,1362349204,1321199780,1279254515,1236538675,

1193077990,1148898640,1104027236,1058490807,1012316784,965532978,918167571,870249095,

821806413,772868706,723465451,673626408,623381597,572761285,521795963,470516330,

418953276,367137860,315101294,262874923,210490206,157978697,105372028,52701887,

0,-52701887,-105372028,-157978697,-210490206,-262874923,-315101294,-367137860,

-418953276,-470516330,-521795963,-572761285,-623381597,-673626408,-723465451,-772868706,

-821806413,-870249095,-918167571,-965532978,-1012316784,-1058490807,-1104027236,-1148898640,

-1193077990,-1236538675,-1279254515,-1321199780,-1362349204,-1402677999,-1442161874,-1480777044,

-1518500249,-1555308767,-1591180425,-1626093615,-1660027308,-1692961061,-1724875039,-1755750016,

-1785567395,-1814309215,-1841958164,-1868497585,-1893911493,-1918184580,-1941302224,-1963250500,

-1984016188,-2003586778,-2021950483,-2039096240,-2055013722,-2069693341,-2083126253,-2095304369,

-2106220351,-2115867625,-2124240379,-2131333571,-2137142926,-2141664947,-2144896909,-2146836865,

};

const int c\_aiTwiddleImag\_256[128] = {

0,-52701887,-105372028,-157978697,-210490206,-262874923,-315101294,-367137860,

-418953276,-470516330,-521795963,-572761285,-623381597,-673626408,-723465451,-772868706,

-821806413,-870249095,-918167571,-965532978,-1012316784,-1058490807,-1104027236,-1148898640,

-1193077990,-1236538675,-1279254515,-1321199780,-1362349204,-1402677999,-1442161874,-1480777044,

-1518500249,-1555308767,-1591180425,-1626093615,-1660027308,-1692961061,-1724875039,-1755750016,

-1785567395,-1814309215,-1841958164,-1868497585,-1893911493,-1918184580,-1941302224,-1963250500,

-1984016188,-2003586778,-2021950483,-2039096240,-2055013722,-2069693341,-2083126253,-2095304369,

-2106220351,-2115867625,-2124240379,-2131333571,-2137142926,-2141664947,-2144896909,-2146836865,

-2147483647,-2146836865,-2144896909,-2141664947,-2137142926,-2131333571,-2124240379,-2115867625,

-2106220351,-2095304369,-2083126253,-2069693341,-2055013722,-2039096240,-2021950483,-2003586778,

-1984016188,-1963250500,-1941302224,-1918184580,-1893911493,-1868497585,-1841958164,-1814309215,

-1785567395,-1755750016,-1724875039,-1692961061,-1660027308,-1626093615,-1591180425,-1555308767,

-1518500249,-1480777044,-1442161874,-1402677999,-1362349204,-1321199780,-1279254515,-1236538675,

-1193077990,-1148898640,-1104027236,-1058490807,-1012316784,-965532978,-918167571,-870249095,

-821806413,-772868706,-723465451,-673626408,-623381597,-572761285,-521795963,-470516330,

-418953276,-367137860,-315101294,-262874923,-210490206,-157978697,-105372028,-52701887,

};

const int c\_aiTwiddleReal\_512[256] = {

2147483647,2147321945,2146836865,2146028479,2144896909,2143442325,2141664947,2139565042,

2137142926,2134398965,2131333571,2127947205,2124240379,2120213650,2115867625,2111202958,

2106220351,2100920555,2095304369,2089372637,2083126253,2076566159,2069693341,2062508835,

2055013722,2047209132,2039096240,2030676268,2021950483,2012920200,2003586778,1993951624,

1984016188,1973781966,1963250500,1952423376,1941302224,1929888719,1918184580,1906191569,

1893911493,1881346201,1868497585,1855367580,1841958164,1828271355,1814309215,1800073848,

1785567395,1770792043,1755750016,1740443580,1724875039,1709046738,1692961061,1676620431,

1660027308,1643184190,1626093615,1608758157,1591180425,1573363067,1555308767,1537020243,

