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**IT Security techniques — Hash-  
functions —**

**Part 3:  
Dedicated hash-functions**

*Techniques de sécurité IT — Fonctions de brouillage —  
Partie 3: Fonctions de brouillage dédiées*



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## Foreword

ISO (the International Organization for Standardization) and IEC (the International Electrotechnical Commission) form the specialized system for worldwide standardization. National bodies that are members of ISO or IEC participate in the development of International Standards through technical committees established by the respective organization to deal with particular fields of technical activity. ISO and IEC technical committees collaborate in fields of mutual interest. Other international organizations, governmental and non-governmental, in liaison with ISO and IEC, also take part in the work.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see [www.iso.org/directives](http://www.iso.org/directives)).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO and IEC shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see [www.iso.org/patents](http://www.iso.org/patents)) or the IEC list of patent declarations received (see <http://patents.iec.ch>).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see [www.iso.org/iso/foreword.html](http://www.iso.org/iso/foreword.html).

This document was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC 27, *IT Security techniques*.

This fourth edition cancels and replaces the third edition (ISO/IEC 10118-3:2004), which has been technically revised. It also incorporates the Amendment ISO/IEC 10118-3:2004/Amd1:2006 and Technical Corrigendum ISO/IEC 10118-3:2004/Cor1:2011.

The main changes compared to the previous edition are as follows:

- SHA-3, STREEBOG and SM3 hash-functions have been included;
- SHA-3 extendable-output functions have been included;
- cautionary notes for hash-functions with short hash-codes have been added.

A list of all parts in the ISO/IEC 10118 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at [www.iso.org/members.html](http://www.iso.org/members.html).

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# IT Security techniques — Hash-functions —

## Part 3: Dedicated hash-functions

### 1 Scope

This document specifies dedicated hash-functions, i.e. specially designed hash-functions. The hash-functions in this document are based on the iterative use of a round-function. Distinct round-functions are specified, giving rise to distinct dedicated hash-functions.

The use of Dedicated Hash-Functions 1, 2 and 3 in new digital signature implementations is deprecated.

**NOTE** As a result of their short hash-code length and/or cryptanalytic results, Dedicated Hash-Functions 1, 2 and 3 do not provide a sufficient level of collision resistance for future digital signature applications and they are therefore, only usable for legacy applications. However, for applications where collision resistance is not required, such as in hash-functions as specified in ISO/IEC 9797-2, or in key derivation functions specified in ISO/IEC 11770-6, their use is not deprecated.

Numerical examples for dedicated hash-functions specified in this document are given in [Annex B](#) as additional information. For information purposes, SHA-3 extendable-output functions are specified in [Annex C](#).

### 2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO/IEC 10118-1, *Information technology — Security techniques — Hash-functions — Part 1: General*

### 3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/IEC 10118-1 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <http://www.electropedia.org/>

#### 3.1

##### **block**

bit string of length  $L_1$ , i.e., the length of the first input to the round-function

#### 3.2

##### **word**

string of bits

#### 3.3

##### **circulant matrix**

matrix with the property that each row, apart from the first, consists of the right cyclic shift by one position of the row immediately above it

### 3.4

#### abelian group

group  $(G, *)$  such that  $a*b = b*a$  for every  $a$  and  $b$  in  $G$

### 3.5

#### field

set of elements  $S$  and a pair of operations  $(+, *)$  defined on  $S$  such that: (i)  $a*(b + c) = a*b + a*c$  for every  $a, b$  and  $c$  in  $S$ , (ii)  $S$  together with  $+$  forms an abelian group (with identity element 0) and (iii)  $S$  excluding 0 together with  $*$  forms an abelian group

## 4 Symbols

### 4.1 Symbols specified in ISO/IEC 10118-1

|              |                                                                                                                                                                      |
|--------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| $B_i$        | byte                                                                                                                                                                 |
| $D$          | data                                                                                                                                                                 |
| $H$          | hash-code                                                                                                                                                            |
| $IV$         | initializing value                                                                                                                                                   |
| $L_1$        | length (in bits) of the first of the two input strings to the round-function $\Phi$                                                                                  |
| $L_2$        | length (in bits) of the second of the two input strings to the round-function $\Phi$ , of the output string from the round-function $\Phi$ and of the $IV$           |
| $L_X$        | length (in bits) of a bit string $X$                                                                                                                                 |
| $X \oplus Y$ | bitwise exclusive-or of bit strings $X$ and $Y$ (where $L_X = L_Y$ )                                                                                                 |
| $X    Y$     | concatenation of strings of bits $X$ and $Y$ in the indicated order                                                                                                  |
| $\Phi$       | a round-function, i.e. if $X, Y$ are bit strings of lengths $L_1$ and $L_2$ respectively, then $\Phi(X, Y)$ is the string obtained by applying $\Phi$ to $X$ and $Y$ |

### 4.2 Symbols specific to this document

|                 |                                                                                                                                                                                                                                                       |
|-----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| $A^i$           | sequence of constant matrices used in the specification of the round-function defined in <a href="#">Clause 16</a>                                                                                                                                    |
| $A^n$           | concatenation of $n$ instances of the word $A$                                                                                                                                                                                                        |
| $a_i, a'_i$     | sequences of indices used in specifications of a round-function                                                                                                                                                                                       |
| $C_i, C'_i$     | constant words used in the round-functions                                                                                                                                                                                                            |
| $C''$           | $8 \times 8$ circulant matrix with entries chosen from $\text{GF}(2^8)$ used in the specification of the round-function in <a href="#">Clause 16</a>                                                                                                  |
| $c_0$           | function taking a string of 64 elements of $\text{GF}(2^8)$ as input and giving an $8 \times 8$ matrix with entries from $\text{GF}(2^8)$ as output, used in specifying the round-function defined in <a href="#">Clause 16</a>                       |
| $c_1, c_2, c_3$ | functions taking an $8 \times 8$ matrix of elements of $\text{GF}(2^8)$ as input and giving an $8 \times 8$ matrix with entries from $\text{GF}(2^8)$ as output, used in the specification of the round-function defined in <a href="#">Clause 16</a> |

|                          |                                                                                                                                                                                                                                                                                                                                                                        |
|--------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| $c_4$                    | function taking two $8 \times 8$ matrices of elements of $\text{GF}(2^8)$ as input and giving an $8 \times 8$ matrix with entries from $\text{GF}(2^8)$ as output, used in the specification of the round-function defined in <a href="#">Clause 16</a>                                                                                                                |
| $D_i$                    | a block derived from the data string after the padding process                                                                                                                                                                                                                                                                                                         |
| $d_i, e_i, f_i, g_i$     | functions taking either one or three words as input and producing a single word as output, used in specifying round-functions                                                                                                                                                                                                                                          |
| $H_i$                    | a string of $L_2$ bits which is used in the hashing operation to store an intermediate result                                                                                                                                                                                                                                                                          |
| $\text{Int}_n$           | an inverse mapping to the mapping $\text{Vec}_n$ , i.e. $\text{Int}_n = \text{Vec}_n^{-1}$                                                                                                                                                                                                                                                                             |
| $\text{GF}(2^8)$         | a field defined as $\text{GF}(2)[x] / p_8(x)$ where $p_8(x) = x^8 + x^4 + x^3 + x^2 + 1$ . The elements of the field are 8-bit strings                                                                                                                                                                                                                                 |
| $M$                      | an $8 \times 8$ matrix whose entries are chosen from $\text{GF}(2^8)$                                                                                                                                                                                                                                                                                                  |
| $q$                      | number of blocks in the data string after the padding and splitting processes                                                                                                                                                                                                                                                                                          |
| $R^n()$                  | operation of right shift by $n$ bits, i.e. if $A$ is a word and $n$ is a non-negative integer then $R^n(A)$ denotes the word obtained by right-shifting the contents of $A$ by $n$ positions                                                                                                                                                                           |
| $S^n()$                  | operation of “circular left shift” by $n$ bit positions, i.e. if $A$ is a word and $n$ is a non-negative integer then $S^n(A)$ denotes the word obtained by left-shifting the contents of $A$ by $n$ places in a cyclic fashion                                                                                                                                        |
| $S'^n()$                 | operation of “circular right shift” by $n$ bit positions, i.e. if $A$ is a word and $n$ is a non-negative integer then $S'^n(A)$ denotes the word obtained by right-shifting the contents of $A$ by $n$ places in a cyclic fashion                                                                                                                                     |
| $s$                      | a function, which replaces an element $x \in \text{GF}(2^8)$ with another element $s[x] \in \text{GF}(2^8)$                                                                                                                                                                                                                                                            |
| $t_i, t'_i$              | shift-values used in specifying a round-function                                                                                                                                                                                                                                                                                                                       |
| $\text{Vec}_n$           | a bijective mapping from $\mathbb{Z}_{2^n}$ to the set of $n$ -bit words, which maps an integer from $\mathbb{Z}_{2^n}$ to its binary representation (i.e. for any integer $z = z_0 + 2z_1 + \dots + 2^{n-1}z_{n-1}$ of the set $\mathbb{Z}_{2^n}$ , where $z_j \in \{0,1\}, j = 0, \dots, n-1$ , by definition $\text{Vec}_n(z) = (z_{n-1} \  \dots \  z_1 \  z_0)$ ) |
| $W, X_i, X'_i, Y_i, Z_i$ | words used to store the results of intermediate computations                                                                                                                                                                                                                                                                                                           |
| $W', X'', K_i, Y', Z'$   | matrices with entries chosen from $\text{GF}(2^8)$ used to store the results of intermediate computations                                                                                                                                                                                                                                                              |
| $\mathbb{Z}_{2^n}$       | set of non-negative integers less than $2^n$ , together with the operations of addition and multiplication modulo $2^n$                                                                                                                                                                                                                                                |
| $\wedge$                 | bitwise logical AND operation on bit strings, i.e. if $A, B$ are words then $A \wedge B$ is the word equal to bitwise logical AND of $A$ and $B$                                                                                                                                                                                                                       |
| $\vee$                   | bitwise logical OR operation on bit strings, i.e. if $A, B$ are words then $A \vee B$ is the word equal to bitwise logical OR of $A$ and $B$                                                                                                                                                                                                                           |
| $\neg$                   | bitwise logical NOT operation on a bit string, i.e. if $A$ is a word then $\neg A$ is the word equal to the bitwise logical NOT of $A$                                                                                                                                                                                                                                 |

- ⊕ addition modulo  $2^w$  operation, where  $w$  is the number of bits in a word; i.e. if  $A$  and  $B$  are  $w$ -bit words, then  $A \oplus B$  is the word obtained by treating  $A$  and  $B$  as the binary representations of integers and computing their sum modulo  $2^w$ , where the result is constrained to lie between 0 and  $2^w - 1$  inclusive. The value of  $w$  is 32 for Dedicated Hash-Functions 1 to 4, defined in [Clauses 7 to 10](#), 64 for Dedicated Hash-Functions 5 and 6, defined in [Clauses 11 and 12](#) and 512 for Dedicated Hash-Functions 11 and 12, defined in [Clauses 17 and 18](#)
- multiplication operation of  $8 \times 8$  matrices with entries chosen from  $\text{GF}(2^8)$ ; i.e. if  $A$  and  $B$  are such matrices, then  $A \cdot B$  is the matrix obtained by multiplying  $A$  and  $B$  in the following way. Treat each entry of either  $A$  or  $B$  as the binary polynomial representation of an integer (for example, the binary polynomial representation of integer 89 (hexadecimal) is  $x^7 + x^3 + 1$ ); treat the multiplication of two of the entries as the remainder when multiplication of the two polynomials is divided by a polynomial  $p_8(x)$ , where  $p_8(x) = x^8 + x^4 + x^3 + x^2 + 1$ ; and treat the sum operation as the operation  $\oplus$
- $:=$  a symbol denoting the “set equal to” operation used in procedural specifications of round-functions, where it indicates that the value of the variable (e.g. word or matrix) on the left side of the symbol should be set equal to the value of the expression on the right side of the symbol

## 5 Requirements

Users who wish to employ a hash-function from this document shall select

- one of the dedicated hash-functions specified below, and
- the length,  $L_H$ , of the hash-code  $H$ .

NOTE 1 All the hash-functions defined in this document take a bit string as input and give a bit string as output; this is independent of the internal byte ordering convention used within each hash-function.

NOTE 2 The choice of  $L_H$  affects the security of the hash-function. All of the hash-functions specified in this document are believed to be collision-resistant hash-functions in environments where performing  $2^{L_H/2}$  hash-code computation is deemed to be computationally infeasible.

[Annex A](#) defines object identifiers that shall be used to identify the hash-functions specified in this document.

## 6 Models for dedicated hash-functions

### 6.1 Use of models

The 17 dedicated hash-functions specified in this document are defined using two different models. Dedicated Hash-Functions 1 to 12 and 17 are defined using the general round-function-based model defined in ISO/IEC 10118-1, which is further described in [6.2](#). Dedicated Hash-Functions 13 to 16 use the sponge construction model as defined in [6.3](#).

### 6.2 Round-function model

Dedicated Hash-Functions 1 to 12 and 17 specified in this document are based on the general model for hash-functions given in ISO/IEC 10118-1.

In the specifications of the hash-functions in this document, it is assumed that the padded data string input to the hash-function is in the form of a sequence of bytes. If the padded data string is in the form of a sequence of  $8n$  bits,  $x_0, x_1, \dots, x_{8n-1}$ , then it shall be interpreted as a sequence of  $n$  bytes,  $B_0, B_1, \dots, B_{n-1}$ , in the following way. Each group of eight consecutive bits is considered as a byte, the first bit of a group being the most significant bit of that byte. Hence,

$$B_i = 2^7 x_{8i} + 2^6 x_{8i+1} + \dots + x_{8i+7}$$

for every  $i$  ( $0 \leq i < n$ ).

The output transformation for the hash-functions specified in this document is defined so that the hash-code,  $H$ , is derived by taking the left-most  $L_H$  bits of the final  $L_2$ -bit output string  $H_q$ .

Identifiers are defined for each of the 17 dedicated hash-functions specified in this document. The hash-function identifiers for the dedicated hash-functions specified in [Clauses 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22](#) and [23](#) are equal to 31, 32, 33, 34, 35, 36, 37, 38, 39, 3A, 3B, 3C, 3D, 3E, 3F, 40 and 11 (hexadecimal), respectively. Some hash-function identifiers are also used in the OSI object identifiers assigned in [Annex A](#).

### 6.3 Sponge model

In [6.3](#), a permutation-based hash-function with sponge construction is specified.

A permutation-based hash-function with sponge construction is defined by a padding method, a permutation and a set of parameters.

The sponge construction<sup>[4]</sup> is a framework for specifying functions on a binary data with arbitrary output length. The construction employs the following three components:

- an underlying function on fixed-length strings, denoted by  $f$ ;
- a parameter called the rate, denoted by  $r$ ;
- a padding rule, denoted by  $\text{pad}$ .

The function that the construction produces from these components is called a sponge function, denoted by  $\text{SPONGE}[f, \text{pad}, r]$ . A sponge function takes two inputs, a bit string,  $N$ , and the bit length,  $d$ , of the output string,  $\text{SPONGE}[f, \text{pad}, r](N, d)$ .

NOTE For further details on the rationale of the sponge construction framework, see Reference [\[5\]](#).

The function,  $f$ , maps strings of a single, fixed length,  $b$ , to strings of the same length.  $b$  is called the width of  $f$ . When the underlying function,  $f$ , is invertible, i.e. a permutation, it is a permutation-based hash-function with sponge construction.

The rate,  $r$ , is a positive integer that is strictly less than the width  $b$ . The capacity,  $c$ , is the positive integer  $b - r$ . Thus,  $r + c = b$ .

In the padding rule,  $\text{pad}$  is a function that produces padding, i.e. a string with an appropriate length to append to another string. In general, given a positive integer  $x$  and a non-negative integer  $m$ , the output  $\text{pad}(x, m)$  is a string with the property that  $m + \text{len}[\text{pad}(x, m)]$  is a positive multiple of  $x$ . Within the sponge construction,  $x = r$  and  $m = \text{len}(N)$ , so that the padded input string can be partitioned into a sequence of  $r$ -bit strings.

Given these three components,  $f$ ,  $\text{pad}$  and  $r$ , as described above, the  $\text{SPONGE}[f, \text{pad}, r]$  function on  $(N, d)$  is specified by  $\text{SPONGE}[f, \text{pad}, r](N, d)$ . The width  $b$  is determined by the choice of  $f$ .

$\text{SPONGE}[f, \text{pad}, r](N, d)$

Input: string  $N$ , non-negative integer  $d$

Output: string  $Z$ , such that  $\text{len}(Z) = d$

Steps:

- a) Let  $P = N \parallel \text{pad}[r, \text{len}(N)]$ .
- b) Let  $q = \text{len}(P)/r$ .

- c) Let  $c = b - r$ .
- d) Let  $P_0, \dots, P_{q-1}$  be the unique sequence of strings of length  $r$ , such that  $P = P_0 \parallel \dots \parallel P_{q-1}$ .
- e) Let  $S = 0^b$ .
- f) For  $i$  from 0 to  $q-1$ , let  $S = f[S \oplus (P_i \parallel 0^c)]$ .
- g) Let  $Z$  be the empty string.
- h) Let  $Z = Z \parallel \text{Trunc}_r(S)$ .
- i) If  $d \leq |Z|$ , then return  $\text{Trunc}_d(Z)$ ; else, continue.
- j) Let  $S = f(S)$  and continue with step h).

Note that the input  $d$  determines the number of bits that  $\text{SPONGE}[f, \text{pad}, r](N, d)$  returns, but it does not affect their values. In principle, the output can be regarded as an infinite string, whose computation, in practice, is halted after the desired number of output bits is produced.

The parameters of a sponge construction include:

- $b$ , the width;
- $r$ , the rate;
- $c$ , the capacity, such that  $b = r + c$ ; and
- $d$ , the output length.

Here, if notations specified in ISO/IEC 10118-1:2016, Clause 3 are used,  $r$  can be considered as  $L_1$ , which is the length of a block of input data (message), while  $b$  can be considered as  $L_2$ , which is the output length of the function  $f$ . Furthermore, the relation between function  $f$  and the round-function  $\Phi$  as defined in ISO/IEC 10118-1:2016, Clause 3 can be represented as  $\Phi(P_i, S_{i-1}) = f[S_{i-1} \oplus (P_i \parallel 0^c)]$ , where  $P_i = D_i$  is the  $i$ th data block, while  $S_{i-1} = H_{i-1}$  is the output of the previous execution. The squeezing stage is considered the output transformation.

## 7 Dedicated Hash-Function 1 (RIPEMD-160)

### 7.1 General

In [Clause 7](#), a padding method, an initializing value and a round-function for use in the general model for hash-functions described in ISO/IEC 10118-1 are specified. The padding method, initializing value and round-function specified here, when used in the above general model, together define Dedicated Hash-Function 1. This dedicated hash-function can be applied to all data strings,  $D$ , containing at most  $2^{64}-1$  bits.

The ISO/IEC hash-function identifier for Dedicated Hash-Function 1 is equal to 31 (hexadecimal).

NOTE 1 Dedicated Hash-Function 1 defined in [Clause 7](#) is commonly called RIPEMD-160<sup>[6]</sup>.

NOTE 2 As a result of a short hash-code length and/or cryptanalytic results, Dedicated Hash-Function 1 does not provide a sufficient level of collision resistance for future digital signature applications and it is, therefore, only used for legacy applications. However, for applications where collision resistance is not required, such as in hash-functions as specified in the ISO/IEC 9797 series or in key derivation functions specified in ISO/IEC 11770-6, its use is not deprecated.

## 7.2 Parameters, functions and constants

### 7.2.1 Parameters

For this hash-function,  $L_1 = 512$ ,  $L_2 = 160$  and  $L_H$  is up to 160.

### 7.2.2 Byte ordering convention

In the specification of the round-function of [Clause 7](#), it is assumed that the block input to the round-function is in the form of a sequence of 32-bit words, each 512-bit block being made up of 16 such words. A sequence of 64 bytes,  $B_0, B_1, \dots, B_{63}$ , shall be interpreted as a sequence of 16 words,  $Z_0, Z_1, \dots, Z_{15}$ , in the following way. Each group of four consecutive bytes is considered as a word, the first byte of a word being the least significant byte of that word. Hence,

$$Z_i = 2^{24}B_{4i+3} + 2^{16}B_{4i+2} + 2^8B_{4i+1} + B_{4i}, \quad (0 \leq i \leq 15).$$

To convert the hash-code from a sequence of words to a byte-sequence, the inverse process shall be followed.

NOTE The byte-ordering specified here is different from that of [9.2.2](#).

### 7.2.3 Functions

To facilitate software implementation, the round-function  $\Phi$  is described in terms of operations on 32-bit words. A sequence of functions  $g_0, g_1, \dots, g_{79}$  is used in this round-function, where each function  $g_i$ ,  $0 \leq i \leq 79$ , takes three words,  $X_0, X_1$  and  $X_2$ , as input and produces a single word as output.

The functions  $g_i$  are defined as follows:

$$\begin{aligned} g_i(X_0, X_1, X_2) &= X_0 \oplus X_1 \oplus X_2, & (0 \leq i \leq 15); \\ g_i(X_0, X_1, X_2) &= (X_0 \wedge X_1) \vee (\neg X_0 \wedge X_2), & (16 \leq i \leq 31); \\ g_i(X_0, X_1, X_2) &= (X_0 \vee \neg X_1) \oplus X_2, & (32 \leq i \leq 47); \\ g_i(X_0, X_1, X_2) &= (X_0 \wedge X_2) \vee (X_1 \wedge \neg X_2), & (48 \leq i \leq 63); \\ g_i(X_0, X_1, X_2) &= X_0 \oplus (X_1 \vee \neg X_2), & (64 \leq i \leq 79). \end{aligned}$$

### 7.2.4 Constants

Two sequences of constant words,  $C_0, C_1, \dots, C_{79}$  and  $C'_0, C'_1, \dots, C'_{79}$ , are used in this round-function. In a hexadecimal representation (where the most significant bit corresponds to the left-most bit), these are defined as follows:

$$\begin{aligned} C_i &= 00000000, & (0 \leq i \leq 15); \\ C_i &= 5A827999, & (16 \leq i \leq 31); \\ C_i &= 6ED9EBA1, & (32 \leq i \leq 47); \\ C_i &= 8F1BBCDC, & (48 \leq i \leq 63); \\ C_i &= A953FD4E, & (64 \leq i \leq 79); \\ C'_i &= 50A28BE6, & (0 \leq i \leq 15); \\ C'_i &= 5C4DD124, & (16 \leq i \leq 31); \\ C'_i &= 6D703EF3, & (32 \leq i \leq 47); \\ C'_i &= 7A6D76E9, & (48 \leq i \leq 63); \\ C'_i &= 00000000, & (64 \leq i \leq 79). \end{aligned}$$

Two sequences of 80 shift-values are used in this round-function, where each shift-value is between 5 and 15. These sequences are denoted by  $(t_0, t_1, \dots, t_{79})$  and  $(t'_0, t'_1, \dots, t'_{79})$ . Two additional sequences of 80 indices are used in this round-function, where each value in the sequence is between 0 and 15. These sequences are denoted as  $(a_0, a_1, \dots, a_{79})$  and  $(a'_0, a'_1, \dots, a'_{79})$ . All four sequences are defined in [Table 1](#).



Table 1 — Sequences for Hash-Function 1

|        |    |    |    |    |    |    |    |   |
|--------|----|----|----|----|----|----|----|---|
| $i$    | 0  | 1  | 2  | 3  | 4  | 5  | 6  | 7 |
| $t_i$  | 11 | 14 | 15 | 12 | 5  | 8  | 7  | 9 |
| $t'_i$ | 8  | 9  | 9  | 11 | 13 | 15 | 15 | 5 |
| $a_i$  | 0  | 1  | 2  | 3  | 4  | 5  | 6  | 7 |
| $a'_i$ | 5  | 14 | 7  | 0  | 9  | 2  | 11 | 4 |

|        |    |    |    |    |    |    |    |    |
|--------|----|----|----|----|----|----|----|----|
| $i$    | 8  | 9  | 10 | 11 | 12 | 13 | 14 | 15 |
| $t_i$  | 11 | 13 | 14 | 15 | 6  | 7  | 9  | 8  |
| $t'_i$ | 7  | 7  | 8  | 11 | 14 | 14 | 12 | 6  |
| $a_i$  | 8  | 9  | 10 | 11 | 12 | 13 | 14 | 15 |
| $a'_i$ | 13 | 6  | 15 | 8  | 1  | 10 | 3  | 12 |

|        |    |    |    |    |    |    |    |    |
|--------|----|----|----|----|----|----|----|----|
| $i$    | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
| $t_i$  | 7  | 6  | 8  | 13 | 11 | 9  | 7  | 15 |
| $t'_i$ | 9  | 13 | 15 | 7  | 12 | 8  | 9  | 11 |
| $a_i$  | 7  | 4  | 13 | 1  | 10 | 6  | 15 | 3  |
| $a'_i$ | 6  | 11 | 3  | 7  | 0  | 13 | 5  | 10 |

|        |    |    |    |    |    |    |    |    |
|--------|----|----|----|----|----|----|----|----|
| $i$    | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 |
| $t_i$  | 7  | 12 | 15 | 9  | 11 | 7  | 13 | 12 |
| $t'_i$ | 7  | 7  | 12 | 7  | 6  | 15 | 13 | 11 |
| $a_i$  | 12 | 0  | 9  | 5  | 2  | 14 | 11 | 8  |
| $a'_i$ | 14 | 15 | 8  | 12 | 4  | 9  | 1  | 2  |

|        |    |    |    |    |    |    |    |    |
|--------|----|----|----|----|----|----|----|----|
| $i$    | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 |
| $t_i$  | 11 | 13 | 6  | 7  | 14 | 9  | 13 | 15 |
| $t'_i$ | 9  | 7  | 15 | 11 | 8  | 6  | 6  | 14 |
| $a_i$  | 3  | 10 | 14 | 4  | 9  | 15 | 8  | 1  |
| $a'_i$ | 15 | 5  | 1  | 3  | 7  | 14 | 6  | 9  |

|        |    |    |    |    |    |    |    |    |
|--------|----|----|----|----|----|----|----|----|
| $i$    | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 |
| $t_i$  | 14 | 8  | 13 | 6  | 5  | 12 | 7  | 5  |
| $t'_i$ | 12 | 13 | 5  | 14 | 13 | 13 | 7  | 5  |
| $a_i$  | 2  | 7  | 0  | 6  | 13 | 11 | 5  | 12 |
| $a'_i$ | 11 | 8  | 12 | 2  | 10 | 0  | 4  | 13 |



|        |     |     |     |     |     |     |     |     |
|--------|-----|-----|-----|-----|-----|-----|-----|-----|
| $i$    | 4 8 | 4 9 | 5 0 | 5 1 | 5 2 | 5 3 | 5 4 | 5 5 |
| $t_i$  | 1 1 | 1 2 | 1 4 | 1 5 | 1 4 | 1 5 | 9   | 8   |
| $t'_i$ | 1 5 | 5   | 8   | 1 1 | 1 4 | 1 4 | 6   | 1 4 |
| $a_i$  | 1   | 9   | 1 1 | 1 0 | 0   | 8   | 1 2 | 4   |
| $a'_i$ | 8   | 6   | 4   | 1   | 3   | 1 1 | 1 5 | 0   |

|        |     |     |     |     |     |     |     |     |
|--------|-----|-----|-----|-----|-----|-----|-----|-----|
| $i$    | 5 6 | 5 7 | 5 8 | 5 9 | 6 0 | 6 1 | 6 2 | 6 3 |
| $t_i$  | 9   | 1 4 | 5   | 6   | 8   | 6   | 5   | 1 2 |
| $t'_i$ | 6   | 9   | 1 2 | 9   | 1 2 | 5   | 1 5 | 8   |
| $a_i$  | 1 3 | 3   | 7   | 1 5 | 1 4 | 5   | 6   | 2   |
| $a'_i$ | 5   | 1 2 | 2   | 1 3 | 9   | 7   | 1 0 | 1 4 |

|        |     |     |     |     |     |     |     |     |
|--------|-----|-----|-----|-----|-----|-----|-----|-----|
| $i$    | 6 4 | 6 5 | 6 6 | 6 7 | 6 8 | 6 9 | 7 0 | 7 1 |
| $t_i$  | 9   | 1 5 | 5   | 1 1 | 6   | 8   | 1 3 | 1 2 |
| $t'_i$ | 8   | 5   | 1 2 | 9   | 1 2 | 5   | 1 4 | 6   |
| $a_i$  | 4   | 0   | 5   | 9   | 7   | 1 2 | 2   | 1 0 |
| $a'_i$ | 1 2 | 1 5 | 1 0 | 4   | 1   | 5   | 8   | 7   |

|        |     |     |     |     |     |     |     |     |
|--------|-----|-----|-----|-----|-----|-----|-----|-----|
| $i$    | 7 2 | 7 3 | 7 4 | 7 5 | 7 6 | 7 7 | 7 8 | 7 9 |
| $t_i$  | 5   | 1 2 | 1 3 | 1 4 | 1 1 | 8   | 5   | 6   |
| $t'_i$ | 8   | 1 3 | 6   | 5   | 1 5 | 1 3 | 1 1 | 1 1 |
| $a_i$  | 1 4 | 1   | 3   | 8   | 1 1 | 6   | 1 5 | 1 3 |
| $a'_i$ | 6   | 2   | 1 3 | 1 4 | 0   | 3   | 9   | 1 1 |

### 7.2.5 Initializing value

For this round-function, the initializing value,  $IV$ , shall always be the following 160-bit string, represented here as a sequence of five words,  $Y_0$ ,  $Y_1$ ,  $Y_2$ ,  $Y_3$  and  $Y_4$ , in a hexadecimal representation, where  $Y_0$  represents the left-most 32 of the 160 bits:

$Y_0 = 67452301;$   
 $Y_1 = \text{EFCDAB89};$   
 $Y_2 = 98BADCFE;$   
 $Y_3 = 10325476;$   
 $Y_4 = \text{C3D2E1F0}.$

### 7.3 Padding method

The data string,  $D$ , needs to be padded to make it contain a number of bits which is an integer multiple of 512. The padding procedure operates as follows.

- $D$  is concatenated with a single "1" bit.
- The result of the previous step is concatenated with between zero and 511 "0" bits such that the length (in bits) of the resultant string is congruent to 448 modulo 512. More explicitly, if the original length of  $D$  is  $L_D$  and letting  $r$  be the remainder when  $L_D$  is divided by 512, then the number

of concatenated zeros is equal to either  $447 - r$  (if  $r \leq 447$ ) or  $959 - r$  (if  $r > 447$ ). The result will be a bit string whose length will be 64 bits short of an integer multiple of 512 bits.

- c) Divide the 64-bit binary representation of  $L_D$  into two 32-bit strings, one representing the “most significant half” of  $L_D$  and the other the “least significant half”. Now concatenate the string resulting from the previous step with these two 32-bit strings, with the “least significant half” preceding the “most significant half”.

In the description of the round-function which follows, each 512-bit data block  $D_i$ ,  $1 \leq i \leq q$ , is treated as a sequence of 16 words,  $Z_0, Z_1, \dots, Z_{15}$ , where  $Z_0$  corresponds to the left-most 32 bits of  $D_i$ .

NOTE The concatenation of the two 32-bit strings of  $L_D$  in step c) is such that these two 32-bit strings are used directly as the words  $Z_{14}$  and  $Z_{15}$  of the last data block; based on the byte ordering convention in 7.2.2, the least significant byte of  $L_D$  is the left-most byte and the most significant byte of  $L_D$  is the right-most byte.

## 7.4 Description of the round-function

The round-function,  $\Phi$ , operates as follows.

NOTE In this description, the symbols  $W, X_0, X_1, X_2, X_3, X_4, X'_0, X'_1, X'_2, X'_3$  and  $X'_4$  are used to denote 11 distinct words which contain values required in the computations.

- a) Suppose the 512-bit (first) input to  $\Phi$  is contained in  $Z_0, Z_1, \dots, Z_{15}$ , where  $Z_0$  contains the left-most 32 of the 512 bits. Suppose also that the 160-bit (second) input to  $\Phi$  is contained in five words,  $Y_0, Y_1, Y_2, Y_3$  and  $Y_4$ .
- b) Let  $X_0 = Y_0, X_1 = Y_1, X_2 = Y_2, X_3 = Y_3$  and  $X_4 = Y_4$ .
- c) Let  $X'_0 = Y_0, X'_1 = Y_1, X'_2 = Y_2, X'_3 = Y_3$  and  $X'_4 = Y_4$ .
- d) For  $i = 0$  to 79, do the following four steps in the order specified:
- 1)  $W = S^{t_i} [X_0 \cup g_i(X_1, X_2, X_3) \cup Z_{a_i} \cup C_i] \cup X_4$ ;
  - 2)  $X_0 = X_4; X_4 = X_3; X_3 = S^{10}(X_2); X_2 = X_1; X_1 = W$ ;
  - 3)  $W = S^{t'_i} [X'_0 \cup g_{79-i}(X'_1, X'_2, X'_3) \cup Z_{a'_i} \cup C'_i] \cup X'_4$ ;
  - 4)  $X'_0 = X'_4; X'_4 = X'_3; X'_3 = S^{10}(X'_2); X'_2 = X'_1; X'_1 = W$ .
- e) Let  $W = Y_0, Y_0 = Y_1 \cup X_2 \cup X'_3, Y_1 = Y_2 \cup X_3 \cup X'_4, Y_2 = Y_3 \cup X_4 \cup X'_0, Y_3 = Y_4 \cup X_0 \cup X'_1$  and  $Y_4 = W \cup X_1 \cup X'_2$ .
- f) The five words,  $Y_0, Y_1, Y_2, Y_3$  and  $Y_4$ , represent the output of the round-function  $\Phi$ . After the final iteration of the round-function, the five words,  $Y_0, Y_1, Y_2, Y_3$  and  $Y_4$ , shall be converted to a sequence of 20 bytes using the inverse of the procedure specified in 7.2.2 and where  $Y_0$  shall yield the first four bytes,  $Y_1$  the next four bytes and so on. Thus, the first (left-most) byte will correspond to the least significant byte of  $Y_0$  and the 20th (right-most) byte will correspond to the most significant byte of  $Y_4$ . The 20 bytes shall be converted to a string of 160 bits using the inverse of the procedure specified in Clause 6, i.e. the first (left-most) bit will correspond to the most significant bit of the first (left-most) byte and the 160th (right-most) bit will correspond to the least significant bit of the 20th (right-most) byte.

Figure 1 shows steps 1) and 2) of item d) of the round-function  $\Phi$  in Dedicated Hash-Function 1 (RIPEMD-160) [the other half, i.e. steps 3) and 4) is similar]. In the round-function  $\Phi$ , steps 1) to 4) of item d) are used 80 times ( $i = 0, \dots, 79$ ).

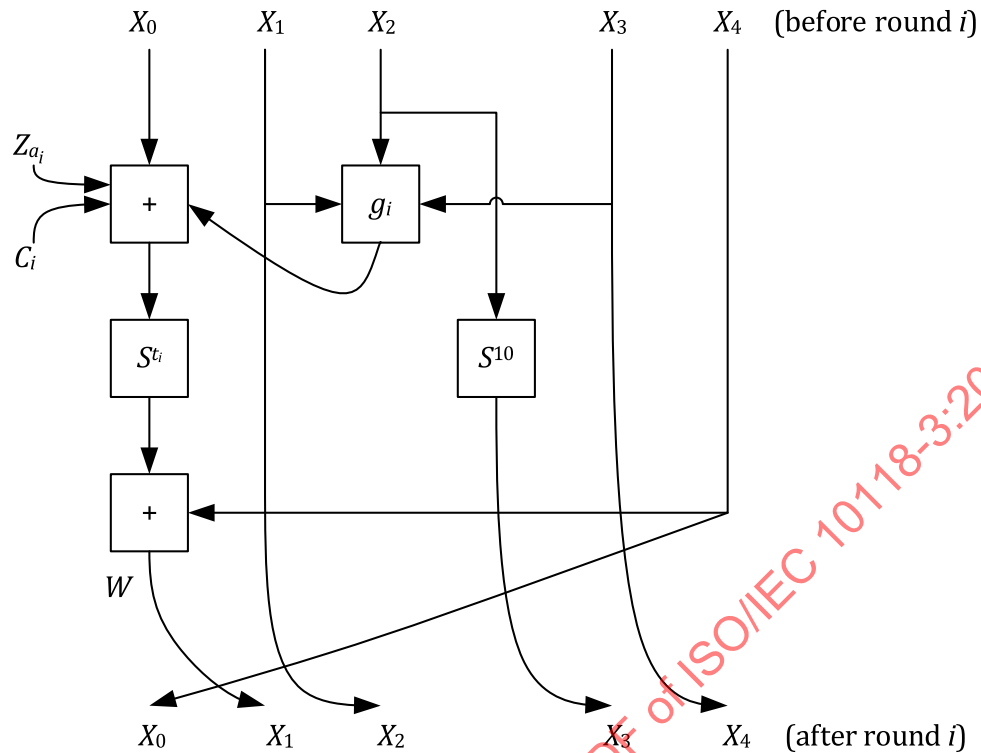


Figure 1 — Part of the round-function in Dedicated Hash-Function 1

## 8 Dedicated Hash-Function 2 (RIPEMD-128)

### 8.1 General

In [Clause 8](#), a padding method, an initializing value and a round-function for use in the general model for hash-functions described in ISO/IEC 10118-1 are specified. The padding method, initializing value and round-function specified here, when used in the above general model, together define Dedicated Hash-Function 2. This dedicated hash-function can be applied to all data strings,  $D$ , containing at most  $2^{64}-1$  bits.

The ISO/IEC hash-function identifier for Dedicated Hash-Function 2 is equal to 32 (hexadecimal).

NOTE 1 Dedicated Hash-Function 2 defined in [Clause 8](#) is commonly called RIPEMD-128<sup>[6]</sup>. This hash-function is only used in applications where a hash-code containing 128 bits or less is considered adequately secure.

NOTE 2 As a result of a short hash-code length and/or cryptanalytic results, Dedicated Hash-Function 2 does not provide a sufficient level of collision resistance for future digital signature applications and it is, therefore, only used for legacy applications. However, for applications where collision resistance is not required, such as in hash-functions as specified in the ISO/IEC 9797 series or in key derivation functions specified in ISO/IEC 11770-6, its use is not deprecated.

### 8.2 Parameters, functions and constants

#### 8.2.1 Parameters

For this hash-function,  $L_1 = 512$ ,  $L_2 = 128$  and  $L_H$  is up to 128.

#### 8.2.2 Byte ordering convention

The byte ordering convention for this hash-function is the same as that for the hash-function of [Clause 7](#).

### 8.2.3 Functions

To facilitate software implementation, the round-function,  $\Phi$ , is described in terms of operations on 32-bit words. A sequence of functions,  $g_0, g_1, \dots, g_{63}$ , is used in this round-function, where each function  $g_i$ ,  $0 \leq i \leq 63$ , takes three words,  $X_0, X_1$  and  $X_2$ , as input and produces a single word as output.

The functions  $g_i$  are defined to be the same as the first 64 of the functions defined in [7.2.3](#).

### 8.2.4 Constants

Two sequences of constant words,  $C_0, C_1, \dots, C_{63}$  and  $C'_0, C'_1, \dots, C'_{63}$ , are used in this round-function. In a hexadecimal representation (where the most significant bit corresponds to the left-most bit), these are defined as follows:

|                     |                         |
|---------------------|-------------------------|
| $C_i = 00000000$ ,  | $(0 \leq i \leq 15)$ ;  |
| $C_i = 5A827999$ ,  | $(16 \leq i \leq 31)$ ; |
| $C_i = 6ED9EBA1$ ,  | $(32 \leq i \leq 47)$ ; |
| $C_i = 8F1BBCDC$ ,  | $(48 \leq i \leq 63)$ . |
| $C'_i = 50A28BE6$ , | $(0 \leq i \leq 15)$ ;  |
| $C'_i = 5C4DD124$ , | $(16 \leq i \leq 31)$ ; |
| $C'_i = 6D703EF3$ , | $(32 \leq i \leq 47)$ ; |
| $C'_i = 00000000$ , | $(48 \leq i \leq 63)$ . |

Two sequences of 64 shift-values are also used in this round-function, where each shift-value is between 5 and 15. These sequences are denoted by  $(t_0, t_1, \dots, t_{63})$  and  $(t'_0, t'_1, \dots, t'_{63})$  and they are defined to be equal to the first 64 values of the corresponding sequences defined in [7.2.4](#).

Finally, two further sequences of 64 indices are used in this round-function, where each value in the sequence is between 0 and 15. These sequences are denoted by  $(a_0, a_1, \dots, a_{63})$  and  $(a'_0, a'_1, \dots, a'_{63})$  and they are defined to be equal to the first 64 values of the corresponding sequences defined in [7.2.4](#).

### 8.2.5 Initializing value

For this hash-function, the initializing value,  $IV$ , shall always be the following 128-bit string, represented here as a sequence of four words,  $Y_0, Y_1, Y_2$  and  $Y_3$ , in a hexadecimal representation, where  $Y_0$  represents the left-most 32 of the 128 bits:

$Y_0 = 67452301$ ;  
 $Y_1 = EFCDA89$ ;  
 $Y_2 = 98BADCFE$ ;  
 $Y_3 = 10325476$ .

## 8.3 Padding method

The padding method to be used with this hash-function shall be the same as the padding method defined in [7.3](#).

## 8.4 Description of the round-function

The round-function,  $\Phi$ , operates as follows.

NOTE In this description, the symbols  $W, X_0, X_1, X_2, X_3, X'_0, X'_1, X'_2$  and  $X'_3$  are used to denote nine distinct words which contain values required in the computations.

- Suppose the 512-bit (first) input to  $\Phi$  is contained in  $Z_0, Z_1, \dots, Z_{15}$ , where  $Z_0$  contains the left-most 32 of the 512 bits. Suppose also that the 128-bit (second) input to  $\Phi$  is contained in four words,  $Y_0, Y_1, Y_2$  and  $Y_3$ .
- Let  $X_0 := Y_0, X_1 := Y_1, X_2 := Y_2$  and  $X_3 := Y_3$ .

- c) Let  $X'_0 := Y_0$ ,  $X'_1 := Y_1$ ,  $X'_2 := Y_2$  and  $X'_3 := Y_3$ .
- d) For  $i := 0$  to 63, do the following four steps in the order specified:
- 1)  $W := S^{t_i} [X_0 \cup g_i(X_1, X_2, X_3) \cup Z_{a_i} \cup C_i]$ ;
  - 2)  $X_0 := X_3$ ;  $X_3 := X_2$ ;  $X_2 := X_1$ ;  $X_1 := W$ ;
  - 3)  $W := S^{t'_i} [X'_0 \cup g_{63-i}(X'_1, X'_2, X'_3) \cup Z_{a'_i} \cup C'_i]$ ;
  - 4)  $X'_0 := X'_3$ ;  $X'_3 := X'_2$ ;  $X'_2 := X'_1$ ;  $X'_1 := W$ .
- e) Let  $W := Y_0$ ,  $Y_0 := Y_1 \cup X_2 \cup X'_3$ ,  $Y_1 := Y_2 \cup X_3 \cup X'_0$ ,  $Y_2 := Y_3 \cup X_0 \cup X'_1$  and  $Y_3 := W \cup X_1 \cup X'_2$ .
- f) The four words,  $Y_0$ ,  $Y_1$ ,  $Y_2$  and  $Y_3$ , represent the output of the round-function  $\Phi$ . After the final iteration of the round-function, the four words,  $Y_0$ ,  $Y_1$ ,  $Y_2$  and  $Y_3$ , shall be converted to a sequence of 16 bytes using the inverse of the procedure specified in 7.2.2 and where  $Y_0$  shall yield the first four bytes,  $Y_1$  the next four bytes and so on. Thus, the first (left-most) byte will correspond to the least significant byte of  $Y_0$  and the 16th (right-most) byte will correspond to the most significant byte of  $Y_3$ . The 16 bytes shall be converted to a string of 128 bits using the inverse of the procedure specified in Clause 6, i.e. the first (left-most) bit will correspond to the most significant bit of the first (left-most) byte and the 128th (right-most) bit will correspond to the least significant bit of the 16th (right-most) byte.

Figure 2 shows steps 1) and 2) of item d) of the round-function  $\Phi$  in Dedicated Hash-Function 2 (RIPEMD-128) [the other half, i.e. steps 3) and 4) is similar]. In the round-function  $\Phi$ , steps 1) to 4) of item d) are used 64 times ( $i = 0, \dots, 63$ ).

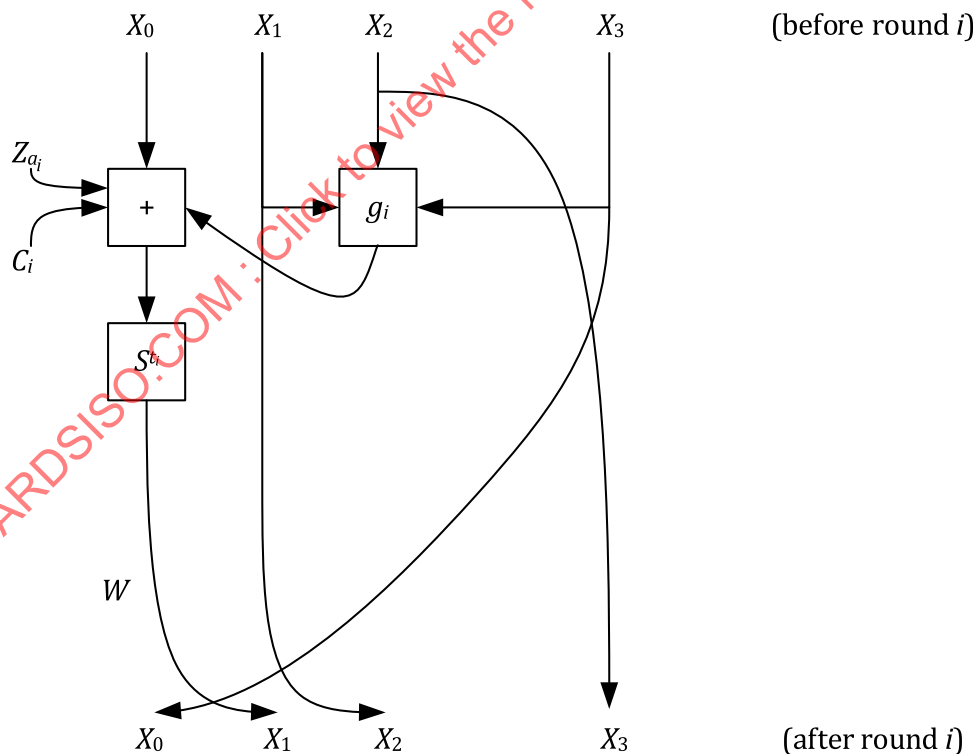


Figure 2 — Part of the round-function in Dedicated Hash-Function 2

## 9 Dedicated Hash-Function 3 (SHA-1)

### 9.1 General

In [Clause 9](#), a padding method, an initializing value and a round-function for use in the general model for hash-functions described in ISO/IEC 10118-1 are specified. The padding method, initializing value and round-function specified here, when used in the above general model, together define the Dedicated Hash-Function 3. This dedicated hash-function can be applied to all data strings,  $D$ , containing at most  $2^{64}-1$  bits.

The ISO/IEC hash-function identifier for Dedicated Hash-Function 3 is equal to 33 (hexadecimal).

NOTE 1 Dedicated Hash-Function 3 defined in [Clause 9](#) is commonly called SHA-1<sup>[1]</sup>.

NOTE 2 As a result of a short hash-code length and/or cryptanalytic results, Dedicated Hash-Function 3 does not provide a sufficient level of collision resistance for future digital signature applications and it is, therefore, only used for legacy applications. However, for applications where collision resistance is not required, such as in hash-functions as specified in the ISO/IEC 9797 series or in key derivation functions specified in ISO/IEC 11770-6, its use is not deprecated.

### 9.2 Parameters, functions and constants

#### 9.2.1 Parameters

For this hash-function,  $L_1 = 512$ ,  $L_2 = 160$  and  $L_H$  is up to 160.

#### 9.2.2 Byte ordering convention

In the specification of the round-function of [Clause 9](#), it is assumed that the block input to the round-function is in the form of a sequence of 32-bit words, each 512-bit block made up of 16 such words. A sequence of 64 bytes,  $B_0, B_1, \dots, B_{63}$ , shall be interpreted as a sequence of 16 words,  $Z_0, Z_1, \dots, Z_{15}$ , in the following way, where each group of four consecutive bytes is considered as a word, the first byte of a word being the most significant byte of that word. Hence,

$$Z_i = 2^{24}B_{4i} + 2^{16}B_{4i+1} + 2^8B_{4i+2} + B_{4i+3}, \quad (0 \leq i \leq 15).$$

To convert the hash-code from a sequence of words to a sequence of bytes, the inverse process shall be followed.

NOTE The byte-ordering specified here is different from that of [7.2.2](#).

#### 9.2.3 Functions

To facilitate software implementation, the round-function  $\Phi$  is described in terms of operations on 32-bit words. A sequence of functions,  $f_0, f_1, \dots, f_{79}$ , is used in this round-function, where each function,  $f_i$ ,  $0 \leq i \leq 79$ , takes three words,  $X_0, X_1$  and  $X_2$ , as input and produces a single word as output.

The functions  $f_i$  are defined as follows:

$$\begin{aligned} f_i(X_0, X_1, X_2) &= (X_0 \wedge X_1) \vee (\neg X_0 \wedge X_2), & (0 \leq i \leq 19); \\ f_i(X_0, X_1, X_2) &= X_0 \oplus X_1 \oplus X_2, & (20 \leq i \leq 39); \\ f_i(X_0, X_1, X_2) &= (X_0 \wedge X_1) \vee (X_0 \wedge X_2) \vee (X_1 \wedge X_2), & (40 \leq i \leq 59); \\ f_i(X_0, X_1, X_2) &= X_0 \oplus X_1 \oplus X_2, & (60 \leq i \leq 79). \end{aligned}$$

#### 9.2.4 Constants

A sequence of constant words,  $C_0, C_1, \dots, C_{79}$ , is used in this round-function. In a hexadecimal representation (where the most significant bit corresponds to the left-most bit), these are defined as follows:

$$\begin{aligned}
C_i &= 5A827999, & (0 \leq i \leq 19); \\
C_i &= 6ED9EBA1, & (20 \leq i \leq 39); \\
C_i &= 8F1BBCDC, & (40 \leq i \leq 59); \\
C_i &= CA62C1D6, & (60 \leq i \leq 79).
\end{aligned}$$

### 9.2.5 Initializing value

For this round-function the initializing value,  $IV$ , shall always be the following 160-bit string, represented here as a sequence of five words,  $Y_0$ ,  $Y_1$ ,  $Y_2$ ,  $Y_3$  and  $Y_4$ , in a hexadecimal representation, where  $Y_0$  represents the left-most 32 of the 160 bits:

$$\begin{aligned}
Y_0 &= 67452301; \\
Y_1 &= EFCDAB89; \\
Y_2 &= 98BADCFE; \\
Y_3 &= 10325476; \\
Y_4 &= C3D2E1F0.
\end{aligned}$$

### 9.3 Padding method

The data string,  $D$ , needs to be padded to make it contain a number of bits which is an integer multiple of 512. The padding procedure operates as follows.

- $D$  is concatenated with a single “1” bit.
- The result of the previous step is concatenated with between zero and 511 “0” bits, such that the length (in bits) of the resultant string is congruent to 448 modulo 512. More explicitly, if the original length of  $D$  is  $L_D$  and letting  $r$  be the remainder when  $L_D$  is divided by 512, then the number of concatenated zeros is equal to either  $447 - r$  (if  $r \leq 447$ ) or  $959 - r$  (if  $r > 447$ ). The result will be a bit string whose length will be 64 bits short of an integer multiple of 512 bits.
- Concatenate the string resulting from the previous step with the 64-bit binary representation of  $L_D$ , most significant bit first.

In the description of the round-function which follows, each 512-bit data block  $D_i$ ,  $1 \leq i \leq q$ , is treated as a sequence of 16 words,  $Z_0, Z_1, \dots, Z_{15}$ , where  $Z_0$  corresponds to the left-most 32 bits of  $D_i$ .

**NOTE** The concatenation of the 64-bit string of  $L_D$  in step c) is such that the most significant 32-bit string and the least significant 32-bit string of  $L_D$  are used respectively as the words  $Z_{14}$  and  $Z_{15}$  of the last data block. Based on the byte ordering convention in 9.2.2, the most significant byte of  $L_D$  is the left-most byte and the least significant byte of  $L_D$  is the right-most byte.

### 9.4 Description of the round-function

The round-function,  $\Phi$ , operates as follows.

**NOTE** In this description, the symbols  $W, X_0, X_1, X_2, X_3, X_4, Z_0, Z_1, \dots, Z_{79}$  are used to denote 86 distinct words which contain values required in the computations.

- Suppose the 512-bit (first) input to  $\Phi$  is contained in  $Z_0, Z_1, \dots, Z_{15}$ , where  $Z_0$  contains the left-most 32 of the 512 bits. Suppose also that the 160-bit (second) input to  $\Phi$  is contained in five words,  $Y_0, Y_1, Y_2, Y_3$  and  $Y_4$ .
- For  $i = 16$  to 79, let  $Z_i = S^1(Z_{i-3} \oplus Z_{i-8} \oplus Z_{i-14} \oplus Z_{i-16})$ .
- Let  $X_0 = Y_0, X_1 = Y_1, X_2 = Y_2, X_3 = Y_3$  and  $X_4 = Y_4$ .
- For  $i = 0$  to 79, do the following two steps:
  - $W = S^5(X_0) \cup f_i(X_1, X_2, X_3) \cup X_4 \cup Z_i \cup C_i$



- 2)  $X_4 := X_3; X_3 := X_2; X_2 := S^{30}(X_1); X_1 := X_0; X_0 := W.$
- e) Let  $Y_0 := Y_0 \cup X_0, Y_1 := Y_1 \cup X_1, Y_2 := Y_2 \cup X_2, Y_3 := Y_3 \cup X_3$  and  $Y_4 := Y_4 \cup X_4.$
- f) The five words,  $Y_0, Y_1, Y_2, Y_3$  and  $Y_4$ , represent the output of the round-function  $\Phi$ . After the final iteration of the round-function, the five words,  $Y_0, Y_1, Y_2, Y_3$  and  $Y_4$ , shall be converted to a sequence of 20 bytes using the inverse of the procedure specified in [9.2.2](#) and where  $Y_0$  shall yield the first four bytes,  $Y_1$  the next four bytes and so on. Thus, the first (left-most) byte will correspond to the most significant byte of  $Y_0$  and the 20th (right-most) byte will correspond to the least significant byte of  $Y_4$ . The 20 bytes shall be converted to a string of 160 bits using the inverse of the procedure specified in [Clause 6](#), i.e. the first (left-most) bit will correspond to the most significant bit of the first (left-most) byte and the 160th (right-most) bit will correspond to the least significant bit of the 20th (right-most) byte.

[Figure 3](#) shows steps 1) and 2) of item d) of the round-function  $\Phi$  in Dedicated Hash-Function 3 (SHA-1). In the round-function  $\Phi$ , steps 1) and 2) of item d) are used 80 times ( $i = 0, \dots, 79$ ).

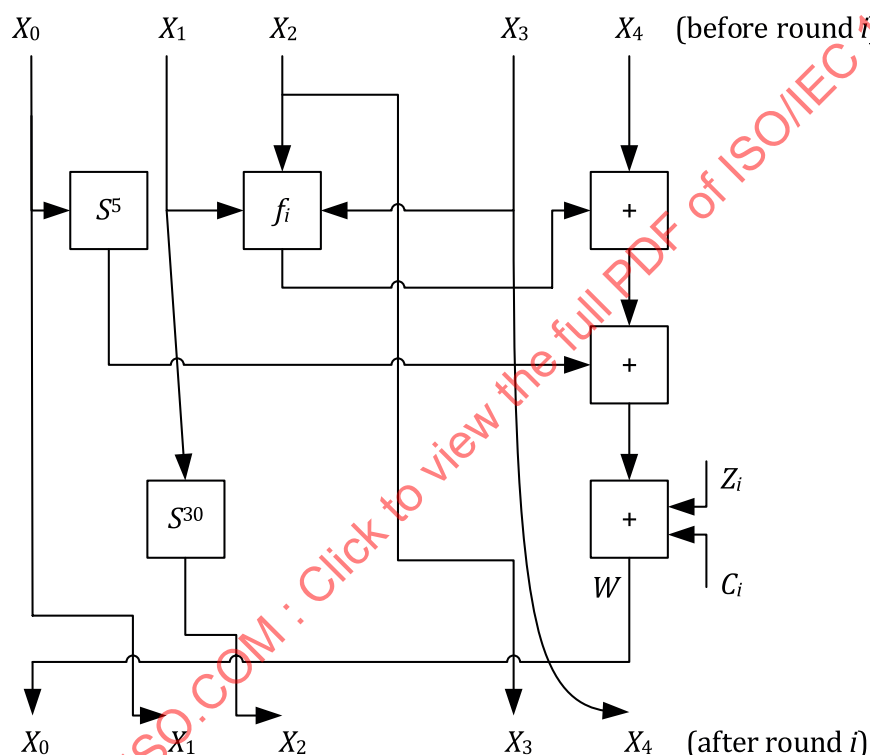


**Figure 3— Part of the round-function in Dedicated Hash-Function 3**

## 10 Dedicated Hash-Function 4 (SHA-256)

## 10.1 General

In [Clause 10](#), a padding method, an initializing value and a round-function for use in the general model for hash-functions described in ISO/IEC 10118-1 are specified. The padding method, initializing value and round-function specified here, when used in the above general model, together define Dedicated Hash-Function 4. This dedicated hash-function can be applied to all data strings,  $D$ , containing at most  $2^{64}-1$  bits.

The ISO/IEC hash-function identifier for Dedicated Hash-Function 4 is equal to 34 (hexadecimal).

NOTE Dedicated Hash-Function 4 defined in [Clause 10](#) is commonly called SHA-256[1].



## 10.2 Parameters, functions and constants

### 10.2.1 Parameters

For this hash-function,  $L_1 = 512$ ,  $L_2 = 256$  and  $L_H$  is up to 256.

### 10.2.2 Byte ordering convention

The byte ordering convention to be used with this hash-function shall be the same as the byte ordering convention defined in 9.2.2.

### 10.2.3 Functions

To facilitate software implementation, the round-function  $\Phi$  is described in terms of operations on 32-bit words. A sequence of functions,  $e_0$ ,  $e_1$ ,  $e_2$ ,  $e_3$ ,  $e_4$  and  $e_5$ , is used in this round-function, where  $e_0$  and  $e_1$  each takes three words,  $X_0$ ,  $X_1$  and  $X_2$ , as input;  $e_2$ ,  $e_3$ ,  $e_4$  and  $e_5$  each takes one word  $X_0$  as input and each of these six functions produces a single 32-bit word as output.

The functions  $e_0$ ,  $e_1$ ,  $e_2$ ,  $e_3$ ,  $e_4$  and  $e_5$  are defined as follows:

$$\begin{aligned} e_0(X_0, X_1, X_2) &= (X_0 \wedge X_1) \oplus (\neg X_0 \wedge X_2); \\ e_1(X_0, X_1, X_2) &= (X_0 \wedge X_1) \oplus (X_0 \wedge X_2) \oplus (X_1 \wedge X_2); \\ e_2(X_0) &= S'^{22}(X_0) \oplus S'^{13}(X_0) \oplus S'^{22}(X_0); \\ e_3(X_0) &= S'^{6}(X_0) \oplus S'^{11}(X_0) \oplus S'^{25}(X_0); \\ e_4(X_0) &= S'^{7}(X_0) \oplus S'^{18}(X_0) \oplus R^3(X_0); \\ e_5(X_0) &= S'^{17}(X_0) \oplus S'^{19}(X_0) \oplus R^{10}(X_0). \end{aligned}$$

### 10.2.4 Constants

A sequence of constant words,  $C_0$ ,  $C_1$ , ...,  $C_{63}$ , is used in this round-function. In a hexadecimal representation (where the most significant bit corresponds to the left-most bit), these are defined as follows, where the words are listed in the order  $C_0$ ,  $C_1$ , ...,  $C_{63}$ .

|          |          |          |          |          |          |          |          |
|----------|----------|----------|----------|----------|----------|----------|----------|
| 428A2F98 | 71374491 | B5C0FBCF | E9B5DBA5 | 3956C25B | 59F111F1 | 923F82A4 | AB1C5ED5 |
| D807AA98 | 12835B01 | 243185BE | 550C7DC3 | 72BE5D74 | 80DEB1FE | 9BDC06A7 | C19BF174 |
| E49B69C1 | EFBE4786 | 0FC19DC6 | 240CA1CC | 2DE92C6F | 4A7484AA | 5CB0A9DC | 76F988DA |
| 983E5152 | A831C66D | B00327C8 | BF597FC7 | C6E00BF3 | D5A79147 | 06CA6351 | 14292967 |
| 27B70A85 | 2E1B2138 | 4D2C6DFC | 53380D13 | 650A7354 | 766A0ABB | 81C2C92E | 92722C85 |
| A2BFE8A1 | A81A664B | C24B8B70 | C76C51A3 | D192E819 | D6990624 | F40E3585 | 106AA070 |
| 19A4C116 | 1E376C08 | 2748774C | 34B0BCB5 | 391C0CB3 | 4ED8AA4A | 5B9CCA4F | 682E6FF3 |
| 748F82EE | 78A5636F | 84C87814 | 8CC70208 | 90BEFFFA | A4506CEB | BEF9A3F7 | C67178F2 |

NOTE These values are the first 32 bits of the fractional parts of the cube roots of the first 64 primes.

### 10.2.5 Initializing value

For this round-function, the initializing value,  $IV$ , shall always be the following 256-bit string, represented here as a sequence of eight words,  $Y_0$ ,  $Y_1$ ,  $Y_2$ ,  $Y_3$ ,  $Y_4$ ,  $Y_5$ ,  $Y_6$  and  $Y_7$ , in a hexadecimal representation, where  $Y_0$  represents the left-most 32 of the 256 bits:

$$\begin{aligned} Y_0 &= 6A09E667; \\ Y_1 &= BB67AE85; \\ Y_2 &= 3C6EF372; \end{aligned}$$

$Y_3 = \text{A54FF53A};$   
 $Y_4 = \text{510E527F};$   
 $Y_5 = \text{9B05688C};$   
 $Y_6 = \text{1F83D9AB};$   
 $Y_7 = \text{5BE0CD19}.$

NOTE These values are obtained by taking the fractional parts of the square roots of the first eight primes.

### 10.3 Padding method

The padding method to be used with this hash-function shall be the same as the padding method defined in [9.3](#).

### 10.4 Description of the round-function

The round-function,  $\Phi$ , operates as follows.

NOTE In this description, the symbols  $W_1, W_2, X_0, X_1, X_2, X_3, X_4, X_5, X_6, X_7, Z_0, Z_1, \dots, Z_{63}$  are used to denote 74 distinct words which contain values required in the computations.

- a) Suppose the 512-bit (first) input to  $\Phi$  is contained in  $Z_0, Z_1, \dots, Z_{15}$ , where  $Z_0$  contains the left-most 32 of the 512 bits. Suppose also that the 256-bit (second) input to  $\Phi$  is contained in eight words,  $Y_0, Y_1, Y_2, Y_3, Y_4, Y_5, Y_6$  and  $Y_7$ .
- b) For  $i = 16$  to  $63$ , let  $Z_i = e_5(Z_{i-2}) \cup Z_{i-7} \cup e_4(Z_{i-15}) \cup Z_{i-16}$ .
- c) Let  $X_0 = Y_0, X_1 = Y_1, X_2 = Y_2, X_3 = Y_3, X_4 = Y_4, X_5 = Y_5, X_6 = Y_6$  and  $X_7 = Y_7$ .
- d) For  $i = 0$  to  $63$ , do the following three steps:
  - 1)  $W_1 = X_7 \cup e_3(X_4) \cup e_0(X_4, X_5, X_6) \cup C_i \cup Z_i$ ;
  - 2)  $W_2 = e_2(X_0) \cup e_1(X_0, X_1, X_2)$ ;
  - 3)  $X_7 = X_6; X_6 = X_5; X_5 = X_4; X_4 = X_3 \cup W_1; X_3 = X_2; X_2 = X_1; X_1 = X_0; X_0 = W_1 \cup W_2$ .
- e) Let  $Y_0 = Y_0 \cup X_0, Y_1 = Y_1 \cup X_1, Y_2 = Y_2 \cup X_2, Y_3 = Y_3 \cup X_3, Y_4 = Y_4 \cup X_4, Y_5 = Y_5 \cup X_5, Y_6 = Y_6 \cup X_6$  and  $Y_7 = Y_7 \cup X_7$ .
- f) The eight words,  $Y_0, Y_1, Y_2, Y_3, Y_4, Y_5, Y_6$  and  $Y_7$ , represent the output of the round-function  $\Phi$ . After the final iteration of the round-function, the eight words,  $Y_0, Y_1, Y_2, Y_3, Y_4, Y_5, Y_6$  and  $Y_7$ , shall be converted to a sequence of 32 bytes using the inverse of the procedure specified in [10.2.2](#) and where  $Y_0$  shall yield the first four bytes,  $Y_1$  the next four bytes and so on. Thus, the first (left-most) byte will correspond to the most significant byte of  $Y_0$  and the 32nd (right-most) byte will correspond to the least significant byte of  $Y_7$ . The 32 bytes shall be converted to a string of 256 bits using the inverse of the procedure specified in [Clause 6](#), i.e. the first (left-most) bit will correspond to the most significant bit of the first (left-most) byte and the 256th (right-most) bit will correspond to the least significant bit of the 32nd (right-most) byte.

[Figure 4](#) shows steps 1), 2) and 3) of item d) of the round-function  $\Phi$  in Dedicated Hash-Function 4 (SHA-256). In the round-function  $\Phi$ , steps 1), 2) and 3) of item d) are used 64 times ( $i = 0, \dots, 63$ ).

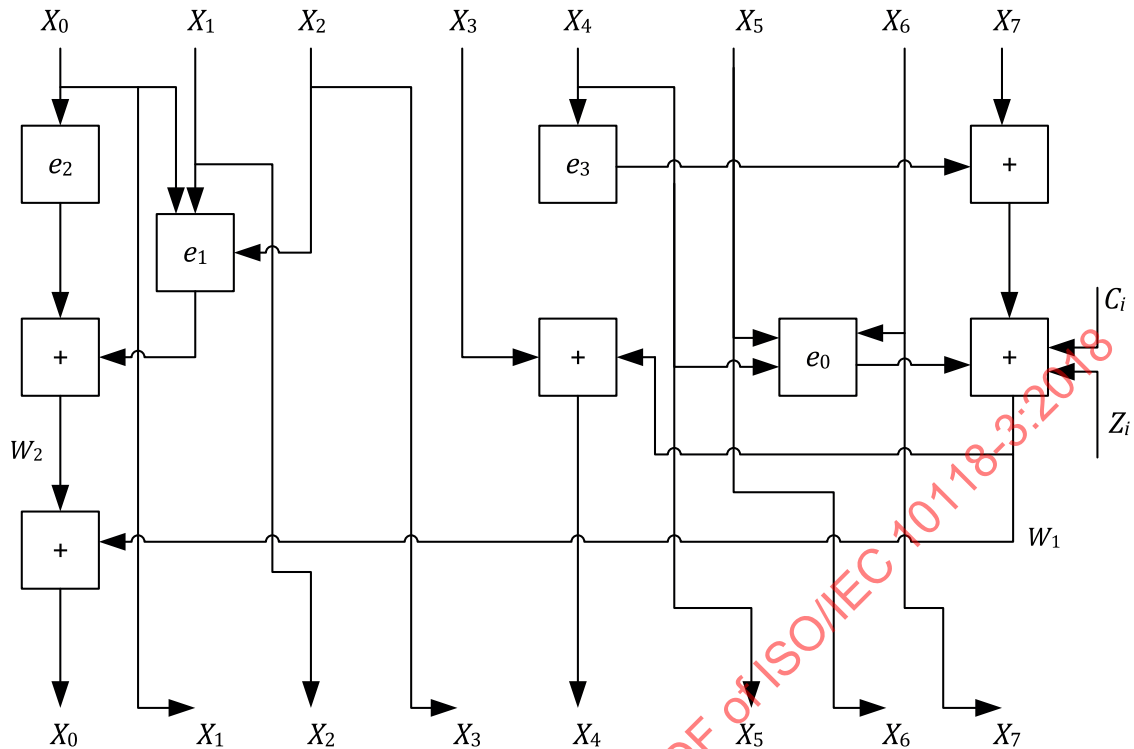


Figure 4 — Part of the round-function in Dedicated Hash-Function 4

## 11 Dedicated Hash-Function 5 (SHA-512)

### 11.1 General

In [Clause 11](#), a padding method, an initializing value and a round-function for use in the general model for hash-functions described in ISO/IEC 10118-1 are specified. The padding method, initializing value and round-function specified here, when used in the above general model, together define Dedicated Hash-Function 5. This dedicated hash-function can be applied to all data strings,  $D$ , containing at most  $2^{128}-1$  bits.

The ISO/IEC hash-function identifier for Dedicated Hash-Function 5 is equal to 35 (hexadecimal).

NOTE Dedicated Hash-Function 5 defined in [Clause 11](#) is commonly called SHA-512[1].

### 11.2 Parameters, functions and constants

#### 11.2.1 Parameters

For this hash-function,  $L_1 = 1\,024$ ,  $L_2 = 512$  and  $L_H$  is up to 512.

#### 11.2.2 Byte ordering convention

In the specification of the round-function of [Clause 11](#), it is assumed that the block input to the round-function is in the form of a sequence of 64-bit words, each 1 024-bit block is made up of 16 such words. A sequence of 128 bytes,  $B_0, B_1, \dots, B_{127}$ , shall be interpreted as a sequence of 16 words,  $Z_0, Z_1, \dots, Z_{15}$ , in the following way. Each group of eight consecutive bytes is considered a word, where the first byte of a word is the most significant byte of that word. Hence,

$$Z_i = 2^{56}B_{8i} + 2^{48}B_{8i+1} + 2^{40}B_{8i+2} + 2^{32}B_{8i+3} + 2^{24}B_{8i+4} + 2^{16}B_{8i+5} + 2^8B_{8i+6} + B_{8i+7}, \quad (0 \leq i \leq 15).$$

To convert the hash-code from a sequence of words to a sequence of bytes, the inverse process shall be followed.