1518500249,1499751575,1480777044,1461579513,1442161874,1422527050,1402677999,1382617710,

1362349204,1341875532,1321199780,1300325059,1279254515,1257991319,1236538675,1214899812,

1193077990,1171076495,1148898640,1126547765,1104027236,1081340445,1058490807,1035481765,

1012316784,988999351,965532978,941921200,918167571,894275670,870249095,846091463,

821806413,797397602,772868706,748223418,723465451,698598533,673626408,648552837,

623381597,598116478,572761285,547319836,521795963,496193509,470516330,444768293,

418953276,393075166,367137860,341145265,315101294,289009871,262874923,236700388,

210490206,184248325,157978697,131685278,105372028,79042909,52701887,26352928,

0,-26352928,-52701887,-79042909,-105372028,-131685278,-157978697,-184248325,

-210490206,-236700388,-262874923,-289009871,-315101294,-341145265,-367137860,-393075166,

-418953276,-444768293,-470516330,-496193509,-521795963,-547319836,-572761285,-598116478,

-623381597,-648552837,-673626408,-698598533,-723465451,-748223418,-772868706,-797397602,

-821806413,-846091463,-870249095,-894275670,-918167571,-941921200,-965532978,-988999351,

-1012316784,-1035481765,-1058490807,-1081340445,-1104027236,-1126547765,-1148898640,-1171076495,

-1193077990,-1214899812,-1236538675,-1257991319,-1279254515,-1300325059,-1321199780,-1341875532,

-1362349204,-1382617710,-1402677999,-1422527050,-1442161874,-1461579513,-1480777044,-1499751575,

-1518500249,-1537020243,-1555308767,-1573363067,-1591180425,-1608758157,-1626093615,-1643184190,

-1660027308,-1676620431,-1692961061,-1709046738,-1724875039,-1740443580,-1755750016,-1770792043,

-1785567395,-1800073848,-1814309215,-1828271355,-1841958164,-1855367580,-1868497585,-1881346201,

-1893911493,-1906191569,-1918184580,-1929888719,-1941302224,-1952423376,-1963250500,-1973781966,

-1984016188,-1993951624,-2003586778,-2012920200,-2021950483,-2030676268,-2039096240,-2047209132,

-2055013722,-2062508835,-2069693341,-2076566159,-2083126253,-2089372637,-2095304369,-2100920555,

-2106220351,-2111202958,-2115867625,-2120213650,-2124240379,-2127947205,-2131333571,-2134398965,

-2137142926,-2139565042,-2141664947,-2143442325,-2144896909,-2146028479,-2146836865,-2147321945,

};

const int c\_aiTwiddleImag\_512[256] = {

0,-26352928,-52701887,-79042909,-105372028,-131685278,-157978697,-184248325,

-210490206,-236700388,-262874923,-289009871,-315101294,-341145265,-367137860,-393075166,

-418953276,-444768293,-470516330,-496193509,-521795963,-547319836,-572761285,-598116478,

-623381597,-648552837,-673626408,-698598533,-723465451,-748223418,-772868706,-797397602,

-821806413,-846091463,-870249095,-894275670,-918167571,-941921200,-965532978,-988999351,

-1012316784,-1035481765,-1058490807,-1081340445,-1104027236,-1126547765,-1148898640,-1171076495,

-1193077990,-1214899812,-1236538675,-1257991319,-1279254515,-1300325059,-1321199780,-1341875532,

-1362349204,-1382617710,-1402677999,-1422527050,-1442161874,-1461579513,-1480777044,-1499751575,

-1518500249,-1537020243,-1555308767,-1573363067,-1591180425,-1608758157,-1626093615,-1643184190,

-1660027308,-1676620431,-1692961061,-1709046738,-1724875039,-1740443580,-1755750016,-1770792043,

-1785567395,-1800073848,-1814309215,-1828271355,-1841958164,-1855367580,-1868497585,-1881346201,

-1893911493,-1906191569,-1918184580,-1929888719,-1941302224,-1952423376,-1963250500,-1973781966,