### 11.2.3 Functions

To facilitate software implementation, the round-function  $\Phi$  is described in terms of operations on 64-bit words. A sequence of functions,  $d_0, d_1, d_2, d_3, d_4$  and  $d_5$ , is used in this round-function, where  $d_0$  and  $d_1$  each takes three 64-bit words,  $X_0, X_1$  and  $X_2$ , as input;  $d_2, d_3, d_4$  and  $d_5$  each takes one 64-bit word  $X_0$  as input and each of these six functions produces a single 64-bit word as output.

The functions  $d_0, d_1, d_2, d_3, d_4$  and  $d_5$  are defined as follows:

$$\begin{aligned}d_0(X_0, X_1, X_2) &= (X_0 \wedge X_1) \oplus (\neg X_0 \wedge X_2); \\d_1(X_0, X_1, X_2) &= (X_0 \wedge X_1) \oplus (X_0 \wedge X_2) \oplus (X_1 \wedge X_2); \\d_2(X_0) &= S'^{28}(X_0) \oplus S'^{34}(X_0) \oplus S'^{39}(X_0); \\d_3(X_0) &= S'^{14}(X_0) \oplus S'^{18}(X_0) \oplus S'^{41}(X_0); \\d_4(X_0) &= S'^1(X_0) \oplus S'^8(X_0) \oplus R^7(X_0); \\d_5(X_0) &= S'^{19}(X_0) \oplus S'^{61}(X_0) \oplus R^6(X_0).\end{aligned}$$

### 11.2.4 Constants

A sequence of constant words,  $C_0, C_1, \dots, C_{79}$ , is used in this round-function. In a hexadecimal representation (where the most significant bit corresponds to the left-most bit), these are defined as follows, where the words are listed in the order  $C_0, C_1, \dots, C_{79}$ .

|                  |                  |                  |                  |
|------------------|------------------|------------------|------------------|
| 428A2F98D728AE22 | 7137449123EF65CD | B5C0FBCEEC4D3B2F | E9B5DBA58189DBBC |
| 3956C25BF348B538 | 59F111F1B605D019 | 923F82A4AF194F9B | AB1C5ED5DA6D8118 |
| D807AA98A3030242 | 12835B0145706FBE | 243185BE4EE4B28C | 550C7DC3D5FFB4E2 |
| 72BE5D74F27B896F | 80DEB1FE3B1696B1 | 9BDC06A725C71235 | C19BF174CF692694 |
| E49B69C19EF14AD2 | EFBE4786384F25E3 | 0FC19DC68B8CD5B5 | 240CA1CC77AC9C65 |
| 2DE92C6F592B0275 | 4A7484AA6EA6E483 | 5CB0A9DCBD41FBD4 | 76F988DA831153B5 |
| 983E5152EE66DFAB | A831C66D2DB43210 | B00327C898FB213F | BF597FC7BEEF0EE4 |
| C6E00BF33DA88FC2 | D5A79147930AA725 | 06CA6351E003826F | 142929670A0E6E70 |
| 27B70A8546D22FFC | 2E1B21385C26C926 | 4D2C6DFC5AC42AED | 53380D139D95B3DF |
| 650A73548BAF63DE | 766A0ABB3C77B2A8 | 81C2C92E47EDAEE6 | 92722C851482353B |
| A2BFE8A14CF10364 | A81A664BBC423001 | C24B8B70D0F89791 | C76C51A30654BE30 |
| D192E819D6EF5218 | D69906245565A910 | F40E35855771202A | 106AA07032BBD1B8 |
| 19A4C116B8D2D0C8 | 1E376C085141AB53 | 2748774CDF8EEB99 | 34B0BCB5E19B48A8 |
| 391C0CB3C5C95A63 | 4ED8AA4AE3418ACB | 5B9CCA4F7763E373 | 682E6FF3D6B2B8A3 |
| 748F82EE5DEFB2FC | 78A5636F43172F60 | 84C87814A1F0AB72 | 8CC702081A6439EC |
| 90BEFFFA23631E28 | A4506CEBDE82BDE9 | BEF9A3F7B2C67915 | C67178F2E372532B |
| CA273ECEEA26619C | D186B8C721C0C207 | EADA7DD6CDE0EB1E | F57D4F7FEE6ED178 |

|                  |                  |                  |                  |
|------------------|------------------|------------------|------------------|
| 06F067AA72176FBA | 0A637DC5A2C898A6 | 113F9804BEF90DAE | 1B710B35131C471B |
| 28DB77F523047D84 | 32CAAB7B40C72493 | 3C9EBE0A15C9BEBE | 431D67C49C100D4C |
| 4CC5D4BECB3E42B6 | 597F299CFC657E2A | 5FCB6FAB3AD6FAEC | 6C44198C4A475817 |

NOTE These values are the first 64 bits of the fractional parts of the cube roots of the first 80 primes.

### 11.2.5 Initializing value

For this round-function, the initializing value,  $IV$ , shall always be the following 512-bit string, represented here as a sequence of eight words,  $Y_0, Y_1, Y_2, Y_3, Y_4, Y_5, Y_6$  and  $Y_7$ , in a hexadecimal representation, where  $Y_0$  represents the left-most 64 of the 512 bits:

$Y_0 = 6A09E667F3BCC908;$   
 $Y_1 = BB67AE8584CAA73B;$   
 $Y_2 = 3C6EF372FE94F82B;$   
 $Y_3 = A54FF53A5F1D36F1;$   
 $Y_4 = 510E527FADE682D1;$   
 $Y_5 = 9B05688C2B3E6C1F;$   
 $Y_6 = 1F83D9ABFB41BD6B;$   
 $Y_7 = 5BE0CD19137E2179.$

NOTE These values are obtained by taking the fractional parts of the square roots of the first eight primes.

### 11.3 Padding method

The data string,  $D$ , needs to be padded to make it contain a number of bits which is an integer multiple of 1 024. The padding procedure is as follows.

- $D$  is concatenated with a single “1” bit.
- The result of the previous step is concatenated with between zero and 1 023 “0” bits, such that the length (in bits) of the resultant string is congruent to 896 modulo 1 024. More explicitly, if the original length of  $D$  is  $L_D$ , and letting  $r$  be the remainder when  $L_D$  is divided by 1 024, then the number of concatenated zeros is equal to either  $895 - r$  (if  $r \leq 895$ ) or  $1\,919 - r$  (if  $r > 895$ ). The result will be a bit string whose length will be 128 bits short of an integer multiple of 1 024 bits.
- Concatenate the string resulting from the previous step with the 128-bit binary representation of  $L_D$ , most significant bit first.

In the description of the round-function which follows, each 1 024-bit data block  $D_i$ ,  $1 \leq i \leq q$ , is treated as a sequence of 16 words,  $Z_0, Z_1, \dots, Z_{15}$ , where  $Z_0$  corresponds to the left-most 64 bits of  $D_i$ .

NOTE The concatenation of the 128-bit string of  $L_D$  in step c) is such that the most significant 64-bit string and the least significant 64-bit string of  $L_D$  are used respectively as the words  $Z_{14}$  and  $Z_{15}$  of the last data block. Based on the byte ordering convention in 11.2.2, the most significant byte of  $L_D$  is the left-most byte and the least significant byte of  $L_D$  is the right-most byte.

### 11.4 Description of the round-function

The round-function,  $\Phi$ , operates as follows.

NOTE In this description, the symbols  $W_1, W_2, X_0, X_1, X_2, X_3, X_4, X_5, X_6, X_7, Z_0, Z_1, \dots, Z_{79}$  are used to denote 90 distinct words which contain values required in the computations.

- Suppose the 1 024-bit (first) input to  $\Phi$  is contained in  $Z_0, Z_1, \dots, Z_{15}$ , where  $Z_0$  contains the left-most 64 of the 1 024 bits. Suppose also that the 512-bit (second) input to  $\Phi$  is contained in eight words,  $Y_0, Y_1, Y_2, Y_3, Y_4, Y_5, Y_6$  and  $Y_7$ .
- For  $i = 16$  to 79, let  $Z_i = d_5(Z_{i-2}) \cup Z_{i-7} \cup d_4(Z_{i-15}) \cup Z_{i-16}$ .

- c) Let  $X_0 := Y_0, X_1 := Y_1, X_2 := Y_2, X_3 := Y_3, X_4 := Y_4, X_5 := Y_5, X_6 := Y_6$  and  $X_7 := Y_7$ .
- d) For  $i = 0$  to 79, do the following three steps:
- 1)  $W_1 := X_7 \oplus d_3(X_4) \oplus d_0(X_4, X_5, X_6) \oplus C_i \oplus Z_i$ ;
  - 2)  $W_2 := d_2(X_0) \oplus d_1(X_0, X_1, X_2)$ ;
  - 3)  $X_7 := X_6; X_6 := X_5; X_5 := X_4; X_4 := X_3 \oplus W_1; X_3 := X_2; X_2 := X_1; X_1 := X_0; X_0 := W_1 \oplus W_2$ .
- e) Let  $Y_0 := Y_0 \oplus X_0, Y_1 := Y_1 \oplus X_1, Y_2 := Y_2 \oplus X_2, Y_3 := Y_3 \oplus X_3, Y_4 := Y_4 \oplus X_4, Y_5 := Y_5 \oplus X_5, Y_6 := Y_6 \oplus X_6$  and  $Y_7 := Y_7 \oplus X_7$ .
- f) The eight words,  $Y_0, Y_1, Y_2, Y_3, Y_4, Y_5, Y_6$  and  $Y_7$ , represent the output of the round-function  $\Phi$ . After the final iteration of the round-function, the eight words,  $Y_0, Y_1, Y_2, Y_3, Y_4, Y_5, Y_6$  and  $Y_7$  shall be converted to a sequence of 64 bytes using the inverse of the procedure specified in 11.2.2 and where  $Y_0$  shall yield the first eight bytes,  $Y_1$  the next eight bytes and so on. Thus, the first (left-most) byte will correspond to the most significant byte of  $Y_0$  and the 64th (right-most) byte will correspond to the least significant byte of  $Y_7$ . The 64 bytes shall be converted to a string of 512 bits using the inverse of the procedure specified in Clause 6, i.e. the first (left-most) bit will correspond to the most significant bit of the first (left-most) byte and the 512th (right-most) bit will correspond to the least significant bit of the 64th (right-most) byte.

Figure 5 shows steps 1), 2) and 3) of item d) of the round-function  $\Phi$  in Dedicated Hash-Function 5 (SHA-512). In the round-function  $\Phi$ , steps 1), 2) and 3) of item d) are used 80 times ( $i = 0, \dots, 79$ ).

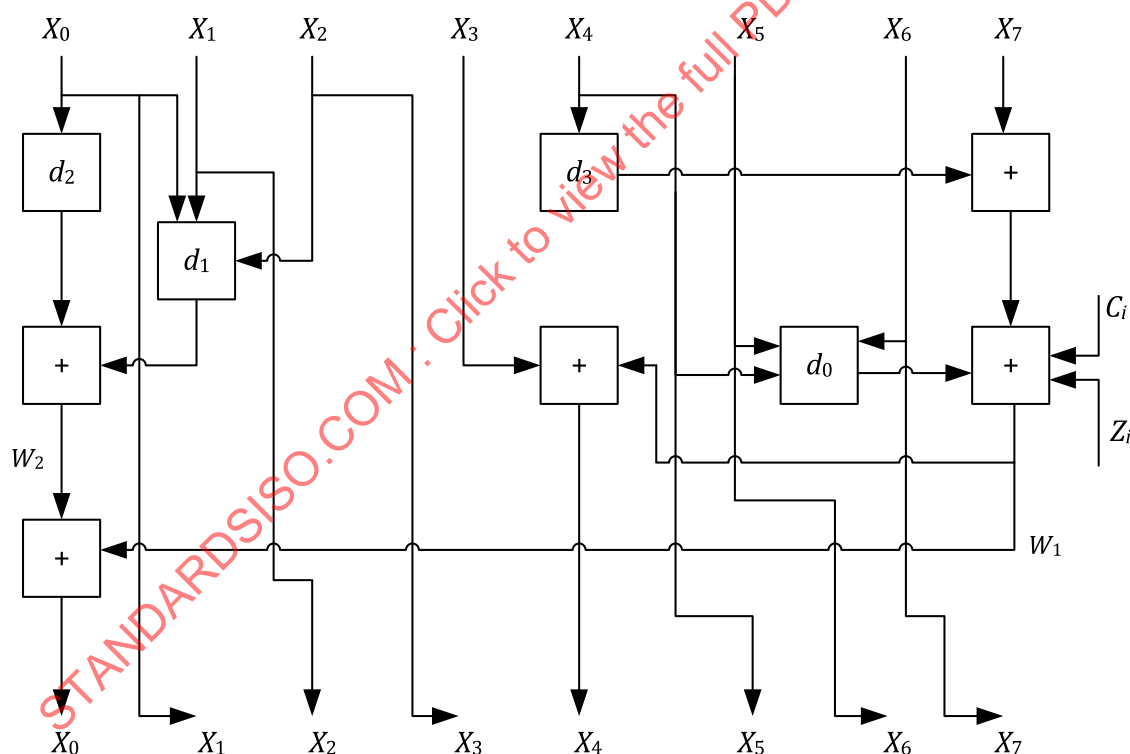


Figure 5 — Part of the round-function in Dedicated Hash-Function 5

## 12 Dedicated Hash-Function 6 (SHA-384)

### 12.1 General

In Clause 12, a padding method, an initializing value and a round-function for use in the general model for hash-functions described in ISO/IEC 10118-1 are specified. The padding method, initializing value

and round-function specified here, when used in the above general model, together define Dedicated Hash-Function 6. This dedicated hash-function can be applied to all data strings,  $D$ , containing at most  $2^{128}-1$  bits.

The ISO/IEC hash-function identifier for Dedicated Hash-Function 6 is equal to 36 (hexadecimal).

NOTE Dedicated Hash-Function 6 defined in [Clause 12](#) is commonly called SHA-384[4].

## 12.2 Parameters, functions and constants

### 12.2.1 Parameters

For this hash-function,  $L_1 = 1\,024$ ,  $L_2 = 512$  and  $L_H = 384$ .

### 12.2.2 Byte ordering convention

The byte ordering convention for this hash-function is the same as that for the hash-function of [Clause 11](#).

### 12.2.3 Functions

The functions for this hash-function are the same as that for the hash-function of [Clause 11](#).

### 12.2.4 Constants

The constants for this hash-function are the same as that for the hash-function of [Clause 11](#).

### 12.2.5 Initializing value

For this round-function, the initializing value,  $IV$ , shall always be the following 512-bit string, represented here as a sequence of eight words,  $Y_0$ ,  $Y_1$ ,  $Y_2$ ,  $Y_3$ ,  $Y_4$ ,  $Y_5$ ,  $Y_6$  and  $Y_7$ , in a hexadecimal representation, where  $Y_0$  represents the left-most 64 of the 512 bits:

$Y_0 = \text{CBBB9D5DC1059ED8};$   
 $Y_1 = \text{629A292A367CD507};$   
 $Y_2 = \text{9159015A3070DD17};$   
 $Y_3 = \text{152FEC8F70E5939};$   
 $Y_4 = \text{67332667FFC00B31};$   
 $Y_5 = \text{8EB44A8768581511};$   
 $Y_6 = \text{DB0C2E0D64F98FA7};$   
 $Y_7 = \text{47B5481DBEFA4FA4}.$

NOTE These values are obtained by taking the fractional parts of the square roots of the 9th to the 16th primes.

## 12.3 Padding method

The padding method to be used with this hash-function shall be the same as the padding method defined in [Clause 11](#).

## 12.4 Description of the round-function

The round-function to be used with this hash-function shall be the same as the round-function defined in [Clause 11](#).

The final 384-bit hash is obtained by truncating the SHA-512-based hash output to its left-most 384 bits.



## 13 Dedicated Hash-Function 7 (WHIRLPOOL)

### 13.1 General

In [Clause 13](#), a padding method, an initializing value and a round-function for use in the general model for hash-functions described in ISO/IEC 10118-1 are specified. The padding method, initializing value and round-function specified here, when used in the above general model, together define Dedicated Hash-Function 7. This dedicated hash-function can be applied to all data strings,  $D$ , containing at most  $2^{256}-1$  bits.

The ISO/IEC hash-function identifier for Dedicated Hash-Function 7 is equal to 37 (hexadecimal).

NOTE Dedicated Hash-Function 7 defined in [Clause 13](#) is commonly called WHIRLPOOL<sup>[3]</sup>.

### 13.2 Parameters, functions and constants

#### 13.2.1 Parameters

For this hash-function,  $L_1 = 512$ ,  $L_2 = 512$  and  $L_H$  is up to 512.

#### 13.2.2 Byte ordering convention

In the specification of the round-function of [Clause 13](#), it is assumed that the block input to the round-function is in the form of a matrix  $M$  [where all matrices here are  $8 \times 8$  matrices with entries chosen from  $\text{GF}(2^8)$ ], each 512-bit block being made up of such a matrix. A sequence of 64 bytes,  $B = (B_0, B_1, \dots, B_{63})$ , shall be interpreted as a matrix  $M$  in the following way. The entry in the first row and the first column of the matrix shall be the left-most byte (where the left-most byte corresponds to the most significant byte) of the sequence  $B$  (i.e.  $B_0$ ), the entry in the first row and the second column of the matrix shall be the second left-most byte of  $B$  (i.e.  $B_1$ ), ..., and the entry in the eighth row and the eighth column of the matrix shall be the right-most byte of  $B$  (i.e.  $B_{63}$ ). This is performed using function  $c_0$  specified in [13.2.3](#).

To convert the hash-code from such a matrix to a sequence of bytes, the inverse process of the function  $c_0$  shall be followed.

#### 13.2.3 Functions

To facilitate software implementation, the round-function  $\Phi$  is described in terms of operations on a matrix  $M$ . A sequence of functions,  $c_0$ ,  $c_1$ ,  $c_2$ ,  $c_3$  and  $c_4$ , is used in this round-function. They are defined as follows.

- a) Function  $c_0$  takes a 64-byte sequence,  $B = (B_0, B_1, \dots, B_{63})$  as input and produces a matrix  $Z' = (z'_{ij})$  as output where:

$$z'_{ij} = B_{8i+j} \quad (0 \leq i, j \leq 7).$$

This means that  $Z' = c_0(B)$ , if and only if,  $z'_{ij} = B_{8i+j}$  ( $0 \leq i, j \leq 7$ ).

- b) Function  $c_1$  takes a matrix  $X'' = (x''_{ij})$  as input and produces another matrix  $W' = (w'_{ij})$  as output where:

$$w'_{ij} = s[x''_{ij}], \quad (0 \leq i, j \leq 7),$$

and where  $s$  is a function defined below. This means  $W' = c_1(X'')$ , if and only if,  $w'_{ij} = s[x''_{ij}]$  ( $0 \leq i, j \leq 7$ ).

The function  $s$  replaces an element  $x \in \text{GF}(2^8)$  with another element  $s[x] \in \text{GF}(2^8)$ . As specified in [Table 2](#), the elements in the first column are the “most significant half” of  $x$  and the elements in the first row are the “least significant half” of  $x$ . For instance, if  $x = 01010110 = 56$  (hexadecimal),  $s[x] = 49$  (hexadecimal) = 01001001.



Table 2 — Values of the s-box

|   | 0  | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | A  | B  | C  | D  | E  | F  |
|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 0 | 18 | 23 | C6 | E8 | 87 | B8 | 01 | 4F | 36 | A6 | D2 | F5 | 79 | 6F | 91 | 52 |
| 1 | 60 | BC | 9B | 8E | A3 | 0C | 7B | 35 | 1D | E0 | D7 | C2 | 2E | 4B | FE | 57 |
| 2 | 15 | 77 | 37 | E5 | 9F | F0 | 4A | DA | 58 | C9 | 29 | 0A | B1 | A0 | 6B | 85 |
| 3 | BD | 5D | 10 | F4 | CB | 3E | 05 | 67 | E4 | 27 | 41 | 8B | A7 | 7D | 95 | D8 |
| 4 | FB | EE | 7C | 66 | DD | 17 | 47 | 9E | CA | 2D | BF | 07 | AD | 5A | 83 | 33 |
| 5 | 63 | 02 | AA | 71 | C8 | 19 | 49 | D9 | F2 | E3 | 5B | 88 | 9A | 26 | 32 | B0 |
| 6 | E9 | 0F | D5 | 80 | BE | CD | 34 | 48 | FF | 7A | 90 | 5F | 20 | 68 | 1A | AE |
| 7 | B4 | 54 | 93 | 22 | 64 | F1 | 73 | 12 | 40 | 08 | C3 | EC | DB | A1 | 8D | 3D |
| 8 | 97 | 00 | CF | 2B | 76 | 82 | D6 | 1B | B5 | AF | 6A | 50 | 45 | F3 | 30 | EF |
| 9 | 3F | 55 | A2 | EA | 65 | BA | 2F | C0 | DE | 1C | FD | 4D | 92 | 75 | 06 | 8A |
| A | B2 | E6 | 0E | 1F | 62 | D4 | A8 | 96 | F9 | C5 | 25 | 59 | 84 | 72 | 39 | 4C |
| B | 5E | 78 | 38 | 8C | D1 | A5 | E2 | 61 | B3 | 21 | 9C | 1E | 43 | C7 | FC | 04 |
| C | 51 | 99 | 6d | 0D | FA | DF | 7E | 24 | 3B | AB | CE | 11 | 8F | 4E | B7 | EB |
| D | 3C | 81 | 94 | F7 | B9 | 13 | 2C | D3 | E7 | 6E | C4 | 03 | 56 | 44 | 7F | A9 |
| E | 2A | BB | C1 | 53 | DC | 0B | 9D | 6C | 31 | 74 | F6 | 46 | AC | 89 | 14 | E1 |
| F | 16 | 3A | 69 | 09 | 70 | B6 | D0 | ED | CC | 42 | 98 | A4 | 28 | 5C | F8 | 86 |

- c) Function  $c_2$  takes a matrix  $X'' = (x''_{ij})$  as input and produces another matrix  $W' = (w'_{ij})$  as output where:

$$w'_{ij} = x''_{(i-j) \bmod 8, j}, \quad (0 \leq i, j \leq 7).$$

This means that  $W' = c_2(X'')$ , if and only if,  $w'_{ij} = x''_{(i-j) \bmod 8, j} \ (0 \leq i, j \leq 7)$ .

- d) Function  $c_3$  takes a matrix  $X''$  as input and produces another matrix  $W'$  as output where:

$$W' = X'' \cdot C'',$$

and where  $C''$  is an  $8 \times 8$  circulant matrix with entries chosen from  $\text{GF}(2^8)$ , as specified below:

$$C'' = \begin{bmatrix} 01 & 01 & 04 & 01 & 08 & 05 & 02 & 09 \\ 09 & 01 & 01 & 04 & 01 & 08 & 05 & 02 \\ 02 & 09 & 01 & 01 & 04 & 01 & 08 & 05 \\ 05 & 02 & 09 & 01 & 01 & 04 & 01 & 08 \\ 08 & 05 & 02 & 09 & 01 & 01 & 04 & 01 \\ 01 & 08 & 05 & 02 & 09 & 01 & 01 & 04 \\ 04 & 01 & 08 & 05 & 02 & 09 & 01 & 01 \\ 01 & 04 & 01 & 08 & 05 & 02 & 09 & 01 \end{bmatrix}$$

This means that  $W' = c_3(X'')$  if and only if  $W' = X'' \cdot C''$ .

- e) Function  $c_4$  takes two matrices  $X'' = (x''_{ij})$  and  $Y' = (y'_{ij})$  as input and produces a single matrix  $W' = (w'_{ij})$  as output where:

$$w'_{ij} = x''_{ij} \oplus y'_{ij}, \quad (0 \leq i, j \leq 7).$$

This means that  $W' = c_4(X'', Y')$ , if and only if,  $w'_{ij} = x''_{ij} \oplus y'_{ij} \ (0 \leq i, j \leq 7)$ .

### 13.2.4 Constants

A sequence of constant matrices,  $A^r = (A_{ij}^r)$  ( $0 < r \leq 10$ ), is used in this round-function. The round constant for the  $r$ th round is a matrix, defined as:

$$\begin{aligned} A_{0j}^r &= s[8(r-1) + j], & (0 \leq j \leq 7), \\ A_{ij}^r &= 0, & (1 \leq i \leq 7, 0 \leq j \leq 7). \end{aligned}$$

### 13.2.5 Initializing value

The initializing value,  $IV$ , is a string of 512 “0” bits.

NOTE 512 “0” bits for the initial value is represented by a matrix  $Y'$  with entries in  $GF(2^8)$ .

### 13.3 Padding method

The data string,  $D$ , needs to be padded to make it contain a number of bits which is an integer multiple of 512. The padding procedure is as follows.

- $D$  is concatenated with a single “1” bit.
- The result of the previous step is concatenated with between zero and 511 “0” bits, such that the length (in bits) of the resultant string is an odd multiple of 256.
- If the original length of  $D$  is  $L_D$ , concatenate the string resulting from the previous step with the 256-bit binary representation of  $L_D$ , most significant bit first.

In the description of the round-function which follows, each 512-bit data block  $D_i$ ,  $1 \leq i \leq q$ , is treated as a matrix  $Z' = (z'_{ij})$  ( $0 \leq i, j \leq 7$ ), as specified in 13.2.3, where  $z'_{00}$  corresponds to the left-most 8 bits of  $D_i$  and  $z'_{77}$  corresponds to the right-most 8 bits of  $D_i$ .

NOTE The concatenation of the 256-bit string of  $L_D$  in step c) is such that the 256-bit string is used directly as the second half of the last data matrix. Based on the byte ordering convention in 13.2.2, the most significant byte of  $L_D$  is the entry in the fifth row and the first column and the least significant byte of  $L_D$  is the entry in the eighth row and the eighth column.

### 13.4 Description of the round-function

The round-function  $\Phi$  operates as follows.

NOTE In this description, the symbols  $W', X'', K_0, K_1, \dots, K_{10}$  are used to denote 13 distinct matrices, each with entries chosen from  $GF(2^8)$ , which contain values required in the computations.

- Suppose the 512-bit (first) input to  $\Phi$  is contained in a matrix  $Z'$  with entries chosen from  $GF(2^8)$  which is formed by using the byte ordering convention specified in 13.2.2. Suppose also that the 512-bit (second) input to  $\Phi$  is contained in a matrix  $Y'$  with entries chosen from  $GF(2^8)$ .
- Let  $K_0 := Y'$  and for  $i = 1$  to 10, let  $K_i := c_4(c_3(c_2(c_1(K_{i-1}))), A^i)$ .

NOTE This step expands the matrix  $Y'$  onto a sequence of round keys  $K_0, \dots, K_{10}$ .

- Let  $X'' := c_4(Z', K_0)$  and for  $j = 1$  to 10, do the following two steps:

- $W' := c_4(c_3(c_2(c_1(X''))), K_j)$ ;
- $X'' := W'$ .

- Let  $Y' := W' \oplus K_0 \oplus Z'$ .

The matrix  $Y'$  represents the output of the round-function  $\Phi$ . After the final iteration of the round-function, the matrix  $Y'$  shall be converted to a sequence of 64 bytes using the inverse of the procedure

specified in 16.2.2 and where the entry in the first row and the first column of the matrix shall yield the first byte, the entry in the first row and the second column of the matrix the next byte, ..., the entry in the eighth row and the eighth column of the matrix the last byte. The 64 bytes shall be converted to a string of 512 bits using the inverse of the procedure specified in Clause 6, i.e. the first (left-most) bit will correspond to the most significant bit of the first (left-most) byte and the 512th (right-most) bit will correspond to the least significant bit of the 64th (right-most) byte.

Figure 6 shows steps 1) and 2) of item c) of the round-function  $\Phi$  in Dedicated Hash-Function 7 (WHIRLPOOL). In the round-function  $\Phi$ , the steps shown in Figure 6 are used 10 times ( $j = 1, \dots, 10$ ).

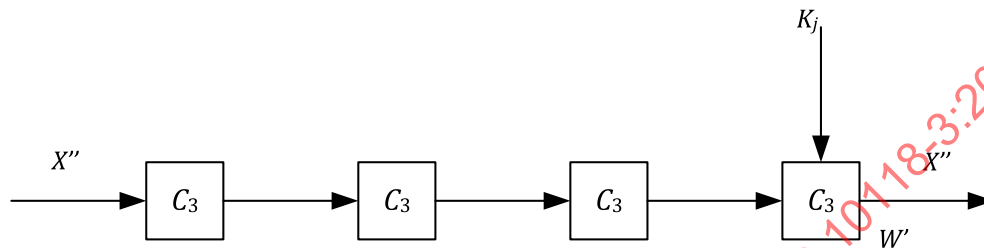


Figure 6 — Part of the round-function in Dedicated Hash-Function 7

## 14 Dedicated Hash-Function 8 (SHA-224)

### 14.1 General

In Clause 14, a padding method, an initializing value and a round-function for use in the general model for hash-functions described in ISO/IEC 10118-1 are specified. The padding method, initializing value and round-function specified here, when used in the above general model, together define Dedicated Hash-Function 8. This dedicated hash-function can be applied to all data strings,  $D$ , containing at most  $2^{64}-1$  bits.

The ISO/IEC hash-function identifier for Dedicated Hash-Function 8 is equal to 38 (hexadecimal).

NOTE Dedicated Hash-Function 8 defined in Clause 14 is commonly called SHA-224[1].

### 14.2 Parameters, functions and constants

#### 14.2.1 Parameters

For this hash-function,  $L_1 = 512$ ,  $L_2 = 256$  and  $L_H = 224$ .

#### 14.2.2 Byte ordering convention

The byte ordering convention for this hash-function is the same as that for the hash-function of Clause 10.

#### 14.2.3 Functions

The functions for this hash-function are the same as those for the hash-function of Clause 10.

#### 14.2.4 Constants

The constants for this hash-function are the same as those for the hash-function of Clause 10.

### 14.2.5 Initializing value

For this round-function, the initializing value,  $IV$ , shall always be the following 256-bit string, represented here as a sequence of eight words,  $Y_0, Y_1, Y_2, Y_3, Y_4, Y_5, Y_6$  and  $Y_7$ , in a hexadecimal representation, where  $Y_0$  represents the left-most 32 of the 256 bits:

$Y_0 = \text{C1059ED8};$   
 $Y_1 = \text{367CD507};$   
 $Y_2 = \text{3070DD17};$   
 $Y_3 = \text{F70E5939};$   
 $Y_4 = \text{FFC00B31};$   
 $Y_5 = \text{68581511};$   
 $Y_6 = \text{64F98FA7};$   
 $Y_7 = \text{BEFA4FA4}.$

NOTE These values are the low order 32 bits of the values specified in [12.2.5](#).

### 14.3 Padding method

The padding method to be used with this hash-function shall be the same as the padding method defined in [10.3](#).

### 14.4 Description of the round-function

The round-function to be used with this hash-function shall be the same as the round-function defined in [10.4](#).

The final 224-bit hash is obtained by truncating the SHA-256-based hash output to its left-most 224 bits.

## 15 Dedicated Hash-Function 9 (SHA-512/224)

### 15.1 General

In [Clause 15](#), a padding method, an initializing value and a round-function for use in the general model for hash-functions described in ISO/IEC 10118-1 are specified. The padding method, initializing value and round-function specified here, when used in the above general model, together define Dedicated Hash-Function 9. This dedicated hash-function can be applied to all data strings,  $D$ , containing at most  $2^{128}-1$  bits.

The ISO/IEC hash-function identifier for Dedicated Hash-Function 9 is equal to 39 (hexadecimal).

NOTE Dedicated Hash-Function 9 defined in [Clause 15](#) is commonly called SHA-512/224[1].

### 15.2 Parameters, functions and constants

#### 15.2.1 Parameters

For this hash-function,  $L_1 = 1\,024$ ,  $L_2 = 512$  and  $L_H$  is up to 224.

#### 15.2.2 Byte ordering convention

The byte ordering convention for this hash-function is the same as that for the hash-function of [Clause 11](#).

#### 15.2.3 Functions

The functions for this hash-function are the same as that for the hash-function of [Clause 11](#).

#### 15.2.4 Constants

The constants for this hash-function are the same as that for the hash-function of [Clause 11](#).

#### 15.2.5 Initializing value

For this round-function, the initializing value,  $IV$ , shall always be the following 512-bit string, represented here as a sequence of eight words,  $Y_0$ ,  $Y_1$ ,  $Y_2$ ,  $Y_3$ ,  $Y_4$ ,  $Y_5$ ,  $Y_6$  and  $Y_7$ , in a hexadecimal representation, where  $Y_0$  represents the left-most 64 of the 512 bits:

```
Y0 = 8C3D37C819544DA2;
Y1 = 73E1996689DCD4D6;
Y2 = 1DFAB7AE32FF9C82;
Y3 = 679DD514582F9FCF;
Y4 = 0F6D2B697BD44DA8;
Y5 = 77E36F7304C48942;
Y6 = 3F9D85A86A1D36C8;
Y7 = 1112E6AD91D692A1.
```

#### 15.3 Padding method

The padding method to be used with this hash-function shall be the same as the padding method defined in [Clause 11](#).

#### 15.4 Description of the round-function

The round-function to be used with this hash-function shall be the same as the round-function defined in [Clause 11](#). The final 224-bit hash is obtained by truncating the SHA-512-based hash output to its left-most 224 bits.

### 16 Dedicated Hash-Function 10 (SHA-512/256)

#### 16.1 General

In [Clause 16](#), a padding method, an initializing value and a round-function for use in the general model for hash-functions described in ISO/IEC 10118-1 are specified. The padding method, initializing value and round-function specified here, when used in the above general model, together define Dedicated Hash-Function 10. This dedicated hash-function can be applied to all data strings,  $D$ , containing at most  $2^{128}-1$  bits.

The ISO/IEC hash-function identifier for Dedicated Hash-Function 10 is equal to 3A (hexadecimal).

NOTE Dedicated Hash-Function 10 defined in [Clause 16](#) is commonly called SHA-512/256<sup>[1]</sup>.

#### 16.2 Parameters, functions and constants

##### 16.2.1 Parameters

For this hash-function,  $L_1 = 1\,024$ ,  $L_2 = 512$  and  $L_H$  is up to 256.

##### 16.2.2 Byte ordering convention

The byte ordering convention for this hash-function is the same as that for the hash-function of [Clause 11](#).

### 16.2.3 Functions

The functions for this hash-function are the same as that for the hash-function of [Clause 11](#).

### 16.2.4 Constants

The constants for this hash-function are the same as that for the hash-function of [Clause 11](#).

### 16.2.5 Initializing value

For this round-function the initializing value,  $IV$ , shall always be the following 512-bit string, represented here as a sequence of eight words,  $Y_0$ ,  $Y_1$ ,  $Y_2$ ,  $Y_3$ ,  $Y_4$ ,  $Y_5$ ,  $Y_6$  and  $Y_7$ , in a hexadecimal representation, where  $Y_0$  represents the left-most 64 of the 512 bits:

$Y_0 = 22312194FC2BF72C;$   
 $Y_1 = 9F555FA3C84C64C2;$   
 $Y_2 = 2393B86B6F53B151;$   
 $Y_3 = 963877195940EABD;$   
 $Y_4 = 96283EE2A88EFFE3;$   
 $Y_5 = BE5E1E2553863992;$   
 $Y_6 = 2B0199FC2C85B8AA;$   
 $Y_7 = 0EB72DDC81C52CA2.$

### 16.3 Padding method

The padding method to be used with this hash-function shall be the same as the padding method defined in [Clause 11](#).