-1984016188,-1993951624,-2003586778,-2012920200,-2021950483,-2030676268,-2039096240,-2047209132,

-2055013722,-2062508835,-2069693341,-2076566159,-2083126253,-2089372637,-2095304369,-2100920555,

-2106220351,-2111202958,-2115867625,-2120213650,-2124240379,-2127947205,-2131333571,-2134398965,

-2137142926,-2139565042,-2141664947,-2143442325,-2144896909,-2146028479,-2146836865,-2147321945,

-2147483647,-2147321945,-2146836865,-2146028479,-2144896909,-2143442325,-2141664947,-2139565042,

-2137142926,-2134398965,-2131333571,-2127947205,-2124240379,-2120213650,-2115867625,-2111202958,

-2106220351,-2100920555,-2095304369,-2089372637,-2083126253,-2076566159,-2069693341,-2062508835,

-2055013722,-2047209132,-2039096240,-2030676268,-2021950483,-2012920200,-2003586778,-1993951624,

-1984016188,-1973781966,-1963250500,-1952423376,-1941302224,-1929888719,-1918184580,-1906191569,

-1893911493,-1881346201,-1868497585,-1855367580,-1841958164,-1828271355,-1814309215,-1800073848,

-1785567395,-1770792043,-1755750016,-1740443580,-1724875039,-1709046738,-1692961061,-1676620431,

-1660027308,-1643184190,-1626093615,-1608758157,-1591180425,-1573363067,-1555308767,-1537020243,

-1518500249,-1499751575,-1480777044,-1461579513,-1442161874,-1422527050,-1402677999,-1382617710,

-1362349204,-1341875532,-1321199780,-1300325059,-1279254515,-1257991319,-1236538675,-1214899812,

-1193077990,-1171076495,-1148898640,-1126547765,-1104027236,-1081340445,-1058490807,-1035481765,

-1012316784,-988999351,-965532978,-941921200,-918167571,-894275670,-870249095,-846091463,

-821806413,-797397602,-772868706,-748223418,-723465451,-698598533,-673626408,-648552837,

-623381597,-598116478,-572761285,-547319836,-521795963,-496193509,-470516330,-444768293,

-418953276,-393075166,-367137860,-341145265,-315101294,-289009871,-262874923,-236700388,

-210490206,-184248325,-157978697,-131685278,-105372028,-79042909,-52701887,-26352928,

};

const int c\_aiTwiddleReal\_1024[512] = {

2147483647,2147443221,2147321945,2147119824,2146836865,2146473079,2146028479,2145503082,

2144896909,2144209981,2143442325,2142593970,2141664947,2140655292,2139565042,2138394239,

2137142926,2135811152,2134398965,2132906419,2131333571,2129680479,2127947205,2126133816,

2124240379,2122266966,2120213650,2118080510,2115867625,2113575079,2111202958,2108751351,

2106220351,2103610053,2100920555,2098151959,2095304369,2092377891,2089372637,2086288719,

2083126253,2079885359,2076566159,2073168776,2069693341,2066139982,2062508835,2058800035,

2055013722,2051150040,2047209132,2043191149,2039096240,2034924561,2030676268,2026351521,

2021950483,2017473320,2012920200,2008291295,2003586778,1998806828,1993951624,1989021349,

1984016188,1978936330,1973781966,1968553291,1963250500,1957873795,1952423376,1946899450,

1941302224,1935631909,1929888719,1924072870,1918184580,1912224072,1906191569,1900087300,

1893911493,1887664382,1881346201,1874957188,1868497585,1861967633,1855367580,1848697673,

1841958164,1835149305,1828271355,1821324571,1814309215,1807225552,1800073848,1792854372,

1785567395,1778213194,1770792043,1763304223,1755750016,1748129706,1740443580,1732691927,

1724875039,1716993211,1709046738,1701035921,1692961061,1684822463,1676620431,1668355276,

1660027308,1651636840,1643184190,1634669675,1626093615,1617456334,1608758157,1599999410,

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