### 16.4 Description of the round-function

The round-function to be used with this hash-function shall be the same as the round-function defined in [Clause 11](#). The final 256-bit hash is obtained by truncating the SHA-512-based hash output to its left-most 256 bits.

## 17 Dedicated Hash-Function 11 (STREEBOG-512)

### 17.1 General

In [Clause 17](#), a padding method, an initializing value and a round-function for use in the general model for hash-functions described in ISO/IEC 10118-1 are specified. The padding method, initializing value and round-function specified here, when used in the above general model, together define Dedicated Hash-Function 11. This dedicated hash-function can be applied to all data strings,  $D$ , containing at most  $2^{512}-1$  bits.

The ISO/IEC hash-function identifier for Dedicated Hash-Function 11 is equal to 3B (hexadecimal).

NOTE Dedicated Hash-Function 11 defined in [Clause 17](#) is one of the functions specified in GOST R 34.11-2012, the national standard of the Russian Federation, commonly called STREEBOG<sup>[2]</sup>.

### 17.2 Parameters, functions and constants

#### 17.2.1 Parameters

For this hash-function,  $L_1 = 512$ ,  $L_2 = 512$  and  $L_H = 512$ .

### 17.2.2 Byte ordering convention

In the specification of the round-function of [Clause 17](#), it is assumed that the block input to the round-function is in the form of a sequence of 512 bits. A sequence of 64 bytes,  $B_0, \dots, B_{63}$ , shall be interpreted as a sequence of consecutive bits in the following way. Each byte is considered as an 8-bit sequence, the most significant bit of the byte shall be the first bit of the sequence. Each 512-bit block is treated as a number in the following format:

$$Z = B_0 + B_1 2^8 + \dots + B_{63} 2^{504}.$$

To convert the hash-code from a sequence of bits to a sequence of bytes, the inverse process shall be followed.

### 17.2.3 Functions

#### 17.2.3.1 General

To calculate the hash-code  $H$  of the data string  $D$ , functions  $X, S, P, L$  and  $\text{MSB}_n$  are used. They are defined in [17.2.3.2](#) to [17.2.3.6](#).

#### 17.2.3.2 Function $X$

Function  $X[k]$  takes a 512-bit word as input and for the given 512-bit word, produces a 512-bit word as output, where  $X[k](a) = k \oplus a$ .

#### 17.2.3.3 Function $S$

Function  $S$  takes a 512-bit word as input, produces a 512-bit word as output and is defined as:

$$S(a) = S(a_{63} \parallel \dots \parallel a_0) = \pi(a_{63}) \parallel \dots \parallel \pi(a_0),$$

where  $a = a_{63} \parallel \dots \parallel a_0$ ,  $a_i$ ,  $i = 0, \dots, 63$ , are 8-bit words and  $\pi$  denotes a function from the set of octet strings to itself.  $\pi$  is defined as:

$$\pi = \text{Vec}_8 \pi' \text{Int}_8,$$

where  $\pi': \mathbb{Z}_{28} \rightarrow \mathbb{Z}_{28}$ .

The function  $\pi'$  is defined by the array  $\pi' = [\pi'(0), \pi'(1), \dots, \pi'(255)]$ :

$\pi' = (252, 238, 221, 17, 207, 110, 49, 22, 251, 196, 250, 218, 35, 197, 4, 77, 233, 119, 240, 219, 147, 46, 153, 186, 23, 54, 241, 187, 20, 205, 95, 193, 249, 24, 101, 90, 226, 92, 239, 33, 129, 28, 60, 66, 139, 1, 142, 79, 5, 132, 2, 174, 227, 106, 143, 160, 6, 11, 237, 152, 127, 212, 211, 31, 235, 52, 44, 81, 234, 200, 72, 171, 242, 42, 104, 162, 253, 58, 206, 204, 181, 112, 14, 86, 8, 12, 118, 18, 191, 114, 19, 71, 156, 183, 93, 135, 21, 161, 150, 41, 16, 123, 154, 199, 243, 145, 120, 111, 157, 158, 178, 177, 50, 117, 25, 61, 255, 53, 138, 126, 109, 84, 198, 128, 195, 189, 13, 87, 223, 245, 36, 169, 62, 168, 67, 201, 215, 121, 214, 246, 124, 34, 185, 3, 224, 15, 236, 222, 122, 148, 176, 188, 220, 232, 40, 80, 78, 51, 10, 74, 167, 151, 96, 115, 30, 0, 98, 68, 26, 184, 56, 130, 100, 159, 38, 65, 173, 69, 70, 146, 39, 94, 85, 47, 140, 163, 165, 125, 105, 213, 149, 59, 7, 88, 179, 64, 134, 172, 29, 247, 48, 55, 107, 228, 136, 217, 231, 137, 225, 27, 131, 73, 76, 63, 248, 254, 141, 83, 170, 144, 202, 216, 133, 97, 32, 113, 103, 164, 45, 43, 9, 91, 203, 155, 37, 208, 190, 229, 108, 82, 89, 166, 116, 210, 230, 244, 180, 192, 209, 102, 175, 194, 57, 75, 99, 182).$

#### 17.2.3.4 Function $P$

Function  $P$  takes a 512-bit word as input, produces a 512-bit word as output and is defined as:

$$P(a) = P(a_{63} \parallel \dots \parallel a_0) = a_{\tau(63)} \parallel \dots \parallel a_{\tau(0)},$$

where  $a = a_{63} \parallel \dots \parallel a_0$ ,  $a_i$ ,  $i = 0, \dots, 63$ , are 8-bit words and  $\tau$  is a permutation of the set  $\{0, 1, \dots, 63\}$  given by the array  $\tau = (\tau(0), \tau(1), \dots, \tau(63))$ :



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

### 17.2.3.5 Function $L$

Function  $L$  takes a 512-bit word as input, produces a 512-bit word as output and is defined as:

$$L(a) = L(a_7 \parallel \dots \parallel a_0) = l(a_7) \parallel \dots \parallel l(a_0),$$

where  $a = a_7 \parallel \dots \parallel a_0$ ,  $a_i$ ,  $i = 0, \dots, 7$ , are 64-bit words and  $l$  is a function equal to right multiplication by the matrix  $A$ , given below, over the field  $\text{GF}(2)$ . The matrix rows are expressed sequentially in hexadecimal notation. The row with number  $j$ ,  $j = 0, \dots, 63$ , (specified in the form  $a_{j,15}, \dots, a_{j,0}$ , where  $a_{j,i} \in \mathbb{F}_{16}$ ,  $i = 0, \dots, 15$ ), is  $\text{Vec}_4(a_{j,15}) \parallel \dots \parallel \text{Vec}_4(a_{j,0})$ .

|                  |                  |                  |                  |
|------------------|------------------|------------------|------------------|
| 8E20FAA72BA0B470 | 47107DDD9B505A38 | AD08B0E0C3282D1C | D8045870EF14980E |
| 6C022C38F90A4C07 | 3601161CF205268D | 1B8E0B0E798C13C8 | 83478B07B2468764 |
| A011D380818E8F40 | 5086E740CE47C920 | 2843FD2067ADEA10 | 14AEF010BDD87508 |
| 0AD97808D06CB404 | 05E23C0468365A02 | 8C711E02341B2D01 | 46B60F011A83988E |
| 90DAB52A387AE76F | 486DD4151C3DFDB9 | 24B86A840E90F0D2 | 125C354207487869 |
| 092E94218D243CBA | 8A174A9EC8121E5D | 4585254F64090FA0 | ACCC9CA9328A8950 |
| 9D4DF05D5F661451 | C0A878A0A1330AA6 | 60543C50DE970553 | 302A1E286FC58CA7 |
| 18150F14B9EC46DD | 0C84890AD27623E0 | 0642CA05693B9F70 | 0321658CBA93C138 |
| 86275DF09CE8AAA8 | 439DA0784E745554 | AFC0503C273AA42A | D960281E9D1D5215 |
| E230140FC0802984 | 71180A8960409A42 | B60C05CA30204D21 | 5B068C651810A89E |
| 456C34887A3805B9 | AC361A443D1C8CD2 | 561B0D22900E4669 | 2B838811480723BA |
| 9BCF4486248D9F5D | C3E9224312C8C1A0 | EFFA11AF0964EE50 | F97D86D98A327728 |
| E4FA2054A80B329C | 727D102A548B194E | 39B008152ACB8227 | 9258048415EB419D |
| 492C024284FBAEC0 | AA16012142F35760 | 550B8E9E21F7A530 | A48B474F9EF5DC18 |
| 70A6A56E2440598E | 3853DC371220A247 | 1CA76E95091051AD | 0EDD37C48A08A6D8 |
| 07E095624504536C | 8D70C431AC02A736 | C83862965601DD1B | 641C314B2B8EE083 |

Each row of the given table contains four rows of the matrix  $A$ . So, the line with number  $i$ ,  $i = 0, \dots, 15$ , specifies the rows of the matrix  $A$  with numbers  $4i + j$ ,  $j = 0, \dots, 3$ , in the following left-to-right order:  $4i + 0, 4i + 1, 4i + 2, 4i + 3$ .

The product of the 64-bit word  $b = b_{63}, \dots, b_0$  and the matrix  $A$  is a 64-bit word  $c$ :

$$c = b_{63}(\text{Vec}_4(a_{0,15}) \parallel \dots \parallel \text{Vec}_4(a_{0,0})) \oplus \dots \oplus b_0(\text{Vec}_4(a_{63,15}) \parallel \dots \parallel \text{Vec}_4(a_{63,0})),$$

where

$$b_i (\text{Vec}_4(a_{63-i,15}) \parallel \dots \parallel \text{Vec}_4(a_{63-i,0})) = \begin{cases} 0^{64}, & \text{if } b_i = 0, \\ (\text{Vec}_4(a_{63-i,15}) \parallel \dots \parallel \text{Vec}_4(a_{63-i,0})), & \text{if } b_i = 1, \end{cases}$$

for all  $i = 0, \dots, 63$ .

### 17.2.3.6 Truncation function

Function  $\text{MSB}_n$  maps the word  $z_{k-1} \parallel \dots \parallel z_1 \parallel z_0$ ,  $k \geq n$  to the word  $z_{k-1} \parallel \dots \parallel z_{k-n+1} \parallel z_{k-n}$ .

### 17.2.4 Constants

Round constants are expressed in hexadecimal notation. The constant value specified in the form  $a_{127}, \dots, a_0$  (where  $a_i \in \mathbb{F}_{16}$ ,  $i = 0, \dots, 127$ ) is  $\text{Vec}_4(a_{127}) \parallel \dots \parallel \text{Vec}_4(a_0)$ :



$C_1 = \text{B1085BDA1ECADAE9EBCB2F81C0657C1F2F6A76432E45D016714EB88D7585C4FC}$   
 $\quad \text{4B7CE09192676901A2422A08A460D31505767436CC744D23DD806559F2A64507};$

$C_2 = \text{6FA3B58AA99D2F1A4FE39D460F70B5D7F3FEEA720A232B9861D55E0F16B50131}$   
 $\quad \text{9AB5176B12D699585CB561C2DB0AA7CA55DDA21BD7CBCD56E679047021B19BB7};$

$C_3 = \text{F574DCAC2BCE2FC70A39FC286A3D843506F15E5F529C1F8BF2EA7514B1297B7B}$   
 $\quad \text{D3E20FE490359EB1C1C93A376062DB09C2B6F443867ADB31991E96F50ABA0AB2};$

$C_4 = \text{EF1FDFB3E81566D2F948E1A05D71E4DD488E857E335C3C7D9D721CAD685E353F}$   
 $\quad \text{A9D72C82ED03D675D8B71333935203BE3453EAA193E837F1220CBEB8C84E3D12E};$

$C_5 = \text{4BEA6BACAD4747999A3F410C6CA923637F151C1F1686104A359E35D7800FFFBD}$   
 $\quad \text{BFCD1747253AF5A3DFFF00B723271A167A56A27EA9EA63F5601758FD7C6CFE57};$

$C_6 = \text{AE4FAEAE1D3AD3D96FA4C33B7A3039C02D66C4F95142A46C187F9AB49AF08EC6}$   
 $\quad \text{CFFAA6B71C9AB7B40AF21F66C2BEC6B6BF71C57236904F35FA68407A46647D6E};$

$C_7 = \text{F4C70E16EEAAC5EC51AC86FEBF240954399EC6C7E6BF87C9D3473E33197A93C9}$   
 $\quad \text{0992ABC52D822C3706476983284A05043517454CA23C4AF38886564D3A14D493};$

$C_8 = \text{9B1F5B424D93C9A703E7AA020C6E41414EB7F8719C36DE1E89B4443B4DDBC49A}$   
 $\quad \text{F4892BCB929B069069D18D2BD1A5C42F36ACC2355951A8D9A47F0DD4BF02E71E};$

$C_9 = \text{378F5A541631229B944C9AD8EC165FDE3A7D3A1B258942243CD955B7E00D0984}$   
 $\quad \text{800A440BDBB2CEB17B2B8A9AA6079C540E38DC92CB1F2A607261445183235ADB};$

$C_{10} = \text{ABBEDEA680056F52382AE548B2E4F3F38941E71CFF8A78DB1FFFE18A1B336103}$   
 $\quad \text{9FE76702AF69334B7A1E6C303B7652F43698FAD1153BB6C374B4C7FB98459CED};$

$C_{11} = \text{7BCD9ED0EFC889FB3002C6CD635AFE94D8FA6BBEBAB07612001802114846679}$   
 $\quad \text{8A1D71EFEA48B9CAEFBACD1D7D476E98DEA2594AC06FD85D6BCAA4CD81F32D1B};$

$C_{12} = \text{378EE767F11631BAD21380B00449B17ACDA43C32BCDF1D77F82012D430219F9B}$   
 $\quad \text{5D80EF9D1891CC86E71DA4AA88E12852FAF417D5D9B21B9948BC924AF11BD720}.$

### 17.2.5 Initializing value

The initializing value,  $IV$ , is equal to  $0^{512}$ .

### 17.3 Padding method

The data string,  $D$ , needs to be padded to make it contain a number of bits which is an integer multiple of 512. The padding procedure is as follows:

- $D$  is concatenated with a single “1” bit (bit placed to the left).
- The result of the previous step is concatenated with between zero and 511 “0” bits (placed to the left) such that the length (in bits) of the resultant string is a multiple of 512.
- If the original length of  $D$  is  $L_D$ , concatenate the string resulting from the previous step with the 512-bit binary representation of  $L_D$ .
- If the data after step b) of padding could be expressed in the form  $D_0, D_1, \dots, D_k$ , where  $D_i$  are 512-bit words and  $k$  is a positive integer, calculate the value  $\Sigma = D_0 \oplus D_1 \oplus \dots \oplus D_k$  and concatenate the string resulting from the previous step with value  $\Sigma$ .

## 17.4 Description of the round-function

The round-function  $\Phi$  operates as follows. Note that in [Clause 17](#), the symbols  $h$ ,  $m$  and  $N$  are used to denote three distinct 512-bit words which contain values required in the computations. The hash-code value of the data string  $D$  is calculated using an iterative procedure. Each iteration is performed using a round-function that transforms two 512-bit words to a 512-bit word and is calculated as:

$$\Phi(m, h) = g_N(h, m) = E(LPS(h \oplus N), m) \oplus h \oplus m,$$

where  $E(K, m) = X[K_{13}]LPSX[K_{12}]...LPSX[K_2]LPSX[K_1](m)$  and where  $N$  denotes a 512-bit word calculated during the iterative procedure.

The values  $K_i \in V_{512}$ ,  $i = 1, \dots, 13$  are calculated as follows:

$$K_1 = K;$$

$$K_i = LPS(K_{i-1} \oplus C_{i-1}), i = 2, \dots, 13.$$

For brevity, instead of  $g_{0^{512}}$ , the notation  $g_0$  is used.

The hash-function operates as follows. The input for calculating the hash-code is the data string,  $D$  (to be hashed), and the initializing value,  $IV$ .

The padding method described in [17.3](#) is accomplished within the algorithm that follows, i.e. that the padding does not actually have to be done prior to running the algorithm.

The algorithm for calculating the hash-code consists of the following stages.

### a) Stage 1

Assign initial values to the following variables:

- 1)  $h := IV$ ;
- 2)  $N := 0^{512}$ ;
- 3)  $\Sigma := 0^{512}$ ;
- 4) Go to Stage 2.

### b) Stage 2

- 1) Check the condition:  $L_D < 512$ .

If it is true, then go to Stage 3.

Else, perform the following calculations:

- i) Let  $m$  be the right-most 512 bits of the message  $D$  (so that  $D = D' \parallel m$ ). Then perform the following calculations:

- $h := g_N(h, m)$ ;
- $N := \text{Vec}_{512}(\text{Int}_{512}(N) \cup 512)$ ;
- $\Sigma := \text{Vec}_{512}(\text{Int}_{512}(\Sigma) \cup \text{Int}_{512}(m))$ ;
- $D := D'$ .

- ii) Go to b)1).

### c) Stage 3

- 1)  $m := 0^{511-L_D} \parallel 1 \parallel D$ .

- 2)  $h := g_N(h, m)$ .
- 3)  $N := \text{Vec}_{512}(\text{Int}_{512}(N) \cup L_D)$ .
- 4)  $\Sigma := \text{Vec}_{512}(\text{Int}_{512}(\Sigma) \cup \text{Int}_{512}(m))$ .
- 5)  $h := g_0(h, N)$ .
- 6)  $h := g_0(h, \Sigma)$ .
- 7) End of the algorithm.

The value of the variable  $h$  [obtained in step 6)] is the hash-code  $H$ .

## 18 Dedicated Hash-Function 12 (STREEBOG-256)

### 18.1 General

In [Clause 18](#), a padding method, an initializing value and a round-function for use in the general model for hash-functions described in ISO/IEC 10118-1 are specified. The padding method, initializing value and round-function specified here, when used in the above general model, together define the Dedicated Hash-Function 12. This dedicated hash-function can be applied to all data strings,  $D$ , containing at most  $2^{512}-1$  bits.

The ISO/IEC hash-function identifier for Dedicated Hash-Function 12 is equal to 3C (hexadecimal).

NOTE Dedicated Hash-Function 12 defined in [Clause 18](#) is one of the functions specified in GOST R 34.11-2012, the national standard of the Russian Federation, commonly called STREEBOG<sup>[2]</sup>.

### 18.2 Parameters, functions and constants

#### 18.2.1 Parameters

For this hash-function,  $L_1 = 512$ ,  $L_2 = 512$  and  $L_H = 256$ .

#### 18.2.2 Byte ordering convention

The byte ordering convention for this hash-function is the same as that for the hash-function of [Clause 17](#).

#### 18.2.3 Functions

The functions for this hash-function are the same as those for the hash-function of [Clause 17](#).

#### 18.2.4 Constants

The constants for this hash-function are the same as those for the hash-function of [Clause 17](#).

#### 18.2.5 Initializing value

The initializing value,  $IV$ , equals  $(000\ 000\ 01)^{64}$ .

### 18.3 Padding method

The padding method to be used with this hash-function shall be the same as the padding method defined in [Clause 17](#).

## 18.4 Description of the round-function

The round-function to be used with this hash-function shall be the same as the round-function defined in [Clause 17](#). The final 256-bit hash is obtained by truncating the STREEBOG-512-based hash output to its most significant 256 bits.

## 19 Dedicated Hash-Function 13 (SHA3-224)

### 19.1 General

In [Clause 19](#), a permutation-based hash-function with sponge construction SHA-224 is specified. The ISO/IEC hash-function identifier for Dedicated Hash-Function 13 is equal to 3D (hexadecimal).

### 19.2 Parameters, functions and constants

#### 19.2.1 Parameters

For this hash-function,  $L_1 = r = 1\,152$ ,  $L_2 = b = 1\,600$ ,  $c = b - r = 448$ ,  $d = 224$ ,  $L_H$  is up to 224.

#### 19.2.2 Byte ordering convention

Each data input  $D$  to the round-function  $\Phi$  is a block of 1 152 bits that is XORed into the part of the state. The permutation  $f$  is then applied to the state. Because the step mappings that comprise the permutation are defined on the array form of the state, it is convenient to regard  $D$  as a sequence of 64-bit words that are XORed directly into the state array. For this purpose, when  $D$  is represented as a sequence of 144 bytes,  $B_0, B_1, \dots, B_{143}$ , then  $D$  shall be interpreted as a sequence of 18 lane words,  $Z_0, Z_1, \dots, Z_{17}$ , as follows:

$$Z_i = 2^{56}B_{8i+7} + 2^{48}B_{8i+6} + 2^{40}B_{8i+5} + 2^{32}B_{8i+4} + 2^{24}B_{8i+3} + 2^{16}B_{8i+2} + 2^8B_{8i+1} + B_{8i},$$

for  $0 \leq i \leq 17$ .

Hence, each group of eight consecutive bytes is a word and the bytes of the word are arranged in increasing order of significance, so that the first byte in the group becomes the least significant byte of the word.

For dedicated hash-function 13, the function is defined on a  $5 \times 5 \times w$  state array. For each array six sub-arrays are defined for step-mappings. Lane is one of the subarrays and defined in [19.2.3.3](#). Under this interpretation,  $D$  is XORed with the state array as follows:

If  $j$  and  $k$  are the elements of  $\{0, 1, 2, 3, 4\}$  such that  $(j, k)$  is the unique pair for which  $i = 5k + j$ , then for  $0 \leq i \leq 17$ ,  $\text{Lane}'(j, k) = Z_i \oplus \text{Lane}(j, k)$ , where  $\text{Lane}'(j, k)$  is the updated value of the lane.

#### 19.2.3 Functions

##### 19.2.3.1 General

In [19.2.3.8](#), the KECCAK- $p$  permutations are specified. A KECCAK- $p$  permutation is determined by two parameters. First, the fixed length of the strings that are permuted, called the *width* of the permutation, is denoted as  $b$ . Second, the number of iterations of an internal transformation, called a *round*, is denoted as  $n_r$ . For the Dedicated Hash-Functions 13, 14, 15 and 16,  $b = 1\,600$  and  $n_r = 24$ . However, in some of the examples, in particular when a figure is used to illustrate the operations, smaller values of  $b$  are used.

A round of a KECCAK- $p$  permutation, denoted by  $Rnd$ , consists of a sequence of five transformations called *step mappings*. The permutation is specified in terms of an array of values for  $b$  ( $= 1\,600$ ) bits that is repeatedly updated, called the *state*. The state is initially set to the input values of the permutation.

**NOTE** The term round is used differently from the term specified in ISO/IEC 10118-1, where a round is a function used to process one single input data block to the hash-function. For the Dedicated Hash-Functions 13, 14, 15 and 16, to process one single data block, the round-function is iterated  $n_r$  ( $= 24$ ) times. That is, each execution of round-function  $\Phi$ , as it is named in ISO/IEC 10118-1, iterates  $Rnd$  24 times.

The notation and terminology for the state are described in 19.2.3.2 to 19.2.3.6. The step mappings are specified in 19.2.3.7. The KECCAK- $p$  permutations, including the round-function  $Rnd$ , are specified in 19.2.3.8.

### 19.2.3.2 State

The input and output states of the permutation are comprised of  $b$  bit strings. To represent the step mappings, a state is represented as a  $5 \times 5 \times w$  array of bits, where  $w = b/25$ . For  $b = 1\,600$ ,  $w = 64$ . If  $S$  denotes a string that represents the state, then its bits are indexed from 0 to  $b-1$ , so that

$$S = S[0] \parallel S[1] \parallel \dots \parallel S[b-2] \parallel S[b-1].$$

If  $\mathbf{A}$  denotes a  $5 \times 5 \times w$  array of bits that represents the state, then its indices are the integer triples  $(x, y, z)$  for which  $0 \leq x < 5$ ,  $0 \leq y < 5$  and  $0 \leq z < w$ . The bit that corresponds to  $(x, y, z)$  is denoted by  $\mathbf{A}[x, y, z]$ . A *state array* is a representation of the state by a three-dimensional array that is indexed in this manner.

### 19.2.3.3 Parts of the state array

The two-dimensional sub-arrays are called *sheets*, *planes* and *slices*; and the single-dimensional sub-arrays are called *rows*, *columns* and *lanes*.

The algebraic definitions of these sub-arrays are as follows.

**Column** For a state array, a sub-array of 5 bits with constant  $x$  and  $z$  coordinates.

**Lane** For a state array of a KECCAK- $p$  permutation with width  $b$ , a sub-array of  $b/25$  bits with constant  $x$  and  $y$  coordinates.

**Plane** For a state array of a KECCAK- $p$  permutation with width  $b$ , a sub-array of  $b/5$  bits with constant  $y$  coordinate.

**Row** For a state array, a sub-array of 5 bits with constant  $y$  and  $z$  coordinates.

**Sheet** For a state array of a KECCAK- $p$  permutation with width  $b$ , a sub-array of  $b/5$  bits with a constant  $x$  coordinate.

**Slice** For a state array, a sub-array of 25 bits with a constant  $z$  coordinate.

### 19.2.3.4 Converting strings to state arrays

Let  $S$  denote a string of  $b$  bits that represents the state for the KECCAK- $p$  permutation. The corresponding state array, denoted by  $\mathbf{A}$ , is defined as follows.

For all triples  $(x, y, z)$ , such that  $0 \leq x < 5$ ,  $0 \leq y < 5$  and  $0 \leq z < w$ ,

$$\mathbf{A}[x, y, z] = S[w(5y + x) + z].$$

For  $b = 1\,600$  and  $w = 64$ ,

|                       |                        |                        |
|-----------------------|------------------------|------------------------|
| $A[0, 0, 0] = S[0]$   | $A[1, 0, 0] = S[64]$   | $A[4, 0, 0] = S[256]$  |
| $A[0, 0, 1] = S[1]$   | $A[1, 0, 1] = S[65]$   | $A[4, 0, 1] = S[257]$  |
| $A[0, 0, 2] = S[2]$   | $A[1, 0, 2] = S[66]$   | $A[4, 0, 2] = S[258]$  |
| $\vdots$              | $\vdots$               | $\vdots$               |
| $A[0, 0, 61] = S[61]$ | $A[1, 0, 61] = S[125]$ | $A[4, 0, 61] = S[317]$ |
| $A[0, 0, 62] = S[62]$ | $A[1, 0, 62] = S[126]$ | $A[4, 0, 62] = S[318]$ |
| $A[0, 0, 63] = S[63]$ | $A[1, 0, 63] = S[127]$ | $A[4, 0, 63] = S[319]$ |

and

|                        |                        |                        |
|------------------------|------------------------|------------------------|
| $A[0, 1, 0] = S[320]$  | $A[1, 1, 0] = S[384]$  | $A[4, 1, 0] = S[576]$  |
| $A[0, 1, 1] = S[321]$  | $A[1, 1, 1] = S[385]$  | $A[4, 1, 1] = S[577]$  |
| $A[0, 1, 2] = S[322]$  | $A[1, 1, 2] = S[386]$  | $A[4, 1, 2] = S[578]$  |
| $\vdots$               | $\vdots$               | $\vdots$               |
| $A[0, 1, 61] = S[381]$ | $A[1, 1, 61] = S[445]$ | $A[4, 1, 61] = S[637]$ |
| $A[0, 1, 62] = S[382]$ | $A[1, 1, 62] = S[446]$ | $A[4, 1, 62] = S[638]$ |
| $A[0, 1, 63] = S[383]$ | $A[1, 1, 63] = S[447]$ | $A[4, 1, 63] = S[639]$ |

and

|                        |                        |                        |
|------------------------|------------------------|------------------------|
| $A[0, 2, 0] = S[640]$  | $A[1, 2, 0] = S[704]$  | $A[4, 2, 0] = S[896]$  |
| $A[0, 2, 1] = S[641]$  | $A[1, 2, 1] = S[705]$  | $A[4, 2, 1] = S[897]$  |
| $A[0, 2, 2] = S[642]$  | $A[1, 2, 2] = S[706]$  | $A[4, 2, 2] = S[898]$  |
| $\vdots$               | $\vdots$               | $\vdots$               |
| $A[0, 2, 61] = S[701]$ | $A[1, 2, 61] = S[765]$ | $A[4, 2, 61] = S[957]$ |
| $A[0, 2, 62] = S[702]$ | $A[1, 2, 62] = S[766]$ | $A[4, 2, 62] = S[958]$ |
| $A[0, 2, 63] = S[703]$ | $A[1, 2, 63] = S[767]$ | $A[4, 2, 63] = S[959]$ |

etc.

### 19.2.3.5 Converting state arrays to strings

Let  $\mathbf{A}$  denote a state array. The corresponding string representation, denoted by  $S$ , can be constructed from the lanes and planes of  $\mathbf{A}$ , as follows:

For each pair of integers  $(i, j)$ , such that  $0 \leq i < 5$  and  $0 \leq j < 5$ , define the string *Lane*  $(i, j)$  by using

$$\text{Lane}(i, j) = A[i, j, 0] \parallel A[i, j, 1] \parallel A[i, j, 2] \parallel \dots \parallel A[i, j, w-2] \parallel A[i, j, w-1].$$

For  $b = 1\ 600$  and  $w = 64$ ,

$$\text{Lane}(0, 0) = A[0, 0, 0] \parallel A[0, 0, 1] \parallel A[0, 0, 2] \parallel \dots \parallel A[0, 0, 62] \parallel A[0, 0, 63]$$

$$\text{Lane}(1, 0) = A[1, 0, 0] \parallel A[1, 0, 1] \parallel A[1, 0, 2] \parallel \dots \parallel A[1, 0, 62] \parallel A[1, 0, 63]$$

$$\text{Lane}(2, 0) = A[2, 0, 0] \parallel A[2, 0, 1] \parallel A[2, 0, 2] \parallel \dots \parallel A[2, 0, 62] \parallel A[2, 0, 63]$$

etc.

For each integer,  $j$ , such that  $0 \leq j < 5$ , define the string *Plane* ( $j$ ) by using

$$\text{Plane}(j) = \text{Lane}(0, j) \parallel \text{Lane}(1, j) \parallel \text{Lane}(2, j) \parallel \text{Lane}(3, j) \parallel \text{Lane}(4, j).$$

Then,

$$S = \text{Plane}(0) \parallel \text{Plane}(1) \parallel \text{Plane}(2) \parallel \text{Plane}(3) \parallel \text{Plane}(4).$$

For  $b = 1\,600$  and  $w = 64$ ,

$$\begin{aligned} S = & \mathbf{A}[0, 0, 0] \parallel \mathbf{A}[0, 0, 1] \parallel \mathbf{A}[0, 0, 2] \parallel \dots \parallel \mathbf{A}[0, 0, 62] \parallel \mathbf{A}[0, 0, 63] \\ & \parallel \mathbf{A}[1, 0, 0] \parallel \mathbf{A}[1, 0, 1] \parallel \mathbf{A}[1, 0, 2] \parallel \dots \parallel \mathbf{A}[1, 0, 62] \parallel \mathbf{A}[1, 0, 63] \\ & \parallel \mathbf{A}[2, 0, 0] \parallel \mathbf{A}[2, 0, 1] \parallel \mathbf{A}[2, 0, 2] \parallel \dots \parallel \mathbf{A}[2, 0, 62] \parallel \mathbf{A}[2, 0, 63] \\ & \parallel \mathbf{A}[3, 0, 0] \parallel \mathbf{A}[3, 0, 1] \parallel \mathbf{A}[3, 0, 2] \parallel \dots \parallel \mathbf{A}[3, 0, 62] \parallel \mathbf{A}[3, 0, 63] \\ & \parallel \mathbf{A}[4, 0, 0] \parallel \mathbf{A}[4, 0, 1] \parallel \mathbf{A}[4, 0, 2] \parallel \dots \parallel \mathbf{A}[4, 0, 62] \parallel \mathbf{A}[4, 0, 63] \\ & \parallel \mathbf{A}[0, 1, 0] \parallel \mathbf{A}[0, 1, 1] \parallel \mathbf{A}[0, 1, 2] \parallel \dots \parallel \mathbf{A}[0, 1, 62] \parallel \mathbf{A}[0, 1, 63] \\ & \parallel \mathbf{A}[1, 1, 0] \parallel \mathbf{A}[1, 1, 1] \parallel \mathbf{A}[1, 1, 2] \parallel \dots \parallel \mathbf{A}[1, 1, 62] \parallel \mathbf{A}[1, 1, 63] \\ & \parallel \mathbf{A}[2, 1, 0] \parallel \mathbf{A}[2, 1, 1] \parallel \mathbf{A}[2, 1, 2] \parallel \dots \parallel \mathbf{A}[2, 1, 62] \parallel \mathbf{A}[2, 1, 63] \\ & \parallel \mathbf{A}[3, 1, 0] \parallel \mathbf{A}[3, 1, 1] \parallel \mathbf{A}[3, 1, 2] \parallel \dots \parallel \mathbf{A}[3, 1, 62] \parallel \mathbf{A}[3, 1, 63] \\ & \parallel \mathbf{A}[4, 1, 0] \parallel \mathbf{A}[4, 1, 1] \parallel \mathbf{A}[4, 1, 2] \parallel \dots \parallel \mathbf{A}[4, 1, 62] \parallel \mathbf{A}[4, 1, 63] \\ & \parallel \mathbf{A}[0, 4, 0] \parallel \mathbf{A}[0, 4, 1] \parallel \mathbf{A}[0, 4, 2] \parallel \dots \parallel \mathbf{A}[0, 4, 62] \parallel \mathbf{A}[0, 4, 63] \\ & \parallel \mathbf{A}[1, 4, 0] \parallel \mathbf{A}[1, 4, 1] \parallel \mathbf{A}[1, 4, 2] \parallel \dots \parallel \mathbf{A}[1, 4, 62] \parallel \mathbf{A}[1, 4, 63] \\ & \parallel \mathbf{A}[2, 4, 0] \parallel \mathbf{A}[2, 4, 1] \parallel \mathbf{A}[2, 4, 2] \parallel \dots \parallel \mathbf{A}[2, 4, 62] \parallel \mathbf{A}[2, 4, 63] \\ & \parallel \mathbf{A}[3, 4, 0] \parallel \mathbf{A}[3, 4, 1] \parallel \mathbf{A}[3, 4, 2] \parallel \dots \parallel \mathbf{A}[3, 4, 62] \parallel \mathbf{A}[3, 4, 63] \\ & \parallel \mathbf{A}[4, 4, 0] \parallel \mathbf{A}[4, 4, 1] \parallel \mathbf{A}[4, 4, 2] \parallel \dots \parallel \mathbf{A}[4, 4, 62] \parallel \mathbf{A}[4, 4, 63]. \end{aligned}$$

### 19.2.3.6 Labelling convention for the state array

In the diagrams of the state that accompany the specifications of the step mappings, the lane that corresponds to the coordinates  $(x, y) = (0, 0)$  is depicted at the centre of the slices.

### 19.2.3.7 Step mappings

#### 19.2.3.7.1 General

The five step mappings that comprise a round of KECCAK- $p$  are denoted by  $\theta$ ,  $\rho$ ,  $\pi$ ,  $\chi$  and  $\iota$ . Specifications for these functions are given in [19.2.3.7.2](#) to [19.2.3.7.6](#).

The algorithm for each step mapping takes a state array, denoted by  $\mathbf{A}$ , as an input and returns an updated state array, denoted by  $\mathbf{A}'$ , as the output.

The  $\iota$  mapping has a second input: an integer called the *round index*, denoted by  $i_r$ , which is defined within Algorithm 5 for KECCAK- $p$ , in [19.2.3.7.6](#). The other step mappings do not depend on the *round index*.

#### 19.2.3.7.2 Specification of $\theta$

Algorithm 1:  $\theta(\mathbf{A})$

Input: state array **A**

Output: state array **A'**

Steps:

- a) For all pairs  $(x, z)$ , such that  $0 \leq x < 5$  and  $0 \leq z < w$ , let
 
$$C[x, z] = A[x, 0, z] \oplus A[x, 1, z] \oplus A[x, 2, z] \oplus A[x, 3, z] \oplus A[x, 4, z].$$
- b) For all pairs  $(x, z)$ , such that  $0 \leq x < 5$  and  $0 \leq z < w$  let
 
$$D[x, z] = C[(x-1) \bmod 5, z] \oplus C[(x+1) \bmod 5, (z-1) \bmod w].$$
- c) For all triples  $(x, y, z)$ , such that  $0 \leq x < 5$ ,  $0 \leq y < 5$  and  $0 \leq z < w$ , let
 
$$A'[x, y, z] = A[x, y, z] \oplus D[x, z].$$

The effect of  $\theta$  is to XOR each bit in the state with the parities of two columns in the array. In particular, for the bit  $A[x_0, y_0, z_0]$ , the  $x$ -coordinate of one of the columns is  $(x_0 - 1) \bmod 5$ , with the same  $z$ -coordinate,  $z_0$ , while the  $x$ -coordinate of the other column is  $(x_0 + 1) \bmod 5$ , with  $z$ -coordinate  $(z_0 - 1) \bmod w$ .

#### 19.2.3.7.3 Specification of $\rho$

Algorithm 2:  $\rho(A)$

Input: state array **A**

Output: state array **A'**

Steps:

- a) For all  $z$  such that  $0 \leq z < w$ , let  $A'[0, 0, z] = A[0, 0, z]$ .
- b) Let  $(x, y) = (1, 0)$ .
- c) For  $t$  from 0 to 23:
  - 1) for all  $z$  such that  $0 \leq z < w$ , let  $A'[x, y, z] = A\{x, y, [z - (t+1)(t+2)/2] \bmod w\}$ ;
  - 2) let  $(x, y) = [y, (2x+3y) \bmod 5]$ .
- d) Return **A'**.

#### 19.2.3.7.4 Specification of $\pi$

Algorithm 3:  $\pi(A)$

Input: state array **A**

Output: state array **A'**

Steps:

- a) For all triples  $(x, y, z)$  such that  $0 \leq x < 5$ ,  $0 \leq y < 5$  and  $0 \leq z < w$ , let
 
$$A'[x, y, z] = A[(x+3y) \bmod 5, x, z].$$
- b) Return **A'**.

#### 19.2.3.7.5 Specification of $\chi$

Algorithm 4:  $\chi(A)$



Input: state array  $\mathbf{A}$

Output: state array  $\mathbf{A}'$

Steps:

- a) For all triples  $(x, y, z)$  such that  $0 \leq x < 5$ ,  $0 \leq y < 5$  and  $0 \leq z < w$ , let
 
$$\mathbf{A}'[x, y, z] = \mathbf{A}[x, y, z] \oplus \langle \mathbf{A}[(x+1) \bmod 5, y, z] \oplus 1 \rangle \wedge \mathbf{A}[(x+2) \bmod 5, y, z].$$
- b) Return  $\mathbf{A}'$ .

The notation  $\wedge$  in the right side of the assignment for step a) is Boolean “AND” operation.

#### 19.2.3.7.6 Specification of $\iota$

The  $\iota$  mapping is parameterized by the round index,  $i_r$ , whose values are specified in step b) of Algorithm 7 for computing KECCAK- $p$ , in 19.2.3.8. Within the specification of  $\iota$  in Algorithm 6, this parameter determines  $l + 1$  bits of a lane value called the *round constant*, denoted by  $RC$ , where  $l = \log(w)$ . When  $w = 64$ ,  $l = 6$ . Each of these 7 bits is generated by a function that is based on a linear feedback shift register. This function, denoted by  $rc$ , is specified in Algorithm 5.

Algorithm 5:  $rc(t)$

Input: integer  $t$

Output: bit  $rc(t)$

Steps:

- a) If  $t \bmod 255 = 0$ , return 1.
- b) Let  $R = 10\,000\,000$ .
- c) For  $i$  from 1 to  $t \bmod 255$ , let:
  - 1)  $R = 0 \parallel R$ ;
  - 2)  $R[0] = R[0] \oplus R[8]$ ;
  - 3)  $R[6] = R[6] \oplus R[8]$ ;
  - 4)  $R[3] = R[3] \oplus R[8]$ ;
  - 5)  $R[2] = R[2] \oplus R[8]$ ;
  - 6)  $R = \text{Trunc}_8[R]$ .
- d) Return  $R[0]$ .

In Algorithm 6,  $RC$  is a  $w$ -bit binary string and denoted as  $RC[0], RC[1], \dots, RC[w-1]$ .

Algorithm 6:  $\iota(\mathbf{A}, i_r)$

Input: state array  $\mathbf{A}$ ; round index  $i_r$

Output: state array  $\mathbf{A}'$

Steps:

- a) For all triples  $(x, y, z)$ , such that  $0 \leq x < 5$ ,  $0 \leq y < 5$  and  $0 \leq z < w$ , let  $\mathbf{A}'[x, y, z] = \mathbf{A}[x, y, z]$ .
- b) Let  $RC = 0^w$ .
- c) For  $j$  from 0 to 6, let  $RC[2j - 1] = rc(j + 7i_r)$ .

- d) For all  $z$ , such that  $0 \leq z < w$ , let  $\mathbf{A}'[0, 0, z] = \mathbf{A}'[0, 0, z] \oplus RC[z]$ .
- e) Return  $\mathbf{A}'$ .

The effect of  $\iota$  is to modify some of the bits of *Lane* (0, 0) in a manner that depends on the round index  $i_r$ . The other 24 lanes are not affected by  $\iota$ .

### 19.2.3.8 KECCAK- $p$

Given a state array  $\mathbf{A}$  and a round index  $i_r$ , the round-function  $Rnd$  is the transformation that results from applying the step mappings  $\theta$ ,  $\rho$ ,  $\pi$ ,  $\chi$  and  $\iota$ , in that order, i.e.:

$$Rnd(\mathbf{A}, i_r) = \iota(\chi(\pi(\rho[\theta(\mathbf{A})])), i_r).$$

The KECCAK- $p$  permutation consists of 24 iterations of  $Rnd$ , as specified in Algorithm 7.

Algorithm 7: KECCAK- $p$  ( $S$ )

Input: string  $S$  of length 1 600 bits

Output: string  $S$  of length 1 600 bits

Steps:

- a) Convert  $S$  into a state array,  $\mathbf{A}$ , as described in [19.2.3.4](#).
- b) For  $i_r$  from 0 to 23, let  $\mathbf{A} = Rnd(\mathbf{A}, i_r)$ .
- c) Convert  $\mathbf{A}$  into a string,  $S'$  of length  $b$ , as described in [19.2.3.5](#).
- d) Return  $S'$ .

## 19.3 Padding method

The data, a binary string  $M$ , will be padded with “01” before applying the padding method  $\text{pad}_{10^*1}(x, m)$ , specified below with  $x = 1\ 152$ .

$\text{pad}_{10^*1}(x, m)$

Input: positive integer  $x$ ; non-negative integer  $m$

Output: string  $P$ , such that  $m + \text{len}(P)$  is a positive multiple of  $x$

Steps:

- a) Let  $j = (-m - 2) \bmod x$ .
- b) Return  $P = 1 \parallel 0_j \parallel 1$ .

Thus, the asterisk in “ $\text{pad}_{10^*1}$ ” indicates that the “0” bit is either omitted or repeated as necessary, in order to produce an output string of the desired length.

That is, the padded data is  $P = M \parallel 01 \parallel 10^*1$ , such that the length of  $P$  is a multiple of 1 152.

## 19.4 Description of a round-function

The round-function for Dedicated Hash-Function 13 is the permutation KECCAK- $p$  specified in [19.2.3.8](#). Notice that KECCAK- $p$  is considered as  $\Phi$  as defined in ISO/IEC 10118-1. However, for each execution of KECCAK- $p$ , it iterates the  $Rnd$  function 24 times. That is, it executes

$$Rnd(\mathbf{A}, i_r) = \iota(\chi(\pi(\rho[\theta(\mathbf{A})])), i_r),$$

for  $i_r = 0, 1, \dots, 23$ .

## 19.5 Output transformation

In step h) of SPONGE[ $f$ , pad,  $r$ ]( $N$ ,  $d$ ),  $f = \text{KECCAK-}p$ , because  $r = 1\,152$ ,  $d = 224$  and  $r > d$ , the  $\text{Trunc}_r(S)$  will be further truncated to  $d$  bits.

## 20 Dedicated Hash-Function 14 (SHA3-256)

### 20.1 General

In [Clause 20](#), a permutation-based hash-function with sponge construction SHA3-256 is specified. The description of permutation-based hash-function with sponge construction is given in [Clause 19](#).

The ISO/IEC hash-function identifier for Dedicated Hash-Function 14 is equal to 3E (hexadecimal).

### 20.2 Parameters, functions and constants

#### 20.2.1 Parameters

For this hash-function,  $L_1 = r = 1\,088$ ,  $L_2 = b = 1\,600$ ,  $c = b - r = 512$ ,  $d = 256$ ,  $L_H$  is up to 256.

#### 20.2.2 Byte ordering convention

Each data input  $D$  to the round-function  $\Phi$  is a block of 1 088 bits that is XORed into the part of the state. The permutation  $f$  is then applied to the state. Because the step mappings that comprise the permutation are defined on the array form of the state, it is convenient to regard  $D$  as a sequence of 64-bit words that are XORed directly into the state array. For this purpose, when  $D$  is represented as a sequence of 136 bytes,  $B_0, B_1, \dots, B_{135}$ , then  $D$  shall be interpreted as a sequence of 17 lane words,  $Z_0, Z_1, \dots, Z_{16}$ , as follows:

$$Z_i = 2^{56}B_{8i+7} + 2^{48}B_{8i+6} + 2^{40}B_{8i+5} + 2^{32}B_{8i+4} + 2^{24}B_{8i+3} + 2^{16}B_{8i+2} + 2^8B_{8i+1} + B_{8i},$$

for  $0 \leq i \leq 16$ .

Hence, each group of eight consecutive bytes is a word and the bytes of the word are arranged in increasing order of significance, so that the first byte in the group becomes the least significant byte of the word.

For dedicated hash-function 14, the function is defined on a  $5 \times 5 \times w$  state array. For each array six sub-arrays are defined for step-mappings. Lane is one of the subarrays and defined in [19.2.3.3](#). Under this interpretation,  $D$  is XORed with the state array as follows.

If  $j$  and  $k$  are the elements of  $\{0, 1, 2, 3, 4\}$  such that  $(j, k)$  is the unique pair for which  $i = 5k + j$ , then for  $0 \leq i \leq 16$ ,  $\text{Lane}'(j, k) = Z_i \oplus \text{Lane}(j, k)$ , where  $\text{Lane}'(j, k)$  is the updated value of the lane.

#### 20.2.3 Functions

The functions, including the function  $Rnd$  and step mappings, for the Dedicated Hash-Function 14 are the same as Dedicated Hash-Function 13 and is specified in [Clause 19](#).

#### 20.2.4 Constants

The constants used for the mapping  $\rho$  are the offsets defined in [Clause 19](#).

#### 20.2.5 Initializing value

The initializing value is a 1 600-bit all-zero string.

## 20.3 Padding method

The data  $M$  will be padded with “01” before applying the padding method  $\text{pad}_{10^*1}(x, m)$  specified in [Clause 19](#), with  $x = 1\ 088$ .

That is, the padded data is  $P = M \parallel 01 \parallel 10^*1$ , such that the length of  $P$  is a multiple of 1 088.

## 20.4 Description of round-function

The round-function for Dedicated Hash-Function 14 is the permutation KECCAK- $p$  specified in [Clause 19](#). Notice that KECCAK- $p$  is considered as  $\Phi$  as defined in ISO/IEC 10118-1. However, for each execution of KECCAK- $p$ , it iterates the  $Rnd$  function 24 times. That is, it executes

$$Rnd(A, i_r) = \iota(\chi < \pi[\rho[\theta(A)]] >, i_r),$$

for  $i_r = 0, 1, \dots, 23$ .

## 20.5 Output transformation

In step h) of SPONGE[ $f, \text{pad}, r$ ]( $N, d$ ), specified in [Clause 19](#),  $f = \text{KECCAK-}p$  because  $r = 1\ 088$ ,  $d = 256$  and  $r > d$ , the  $\text{Trunc}_r(S)$  will be further truncated to  $d$  bits.

# 21 Dedicated Hash-Function 15 (SHA3-384)

## 21.1 General

In [Clause 21](#), a permutation-based hash-function with sponge construction SHA3-384 is specified. The description of permutation-based hash-function with sponge construction is given in [Clause 19](#).

The ISO/IEC hash-function identifier for Dedicated Hash-Function 15 is equal to 3F (hexadecimal).

## 21.2 Parameters, functions and constants

### 21.2.1 Parameters

For this hash-function,  $L_1 = r = 832$ ,  $L_2 = b = 1\ 600$ ,  $c = b - r = 768$ ,  $d = 384$ ,  $L_H$  is up to 384.

### 21.2.2 Byte ordering convention

Each data input  $D$  to the round-function  $\Phi$  is a block of 832 bits that is XORed into the part of the state; the permutation  $f$  is then applied to the state. Because the step mappings that comprise the permutation are defined on the array form of the state, it is convenient to regard  $D$  as a sequence of 64-bit words that are XORed directly into the state array. For this purpose, when  $D$  is represented as a sequence of 104 bytes,  $B_0, B_1, \dots, B_{103}$ , then  $D$  shall be interpreted as a sequence of 13 lane words,  $Z_0, Z_1, \dots, Z_{12}$ , as follows:

$$Z_i = 2^{56}B_{8i+7} + 2^{48}B_{8i+6} + 2^{40}B_{8i+5} + 2^{32}B_{8i+4} + 2^{24}B_{8i+3} + 2^{16}B_{8i+2} + 2^8B_{8i+1} + B_{8i},$$

for  $0 \leq i \leq 12$ .

Hence, each group of eight consecutive bytes is a word and the bytes of the word are arranged in increasing order of significance, so that the first byte in the group becomes the least significant byte of the word.

For dedicated hash-function 14, the function is defined on a  $5 \times 5 \times w$  state array. For each array six sub-arrays are defined for step-mappings. Lane is one of the subarrays and defined in [19.2.3.3](#). Under this interpretation,  $D$  is XORed with the state array as follows.

If  $j$  and  $k$  are the elements of  $\{0, 1, 2, 3, 4\}$  such that  $(j, k)$  is the unique pair for which  $i = 5k + j$ , then for  $0 \leq i \leq 12$ ,  $\text{Lane}'(j, k) = Z_i \oplus \text{Lane}(j, k)$ , where  $\text{Lane}'(j, k)$  is the updated value of the lane.

### 21.2.3 Functions

The functions, including the function *Rnd* and step mappings, for the Dedicated Hash-Function 15 are the same as Dedicated Hash-Function 13 and is specified in [Clause 19](#).

### 21.2.4 Constants

The constants used for the mapping  $\rho$  are the offsets defined in [Clause 19](#).

### 21.2.5 Initializing value

The initializing value is a 1 600-bit all-zero string.

## 21.3 Padding method

The data  $M$  will be padded with “01” before applying the padding method  $\text{pad}_{10^*1}(x, m)$  specified in [Clause 19](#), with  $x = 832$ .

That is, the padded data is  $P = M \parallel 01 \parallel 10^*1$ , such that the length of  $P$  is a multiple of 832.

## 21.4 Description of round-function

The round-function for Dedicated Hash-Function 15 is the permutation  $\text{KECCAK-}p$  specified in [Clause 19](#). Notice that  $\text{KECCAK-}p$  is considered as  $\Phi$  as defined in ISO/IEC 10118-1. However, for each execution of  $\text{KECCAK-}p$ , it iterates the *Rnd* function 24 times. That is, it executes

$$\text{Rnd}(\mathbf{A}, i_r) = \iota(\chi < \pi\{\rho[\theta(\mathbf{A})]\} >, i_r),$$

for  $i_r = 0, 1, \dots, 23$ .

## 21.5 Output transformation

In step h) of  $\text{SPONGE}[f, \text{pad}, r](N, d)$  specified in [Clause 19](#), because  $r = 832$ ,  $d = 384$  and  $r > d$ , the  $\text{Trunc}_r(S)$  will be further truncated to  $d$  bits.

## 22 Dedicated Hash-Function 16 (SHA3-512)

### 22.1 General

In [Clause 22](#), a permutation-based hash-function with sponge construction SHA3-512 is specified. The description of permutation-based hash-function with sponge construction is given in [Clause 19](#).

The ISO/IEC hash-function identifier for Dedicated Hash-Function 16 is equal to 40 (hexadecimal).

### 22.2 Parameters, functions and constants

#### 22.2.1 Parameters

For this hash-function,  $L_1 = r = 576$ ,  $L_2 = b = 1\,600$ ,  $c = b - r = 1\,024$ ,  $d = 512$ ,  $L_H$  is up to 512.

#### 22.2.2 Byte ordering convention

Each data input  $D$  to the round-function  $\Phi$  is a block of 576 bits that is XORed into the part of the state. The permutation  $f$  is then applied to the state. Because the step mappings that comprise the permutation are defined on the array form of the state, it is convenient to regard  $D$  as a sequence of 64-bit words that are XORed directly into the state array. For this purpose, when  $D$  is represented as a sequence of 72 bytes,  $B_0, B_1, \dots, B_{71}$ , then  $D$  shall be interpreted as a sequence of 9 lane words,  $Z_0, Z_1, \dots, Z_8$ , as follows:

$$Z_i = 2^{56}B_{8i+7} + 2^{48}B_{8i+6} + 2^{40}B_{8i+5} + 2^{32}B_{8i+4} + 2^{24}B_{8i+3} + 2^{16}B_{8i+2} + 2^8B_{8i+1} + B_{8i},$$

for  $0 \leq i \leq 8$ .

Hence, each group of eight consecutive bytes is a word and the bytes of the word are arranged in increasing order of significance, so that the first byte in the group becomes the least significant byte of the word.

For dedicated hash-function 14, the function is defined on a  $5 \times 5 \times w$  state array. For each array six sub-arrays are defined for step-mappings. Lane is one of the subarrays and defined in [19.2.3.3](#). Under this interpretation,  $D$  is XORed with the state array as follows.

If  $j$  and  $k$  are the elements of  $\{0, 1, 2, 3, 4\}$  such that  $(j, k)$  is the unique pair for which  $i = 5k + j$ , then for  $0 \leq i \leq 8$ ,  $Lane'(j, k) = Z_i \oplus Lane(j, k)$ , where  $Lane'(j, k)$  is the updated value of the lane.

### 22.2.3 Functions

The functions, including the function  $Rnd$  and step mappings, for the Dedicated Hash-Function 16 are the same as Dedicated Hash-Function 13 and is specified in [Clause 19](#).

### 22.2.4 Constants

The constants used for the mapping  $\rho$  are the offsets defined in [Clause 19](#).

### 22.2.5 Initializing value

The initializing value is a 1 600-bit all-zero string.

## 22.3 Padding method

The data  $M$  will be padded with “01” before applying the padding method  $\text{pad}_{10^*1}(x, m)$  specified in [Clause 19](#), with  $x = 576$ .

That is, the padded data is  $P = M \parallel 01 \parallel 10^*1$ , such that the length of  $P$  is a multiple of 576.

## 22.4 Description of round-function

The round-function for Dedicated Hash-Function 16 is the permutation KECCAK- $p$  specified in [Clause 19](#). Notice that KECCAK- $p$  is considered as  $\phi$  as defined in ISO/IEC 10118-1. However, for each execution of KECCAK- $p$ , it iterates the  $Rnd$  function 24 times. That is, it executes

$$Rnd(\mathbf{A}, i_r) = \iota(\chi < \pi\{\rho[\theta(\mathbf{A})]\} >, i_r),$$

for  $i_r = 0, 1, \dots, 23$ .

## 22.5 Output transformation

In step h) of SPONGE[ $f, \text{pad}, r$ ]( $N, d$ ) specified in [Clause 19](#),  $f = \text{KECCAK-}p$ , because  $r = 576$ ,  $d = 512$  and  $r > d$ , the  $\text{Trunc}_r(S)$  will be further truncated to  $d$  bits.

# 23 Dedicated Hash-Function 17 (SM3)

## 23.1 General

In [Clause 23](#), a padding method, an initializing value and a round-function for use in the general model for hash-functions described in ISO/IEC 10118-1 are specified. The padding method, initializing value and round-function specified here, when used in the above general model, together define Dedicated

Hash-Function 17. This dedicated hash-function can be applied to all data strings,  $D$ , containing at most  $2^{64}-1$  bits.

The ISO/IEC hash-function identifier for Dedicated Hash-Function 17 is equal to 11 (hexadecimal).

NOTE Dedicated Hash-Function 17 defined in [Clause 23](#) is commonly called SM3[7][8].

## 23.2 Parameters, functions and constants

### 23.2.1 Parameters

For this hash-function,  $L_1 = 512$ ,  $L_2 = 256$  and  $L_H$  is up to 256.

### 23.2.2 Byte ordering convention

The byte ordering convention to be used with this hash-function shall be the same as the byte ordering convention defined in [9.2.2](#).

### 23.2.3 Functions

To facilitate software implementation, the round-function  $\Phi$  is described in terms of operations on 32-bit words.

Two sequences of functions  $b_0, b_1, \dots, b_{63}$  and  $b'_0, b'_1, \dots, b'_{63}$  are used in this round-function, where each takes three words,  $X_0, X_1$  and  $X_2$ , as input and produces a single word as output. Two functions,  $P_0$  and  $P_1$ , are also used in this round-function, where each takes one word,  $X_0$ , as input and produces a single word as output.

The functions  $b_0, b_1, \dots, b_{63}, b'_0, b'_1, \dots, b'_{63}, P_0, P_1$  are defined as follows:

$$b_i(X_0, X_1, X_2) = \begin{cases} X_0 \oplus X_1 \oplus X_2, & 0 \leq i \leq 15, \\ (X_0 \wedge X_1) \vee (X_0 \wedge X_2) \vee (X_1 \wedge X_2), & 16 \leq i \leq 63, \end{cases}$$

$$b'_i(X_0, X_1, X_2) = \begin{cases} X_0 \oplus X_1 \oplus X_2, & 0 \leq i \leq 15, \\ (X_0 \wedge X_1) \vee (\neg X_0 \wedge X_2), & 16 \leq i \leq 63, \end{cases}$$

$$P_0(X_0) = X_0 \oplus S^9(X_0) \oplus S^{17}(X_0),$$

$$P_1(X_0) = X_0 \oplus S^{15}(X_0) \oplus S^{23}(X_0).$$

### 23.2.4 Constants

A sequence of constant words,  $C_0, C_1, \dots, C_{63}$ , is used in this round-function. In a hexadecimal representation (the most significant bit corresponds to the left-most bit), these are defined as follows:

$$C_i = \begin{cases} 79CC4519 & 0 \leq i \leq 15, \\ 7A879D8A & 16 \leq i \leq 63. \end{cases}$$

### 23.2.5 Initializing value

For this round-function the initializing value,  $IV$ , shall always be the following 256-bit string, represented here as a sequence of eight words,  $Y_0, Y_1, \dots, Y_7$ , in a hexadecimal representation, where  $Y_0$  represents the left-most 32 of the 256 bits.

$$Y_0 = 7380166F;$$

$$Y_1 = 4914B2B9;$$



$Y_2 = 172442D7;$   
 $Y_3 = DA8A0600;$   
 $Y_4 = A96F30BC;$   
 $Y_5 = 163138AA;$   
 $Y_6 = E38DEE4D;$   
 $Y_7 = B0FB0E4E.$

### 23.3 Padding method

The padding method to be used with this hash-function shall be the same as the padding method defined in [9.3](#).

### 23.4 Description of the round-function

The round-function,  $\Phi$ , operates as follows.

NOTE In this description, the symbols  $W_1, W_2, W_3, W_4, X_0, X_1, X_2, X_3, X_4, X_5, X_6, X_7, Z_0, Z_1, \dots, Z_{67}, Z'_0, Z'_1, \dots, Z'_{63}$  are used to denote 144 distinct words which contain values required in the computations.

- a) Suppose the 512-bit (first) input to  $\Phi$  is contained in  $Z_0, Z_1, \dots, Z_{15}$ , where  $Z_0$  contains the left-most 32 of the 512 bits. Suppose also that the 256-bit (second) input to  $\Phi$  is contained in eight words,  $Y_0, Y_1, \dots, Y_7$ .
- b) For  $i = 16$  to  $67$ , let  $Z_i := P_1[Z_{i-16} \oplus Z_{i-9} \oplus S^{15}(Z_{i-3})] \oplus S^7(Z_{i-13}) \oplus Z_{i-6}$ .
- c) For  $i = 0$  to  $63$ , let  $Z'_i := Z_i \oplus Z_{i+4}$ .
- d) Let  $X_0 := Y_0, X_1 := Y_1, X_2 := Y_2, X_3 := Y_3, X_4 := Y_4, X_5 := Y_5, X_6 := Y_6, X_7 := Y_7$ .
- e) For  $i = 0$  to  $63$ , do the following five steps:
  - 1)  $W_1 := S^7[S^{12}(X_0) \cup X_4 \cup S^i(C_i)];$
  - 2)  $W_2 := W_1 \oplus S^{12}(X_0);$
  - 3)  $W_3 := b_i(X_0, X_1, X_2) \cup X_3 \cup W_2 \cup Z_i;$
  - 4)  $W_4 := b'_i(X_4, X_5, X_6) \cup X_7 \cup W_1 \cup Z_i;$
  - 5)  $X_7 := X_6, X_6 := S^{19}(X_5), X_5 := X_4, X_4 := P_0(W_4), X_3 := X_2, X_2 := S^9(X_1), X_1 := X_0, X_0 := W_3;$
- f) Let  $Y_0 := Y_0 \oplus X_0, Y_1 := Y_1 \oplus X_1, Y_2 := Y_2 \oplus X_2, Y_3 := Y_3 \oplus X_3, Y_4 := Y_4 \oplus X_4, Y_5 := Y_5 \oplus X_5, Y_6 := Y_6 \oplus X_6$  and  $Y_7 := Y_7 \oplus X_7$ .
- g) The eight words,  $Y_0, Y_1, \dots, Y_7$ , represent the output of the round-function  $\Phi$ . After the final iteration of the round-function, the eight words,  $Y_0, Y_1, \dots, Y_7$ , shall be converted to a sequence of 32 bytes using the inverse of the procedure specified in [Clause 9](#), where  $Y_0$  shall yield the first four bytes,  $Y_1$  the next four bytes and so on. Thus, the first (left-most) byte will correspond to the most significant byte of  $Y_0$  and the 32nd (right-most) byte will correspond to the least significant byte of  $Y_7$ . The 32 bytes shall be converted to a string of 256 bits using the inverse of the procedure specified in [Clause 6](#), i.e. the first (left-most) bit will correspond to the most significant bit of the first (left-most) byte and the 256th (right-most) bit will correspond to the least significant bit of the 32nd (right-most) byte.

[Figure 7](#) shows steps 1), 2), 3), 4) and 5) of item e) of the round-function  $\Phi$  in SM3. In the round-function  $\Phi$ , steps 1), 2), 3), 4) and 5) of item e) are used 64 times ( $i = 0, 1, \dots, 63$ ).



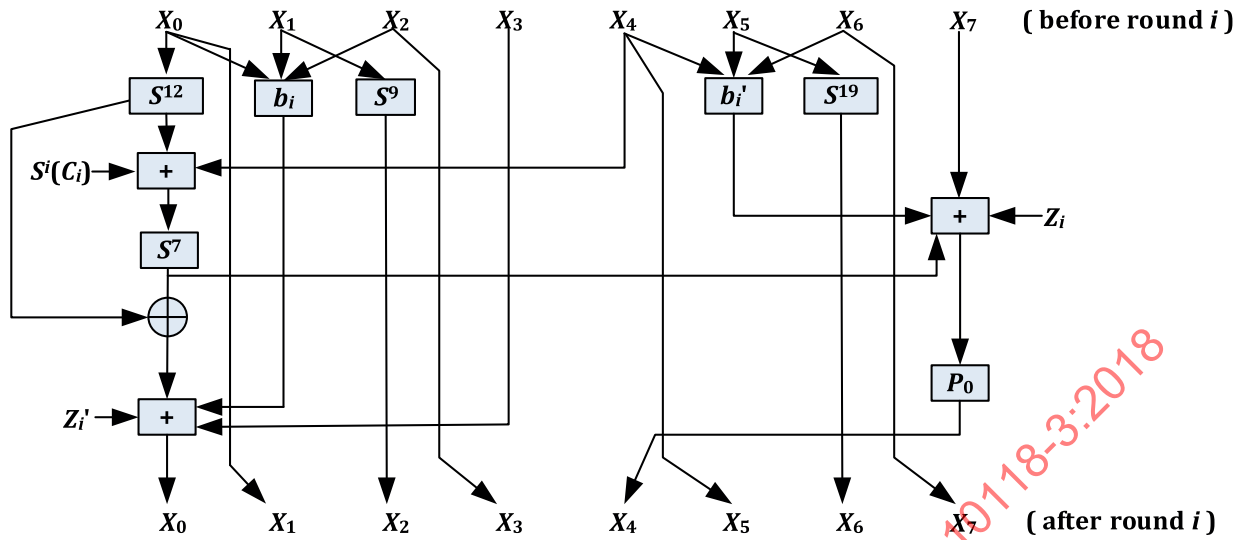


Figure 7 — Part of the round-function in Dedicated Hash-Function 17

## Annex A (normative)

### Object identifiers

Annex A lists the object identifiers assigned to the dedicated hash-functions specified in this document.

```
--
-- Draft object identifiers of ISO/IEC 10118-3
-- Based on ISO/IEC JTC 1/SC 27 N XXXX XXXX-XX-XX
--

DedicatedHashFunctions {
iso(1) standard(0) hash-functions(10118) part3(3)
asn1-module(1) dedicated-hash-functions(0) }
DEFINITIONS EXPLICIT TAGS ::= BEGIN

-- EXPORTS All; --

-- IMPORTS None; --

OID ::= OBJECT IDENTIFIER -- alias

-- Synonyms --

id-dhf OID ::= {
iso(1) standard(0) hash-functions(10118) part3(3) algorithm(0) }

-- Assignments --

id-dhf-ripemd160 OID ::= { id-dhf ripemd160 (49) }
id-dhf-ripemd128 OID ::= { id-dhf ripemd128 (50) }
id-dhf-whirlpool OID ::= { id-dhf whirlpool (55) }
id-dhf-streebog512 OID ::= { id-dhf streebog512 (59) }
id-dhf-streebog256 OID ::= { id-dhf streebog256 (60) }
id-dhf-SM3 OID ::= { id-dhf sm3 (65) }

-- note: assign any new OIDs above 68

-- FIPS 180-4 and FIPS 202 Secure Hash Algorithm --

id-sha1 OID ::= {
iso(1) identified-organization(3) oiw(14) secsig(3)
algorithm(2) 26
}

sha2Algorithm OID ::= {
joint-iso-itu-t(2) country(16) us(840) organization(1) gov(101)
csor(3) nistAlgorithm(4) hashAlgs(2)
}

id-sha256 OID ::= { sha2Algorithm sha256(1) }
id-sha384 OID ::= { sha2Algorithm sha384(2) }
id-sha512 OID ::= { sha2Algorithm sha512(3) }
id-sha224 OID ::= { sha2Algorithm sha224(4) }
```

```

id-sha512-224 OID ::= { sha2Algorithm sha512-224(5) }
id-sha512-256 OID ::= { sha2Algorithm sha512-256(6) }
id-sha3-224 OID ::= { sha2Algorithm sha3-224(7) }
id-sha3-256 OID ::= { sha2Algorithm sha3-256(8) }
id-sha3-384 OID ::= { sha2Algorithm sha3-384(9) }
id-sha3-512 OID ::= { sha2Algorithm sha3-512(10) }
id-shake128 OID ::= { sha2Algorithm shake128(11) }
id-shake256 OID ::= { sha2Algorithm shake256(12) }

HashFunctions ::= SEQUENCE {
  algorithm ALGORITHM.&id({HashFunctionAlgs}),
  parameters ALGORITHM.&Type({HashFunctionAlgs}{@algorithm}) OPTIONAL
}

HashFunctionAlgs ALGORITHM ::= {
  dhf-ripemd160 |
  dhf-ripemd128 |
  dhf-whirlpool |
  dhf-streebog256 |
  dhf-streebog512 |
  sha3-224 |
  sha3-256 |
  sha3-384 |
  sha3-512 |
  dhf-sm3 |
  shake128 |
  shake256 |
  SHA-Algorithms,

  ... -- Expect additional algorithms --
}

dhf-ripemd160 ALGORITHM ::= {
  OID id-dhf-ripemd160 PARMS NullParms
}

dhf-ripemd128 ALGORITHM ::= {
  OID id-dhf-ripemd128 PARMS NullParms
}

dhf-whirlpool ALGORITHM ::= {
  OID id-dhf-whirlpool PARMS NullParms
}

dhf-streebog256 ALGORITHM ::= {
  OID id-dhf-streebog256 PARMS NullParms
}

dhf-streebog512 ALGORITHM ::= {
  OID id-dhf-streebog512 PARMS NullParms
}

sha3-224 ALGORITHM ::= {
  OID id-sha3-224 PARMS NullParms
}

sha3-256 ALGORITHM ::= {
  OID id-sha3-256 PARMS NullParms
}

sha3-384 ALGORITHM ::= {
  OID id-sha3-384 PARMS NullParms
}

```

```

sha3-512 ALGORITHM ::= {
OID id-sha3-512 PARMS NullParms
}

dhf-SM3 ALGORITHM ::= {
OID id-dhf-sm3 PARMS NullParms
}

shake128 ALGORITHM ::= {
OID id-shake128 PARMS NullParms
}

shake256 ALGORITHM ::= {
OID id-shake256 PARMS NullParms
}

SHA-Algorithms ALGORITHM ::= {

-- The parameters associated with id-sha1, id-sha256, id-sha384, --
-- id-sha512, id-sha224, id-sha512-224 and id-sha512-256 should --
-- be omitted, but if present, should have --
-- a value of ASN.1 type NULL. This is to align with the original --
-- NIST definitions (which did not have parameters) and certain --
-- existing implementations (which have them). For these SHA --
-- algorithms, implementations should accept AlgorithmIdentifier --
-- values with NULL parameters and with the optional parameters --
-- component not present. --

sha-1      |
sha-256    |
sha-384    |
sha-512    |
sha-224    |
sha-512-224 |
sha-512-256,

... -- Expect additional algorithms --
}

sha-1 ALGORITHM ::= {
OID id-sha1 PARMS NullParms
}

sha-256 ALGORITHM ::= {
OID id-sha256 PARMS NullParms
}

sha-384 ALGORITHM ::= {
OID id-sha384 PARMS NullParms
}

sha-512 ALGORITHM ::= {
OID id-sha512 PARMS NullParms
}

sha-224 ALGORITHM ::= {
OID id-sha224 PARMS NullParms
}

sha-512-224 ALGORITHM ::= {
OID id-sha512-224 PARMS NullParms
}

sha-512-256 ALGORITHM ::= {
OID id-sha512-256 PARMS NullParms
}

NullParms ::= NULL

-- Cryptographic algorithm identification --

```

```
ALGORITHM ::= CLASS {  
  &id      OBJECT IDENTIFIER  UNIQUE,  
  &Type    OPTIONAL  
}  
WITH SYNTAX { OID &id [PARMS &Type] }  
  
END -- DedicatedHashFunctions --
```

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## Annex B (informative)

### Numerical examples

#### B.1 General

This annex gives numerical examples for the computation of Dedicated Hash-Functions 1 to 17. For each of the hash-functions, intermediate values derived during the hash-function's operation are given for some examples.

Throughout this annex, it is referred to as ASCII coding of data strings, which is equivalent to coding using ISO/IEC 646.

#### B.2 Dedicated Hash-Function 1 (RIPEMD-160)

NOTE Reference [4] contains a pseudocode description of Dedicated Hash-Function 1.

##### B.2.1 Example 1

In this example, the data string is the empty string, i.e., the string of length zero.

The hash-code is the following 160-bit string.

9C 11 85 A5 C5 E9 FC 54 61 28 08 97 7E E8 F5 48 B2 25 8D 31

##### B.2.2 Example 2

In this example, the data string consists of a single byte, namely the ASCII-coded version of the letter "a".

The hash-code is the following 160-bit string.

0B DC 9D 2D 25 6B 3E E9 DA AE 34 7B E6 F4 DC 83 5A 46 7F FE

##### B.2.3 Example 3

In this example, the data string is the 3-byte string consisting of the ASCII-coded version of "abc". This is equivalent to the bit string "01100001 01100010 01100011".

After the padding process, the single 16-word block derived from the data string is as follows.

80 63 62 61 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000  
00000000 00000000 00000000 00000000 00000000 00000000 00000018 00000000

The following are (hexadecimal representations of) the successive values of the variables  $X_0, X_1, X_2, X_3, X_4, X'_0, X'_1, X'_2, X'_3$  and  $X'_4$ .

67452301, EFCDAB89, 98BADCFE, 10325476, C3D2E1F0, 67452301, EFCDAB89, 98BADCFE, 10325476, C3D2E1F0  
C3D2E1F0, 3115FC67, EFCDAB89, EB73FA62, 10325476, C3D2E1F0, DDD63FB8, EFCDAB89, EB73FA62, 10325476  
10325476, B41192D5, 3115FC67, 36AE27BF, EB73FA62, 10325476, 322E7AE3, DDD63FB8, 36AE27BF, EB73FA62  
EB73FA62, 3A35DC50, B41192D5, 57F19CC4, 36AE27BF, EB73FA62, 883EE903, 322E7AE3, 58FEE377, 36AE27BF  
36AE27BF, D3786413, 3A35DC50, 464B56D0, 57F19CC4, 36AE27BF, 92B2B79B, 883EE903, B9EB8CC8, 58FEE377  
57F19CC4, 0E946720, D3786413, D77140E8, 464B56D0, 58FEE377, F9091FF2, 92B2B79B, FBA40E20, B9EB8CC8

|           |           |           |           |           |           |           |           |           |          |
|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|----------|
| 464B56D0, | D52BF632, | 0E946720, | E1904F4D, | D77140E8, | B9EB8CC8, | E5B09992, | F9091FF2, | CADE6E4A, | FBA40E20 |
| D77140E8, | 150BD8A8, | D52BF632, | 519C803A, | E1904F4D, | FBA40E20, | 8B2D9FB3, | E5B09992, | 247FCBE4, | CADE6E4A |
| E1904F4D, | 3D6F601F, | 150BD8A8, | AFD8CB54, | 519C803A, | CADE6E4A, | E755F422, | 8B2D9FB3, | C2664B96, | 247FCBE4 |
| 519C803A, | B7B60384, | 3D6F601F, | 2F62A054, | AFD8CB54, | 247FCBE4, | 5922D09E, | E755F422, | B67ECE2C, | C2664B96 |
| AFD8CB54, | B85A0A3F, | B7B60384, | BD807CF5, | 2F62A054, | C2664B96, | CF24E72C, | 5922D09E, | 57D08B9D, | B67ECE2C |
| 2F62A054, | 7F8B38E5, | B85A0A3F, | D80E12DE, | BD807CF5, | B67ECE2C, | CA6A1C75, | CF24E72C, | 8B427964, | 57D08B9D |
| BD807CF5, | 9DACA495, | 7F8B38E5, | 6828FEE1, | D80E12DE, | 57D08B9D, | 227F6D84, | CA6A1C75, | 939CB33C, | 8B427964 |
| D80E12DE, | BC05F46F, | 9DACA495, | 2CE395FE, | 6828FEE1, | 8B427964, | 5D801685, | 227F6D84, | A871D729, | 939CB33C |
| 6828FEE1, | 1494F053, | BC05F46F, | B2925676, | 2CE395FE, | 939CB33C, | B3C3F4D5, | 5D801685, | FDB61089, | A871D729 |
| 2CE395FE, | 85861D02, | 1494F053, | 17D1BEF0, | B2925676, | A871D729, | 3D16242D, | B3C3F4D5, | 005A1576, | FDB61089 |
| B2925676, | 597BF629, | 85861D02, | 53C14C52, | 17D1BEF0, | FDB61089, | FF459078, | 3D16242D, | 0FD356CF, | 005A1576 |
| 17D1BEF0, | 6347EF78, | 597BF629, | 18740A16, | 53C14C52, | 005A1576, | 927E40A8, | FF459078, | 5890B4F4, | 0FD356CF |
| 53C14C52, | 45C8FA44, | 6347EF78, | EFD8A565, | 18740A16, | 0FD356CF, | ACBB994E, | 927E40A8, | 1641E3FD, | 5890B4F4 |
| 18740A16, | AD2956AF, | 45C8FA44, | 1FBDE18D, | EFD8A565, | 5890B4F4, | AD30AD24, | ACBB994E, | F902A249, | 1641E3FD |
| EFD8A565, | 5EAF16B7, | AD2956AF, | 23E91117, | 1FBDE18D, | 1641E3FD, | 6261732E, | AD30AD24, | EE653AB2, | F902A249 |
| 1FBDE18D, | 41730D4B, | 5EAF16B7, | A55ABEB4, | 23E91117, | F902A249, | 45ED27AF, | 6261732E, | C2B492B4, | EE653AB2 |
| 23E91117, | FC0CCBD3, | 41730D4B, | BC5ADD7A, | A55ABEB4, | EE653AB2, | 243C5668, | 45ED27AF, | 85CCB989, | C2B492B4 |
| A55ABEB4, | 042ECC93, | FC0CCBD3, | CC352D05, | BC5ADD7A, | C2B492B4, | 82F89BD1, | 243C5668, | B49EBD17, | 85CCB989 |
| BC5ADD7A, | 4D4D4377, | 042ECC93, | 332F4FF0, | CC352D05, | 85CCB989, | 5FC74686, | 82F89BD1, | F159A090, | B49EBD17 |
| CC352D05, | 5207002B, | 4D4D4377, | BB324C10, | 332F4FF0, | B49EBD17, | B2720031, | 5FC74686, | E26F460B, | F159A090 |
| 332F4FF0, | 388278F5, | 5207002B, | 350DDD35, | BB324C10, | F159A090, | 58A100F8, | B2720031, | 1D1A197F, | E26F460B |
| BB324C10, | 62879D70, | 388278F5, | 1C00AD48, | 350DDD35, | E26F460B, | 5992068B, | 58A100F8, | C800C6C9, | 1D1A197F |
| 350DDD35, | A30A1FD9, | 62879D70, | 09E3D4E2, | 1C00AD48, | 1D1A197F, | CC290DCA, | 5992068B, | 8403E162, | C800C6C9 |
| 1C00AD48, | BDA2B31B, | A30A1FD9, | 1E75C18A, | 09E3D4E2, | C800C6C9, | 863D625E, | CC290DCA, | 481A2D66, | 8403E162 |
| 09E3D4E2, | F7211DEE, | BDA2B31B, | 287F668C, | 1E75C18A, | 8403E162, | 6061B5A5, | 863D625E, | A4372B30, | 481A2D66 |
| 1E75C18A, | B6A665C6, | F7211DEE, | 8ACC6EF6, | 287F668C, | 481A2D66, | AA98ADB5, | 6061B5A5, | F5897A18, | A4372B30 |
| 287F668C, | 2D30FA02, | B6A665C6, | 8477BBDC, | 8ACC6EF6, | A4372B30, | 2999255A, | AA98ADB5, | 86D69581, | F5897A18 |
| 8ACC6EF6, | C76D12F9, | 2D30FA02, | 99971ADA, | 8477BBDC, | F5897A18, | 98237631, | 2999255A, | 62B6D6AA, | 86D69581 |
| 8477BBDC, | 516F84DF, | C76D12F9, | C3E808B4, | 99971ADA, | 86D69581, | 6C472A90, | 98237631, | 649568A6, | 62B6D6AA |
| 99971ADA, | F3FA5B05, | 516F84DF, | B44BE71D, | C3E808B4, | 62B6D6AA, | 2EAD5672, | 6C472A90, | 8DD8C660, | 649568A6 |
| C3E808B4, | D539625E, | F3FA5B05, | BE137D45, | B44BE71D, | 649568A6, | C5CB48BA, | 2EAD5672, | 1CAA41B1, | 8DD8C660 |
| B44BE71D, | D8500C99, | D539625E, | E96C17CF, | BE137D45, | 8DD8C660, | 05286DFB, | C5CB48BA, | B559C8BA, | 1CAA41B1 |
| BE137D45, | 7ECDE5B2, | D8500C99, | E5897B54, | E96C17CF, | 1CAA41B1, | 88396DD2, | 05286DFB, | 2D22EB17, | B559C8BA |
| E96C17CF, | 681D30B9, | 7ECDE5B2, | 40326761, | E5897B54, | B559C8BA, | 333F2212, | 88396DD2, | A1B7EC14, | 2D22EB17 |
| E5897B54, | 960F7BFD, | 681D30B9, | 3796C9FB, | 40326761, | 2D22EB17, | C699295B, | 333F2212, | E5B74A20, | A1B7EC14 |
| 40326761, | 6770E498, | 960F7BFD, | 74C2E5A0, | 3796C9FB, | A1B7EC14, | BFD68874, | C699295B, | FC8848CC, | E5B74A20 |
| 3796C9FB, | 75EB06C5, | 6770E498, | 3DEFF658, | 74C2E5A0, | E5B74A20, | BDDF3474, | BFD68874, | 64A56F1A, | FC8848CC |
| 74C2E5A0, | 14FA827A, | 75EB06C5, | C392619D, | 3DEFF658, | FC8848CC, | 8CBC87E9, | BDDF3474, | 5A21D2FF, | 64A56F1A |
| 3DEFF658, | 804B0068, | 14FA827A, | AC1B15D7, | C392619D, | 64A56F1A, | CDDA6EBF, | 8CBC87E9, | 7CD1D2F7, | 5A21D2FF |
| C392619D, | 475BA81B, | 804B0068, | EA09E853, | AC1B15D7, | 5A21D2FF, | 656C7DA3, | CDDA6EBF, | F21FA632, | 7CD1D2F7 |
| AC1B15D7, | D26BC25D, | 475BA81B, | 2C01A201, | EA09E853, | 7CD1D2F7, | 76D66CA3, | 656C7DA3, | 69BAFF37, | F21FA632 |
| EA09E853, | DBC5A2CB, | D26BC25D, | 6EA06D1D, | 2C01A201, | F21FA632, | C9B17F72, | 76D66CA3, | B1F68D95, | 69BAFF37 |
| 2C01A201, | 77367F5E, | DBC5A2CB, | AF097749, | 6EA06D1D, | 69BAFF37, | 65A60151, | C9B17F72, | 59B28DDB, | B1F68D95 |
| 6EA06D1D, | 8155A6B4, | 77367F5E, | 168B2F6F, | AF097749, | B1F68D95, | 33F3AC81, | 65A60151, | C5FDCB26, | 59B28DDB |
| AF097749, | C90C4D38, | 8155A6B4, | D9FD79DC, | 168B2F6F, | 59B28DDB, | 9BFB827D, | 33F3AC81, | 98054596, | C5FDCB26 |
| 168B2F6F, | 9762713B, | C90C4D38, | 569AD205, | D9FD79DC, | C5FDCB26, | DDC8130E, | 9BFB827D, | CEB204CF, | 98054596 |
| D9FD79DC, | 7EBF9C32, | 9762713B, | 3134E324, | 569AD205, | 98054596, | C24C2C79, | DDC8130E, | EE09F66F, | CEB204CF |
| 569AD205, | 20EFFA01, | 7EBF9C32, | 89C4EE5D, | 3134E324, | CEB204CF, | F255847E, | C24C2C79, | 204C3B77, | EE09F66F |
| 3134E324, | 75B7117F, | 20EFFA01, | FE70C9FA, | 89C4EE5D, | EE09F66F, | DCD63949, | F255847E, | 30B1E709, | 204C3B77 |
| 89C4EE5D, | A96BE4C7, | 75B7117F, | BFE80483, | FE70C9FA, | 204C3B77, | 5B99238D, | DCD63949, | 5611FBC9, | 30B1E709 |
| FE70C9FA, | 5E3201FC, | A96BE4C7, | DC45FDD6, | BFE80483, | 30B1E709, | B43484F4, | 5B99238D, | 58E52773, | 5611FBC9 |
| BFE80483, | 2CF95A98, | 5E3201FC, | AF931EA5, | DC45FDD6, | 5611FBC9, | 52325A09, | B43484F4, | 648E356E, | 58E52773 |
| DC45FDD6, | 1393F0C3, | 2CF95A98, | C807F178, | AF931EA5, | 58E52773, | D015577D, | 52325A09, | D213D2D0, | 648E356E |

AF931EA5, BB49CCF7, 1393F0C3, E56A60B3, C807F178, 648E356E, BB9C87C4, D015577D, C9682548, D213D2D0  
C807F178, 6A330EB4, BB49CCF7, 4FC30C4E, E56A60B3, D213D2D0, B1BB1A2E, BB9C87C4, 555DF740, C9682548  
E56A60B3, 14E58204, 6A330EB4, 2733DEED, 4FC30C4E, C9682548, AC77F96D, B1BB1A2E, 721F12EE, 555DF740  
4FC30C4E, 79AAF53E, 14E58204, CC3AD1A8, 2733DEED, 555DF740, 1774D326, AC77F96D, EC68BAC6, 721F12EE  
2733DEED, 210769B3, 79AAF53E, 96081053, CC3AD1A8, 721F12EE, A625F112, 1774D326, DFE5B6B1, EC68BAC6  
CC3AD1A8, F44B53A7, 210769B3, ABD4F9E6, 96081053, EC68BAC6, 5DCA4D12, A625F112, D34C985D, DFE5B6B1  
96081053, 7C1E3640, F44B53A7, 1DA6CC84, ABD4F9E6, DFE5B6B1, EBC4D9C6, 5DCA4D12, 97C44A98, D34C985D  
ABD4F9E6, 06B59EE8, 7C1E3640, 2D4E9FD1, 1DA6CC84, D34C985D, 095F37FD, EBC4D9C6, 29344977, 97C44A98  
1DA6CC84, C422C3CD, 06B59EE8, 78D901F0, 2D4E9FD1, 97C44A98, 5BBEE487, 095F37FD, 13671BAF, 29344977  
2D4E9FD1, AD864025, C422C3CD, D67BA01A, 78D901F0, 29344977, BF5B2529, 5BBEE487, 7CDFF425, 13671BAF  
78D901F0, 29A83BB5, AD864025, 8B0F3710, D67BA01A, 13671BAF, FB5747C5, BF5B2529, FB921D6E, 7CDFF425  
D67BA01A, 626E3910, 29A83BB5, 190096B6, 8B0F3710, 7CDFF425, DD935A5F, FB5747C5, 6C94A6FD, FB921D6E  
8B0F3710, A719D8BC, 626E3910, A0EED4A6, 190096B6, FB921D6E, 27754F3A, DD935A5F, 5D1F17ED, 6C94A6FD  
190096B6, BA84C782, A719D8BC, B8E44189, A0EED4A6, 6C94A6FD, 4F5CA4A5, 27754F3A, 4D697F76, 5D1F17ED  
A0EED4A6, 9F6887A9, BA84C782, 6762F29C, B8E44189, 5D1F17ED, 325AFE7E, 4F5CA4A5, D53CE89D, 4D697F76  
B8E44189, 3A88288C, 9F6887A9, 131E0AEA, 6762F29C, 4D697F76, 86AFE021, 325AFE7E, 7292953D, D53CE89D  
6762F29C, AB23F78F, 3A88288C, A21EA67D, 131E0AEA, D53CE89D, C97F9EA1, 86AFE021, 6BF9F8C9, 7292953D  
131E0AEA, 7299044A, AB23F78F, 20A230EA, A21EA67D, 7292953D, 9F60751C, C97F9EA1, BF80861A, 6BF9F8C9  
A21EA67D, 6A3F10CF, 7299044A, 8FDE3EAC, 20A230EA, 6BF9F8C9, 1E9CE713, 9F60751C, FE7A8725, BF80861A  
20A230EA, 1A1B904D, 6A3F10CF, 641129CA, 8FDE3EAC, BF80861A, C13F038A, 1E9CE713, 81D4727D, FE7A8725  
8FDE3EAC, 0B2CDC01, 1A1B904D, FC433DA8, 641129CA, FE7A8725, BF627814, C13F038A, 739C4C7A, 81D4727D  
641129CA, D563BFDC, 0B2CDC01, 6E413468, FC433DA8, 81D4727D, 5ECCBADE, BF627814, FC0E2B04, 739C4C7A

The hash-code is the following 160-bit string.

8E B2 08 F7 E0 5D 98 7A 9B 04 4A 8E 98 C6 B0 87 F1 5A 0B FC

#### B.2.4 Example 4

In this example, the data string is the 14-byte string consisting of the ASCII-coded version of

“message digest”

The hash-code is the following 160-bit string.

5D 06 89 EF 49 D2 FA E5 72 B8 81 B1 23 A8 5F FA 21 59 5F 36

#### B.2.5 Example 5

In this example, the data string is the 26-byte string consisting of the ASCII-coded version of

“abcdefghijklmnopqrstuvwxyz”

The hash-code is the following 160-bit string.

F7 1C 27 10 9C 69 2C 1B 56 BB DC EB 5B 9D 28 65 B3 70 8D BC

#### B.2.6 Example 6

In this example, the data string is the 62-byte string consisting of the ASCII-coded version of

“ABCDEFGHIJKLMNOPQRSTUVWXYZabcdefghijklmnopqrstuvwxyz0123456789”

The hash-code is the following 160-bit string.

B0 E2 0B 6E 31 16 64 02 86 ED 3A 87 A5 71 30 79 B2 1F 51 89



### B.2.7 Example 7

In this example, the data string is the 80-byte string consisting of the ASCII-coded version of eight repetitions of

“1234567890”

The hash-code is the following 160-bit string.

9B 75 2E 45 57 3D 4B 39 F4 DB D3 32 3C AB 82 BF 63 32 6B FB

### B.2.8 Example 8

In this example, the data string is the 56-byte string consisting of the ASCII-coded version of

“abcdbcdecdefdefgfehgfhghighijhijkijklklmklmnlmnomnopnopq”

After the padding process, the two 16-word blocks derived from the data string are as follows.

|          |          |          |          |          |          |          |          |
|----------|----------|----------|----------|----------|----------|----------|----------|
| 64636261 | 65646362 | 66656463 | 67666564 | 68676665 | 69686766 | 6A696867 | 6B6A6968 |
| 6C6B6A69 | 6D6C6B6A | 6E6D6C6B | 6F6E6D6C | 706F6E6D | 71706F6E | 00000080 | 00000000 |
| 00000000 | 00000000 | 00000000 | 00000000 | 00000000 | 00000000 | 00000000 | 00000000 |
| 00000000 | 00000000 | 00000000 | 00000000 | 00000000 | 00000000 | 000001C0 | 00000000 |

The following are (hexadecimal representations of) the successive values of the variables  $X_0, X_1, X_2, X_3, X_4, X'_0, X'_1, X'_2, X'_3$  and  $X'_4$ , obtained during the processing of the first block.

|           |           |           |           |           |           |           |           |           |          |
|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|----------|
| 67452301, | EFCDAB89, | 98BADCFE, | 10325476, | C3D2E1F0, | 67452301, | EFCDAB89, | 98BADCFE, | 10325476, | C3D2E1F0 |
| C3D2E1F0, | 3115FB87, | EFCDAB89, | EB73FA62, | 10325476, | C3D2E1F0, | 463DA521, | EFCDAB89, | EB73FA62, | 10325476 |
| 10325476, | CC21EC2E, | 3115FB87, | 36AE27BF, | EB73FA62, | 10325476, | DB247A12, | 463DA521, | 36AE27BF, | EB73FA62 |
| EB73FA62, | DFEB9B7A, | CC21EC2E, | 57EE1CC4, | 36AE27BF, | EB73FA62, | 1D166A23, | DB247A12, | F6948518, | 36AE27BF |
| 36AE27BF, | 2363912E, | DFEB9B7A, | 87B0BB30, | 57EE1CC4, | 36AE27BF, | CE7A12F6, | 1D166A23, | 91E84B6C, | F6948518 |
| 57EE1CC4, | A1B60DC7, | 2363912E, | AE6DEB7F, | 87B0BB30, | F6948518, | 57FF19DD, | CE7A12F6, | 59A88C74, | 91E84B6C |
| 87B0BB30, | 96AC7C1E, | A1B60DC7, | 8E44B88D, | AE6DEB7F, | 91E84B6C, | 01A9FEFA, | 57FF19DD, | E84BDB39, | 59A88C74 |
| AE6DEB7F, | 6AE46154, | 96AC7C1E, | D8371E86, | 8E44B88D, | 59A88C74, | 5D9A609C, | 01A9FEFA, | FC67755F, | E84BDB39 |
| 8E44B88D, | 3CF61F09, | 6AE46154, | B1F07A5A, | D8371E86, | E84BDB39, | 030F7FE7, | 5D9A609C, | A7FBE806, | FC67755F |
| D8371E86, | 696F0D9A, | 3CF61F09, | 918551AB, | B1F07A5A, | FC67755F, | 7456C8E3, | 030F7FE7, | 69827176, | A7FBE806 |
| B1F07A5A, | AB957B91, | 696F0D9A, | D87C24F3, | 918551AB, | A7FBE806, | F64C4453, | 7456C8E3, | 3DFF9C0C, | 69827176 |
| 918551AB, | 9FF4A064, | AB957B91, | BC3669A5, | D87C24F3, | 69827176, | 22A5FE6E, | F64C4453, | 5B238DD1, | 3DFF9C0C |
| D87C24F3, | 912FE998, | 9FF4A064, | 55EE46AE, | BC3669A5, | 3DFF9C0C, | 8D7E53E4, | 22A5FE6E, | 31114FD9, | 5B238DD1 |
| BC3669A5, | C45F164E, | 912FE998, | D281927F, | 55EE46AE, | 5B238DD1, | 695B23B7, | 8D7E53E4, | 97F9B88A, | 31114FD9 |
| 55EE46AE, | 2211A508, | C45F164E, | BFA66244, | D281927F, | 31114FD9, | 6FAA776F, | 695B23B7, | F94F9235, | 97F9B88A |
| D281927F, | 80B1F3DE, | 2211A508, | 7C593B11, | BFA66244, | 97F9B88A, | 4D94F720, | 6FAA776F, | 6C8EDDA5, | F94F9235 |
| BFA66244, | 3AA6A8F5, | 80B1F3DE, | 46942088, | 7C593B11, | F94F9235, | D81C6137, | 4D94F720, | A9DDBDBE, | 6C8EDDA5 |
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| 65DD1D46, | C45681A6, | 2B59B58A, | 4007C0A7, | 4C4CB308, | A5CA5FEB, | D718432A, | 56C66FD3, | C1A3BC61, | F968FE21 |
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| 66D628AD, | 989BC126, | 5C712D51, | CB2858B8, | 5A069B11, | 19BF4D5B, | 44DCD35A, | 6243D22F, | 6E89F5DD, | 610CAB5C        |
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| 1AA03F70, | 100A6B19, | A1755F6B, | 1EF13D56, | 487F156F, | 248D32A9, | 44272219, | 69C12F76, | A1BF4336, | 4CB65509        |
| 487F156F, | AA2CFD07, | 100A6B19, | D57DAE85, | 1EF13D56, | 4CB65509, | CBD360C3, | 44272219, | 04BDD9A7, | A1BF4336        |
| 1EF13D56, | 28246D22, | AA2CFD07, | 29AC6440, | D57DAE85, | A1BF4336, | 27A64C2D, | CBD360C3, | 9C886510, | 04BDD9A7        |
| D57DAE85, | 4909C2BD, | 28246D22, | B3F41EA8, | 29AC6440, | 04BDD9A7, | CCB70B88, | 27A64C2D, | 4D830F2F, | 9C886510        |
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| 809C6E40, | DF212B9C, | 39BAC08A, | E747E3E1, | 5F60E295, | 8303F080, | 44C068DD, | A0AB24D8, | 9BAFE429, | 078421D5        |
| 5F60E295, | 46F2CD86, | DF212B9C, | EB0228E6, | E747E3E1, | 078421D5, | 3F8B3B48, | 44C068DD, | AC936282, | 9BAFE429        |
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| DD9BD285, | 79D46BD1, | 98554E1C, | 8C37664E, | 82A807F0, | E907121C, | 93451653, | 07B2EA78, | D17D3DEC, | 5A7AD28A        |
| 82A807F0, | 5FBC55DB, | 79D46BD1, | 55387261, | 8C37664E, | 5A7AD28A, | AA0DF949, | 93451653, | CBA9E01E, | D17D3DEC        |
| 8C37664E, | DEF23A3B, | 5FBC55DB, | 51AF45E7, | 55387261, | D17D3DEC, | 030FFB9A, | AA0DF949, | 14594E4D, | CBA9E01E        |
| 55387261, | 287DB1EB, | DEF23A3B, | F1576D7E, | 51AF45E7, | CBA9E01E, | 0D9CD217, | 030FFB9A, | 37E526A8, | 14594E4D        |
| 51AF45E7, | CF955B8E, | 287DB1EB, | C8E8EF7B, | F1576D7E, | 14594E4D, | BECE1BBB, | 0D9CD217, | 3FEE680C, | 37E526A8        |
| F1576D7E, | 83B6B7E8, | CF955B8E, | F6C7ACA1, | C8E8EF7B, | 37E526A8, | D97CFEEC, | BECE1BBB, | 73485C36, | 3FEE680C        |
| C8E8EF7B, | 7943C443, | 83B6B7E8, | 556E3B3E, | F6C7ACA1, | 3FEE680C, | DBEA79F5, | D97CFEEC, | 386EF6FB, | 73485C36        |
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| 556E3B3E, | 2FF847D6, | F336AA45, | 0F110DE5, | DADFA20E, | 386EF6FB, | 40CBA97D, | 91704BDB, | A9E7D76F, | F3FBB365        |
| DADFA20E, | 33FE64C9, | 2FF847D6, | DAA917CC, | 0F110DE5, | F3FBB365, | B0BD2456, | 40CBA97D, | C12F6E45, | A9E7D76F        |
| 0F110DE5, | 78378FE9, | 33FE64C9, | E11F58BF, | DAA917CC, | A9E7D76F, | CA09D415, | B0BD2456, | 2EA5F503, | C12F6E45        |

The following are (hexadecimal representations of) the successive values of the variables  $X_0, X_1, X_2, X_3, X_4, X'_0, X'_1, X'_2, X'_3$  and  $X'_4$ , obtained during the processing of the second block.

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 D73614F3, E8FEFBC6, E5471921, AAD89F30, 1D5BE6DB, 0001F67E, 4B55D832, 95FE46E6, 35D68A83, 2262F824

|           |           |           |           |           |           |           |           |           |          |
|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|----------|
| 1D5E6DB,  | 788FFBE7, | E8FEFBC6, | 1C648795, | AAD89F30, | 2262F824, | 681302D4, | 4B55D832, | F91B9A57, | 35D68A83 |
| AAD89F30, | FA97F1BB, | 788FFBE7, | FBEF1BA3, | 1C648795, | 35D68A83, | 860F8E32, | 681302D4, | 5760C92D, | F91B9A57 |
| 1C648795, | 2FE154B4, | FA97F1BB, | 3FEF9DE2, | FBEF1BA3, | F91B9A57, | CA3DDAC0, | 860F8E32, | 4C0B51A0, | 5760C92D |
| FBEF1BA3, | D884695B, | 2FE154B4, | 5FC6EFEA, | 3FEF9DE2, | 5760C92D, | 7E790793, | CA3DDAC0, | 3E38CA18, | 4C0B51A0 |
| 3FEF9DE2, | A09357E9, | D884695B, | 8552D0BF, | 5FC6EFEA, | 4C0B51A0, | 4E0DF927, | 7E790793, | F76B0328, | 3E38CA18 |
| 5FC6EFEA, | 019B9791, | A09357E9, | 11A56F62, | 8552D0BF, | 3E38CA18, | 311DFB90, | 4E0DF927, | E41E4DF9, | F76B0328 |
| 8552D0BF, | 70DB6FDF, | 019B9791, | 4D5FA682, | 11A56F62, | F76B0328, | 24FA9DC7, | 311DFB90, | 37E49D38, | E41E4DF9 |
| 11A56F62, | 82F104B4, | 70DB6FDF, | 6E5E4406, | 4D5FA682, | E41E4DF9, | CE45E142, | 24FA9DC7, | 77EE40C4, | 37E49D38 |
| 4D5FA682, | BFAB29F8, | 82F104B4, | 6DBF7DC3, | 6E5E4406, | 37E49D38, | 9C4F267F, | CE45E142, | EA771C93, | 77EE40C4 |
| 6E5E4406, | 880198A9, | BFAB29F8, | C412D20B, | 6DBF7DC3, | 77EE40C4, | 06880805, | 9C4F267F, | 17850B39, | EA771C93 |
| 6DBF7DC3, | 917C197C, | 880198A9, | ACA7E2FE, | C412D20B, | EA771C93, | 7625BD09, | 06880805, | 3C99FE71, | 17850B39 |
| C412D20B, | 03E7992A, | 917C197C, | 0662A620, | ACA7E2FE, | 17850B39, | 8720C8E7, | 7625BD09, | 2020141A, | 3C99FE71 |
| ACA7E2FE, | 824CEF7A, | 03E7992A, | F065F245, | 0662A620, | 3C99FE71, | CBB7DA7A, | 8720C8E7, | 96F425D8, | 2020141A |
| 0662A620, | AF16F218, | 824CEF7A, | 9E64A80F, | F065F245, | 2020141A, | 88851068, | CBB7DA7A, | 83239E1C, | 96F425D8 |
| F065F245, | EFC8943D, | AF16F218, | 33BDEA09, | 9E64A80F, | 96F425D8, | C85C4EB8, | 88851068, | DF69EB2E, | 83239E1C |
| 9E64A80F, | C80FF53B, | EFC8943D, | 5BC862BC, | 33BDEA09, | 83239E1C, | 57BF18E2, | C85C4EB8, | 1441A222, | DF69EB2E |
| 33BDEA09, | 28DF9E36, | C80FF53B, | 2250F7BF, | 5BC862BC, | DF69EB2E, | 48932C1A, | 57BF18E2, | 713AE321, | 1441A222 |
| 5BC862BC, | 6E1D8950, | 28DF9E36, | 3FD4EF20, | 2250F7BF, | 1441A222, | 15C7B0BD, | 48932C1A, | FC63895E, | 713AE321 |
| 2250F7BF, | 21EEE621, | 6E1D8950, | 7E78D8A3, | 3FD4EF20, | 713AE321, | FCBC9E78, | 15C7B0BD, | 4CB06922, | FC63895E |
| 3FD4EF20, | 561379BA, | 21EEE621, | 762541B8, | 7E78D8A3, | FC63895E, | DD28EA60, | FCBC9E78, | 1EC2F457, | 4CB06922 |
| 7E78D8A3, | 4D0255C5, | 561379BA, | BB988487, | 762541B8, | 4CB06922, | CF1BB810, | DD28EA60, | F279E3F2, | 1EC2F457 |
| 762541B8, | 966845EC, | 4D0255C5, | 4DE6E958, | BB988487, | 1EC2F457, | 5D899D62, | CF1BB810, | A3A98374, | F279E3F2 |
| BB988487, | D922DEB8, | 966845EC, | 09571534, | 4DE6E958, | F279E3F2, | F1144141, | 5D899D62, | 6EE0433C, | A3A98374 |
| 4DE6E958, | B919B2A3, | D922DEB8, | A117B259, | 09571534, | A3A98374, | 940BBA12, | F1144141, | 26758976, | 6EE0433C |
| 09571534, | D3CF80F9, | B919B2A3, | 8B7AE364, | A117B259, | 6EE0433C, | 33DDA9B5, | 940BBA12, | 510507C4, | 26758976 |
| A117B259, | F548EA98, | D3CF80F9, | 66CA8EE4, | 8B7AE364, | 26758976, | DCE0B562, | 33DDA9B5, | 2EE84A50, | 510507C4 |
| 8B7AE364, | A1D3372D, | F548EA98, | 3E03E74F, | 66CA8EE4, | 510507C4, | C103FBE9, | DCE0B562, | 76A6D4CF, | 2EE84A50 |
| 66CA8EE4, | 6578D66C, | A1D3372D, | 23AA63D5, | 3E03E74F, | 2EE84A50, | 832961D9, | C103FBE9, | 82D58B73, | 76A6D4CF |
| 3E03E74F, | 57C29604, | 6578D66C, | 4CDCB687, | 23AA63D5, | 76A6D4CF, | B183744E, | 832961D9, | 0FEFA704, | 82D58B73 |
| 23AA63D5, | 27F5E937, | 57C29604, | E359B195, | 4CDCB687, | 82D58B73, | E710A112, | B183744E, | A587660C, | 0FEFA704 |

The hash-code is the following 160-bit string.

12 A0 53 38 4A 9C 0C 88 E4 05 A0 6C 27 DC F4 9A DA 62 EB 2B

### B.2.9 Example 9

In this example, the data string is the 1 000 000-byte string consisting of the ASCII-coded version of “a” repeated  $10^6$  times.

The hash-code is the following 160-bit string.

52 78 32 43 C1 69 7B DB E1 6D 37 F9 7F 68 F0 83 25 DC 15 28

### B.2.10 Example 10

In this example, the data string is the 112-byte string consisting of the ASCII-coded version of

“abcdefghijklmnopqrstuvwxyz  
abcdefghijklmnopqrstuvwxyz”

(with no line break after the first n).

The hash-code is the following 160-bit string.

6F 3F A3 9B 6B 50 3C 38 4F 91 9A 49 A7 AA 5C 2C 08 BD FB 45

### B.2.11 Example 11

In this example, the data string is the 32-byte string consisting of the ASCII-coded version of

“abcdbcdecdefdefgefghfghighijhijk”

The hash-code is the following 160-bit string.

94 C2 64 11 54 04 E6 33 79 0D FC C8 7B 58 7D 36 77 06 7D 9F

## B.3 Dedicated Hash-Function 2 (RIPEMD-128)

### B.3.1 Example 1

In this example, the data string is the empty string, i.e., the string of length zero.

The hash-code is the following 128-bit string.

CD F2 62 13 A1 50 DC 3E CB 61 0F 18 F6 B3 8B 46

### B.3.2 Example 2

In this example, the data string consists of a single byte, namely the ASCII-coded version of the letter “a”.

The hash-code is the following 128-bit string.

86 BE 7A FA 33 9D 0F C7 CF C7 85 E7 2F 57 8D 33

### B.3.3 Example 3

In this example, the data string is the 3-byte string consisting of the ASCII-coded version of “abc”. This is equivalent to the bit string “01100001 01100010 01100011”.

After the padding process, the single 16-word block derived from the data string is as follows.

80636261 00000000 00000000 00000000 00000000 00000000 00000000 00000000  
00000000 00000000 00000000 00000000 00000000 00000000 00000018 00000000

The following are (hexadecimal representations of) the successive values of the variables  $X_0, X_1, X_2, X_3, X'_0, X'_1, X'_2$  and  $X'_3$ .

67452301, EFCDAB89, 98BADCFE, 10325476, 67452301, EFCDAB89, 98BADCFE, 10325476  
10325476, 6D431A77, EFCDAB89, 98BADCFE, 10325476, 70376F40, EFCDAB89, 98BADCFE  
98BADCFE, B05D8A99, 6D431A77, EFCDAB89, 98BADCFE, 989F6BB0, 70376F40, EFCDAB89  
EFCDAB89, 0C32E5C7, B05D8A99, 6D431A77, EFCDAB89, 39B14904, 989F6BB0, 70376F40  
6D431A77, A20B2C0F, 0C32E5C7, B05D8A99, 70376F40, 671C03CC, 39B14904, 989F6BB0  
B05D8A99, 74EBB911, A20B2C0F, 0C32E5C7, 989F6BB0, BFD55C42, 671C03CC, 39B14904  
0C32E5C7, 2FFB728B, 74EBB911, A20B2C0F, 39B14904, A12F346F, BFD55C42, 671C03CC  
A20B2C0F, A766AE02, 2FFB728B, 74EBB911, 671C03CC, 989C2210, A12F346F, BFD55C42  
74EBB911, 03234F3D, A766AE02, 2FFB728B, BFD55C42, 0F95FBEA, 989C2210, A12F346F  
2FFB728B, 52662805, 03234F3D, A766AE02, A12F346F, 068D5115, 0F95FBEA, 989C2210  
A766AE02, E778A4C3, 52662805, 03234F3D, 989C2210, AFCD27FC, 068D5115, 0F95FBEA  
03234F3D, 1C7F5769, E778A4C3, 52662805, 0F95FBEA, CBD1F3F8, AFCD27FC, 068D5115  
52662805, 95765642, 1C7F5769, E778A4C3, 068D5115, CFFE405F, CBD1F3F8, AFCD27FC  
E778A4C3, 35F37B70, 95765642, 1C7F5769, AFCD27FC, 2B55C9C3, CFFE405F, CBD1F3F8  
1C7F5769, 398F8F52, 35F37B70, 95765642, CBD1F3F8, DD6A43FB, 2B55C9C3, CFFE405F  
95765642, 13F3C36B, 398F8F52, 35F37B70, CFFE405F, 049B909E, DD6A43FB, 2B55C9C3

35F37B70, 058D8BB5, 13F3C36B, 398F8F52, 2B55C9C3, 3713BFFD, 049B909E, DD6A43FB  
 398F8F52, FCBE3664, 058D8BB5, 13F3C36B, DD6A43FB, 82ADDB53, 3713BFFD, 049B909E  
 13F3C36B, F7F306A6, FCBE3664, 058D8BB5, 049B909E, CC1D8105, 82ADDB53, 3713BFFD  
 058D8BB5, 34CC3963, F7F306A6, FCBE3664, 3713BFFD, BE09159A, CC1D8105, 82ADDB53  
 FCBE3664, 416E8BA0, 34CC3963, F7F306A6, 82ADDB53, 541AE568, BE09159A, CC1D8105  
 F7F306A6, EDE91870, 416E8BA0, 34CC3963, CC1D8105, 27D40F94, 541AE568, BE09159A  
 34CC3963, C352C547, EDE91870, 416E8BA0, BE09159A, 675C363A, 27D40F94, 541AE568  
 416E8BA0, 5D5EEE28, C352C547, EDE91870, 541AE568, 77F3A38B, 675C363A, 27D40F94  
 EDE91870, 6CC4BEF2, 5D5EEE28, C352C547, 27D40F94, 84D73C44, 77F3A38B, 675C363A  
 C352C547, E140970B, 6CC4BEF2, 5D5EEE28, 675C363A, D2958F37, 84D73C44, 77F3A38B  
 5D5EEE28, 79F631A9, E140970B, 6CC4BEF2, 77F3A38B, FC39C927, D2958F37, 84D73C44  
 6CC4BEF2, 038E0E91, 79F631A9, E140970B, 84D73C44, E3A5A4DE, FC39C927, D2958F37  
 E140970B, 1B942D52, 038E0E91, 79F631A9, D2958F37, 4BA3A889, E3A5A4DE, FC39C927  
 79F631A9, 496AECFD, 1B942D52, 038E0E91, FC39C927, A964BA74, 4BA3A889, E3A5A4DE  
 038E0E91, FE6CD56F, 496AECFD, 1B942D52, E3A5A4DE, 7AF9DBB0, A964BA74, 4BA3A889  
 1B942D52, 2E94F501, FE6CD56F, 496AECFD, 4BA3A889, 7DA68EA9, 7AF9DBB0, A964BA74  
 496AECFD, 584E8E58, 2E94F501, FE6CD56F, A964BA74, 9C7247E5, 7DA68EA9, 7AF9DBB0  
 FE6CD56F, 41A17EFA, 584E8E58, 2E94F501, 7AF9DBB0, 0130312B, 9C7247E5, 7DA68EA9  
 2E94F501, 8981C6CD, 41A17EFA, 584E8E58, 7DA68EA9, 90552232, 0130312B, 9C7247E5  
 584E8E58, 400A93E1, 8981C6CD, 41A17EFA, 9C7247E5, 99C1FBA4, 90552232, 0130312B  
 41A17EFA, 841F817F, 400A93E1, 8981C6CD, 0130312B, 9D481CD2, 99C1FBA4, 90552232  
 8981C6CD, 659379BE, 841F817F, 400A93E1, 90552232, F5AABE07, 9D481CD2, 99C1FBA4  
 400A93E1, AB3D9A70, 659379BE, 841F817F, 99C1FBA4, C3AFB7E6, F5AABE07, 9D481CD2  
 841F817F, D3D21DC8, AB3D9A70, 659379BE, 9D481CD2, 473E2B79, C3AFB7E6, F5AABE07  
 659379BE, 38C8D29D, D3D21DC8, AB3D9A70, F5AABE07, C4CAFF99, 473E2B79, C3AFB7E6  
 AB3D9A70, 738B9B0F, 38C8D29D, D3D21DC8, C3AFB7E6, A2879AA4, C4CAFF99, 473E2B79  
 D3D21DC8, 8528B83E, 738B9B0F, 38C8D29D, 473E2B79, 56565EDB, A2879AA4, C4CAFF99  
 38C8D29D, 7345AF18, 8528B83E, 738B9B0F, C4CAFF99, E7A4BD86, 56565EDB, A2879AA4  
 738B9B0F, FFCC52B, 7345AF18, 8528B83E, A2879AA4, 974B9E10, E7A4BD86, 56565EDB  
 8528B83E, A77E902B, FFCC52B, 7345AF18, 56565EDB, 96CC5AE1, 974B9E10, E7A4BD86  
 7345AF18, CB9C6C83, A77E902B, FFCC52B, E7A4BD86, 57E6A772, 96CC5AE1, 974B9E10  
 FFCC52B, 38A2DA83, CB9C6C83, A77E902B, 974B9E10, F10B6CF5, 57E6A772, 96CC5AE1  
 A77E902B, 487F9401, 38A2DA83, CB9C6C83, 96CC5AE1, 90426E6B, F10B6CF5, 57E6A772  
 CB9C6C83, C7184576, 487F9401, 38A2DA83, 57E6A772, 0066E6BE, 90426E6B, F10B6CF5  
 38A2DA83, 56D619B1, C7184576, 487F9401, F10B6CF5, 22D17257, 0066E6BE, 90426E6B  
 487F9401, 3A35A3C5, 56D619B1, C7184576, 90426E6B, 016777A4, 22D17257, 0066E6BE  
 C7184576, B5517538, 3A35A3C5, 56D619B1, 0066E6BE, 9A8DC5A0, 016777A4, 22D17257  
 56D619B1, 4609C4C2, B5517538, 3A35A3C5, 22D17257, A9C46E68, 9A8DC5A0, 016777A4  
 3A35A3C5, D5C2B699, 4609C4C2, B5517538, 016777A4, 13B0D540, A9C46E68, 9A8DC5A0  
 B5517538, 342AF741, D5C2B699, 4609C4C2, 9A8DC5A0, 983D8B08, 13B0D540, A9C46E68  
 4609C4C2, 38286DDA, 342AF741, D5C2B699, A9C46E68, 96084F4E, 983D8B08, 13B0D540  
 D5C2B699, 9BCCEC0A, 38286DDA, 342AF741, 13B0D540, D25FDBB1, 96084F4E, 983D8B08  
 342AF741, 5803DF3A, 9BCCEC0A, 38286DDA, 983D8B08, 35EA6FE0, D25FDBB1, 96084F4E  
 38286DDA, E1B026EB, 5803DF3A, 9BCCEC0A, 96084F4E, B862709F, 35EA6FE0, D25FDBB1  
 9BCCEC0A, 31587C22, E1B026EB, 5803DF3A, D25FDBB1, C02839EB, B862709F, 35EA6FE0  
 5803DF3A, 9B25E1DC, 31587C22, E1B026EB, 35EA6FE0, 00245200, C02839EB, B862709F  
 E1B026EB, 2205379E, 9B25E1DC, 31587C22, B862709F, CB116A95, 00245200, C02839EB  
 31587C22, 5E3334A3, 2205379E, 9B25E1DC, C02839EB, B90EE1BF, CB116A95, 00245200  
 9B25E1DC, 56F80FA9, 5E3334A3, 2205379E, 00245200, 64132D32, B90EE1BF, CB116A95



The hash-code is the following 128-bit string.

C1 4A 12 19 9C 66 E4 BA 84 63 6B 0F 69 14 4C 77

#### B.3.4 Example 4

In this example, the data string is the 14-byte string consisting of the ASCII-coded version of

“message digest”

The hash-code is the following 128-bit string.

9E 32 7B 3D 6E 52 30 62 AF C1 13 2D 7D F9 D1 B8

#### B.3.5 Example 5

In this example, the data string is the 26-byte string consisting of the ASCII-coded version of

“abcdefghijklmnopqrstuvwxyz”

The hash-code is the following 128-bit string.

FD 2A A6 07 F7 1D C8 F5 10 71 49 22 B3 71 83 4E

#### B.3.6 Example 6

In this example, the data string is the 62-byte string consisting of the ASCII-coded version of

“ABCDEFGHJKLMNOPQRSTUVWXYZabcdefghijklmnopqrstuvwxyz0123456789”

The hash-code is the following 128-bit string.

D1 E9 59 EB 17 9C 91 1F AE A4 62 4C 60 C5 C7 02

#### B.3.7 Example 7

In this example, the data string is the 80-byte string consisting of the ASCII-coded version of eight repetitions of

“1234567890”

The hash-code is the following 128-bit string.

3F 45 EF 19 47 32 C2 DB B2 C4 A2 C7 69 79 5F A3

#### B.3.8 Example 8

In this example, the data string is the 56-byte string consisting of the ASCII-coded version of

“abcdcbcdcedefdefghfghghijhijkijklklmklmnlmnomnopnopq”

After the padding process, the two 16-word blocks derived from the data string are as follows.

|          |          |          |          |          |          |          |          |
|----------|----------|----------|----------|----------|----------|----------|----------|
| 64636261 | 65646362 | 66656463 | 67666564 | 68676665 | 69686766 | 6A696867 | 6B6A6968 |
| 6C6B6A69 | 6D6C6B6A | 6E6D6C6B | 6F6E6D6C | 706F6E6D | 71706F6E | 00000080 | 00000000 |
| 00000000 | 00000000 | 00000000 | 00000000 | 00000000 | 00000000 | 00000000 | 00000000 |
| 00000000 | 00000000 | 00000000 | 00000000 | 00000000 | 00000000 | 000001C0 | 00000000 |

The following are (hexadecimal representations of) the successive values of the variables  $X_0, X_1, X_2, X_3, X'_0, X'_1, X'_2$  and  $X'_3$  obtained during the processing of the first block.

67452301, EFCDAB89, 98BADCFE, 10325476, 67452301, EFCDAB89, 98BADCFE, 10325476  
 10325476, 6D431997, EFCDAB89, 98BADCFE, 10325476, D89ED5A9, EFCDAB89, 98BADCFE  
 98BADCFE, C9AE23F2, 6D431997, EFCDAB89, 98BADCFE, 69B10AC1, D89ED5A9, EFCDAB89  
 EFCDAB89, 69A6A520, C9AE23F2, 6D431997, EFCDAB89, B661DB9C, 69B10AC1, D89ED5A9  
 6D431997, FB032247, 69A6A520, C9AE23F2, D89ED5A9, ABACC2AF, B661DB9C, 69B10AC1  
 C9AE23F2, 16C49226, FB032247, 69A6A520, 69B10AC1, D412CAD1, ABACC2AF, B661DB9C  
 69A6A520, 77A099B7, 16C49226, FB032247, B661DB9C, E2DEDF22, D412CAD1, ABACC2AF  
 FB032247, 3B9BAEB7, 77A099B7, 16C49226, ABACC2AF, CFB03688, E2DEDF22, D412CAD1  
 16C49226, DA61AB82, 3B9BAEB7, 77A099B7, D412CAD1, 72599389, CFB03688, E2DEDF22  
 77A099B7, 54C888CC, DA61AB82, 3B9BAEB7, E2DEDF22, CF3CD682, 72599389, CFB03688  
 3B9BAEB7, F2635347, 54C888CC, DA61AB82, CFB03688, B235784E, CF3CD682, 72599389  
 DA61AB82, E2CAC9B4, F2635347, 54C888CC, 72599389, 881678DF, B235784E, CF3CD682  
 54C888CC, 9596C718, E2CAC9B4, F2635347, CF3CD682, E815373B, 881678DF, B235784E  
 F2635347, 9DD54912, 9596C718, E2CAC9B4, B235784E, BD994B56, E815373B, 881678DF  
 E2CAC9B4, 2E8539A7, 9DD54912, 9596C718, 881678DF, B0055655, BD994B56, E815373B  
 9596C718, 2303C213, 2E8539A7, 9DD54912, E815373B, CC87EF5A, B0055655, BD994B56  
 9DD54912, EA79BE25, 2303C213, 2E8539A7, BD994B56, 6B24384D, CC87EF5A, B0055655  
 2E8539A7, 23D7CB45, EA79BE25, 2303C213, B0055655, 93E7329F, 6B24384D, CC87EF5A  
 2303C213, F028EF04, 23D7CB45, EA79BE25, CC87EF5A, 35B95AE7, 93E7329F, 6B24384D  
 EA79BE25, 48863F19, F028EF04, 23D7CB45, 6B24384D, 06C6536D, 35B95AE7, 93E7329F  
 23D7CB45, 514C81B6, 48863F19, F028EF04, 93E7329F, FF1C5DC7, 06C6536D, 35B95AE7  
 F028EF04, 6102CE67, 514C81B6, 48863F19, 35B95AE7, D0D541F1, FF1C5DC7, 06C6536D  
 48863F19, 330485FD, 6102CE67, 514C81B6, 06C6536D, A94C0DD9, D0D541F1, FF1C5DC7  
 514C81B6, 289E8C82, 330485FD, 6102CE67, FF1C5DC7, DEDC1E39, A94C0DD9, D0D541F1  
 6102CE67, 13CC3A1D, 289E8C82, 330485FD, D0D541F1, 12D926C0, DEDC1E39, A94C0DD9  
 330485FD, 40A226A6, 13CC3A1D, 289E8C82, A94C0DD9, ED7EDA63, 12D926C0, DEDC1E39  
 289E8C82, 70BFB1A8, 40A226A6, 13CC3A1D, DEDC1E39, 9E52219C, ED7EDA63, 12D926C0  
 13CC3A1D, CE1D1A37, 70BFB1A8, 40A226A6, 12D926C0, F5D22339, 9E52219C, ED7EDA63  
 40A226A6, EC9F7830, CE1D1A37, 70BFB1A8, ED7EDA63, 0BC5B4FC, F5D22339, 9E52219C  
 70BFB1A8, 3CF2D6EE, EC9F7830, CE1D1A37, 9E52219C, FCFBD391, 0BC5B4FC, F5D22339  
 CE1D1A37, F0C1F95C, 3CF2D6EE, EC9F7830, F5D22339, 2B6A389B, FCFBD391, 0BC5B4FC  
 EC9F7830, 9A351A9D, F0C1F95C, 3CF2D6EE, 0BC5B4FC, FBF85B05, 2B6A389B, FCFBD391  
 3CF2D6EE, 138B0685, 9A351A9D, F0C1F95C, FCFBD391, F7BBBE8B, FBF85B05, 2B6A389B  
 F0C1F95C, EA3574D1, 138B0685, 9A351A9D, 2B6A389B, C8592ACC, F7BBBE8B, FBF85B05  
 9A351A9D, 4719C849, EA3574D1, 138B0685, FBF85B05, FE2D3EFA, C8592ACC, F7BBBE8B  
 138B0685, 57F52A13, 4719C849, EA3574D1, F7BBBE8B, 5411CC34, FE2D3EFA, C8592ACC  
 EA3574D1, 4751F880, 57F52A13, 4719C849, C8592ACC, DC8ED546, 5411CC34, FE2D3EFA  
 4719C849, 80605BAF, 4751F880, 57F52A13, FE2D3EFA, 55C1E317, DC8ED546, 5411CC34  
 57F52A13, 1E53AD4A, 80605BAF, 4751F880, 5411CC34, 0B92E4F0, 55C1E317, DC8ED546  
 4751F880, 1ABEED79, 1E53AD4A, 80605BAF, DC8ED546, 5E192900, 0B92E4F0, 55C1E317  
 80605BAF, 75EACBB7, 1ABEED79, 1E53AD4A, 55C1E317, 186EB0CF, 5E192900, 0B92E4F0  
 1E53AD4A, 08AC1056, 75EACBB7, 1ABEED79, 0B92E4F0, 8F3A64E3, 186EB0CF, 5E192900  
 1ABEED79, 9BDB7A88, 08AC1056, 75EACBB7, 5E192900, 3701E7B3, 8F3A64E3, 186EB0CF  
 75EACBB7, ADF32F05, 9BDB7A88, 08AC1056, 186EB0CF, 6CE969E9, 3701E7B3, 8F3A64E3  
 08AC1056, 2277B80D, ADF32F05, 9BDB7A88, 8F3A64E3, EE7224D5, 6CE969E9, 3701E7B3  
 9BDB7A88, 535DBB9A, 2277B80D, ADF32F05, 3701E7B3, 3E849D0F, EE7224D5, 6CE969E9  
 ADF32F05, 2A494EC5, 535DBB9A, 2277B80D, 6CE969E9, DDBD8EE7, 3E849D0F, EE7224D5  
 2277B80D, 693C7A09, 2A494EC5, 535DBB9A, EE7224D5, C3DDAC40, DDBD8EE7, 3E849D0F  
 535DBB9A, 148A5796, 693C7A09, 2A494EC5, 3E849D0F, 5E0E10B9, C3DDAC40, DDBD8EE7



2A494EC5, D2932448, 148A5796, 693C7A09, DDBD8EE7, 1CCB75AF, 5E0E10B9, C3DDAC40  
 693C7A09, 39CA97B6, D2932448, 148A5796, C3DDAC40, 27F81499, 1CCB75AF, 5E0E10B9  
 148A5796, 770BCE98, 39CA97B6, D2932448, 5E0E10B9, 82843491, 27F81499, 1CCB75AF  
 D2932448, 8C4DC6AF, 770BCE98, 39CA97B6, 1CCB75AF, 4E4E13E9, 82843491, 27F81499  
 39CA97B6, 048CC517, 8C4DC6AF, 770BCE98, 27F81499, 03BD1BD9, 4E4E13E9, 82843491  
 770BCE98, 419960CF, 048CC517, 8C4DC6AF, 82843491, 6FA999B7, 03BD1BD9, 4E4E13E9  
 8C4DC6AF, 407700EE, 419960CF, 048CC517, 4E4E13E9, 37B18629, 6FA999B7, 03BD1BD9  
 048CC517, E60ABEC4, 407700EE, 419960CF, 03BD1BD9, 9EA44395, 37B18629, 6FA999B7  
 419960CF, 0E248A8B, E60ABEC4, 407700EE, 6FA999B7, F877D28C, 9EA44395, 37B18629  
 407700EE, 10667792, 0E248A8B, E60ABEC4, 37B18629, F63EA862, F877D28C, 9EA44395  
 E60ABEC4, 646BB7A8, 10667792, 0E248A8B, 9EA44395, 424072F0, F63EA862, F877D28C  
 0E248A8B, 625CCE22, 646BB7A8, 10667792, F877D28C, 3B7642B8, 424072F0, F63EA862  
 10667792, 8E0E1101, 625CCE22, 646BB7A8, F63EA862, CD620F4E, 3B7642B8, 424072F0  
 646BB7A8, C23D3583, 8E0E1101, 625CCE22, 424072F0, BFAA1A02, CD620F4E, 3B7642B8  
 625CCE22, 81DE3DC5, C23D3583, 8E0E1101, 3B7642B8, 1BA7FD36, BFAA1A02, CD620F4E  
 8E0E1101, D24E4181, 81DE3DC5, C23D3583, CD620F4E, E62B2A4, 1BA7FD36, BFAA1A02

The following are (hexadecimal representations of) the successive values of the variables  $X_0, X_1, X_2, X_3$ ,  $X'_0, X'_1, X'_2$  and  $X'_3$  obtained during the processing of the second block.

31560350, 285A21CF, 846C181B, 553B61B8, 31560350, 285A21CF, 846C181B, 553B61B8  
 553B61B8, 1ADDE153, 285A21CF, 846C181B, 553B61B8, 56C8C102, 285A21CF, 846C181B  
 846C181B, CE8FC309, 1ADDE153, 285A21CF, 846C181B, 702249A4, 56C8C102, 285A21CF  
 285A21CF, 0DD8403A, CE8FC309, 1ADDE153, 285A21CF, 22CB0A97, 702249A4, 56C8C102  
 1ADDE153, 4842F01E, 0DD8403A, CE8FC309, 56C8C102, 35B2DCDF, 22CB0A97, 702249A4  
 CE8FC309, BE6A9014, 4842F01E, 0DD8403A, 702249A4, D2EFFB4A, 35B2DCDF, 22CB0A97  
 0DD8403A, 7FE339CA, BE6A9014, 4842F01E, 22CB0A97, 59EA6C60, D2EFFB4A, 35B2DCDF  
 4842F01E, D1CCFD4B, 7FE339CA, BE6A9014, 35B2DCDF, 82DEA3AE, 59EA6C60, D2EFFB4A  
 BE6A9014, 108966B1, D1CCFD4B, 7FE339CA, D2EFFB4A, 4481FDE2, 82DEA3AE, 59EA6C60  
 7FE339CA, 899223E8, 108966B1, D1CCFD4B, 59EA6C60, 13BB8F73, 4481FDE2, 82DEA3AE  
 D1CCFD4B, 5E3B9917, 899223E8, 108966B1, 82DEA3AE, 946BD478, 13BB8F73, 4481FDE2  
 108966B1, 7666663B, 5E3B9917, 899223E8, 4481FDE2, BD0605EA, 946BD478, 13BB8F73  
 899223E8, A1BAD92C, 7666663B, 5E3B9917, 13BB8F73, 36F99153, BD0605EA, 946BD478  
 5E3B9917, DE527A04, A1BAD92C, 7666663B, 946BD478, EB4AE872, 36F99153, BD0605EA  
 7666663B, E52F1533, DE527A04, A1BAD92C, BD0605EA, 7C346442, EB4AE872, 36F99153  
 A1BAD92C, 5C3C2C22, E52F1533, DE527A04, 36F99153, AFA320AD, 7C346442, EB4AE872  
 DE527A04, FC1C4108, 5C3C2C22, E52F1533, EB4AE872, B4905651, AFA320AD, 7C346442  
 E52F1533, 0A03E84B, FC1C4108, 5C3C2C22, 7C346442, 02E94FA1, B4905651, AFA320AD  
 5C3C2C22, FB74BD26, 0A03E84B, FC1C4108, AFA320AD, E08D1799, 02E94FA1, B4905651  
 FC1C4108, C78DC5C4, FB74BD26, 0A03E84B, B4905651, 69AFAA80, E08D1799, 02E94FA1  
 0A03E84B, ACF60434, C78DC5C4, FB74BD26, 02E94FA1, FA665E46, 69AFAA80, E08D1799  
 FB74BD26, 58F751E0, ACF60434, C78DC5C4, E08D1799, 269AB7E3, FA665E46, 69AFAA80  
 C78DC5C4, EB75C7CB, 58F751E0, ACF60434, 69AFAA80, 0F06388B, 269AB7E3, FA665E46  
 ACF60434, 83C0A8B7, EB75C7CB, 58F751E0, FA665E46, FD44FBD5, 0F06388B, 269AB7E3  
 58F751E0, 27C87178, 83C0A8B7, EB75C7CB, 269AB7E3, DBBC0190, FD44FBD5, 0F06388B  
 EB75C7CB, B7B9163F, 27C87178, 83C0A8B7, 0F06388B, D0E3FC2B, DBBC0190, FD44FBD5  
 83C0A8B7, 0FA1C6DC, B7B9163F, 27C87178, FD44FBD5, 7D87B4BA, D0E3FC2B, DBBC0190  
 27C87178, 2CC60316, 0FA1C6DC, B7B9163F, DBBC0190, 68367FDB, 7D87B4BA, D0E3FC2B  
 B7B9163F, 08029C44, 2CC60316, 0FA1C6DC, D0E3FC2B, 53AB5439, 68367FDB, 7D87B4BA  
 0FA1C6DC, F693A10E, 08029C44, 2CC60316, 7D87B4BA, E78B75B5, 53AB5439, 68367FDB  
 2CC60316, 356224B9, F693A10E, 08029C44, 68367FDB, 830530DF, E78B75B5, 53AB5439

|           |           |           |           |           |           |           |          |
|-----------|-----------|-----------|-----------|-----------|-----------|-----------|----------|
| 08029C44, | 669F7869, | 356224B9, | F693A10E, | 53AB5439, | 67FCB1AC, | 830530DF, | E78B75B5 |
| F693A10E, | 7B70C168, | 669F7869, | 356224B9, | E78B75B5, | 757BB243, | 67FCB1AC, | 830530DF |
| 356224B9, | 037FB19C, | 7B70C168, | 669F7869, | 830530DF, | F0CA8878, | 757BB243, | 67FCB1AC |
| 669F7869, | 9B0A10B3, | 037FB19C, | 7B70C168, | 67FCB1AC, | FA10CB33, | F0CA8878, | 757BB243 |
| 7B70C168, | 9D015956, | 9B0A10B3, | 037FB19C, | 757BB243, | 5487E56C, | FA10CB33, | F0CA8878 |
| 037FB19C, | 6A7DE5F4, | 9D015956, | 9B0A10B3, | F0CA8878, | A5D33699, | 5487E56C, | FA10CB33 |
| 9B0A10B3, | E522D913, | 6A7DE5F4, | 9D015956, | FA10CB33, | BEB495BC, | A5D33699, | 5487E56C |
| 9D015956, | 0EFD42E5, | E522D913, | 6A7DE5F4, | 5487E56C, | 05202F93, | BEB495BC, | A5D33699 |
| 6A7DE5F4, | 7902100B, | 0EFD42E5, | E522D913, | A5D33699, | BACE7DD9, | 05202F93, | BEB495BC |
| E522D913, | 1ACEFABC, | 7902100B, | 0EFD42E5, | BEB495BC, | 08D045DD, | BACE7DD9, | 05202F93 |
| 0EFD42E5, | E07378FF, | 1ACEFABC, | 7902100B, | 05202F93, | 5448A3A0, | 08D045DD, | BACE7DD9 |
| 7902100B, | 489C7A1A, | E07378FF, | 1ACEFABC, | BACE7DD9, | D98BE3AA, | 5448A3A0, | 08D045DD |
| 1ACEFABC, | C02A45A5, | 489C7A1A, | E07378FF, | 08D045DD, | 12EC982F, | D98BE3AA, | 5448A3A0 |
| E07378FF, | 3068DDE8, | C02A45A5, | 489C7A1A, | 5448A3A0, | 4A1EB2B2, | 12EC982F, | D98BE3AA |
| 489C7A1A, | D5DD5018, | 3068DDE8, | C02A45A5, | D98BE3AA, | D677AAA8, | 4A1EB2B2, | 12EC982F |
| C02A45A5, | B9D75D76, | D5DD5018, | 3068DDE8, | 12EC982F, | 5AA89133, | D677AAA8, | 4A1EB2B2 |
| 3068DDE8, | 51A9B2DD, | B9D75D76, | D5DD5018, | 4A1EB2B2, | 49BCE169, | 5AA89133, | D677AAA8 |
| D5DD5018, | 36F589C4, | 51A9B2DD, | B9D75D76, | D677AAA8, | CF4FA8D2, | 49BCE169, | 5AA89133 |
| B9D75D76, | B5C60EAF, | 36F589C4, | 51A9B2DD, | 5AA89133, | C1985969, | CF4FA8D2, | 49BCE169 |
| 51A9B2DD, | 725DF80C, | B5C60EAF, | 36F589C4, | 49BCE169, | 427440B4, | C1985969, | CF4FA8D2 |
| 36F589C4, | 3F7A2507, | 725DF80C, | B5C60EAF, | CF4FA8D2, | 60927896, | 427440B4, | C1985969 |
| B5C60EAF, | 9D539EB6, | 3F7A2507, | 725DF80C, | C1985969, | 7050ED96, | 60927896, | 427440B4 |
| 725DF80C, | 5A249895, | 9D539EB6, | 3F7A2507, | 427440B4, | CBC74513, | 7050ED96, | 60927896 |
| 3F7A2507, | A7CECDCD, | 5A249895, | 9D539EB6, | 60927896, | 8431C75E, | CBC74513, | 7050ED96 |
| 9D539EB6, | F8DCD12B, | A7CECDCD, | 5A249895, | 7050ED96, | 0E3A1C68, | 8431C75E, | CBC74513 |
| 5A249895, | 3E30DB2A, | F8DCD12B, | A7CECDCD, | CBC74513, | 62EEEC87, | 0E3A1C68, | 8431C75E |
| A7CECDCD, | A25D36CE, | 3E30DB2A, | F8DCD12B, | 8431C75E, | 2B1F312D, | 62EEEC87, | 0E3A1C68 |
| F8DCD12B, | A92CF759, | A25D36CE, | 3E30DB2A, | 0E3A1C68, | FB124197, | 2B1F312D, | 62EEEC87 |
| 3E30DB2A, | 0CD0BA66, | A92CF759, | A25D36CE, | 62EEEC87, | DB8A5C11, | FB124197, | 2B1F312D |
| A25D36CE, | AF62D775, | 0CD0BA66, | A92CF759, | 2B1F312D, | EC3264DC, | DB8A5C11, | FB124197 |
| A92CF759, | 69D4E1DF, | AF62D775, | 0CD0BA66, | FB124197, | 9AA87F7C, | EC3264DC, | DB8A5C11 |
| 0CD0BA66, | 0EE66339, | 69D4E1DF, | AF62D775, | DB8A5C11, | 04512915, | 9AA87F7C, | EC3264DC |
| AF62D775, | 5C5B5FBD, | 0EE66339, | 69D4E1DF, | EC3264DC, | C763272A, | 04512915, | 9AA87F7C |
| 69D4E1DF, | 0D80E8CF, | 5C5B5FBD, | 0EE66339, | 9AA87F7C, | CCD7DF45, | C763272A, | 04512915 |

The hash-code is the following 128-bit string.

A1 AA 06 89 D0 FA FA 2D DC 22 E8 8B 49 13 3A 06

### B.3.9 Example 9

In this example, the data string is the 1 000 000-byte string consisting of the ASCII-coded version of “a” repeated  $10^6$  times.

The hash-code is the following 128-bit string.

4A 7F 57 23 F9 54 EB A1 21 6C 9D 8F 63 20 43 1F

### B.3.10 Example 10

In this example, the data string is the 112-byte string consisting of the ASCII-coded version of

“abcdefghijklmnopqrstuvwxyz  
abcdefghijklmnopqrstuvwxyz”

(with no line break after the first n).

The hash-code is the following 128-bit string.

D4 EC C9 13 E1 DF 77 6B F4 8D E9 D5 5B 1F 25 46

### B.3.11 Example 11

In this example, the data string is the 32-byte string consisting of the ASCII-coded version of

“abcdbcdecdefdefgefghfghighijhijk”

The hash-code is the following 128-bit string.

13 FC 13 E8 EF FF 34 7D E1 93 FF 46 DB AC CF D4

## B.4 Dedicated Hash-Function 3 (SHA-1)

### B.4.1 Example 1

In this example, the data string is the empty string, i.e., the string of length zero.

The hash-code is the following 160-bit string.

DA 39 A3 EE 5E 6B 4B 0D 32 55 BF EF 95 60 18 90 AF D8 07 09

### B.4.2 Example 2

In this example, the data string consists of a single byte, namely the ASCII-coded version of the letter “a”.

The hash-code is the following 160-bit string.

86 F7 E4 37 FA A5 A7 FC E1 5D 1D DC B9 EA EA EA 37 76 67 B8

### B.4.3 Example 3

In this example, the data string is the 3-byte string consisting of the ASCII-coded version of “abc”. This is equivalent to the bit string “01100001 01100010 01100011”.

After the padding process, the single 16-word block derived from the data string is as follows.

61626380 00000000 00000000 00000000 00000000 00000000 00000000 00000000  
00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000018

The following are (hexadecimal representations of) the successive values of the variables  $X_0$ ,  $X_1$ ,  $X_2$ ,  $X_3$  and  $X_4$ .

0116FC33, 67452301, 7BF36AE2, 98BADCFE, 10325476  
8990536D, 0116FC33, 59D148C0, 7BF36AE2, 98BADCFE  
A1390F08, 8990536D, C045BF0C, 59D148C0, 7BF36AE2  
CDD8E11B, A1390F08, 626414DB, C045BF0C, 59D148C0  
CFD499DE, CDD8E11B, 284E43C2, 626414DB, C045BF0C  
3FC7CA40, CFD499DE, F3763846, 284E43C2, 626414DB  
993E30C1, 3FC7CA40, B3F52677, F3763846, 284E43C2  
9E8C07D4, 993E30C1, 0FF1F290, B3F52677, F3763846  
4B6AE328, 9E8C07D4, 664F8C30, 0FF1F290, B3F52677  
8351F929, 4B6AE328, 27A301F5, 664F8C30, 0FF1F290  
FBDA9E89, 8351F929, 12DAB8CA, 27A301F5, 664F8C30

63188FE4, FBDA9E89, 60D47E4A, 12DAB8CA, 27A301F5  
 4607B664, 63188FE4, 7EF6A7A2, 60D47E4A, 12DAB8CA  
 9128F695, 4607B664, 18C623F9, 7EF6A7A2, 60D47E4A  
 196BEE77, 9128F695, 1181ED99, 18C623F9, 7EF6A7A2  
 20BDD62F, 196BEE77, 644A3DA5, 1181ED99, 18C623F9  
 4E925823, 20BDD62F, C65AFB9D, 644A3DA5, 1181ED99  
 82AA6728, 4E925823, C82F758B, C65AFB9D, 644A3DA5  
 DC64901D, 82AA6728, D3A49608, C82F758B, C65AFB9D  
 FD9E1D7D, DC64901D, 20AA99CA, D3A49608, C82F758B  
 1A37B0CA, FD9E1D7D, 77192407, 20AA99CA, D3A49608  
 33A23BFC, 1A37B0CA, 7F67875F, 77192407, 20AA99CA  
 21283486, 33A23BFC, 868DEC32, 7F67875F, 77192407  
 D541F12D, 21283486, 0CE88EFF, 868DEC32, 7F67875F  
 C7567DC6, D541F12D, 884A0D21, 0CE88EFF, 868DEC32  
 48413BA4, C7567DC6, 75507C4B, 884A0D21, 0CE88EFF  
 BE35FBD5, 48413BA4, B1D59F71, 75507C4B, 884A0D21  
 4AA84D97, BE35FBD5, 12104EE9, B1D59F71, 75507C4B  
 8370B52E, 4AA84D97, 6F8D7EF5, 12104EE9, B1D59F71  
 C5FBAF5D, 8370B52E, D2AA1365, 6F8D7EF5, 12104EE9  
 1267B407, C5FBAF5D, A0DC2D4B, D2AA1365, 6F8D7EF5  
 3B845D33, 1267B407, 717EEBD7, A0DC2D4B, D2AA1365  
 046FAA0A, 3B845D33, C499ED01, 717EEBD7, A0DC2D4B  
 2C0EBC11, 046FAA0A, CEE1174C, C499ED01, 717EEBD7  
 21796AD4, 2C0EBC11, 811BEA82, CEE1174C, C499ED01  
 DCBBB0CB, 21796AD4, 4B03AF04, 811BEA82, CEE1174C  
 0F511FD8, DCBBB0CB, 085E5AB5, 4B03AF04, 811BEA82  
 DC63973F, 0F511FD8, F72EEC32, 085E5AB5, 4B03AF04  
 4C986405, DC63973F, 03D447F6, F72EEC32, 085E5AB5  
 32DE1CBA, 4C986405, F718E5CF, 03D447F6, F72EEC32  
 FC87DEDF, 32DE1CBA, 53261901, F718E5CF, 03D447F6  
 970A0D5C, FC87DEDF, 8CB7872E, 53261901, F718E5CF  
 7F193DC5, 970A0D5C, FF21F7B7, 8CB7872E, 53261901  
 EE1B1AAF, 7F193DC5, 25C28357, FF21F7B7, 8CB7872E  
 40F28E09, EE1B1AAF, 5FC64F71, 25C28357, FF21F7B7  
 1C51E1F2, 40F28E09, FB86C6AB, 5FC64F71, 25C28357  
 A01B846C, 1C51E1F2, 503CA382, FB86C6AB, 5FC64F71  
 BEAD02CA, A01B846C, 8714787C, 503CA382, FB86C6AB  
 BAF39337, BEAD02CA, 2806E11B, 8714787C, 503CA382  
 120731C5, BAF39337, AFAB40B2, 2806E11B, 8714787C  
 641DB2CE, 120731C5, EEBCE4CD, AFAB40B2, 2806E11B  
 3847AD66, 641DB2CE, 4481CC71, EEBCE4CD, AFAB40B2  
 E490436D, 3847AD66, 99076CB3, 4481CC71, EEBCE4CD  
 27E9F1D8, E490436D, 8E11EB59, 99076CB3, 4481CC71  
 7B71F76D, 27E9F1D8, 792410DB, 8E11EB59, 99076CB3  
 5E6456AF, 7B71F76D, 09FA7C76, 792410DB, 8E11EB59  
 C846093F, 5E6456AF, 5EDC7DDB, 09FA7C76, 792410DB  
 D262FF50, C846093F, D79915AB, 5EDC7DDB, 09FA7C76  
 09D785FD, D262FF50, F211824F, D79915AB, 5EDC7DDB  
 3F52DE5A, 09D785FD, 3498BFD4, F211824F, D79915AB  
 D756C147, 3F52DE5A, 4275E17F, 3498BFD4, F211824F  
 548C9CB2, D756C147, 8FD4B796, 4275E17F, 3498BFD4

B66C020B, 548C9CB2, F5D5B051, 8FD4B796, 4275E17F  
 6B61C9E1, B66C020B, 9523272C, F5D5B051, 8FD4B796  
 19DFA7AC, 6B61C9E1, ED9B0082, 9523272C, F5D5B051  
 101655F9, 19DFA7AC, 5AD87278, ED9B0082, 9523272C  
 0C3DF2B4, 101655F9, 0677E9EB, 5AD87278, ED9B0082  
 78DD4D2B, 0C3DF2B4, 4405957E, 0677E9EB, 5AD87278  
 497093C0, 78DD4D2B, 030F7CAD, 4405957E, 0677E9EB  
 3F2588C2, 497093C0, DE37534A, 030F7CAD, 4405957E  
 C199F8C7, 3F2588C2, 125C24F0, DE37534A, 030F7CAD  
 39859DE7, C199F8C7, 8FC96230, 125C24F0, DE37534A  
 EDB42DE4, 39859DE7, F0667E31, 8FC96230, 125C24F0  
 11793F6F, EDB42DE4, CE616779, F0667E31, 8FC96230  
 5EE76897, 11793F6F, 3B6D0B79, CE616779, F0667E31  
 63F7DAB7, 5EE76897, C45E4FDB, 3B6D0B79, CE616779  
 A079B7D9, 63F7DAB7, D7B9DA25, C45E4FDB, 3B6D0B79  
 860D21CC, A079B7D9, D8FDF6AD, D7B9DA25, C45E4FDB  
 5738D5E1, 860D21CC, 681E6DF6, D8FDF6AD, D7B9DA25  
 42541B35, 5738D5E1, 21834873, 681E6DF6, D8FDF6AD

The hash-code is the following 160-bit string.

A9 99 3E 36 47 06 81 6A BA 3E 25 71 78 50 C2 6C 9C D0 D8 9D

#### B.4.4 Example 4

In this example, the data string is the 14-byte string consisting of the ASCII-coded version of  
 “message digest”

The hash-code is the following 160-bit string.

C1 22 52 CE DA 8B E8 99 4D 5F A0 29 0A 47 23 1C 1D 16 AA E3

#### B.4.5 Example 5

In this example, the data string is the 26-byte string consisting of the ASCII-coded version of

“abcdefghijklmnopqrstuvwxy”

The hash-code is the following 160-bit string.

32 D1 0C 7B 8C F9 65 70 CA 04 CE 37 F2 A1 9D 84 24 0D 3A 89

#### B.4.6 Example 6

In this example, the data string is the 62-byte string consisting of the ASCII-coded version of

“ABCDEFGHJKLMNOPQRSTUVWXYZabcdefghijklmnopqrstuvwxy0123456789”

The hash-code is the following 160-bit string.

76 1C 45 7B F7 3B 14 D2 7E 9E 92 65 C4 6F 4B 4D DA 11 F9 40

### B.4.7 Example 7

In this example, the data string is the 80-byte string consisting of the ASCII-coded version of eight repetitions of

“1234567890”

The hash-code is the following 160-bit string.

50 AB F5 70 6A 15 09 90 A0 8B 2C 5E A4 0F A0 E5 85 55 47 32

### B.4.8 Example 8

In this example, the data string is the 56-byte string consisting of the ASCII-coded version of

“abcbcbcdcedfdefgefghghighijhijkjklklmklmnlmnopnopq”

After the padding process, the two 16-word blocks derived from the data string are as follows.

|          |          |          |          |          |          |          |          |
|----------|----------|----------|----------|----------|----------|----------|----------|
| 61626364 | 62636465 | 63646566 | 64656667 | 65666768 | 66676869 | 6768696A | 68696A6B |
| 696A6B6C | 6A6B6C6D | 6B6C6D6E | 6C6D6E6F | 6D6E6F70 | 6E6F7071 | 80000000 | 00000000 |
| 00000000 | 00000000 | 00000000 | 00000000 | 00000000 | 00000000 | 00000000 | 00000000 |
| 00000000 | 00000000 | 00000000 | 00000000 | 00000000 | 00000000 | 00000000 | 000001C0 |

The following are (hexadecimal representations of) the successive values of the variables  $X_0$ ,  $X_1$ ,  $X_2$ ,  $X_3$  and  $X_4$  obtained during the processing of the first block.

0116FC17, 67452301, 7BF36AE2, 98BADCFE, 10325476  
 EBF3B452, 0116FC17, 59D148C0, 7BF36AE2, 98BADCFE  
 5109913A, EBF3B452, C045BF05, 59D148C0, 7BF36AE2  
 2C4F6EAC, 5109913A, BAFCE14, C045BF05, 59D148C0  
 33F4AE5B, 2C4F6EAC, 9442644E, BAFCE14, C045BF05  
 96B85189, 33F4AE5B, 0B13DBAB, 9442644E, BAFCE14  
 DB04CB58, 96B85189, CCFD2B96, 0B13DBAB, 9442644E  
 45833F0F, DB04CB58, 65AE1462, CCFD2B96, 0B13DBAB  
 C565C35E, 45833F0F, 36C132D6, 65AE1462, CCFD2B96  
 6350AFDA, C565C35E, D160CFC3, 36C132D6, 65AE1462  
 8993EA77, 6350AFDA, B15970D7, D160CFC3, 36C132D6  
 E19ECAA2, 8993EA77, 98D42BF6, B15970D7, D160CFC3  
 8603481E, E19ECAA2, E264FA9D, 98D42BF6, B15970D7  
 32F94A85, 8603481E, B867B2A8, E264FA9D, 98D42BF6  
 B2E7A8BE, 32F94A85, A180D207, B867B2A8, E264FA9D  
 42637E39, B2E7A8BE, 4CBE52A1, A180D207, B867B2A8  
 6B068048, 42637E39, ACB9EA2F, 4CBE52A1, A180D207  
 426B9C35, 6B068048, 5098DF8E, ACB9EA2F, 4CBE52A1  
 944B1BD1, 426B9C35, 1AC1A012, 5098DF8E, ACB9EA2F  
 6C445652, 944B1BD1, 509AE70D, 1AC1A012, 5098DF8E  
 95836DA5, 6C445652, 6512C6F4, 509AE70D, 1AC1A012  
 09511177, 95836DA5, 9B111594, 6512C6F4, 509AE70D  
 E2B92DC4, 09511177, 6560DB69, 9B111594, 6512C6F4  
 FD224575, E2B92DC4, C254445D, 6560DB69, 9B111594  
 EEB82D9A, FD224575, 38AE4B71, C254445D, 6560DB69  
 5A142C1A, EEB82D9A, 7F48915D, 38AE4B71, C254445D  
 2972F7C7, 5A142C1A, BBAE0B66, 7F48915D, 38AE4B71  
 D526A644, 2972F7C7, 96850B06, BBAE0B66, 7F48915D

E1122421, D526A644, CA5CBDF1, 96850B06, BBAE0B66  
 05B457B2, E1122421, 3549A991, CA5CBDF1, 96850B06  
 A9C84BEC, 05B457B2, 78448908, 3549A991, CA5CBDF1  
 52E31F60, A9C84BEC, 816D15EC, 78448908, 3549A991  
 5AF3242C, 52E31F60, 2A7212FB, 816D15EC, 78448908  
 31C756A9, 5AF3242C, 14B8C7D8, 2A7212FB, 816D15EC  
 E9AC987C, 31C756A9, 16BCC90B, 14B8C7D8, 2A7212FB  
 AB7C32EE, E9AC987C, 4C71D5AA, 16BCC90B, 14B8C7D8  
 5933FC99, AB7C32EE, 3A6B261F, 4C71D5AA, 16BCC90B  
 43F87AE9, 5933FC99, AADF0CBB, 3A6B261F, 4C71D5AA  
 24957F22, 43F87AE9, 564CFF26, AADF0CBB, 3A6B261F  
 ADEB7478, 24957F22, 50FE1EBA, 564CFF26, AADF0CBB  
 D70E5010, ADEB7478, 89255FC8, 50FE1EBA, 564CFF26  
 79BCFB08, D70E5010, 2B7ADD1E, 89255FC8, 50FE1EBA  
 F9BCB8DE, 79BCFB08, 35C39404, 2B7ADD1E, 89255FC8  
 633E9561, F9BCB8DE, 1E6F3EC2, 35C39404, 2B7ADD1E  
 98C1EA64, 633E9561, BE6F2E37, 1E6F3EC2, 35C39404  
 C6EA241E, 98C1EA64, 58CFA558, BE6F2E37, 1E6F3EC2  
 A2AD4F02, C6EA241E, 26307A99, 58CFA558, BE6F2E37  
 C8A69090, A2AD4F02, B1BA8907, 26307A99, 58CFA558  
 88341600, C8A69090, A8AB53C0, B1BA8907, 26307A99  
 7E846F58, 88341600, 3229A424, A8AB53C0, B1BA8907  
 86E358BA, 7E846F58, 220D0580, 3229A424, A8AB53C0  
 8D2E76C8, 86E358BA, 1FA11BD6, 220D0580, 3229A424  
 CE892E10, 8D2E76C8, A1B8D62E, 1FA11BD6, 220D0580  
 EDEA95B1, CE892E10, 234B9DB2, A1B8D62E, 1FA11BD6  
 36D1230A, EDEA95B1, 33A24B84, 234B9DB2, A1B8D62E  
 776C3910, 36D1230A, 7B7AA56C, 33A24B84, 234B9DB2  
 A681B723, 776C3910, 8DB448C2, 7B7AA56C, 33A24B84  
 AC0A794F, A681B723, 1DDB0E44, 8DB448C2, 7B7AA56C  
 F03D3782, AC0A794F, E9A06DC8, 1DDB0E44, 8DB448C2  
 9EF775C3, F03D3782, EB029E53, E9A06DC8, 1DDB0E44  
 36254B13, 9EF775C3, BC0F4DE0, EB029E53, E9A06DC8  
 4080D4DC, 36254B13, E7BDDD70, BC0F4DE0, EB029E53  
 2BFAF7A8, 4080D4DC, CD8952C4, E7BDDD70, BC0F4DE0  
 513F9CA0, 2BFAF7A8, 10203537, CD8952C4, E7BDDD70  
 E5895C81, 513F9CA0, 0AFEBDEA, 10203537, CD8952C4  
 1037D2D5, E5895C81, 144FE728, 0AFEBDEA, 10203537  
 14A82DA9, 1037D2D5, 79625720, 144FE728, 0AFEBDEA  
 6D17C9FD, 14A82DA9, 440DF4B5, 79625720, 144FE728  
 2C7B07BD, 6D17C9FD, 452A0B6A, 440DF4B5, 79625720  
 FDF6EFFF, 2C7B07BD, 5B45F27F, 452A0B6A, 440DF4B5  
 112B96E3, FDF6EFFF, 4B1EC1EF, 5B45F27F, 452A0B6A  
 84065712, 112B96E3, FF7DBBFF, 4B1EC1EF, 5B45F27F  
 AB89FB71, 84065712, C44AE5B8, FF7DBBFF, 4B1EC1EF  
 C5210E35, AB89FB71, A10195C4, C44AE5B8, FF7DBBFF  
 352D9F4B, C5210E35, 6AE27EDC, A10195C4, C44AE5B8  
 1A0E0E0A, 352D9F4B, 7148438D, 6AE27EDC, A10195C4  
 D0D47349, 1A0E0E0A, CD4B67D2, 7148438D, 6AE27EDC



AD38620D, D0D47349, 86838382, CD4B67D2, 7148438D  
 D3AD7C25, AD38620D, 74351CD2, 86838382, CD4B67D2  
 8CE34517, D3AD7C25, 6B4E1883, 74351CD2, 86838382

The following are (hexadecimal representations of) the successive values of the variables  $X_0$ ,  $X_1$ ,  $X_2$ ,  $X_3$  and  $X_4$ , obtained during the processing of the second block.

2DF257E9, F4286818, B0DEC9EB, 0408F581, 84677148  
 4D3DC58F, 2DF257E9, 3D0A1A06, B0DEC9EB, 0408F581  
 C352BB05, 4D3DC58F, 4B7C95FA, 3D0A1A06, B0DEC9EB  
 EEF743C6, C352BB05, D34F7163, 4B7C95FA, 3D0A1A06  
 41E34277, EEF743C6, 70D4AEC1, D34F7163, 4B7C95FA  
 5443915C, 41E34277, BBBDD0F1, 70D4AEC1, D34F7163  
 E7FA0377, 5443915C, D078D09D, BBBDD0F1, 70D4AEC1  
 C6946813, E7FA0377, 1510E457, D078D09D, BBBDD0F1  
 FDDE1DE1, C6946813, F9FE80DD, 1510E457, D078D09D  
 B8538ACA, FDDE1DE1, F1A51A04, F9FE80DD, 1510E457  
 6BA94F63, B8538ACA, 7F778778, F1A51A04, F9FE80DD  
 43A2792F, 6BA94F63, AE14E2B2, 7F778778, F1A51A04  
 FECD7BBF, 43A2792F, DAEA53D8, AE14E2B2, 7F778778  
 A2604CA8, FECD7BBF, D0E89E4B, DAEA53D8, AE14E2B2  
 258B0BAA, A2604CA8, FFB35EEF, D0E89E4B, DAEA53D8  
 D9772360, 258B0BAA, 2898132A, FFB35EEF, D0E89E4B  
 5507DB6E, D9772360, 8962C2EA, 2898132A, FFB35EEF  
 A51B58BC, 5507DB6E, 365DC8D8, 8962C2EA, 2898132A  
 C2EB709F, A51B58BC, 9541F6DB, 365DC8D8, 8962C2EA  
 D8992153, C2EB709F, 2946D62F, 9541F6DB, 365DC8D8  
 37482F5F, D8992153, F0BADC27, 2946D62F, 9541F6DB  
 EE8700BD, 37482F5F, F6264854, F0BADC27, 2946D62F  
 9AD594B9, EE8700BD, CDD20BD7, F6264854, F0BADC27  
 8FBAA5B9, 9AD594B9, 7BA1C02F, CDD20BD7, F6264854  
 88FB5867, 8FBAA5B9, 66B5652E, 7BA1C02F, CDD20BD7  
 EEC50521, 88FB5867, 63EEA96E, 66B5652E, 7BA1C02F  
 50BCE434, EEC50521, E23ED619, 63EEA96E, 66B5652E  
 5C416DAF, 50BCE434, 7BB14148, E23ED619, 63EEA96E  
 2429BE5F, 5C416DAF, 142F390D, 7BB14148, E23ED619  
 0A2FB108, 2429BE5F, D7105B6B, 142F390D, 7BB14148  
 17986223, 0A2FB108, C90A6F97, D7105B6B, 142F390D  
 8A4AF384, 17986223, 028BEC42, C90A6F97, D7105B6B  
 6B629993, 8A4AF384, C5E61888, 028BEC42, C90A6F97  
 F15F04F3, 6B629993, 2292BCE1, C5E61888, 028BEC42  
 295CC25B, F15F04F3, DAD8A664, 2292BCE1, C5E61888  
 696DA404, 295CC25B, FC57C13C, DAD8A664, 2292BCE1  
 CEF5AE12, 696DA404, CA573096, FC57C13C, DAD8A664  
 87D5B80C, CEF5AE12, 1A5B6901, CA573096, FC57C13C  
 84E2A5F2, 87D5B80C, B3BD6B84, 1A5B6901, CA573096  
 03BB6310, 84E2A5F2, 21F56E03, B3BD6B84, 1A5B6901  
 C2D8F75F, 03BB6310, A138A97C, 21F56E03, B3BD6B84  
 BFB25768, C2D8F75F, 00EED8C4, A138A97C, 21F56E03  
 28589152, BFB25768, F0B63DD7, 00EED8C4, A138A97C  
 EC1D3D61, 28589152, 2FEC95DA, F0B63DD7, 00EED8C4  
 3CAED7AF, EC1D3D61, 8A162454, 2FEC95DA, F0B63DD7



C3D033EA, 3CAED7AF, 7B074F58, 8A162454, 2FEC95DA  
 7316056A, C3D033EA, CF2BB5EB, 7B074F58, 8A162454  
 46F93B68, 7316056A, B0F40CFA, CF2BB5EB, 7B074F58  
 DC8E7F26, 46F93B68, 9CC5815A, B0F40CFA, CF2BB5EB  
 850D411C, DC8E7F26, 11BE4EDA, 9CC5815A, B0F40CFA  
 7E4672C0, 850D411C, B7239FC9, 11BE4EDA, 9CC5815A  
 89FBD41D, 7E4672C0, 21435047, B7239FC9, 11BE4EDA  
 1797E228, 89FBD41D, 1F919CB0, 21435047, B7239FC9  
 431D65BC, 1797E228, 627EF507, 1F919CB0, 21435047  
 2BDBB8CB, 431D65BC, 05E5F88A, 627EF507, 1F919CB0  
 6DA72E7F, 2BDBB8CB, 10C7596F, 05E5F88A, 627EF507  
 A8495A9B, 6DA72E7F, CAF6EE32, 10C7596F, 05E5F88A  
 E785655A, A8495A9B, DB69CB9F, CAF6EE32, 10C7596F  
 5B086C42, E785655A, EA1256A6, DB69CB9F, CAF6EE32  
 A65818F7, 5B086C42, B9E15956, EA1256A6, DB69CB9F  
 7AAB101B, A65818F7, 96C21B10, B9E15956, EA1256A6  
 93614C9C, 7AAB101B, E996063D, 96C21B10, B9E15956  
 F66D9BF4, 93614C9C, DEAC406, E996063D, 96C21B10  
 D504902B, F66D9BF4, 24D85327, DEAC406, E996063D  
 60A9DA62, D504902B, 3D9B66FD, 24D85327, DEAC406  
 8B687819, 60A9DA62, F541240A, 3D9B66FD, 24D85327  
 083E90C3, 8B687819, 982A7698, F541240A, 3D9B66FD  
 F6226BBF, 083E90C3, 62DA1E06, 982A7698, F541240A  
 76C0563B, F6226BBF, C20FA430, 62DA1E06, 982A7698  
 989DD165, 76C0563B, FD889AEF, C20FA430, 62DA1E06  
 8B2C7573, 989DD165, DDB0158E, FD889AEF, C20FA430  
 AE1B8E7B, 8B2C7573, 66277459, DDB0158E, FD889AEF  
 CA1840DE, AE1B8E7B, E2CB1D5C, 66277459, DDB0158E  
 16F3BABB, CA1840DE, EB86E39E, E2CB1D5C, 66277459  
 D28D83AD, 16F3BABB, B2861037, EB86E39E, E2CB1D5C  
 6BC02DFE, D28D83AD, C5BCEEAE, B2861037, EB86E39E  
 D3A6E275, 6BC02DFE, 74A360EB, C5BCEEAE, B2861037  
 DA955482, D3A6E275, 9AF00B7F, 74A360EB, C5BCEEAE  
 58C0AAC0, DA955482, 74E9B89D, 9AF00B7F, 74A360EB  
 906FD62C, 58C0AAC0, B6A55520, 74E9B89D, 9AF00B7F

The hash-code is the following 160-bit string.

84 98 3E 44 1C 3B D2 6E BA AE 4A A1 F9 51 29 E5 E5 46 70 F1

#### B.4.9 Example 9

In this example, the data string is the 1 000 000-byte string consisting of the ASCII-coded version of “a” repeated  $10^6$  times.

The hash-code is the following 160-bit string.

34 AA 97 3C D4 C4 DA A4 F6 1E EB 2B DB AD 27 31 65 34 01 6F

**B.4.10 Example 10**

In this example, the data string is the 112-byte string consisting of the ASCII-coded version of

“abcdefghijklmnopqrstuvwxyz  
hijklmnopqrstuvwxyz”

(with no line break after the first n).

The hash-code is the following 160-bit string.

A4 9B 24 46 A0 2C 64 5B F4 19 F9 95 B6 70 91 25 3A 04 A2 59

**B.4.11 Example 11**

In this example, the data string is the 32-byte string consisting of the ASCII-coded version of

“abcdefghijklmnopqrstuvwxyz”

The hash-code is the following 160-bit string.

37 BC 52 21 AD E3 BC 09 CA D1 5E 47 84 F3 C7 05 14 54 B1 B3

**B.5 Dedicated Hash-Function 4 (SHA-256)****B.5.1 Example 1**

In this example, the data string is the empty string, i.e., the string of length zero.

The hash-code is the following 256-bit string.

E3B0C442 98FC1C14 9AFBF4C8 996FB924 27AE41E4 649B934C A495991B 7852B855

**B.5.2 Example 2**

In this example, the data string consists of a single byte, namely the ASCII-coded version of the letter “a”.

The hash-code is the following 256-bit string.

CA978112 CA1BB9CA FAC231B3 9A23DC4D A786EFF8 147C4E72 B9807785 AFEE48BB

**B.5.3 Example 3**

In this example, the data string is the 3-byte string consisting of the ASCII-coded version of “abc”. This is equivalent to the bit string “01100001 01100010 01100011”.

After the padding process, the single 16-word block derived from the data string is as follows.

61626380 00000000 00000000 00000000 00000000 00000000 00000000 00000000  
00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000018

The following are (hexadecimal representations of) the successive values of the variables  $X_0$ ,  $X_1$ ,  $X_2$ ,  $X_3$ ,  $X_4$ ,  $X_5$ ,  $X_6$  and  $X_7$ .

INIT: 6A09E667 BB67AE85 3C6EF372 A54FF53A 510E527F 9B05688C 1F83D9AB 5BE0CD19  
0 5D6AEBCD 6A09E667 BB67AE85 3C6EF372 FA2A4622 510E527F 9B05688C 1F83D9AB  
1 5A6AD9AD 5D6AEBCD 6A09E667 BB67AE85 78CE7989 FA2A4622 510E527F 9B05688C  
2 C8C347A7 5A6AD9AD 5D6AEBCD 6A09E667 F92939EB 78CE7989 FA2A4622 510E527F  
3 D550F666 C8C347A7 5A6AD9AD 5D6AEBCD 24E00850 F92939EB 78CE7989 FA2A4622

4 04409A6A D550F666 C8C347A7 5A6AD9AD 43ADA245 24E00850 F92939EB 78CE7989  
 5 2B4209F5 04409A6A D550F666 C8C347A7 714260AD 43ADA245 24E00850 F92939EB  
 6 E5030380 2B4209F5 04409A6A D550F666 9B27A401 714260AD 43ADA245 24E00850  
 7 85A07B5F E5030380 2B4209F5 04409A6A 0C657A79 9B27A401 714260AD 43ADA245  
 8 8E04ECB9 85A07B5F E5030380 2B4209F5 32CA2D8C 0C657A79 9B27A401 714260AD  
 9 8C87346B 8E04ECB9 85A07B5F E5030380 1CC92596 32CA2D8C 0C657A79 9B27A401  
 10 4798A3F4 8C87346B 8E04ECB9 85A07B5F 436B23E8 1CC92596 32CA2D8C 0C657A79  
 11 F71FC5A9 4798A3F4 8C87346B 8E04ECB9 816FD6E9 436B23E8 1CC92596 32CA2D8C  
 12 87912990 F71FC5A9 4798A3F4 8C87346B 1E578218 816FD6E9 436B23E8 1CC92596  
 13 D932EB16 87912990 F71FC5A9 4798A3F4 745A48DE 1E578218 816FD6E9 436B23E8  
 14 C0645FDE D932EB16 87912990 F71FC5A9 0B92F20C 745A48DE 1E578218 816FD6E9  
 15 B0FA238E C0645FDE D932EB16 87912990 07590DCD 0B92F20C 745A48DE 1E578218  
 16 21DA9A9B B0FA238E C0645FDE D932EB16 8034229C 07590DCD 0B92F20C 745A48DE  
 17 C2FBD9D1 21DA9A9B B0FA238E C0645FDE 846EE454 8034229C 07590DCD 0B92F20C  
 18 FE777BBF C2FBD9D1 21DA9A9B B0FA238E CC899961 846EE454 8034229C 07590DCD  
 19 E1F20C33 FE777BBF C2FBD9D1 21DA9A9B B0638179 CC899961 846EE454 8034229C  
 20 9DC68B63 E1F20C33 FE777BBF C2FBD9D1 8ADA8930 B0638179 CC899961 846EE454  
 21 C2606D6D 9DC68B63 E1F20C33 FE777BBF E1257970 8ADA8930 B0638179 CC899961  
 22 A7A3623F C2606D6D 9DC68B63 E1F20C33 49F5114A E1257970 8ADA8930 B0638179  
 23 C5D53D8D A7A3623F C2606D6D 9DC68B63 AA47C347 49F5114A E1257970 8ADA8930  
 24 1C2C2838 C5D53D8D A7A3623F C2606D6D 2823EF91 AA47C347 49F5114A E1257970  
 25 CDE8037D 1C2C2838 C5D53D8D A7A3623F 14383D8E 2823EF91 AA47C347 49F5114A  
 26 B62EC4BC CDE8037D 1C2C2838 C5D53D8D C74C6516 14383D8E 2823EF91 AA47C347  
 27 77D37528 B62EC4BC CDE8037D 1C2C2838 EDFFBFF8 C74C6516 14383D8E 2823EF91  
 28 363482C9 77D37528 B62EC4BC CDE8037D 6112A3B7 EDFFBFF8 C74C6516 14383D8E  
 29 A0060B30 363482C9 77D37528 B62EC4BC ADE79437 6112A3B7 EDFFBFF8 C74C6516  
 30 EA992A22 A0060B30 363482C9 77D37528 0109AB3A ADE79437 6112A3B7 EDFFBFF8  
 31 73B33BF5 EA992A22 A0060B30 363482C9 BA591112 0109AB3A ADE79437 6112A3B7  
 32 98E12507 73B33BF5 EA992A22 A0060B30 9CD9F5F6 BA591112 0109AB3A ADE79437  
 33 FE604DF5 98E12507 73B33BF5 EA992A22 59249DD3 9CD9F5F6 BA591112 0109AB3A  
 34 A9A7738C FE604DF5 98E12507 73B33BF5 085F3833 59249DD3 9CD9F5F6 BA591112  
 35 65A0CFE4 A9A7738C FE604DF5 98E12507 F4B002D6 085F3833 59249DD3 9CD9F5F6  
 36 41A65CB1 65A0CFE4 A9A7738C FE604DF5 0772A26B F4B002D6 085F3833 59249DD3  
 37 34DF1604 41A65CB1 65A0CFE4 A9A7738C A507A53D 0772A26B F4B002D6 085F3833  
 38 6DC57A8A 34DF1604 41A65CB1 65A0CFE4 F0781BC8 A507A53D 0772A26B F4B002D6  
 39 79EA687A 6DC57A8A 34DF1604 41A65CB1 1EFBC0A0 F0781BC8 A507A53D 0772A26B  
 40 D6670766 79EA687A 6DC57A8A 34DF1604 26352D63 1EFBC0A0 F0781BC8 A507A53D  
 41 DF46652F D6670766 79EA687A 6DC57A8A 838B2711 26352D63 1EFBC0A0 F0781BC8  
 42 17AA0DFE DF46652F D6670766 79EA687A DECD4715 838B2711 26352D63 1EFBC0A0  
 43 9D4BAF93 17AA0DFE DF46652F D6670766 FDA24C2E DECD4715 838B2711 26352D63  
 44 26628815 9D4BAF93 17AA0DFE DF46652F A80F11F0 FDA24C2E DECD4715 838B2711  
 45 72AB4B91 26628815 9D4BAF93 17AA0DFE B7755DA1 A80F11F0 FDA24C2E DECD4715  
 46 A14C14B0 72AB4B91 26628815 9D4BAF93 D57B94A9 B7755DA1 A80F11F0 FDA24C2E  
 47 4172328D A14C14B0 72AB4B91 26628815 FECF0BC6 D57B94A9 B7755DA1 A80F11F0  
 48 05757CEB 4172328D A14C14B0 72AB4B91 BD714038 FECF0BC6 D57B94A9 B7755DA1  
 49 F11BFAA8 05757CEB 4172328D A14C14B0 6E5C390C BD714038 FECF0BC6 D57B94A9  
 50 7A0508A1 F11BFAA8 05757CEB 4172328D 52F1CCF7 6E5C390C BD714038 FECF0BC6  
 51 886E7A22 7A0508A1 F11BFAA8 05757CEB 49231C1E 52F1CCF7 6E5C390C BD714038

52 101FD28F 886E7A22 7A0508A1 F11BF8A8 529E7D00 49231C1E 52F1CCF7 6E5C390C  
 53 F5702FDB 101FD28F 886E7A22 7A0508A1 9F4787C3 529E7D00 49231C1E 52F1CCF7  
 54 3EC45CDB F5702FDB 101FD28F 886E7A22 E50E1B4F 9F4787C3 529E7D00 49231C1E  
 55 38CC9913 3EC45CDB F5702FDB 101FD28F 54CB266B E50E1B4F 9F4787C3 529E7D00  
 56 FCD1887B 38CC9913 3EC45CDB F5702FDB 9B5E906C 54CB266B E50E1B4F 9F4787C3  
 57 C062D46F FCD1887B 38CC9913 3EC45CDB 7E44008E 9B5E906C 54CB266B E50E1B4F  
 58 FFB70472 C062D46F FCD1887B 38CC9913 6D83BFC6 7E44008E 9B5E906C 54CB266B  
 59 B6AE8FFF FFB70472 C062D46F FCD1887B B21BAD3D 6D83BFC6 7E44008E 9B5E906C  
 60 B85E2CE9 B6AE8FFF FFB70472 C062D46F 961F4894 B21BAD3D 6D83BFC6 7E44008E  
 61 04D24D6C B85E2CE9 B6AE8FFF FFB70472 948D25B6 961F4894 B21BAD3D 6D83BFC6  
 62 D39A2165 04D24D6C B85E2CE9 B6AE8FFF FB121210 948D25B6 961F4894 B21BAD3D  
 63 506E3058 D39A2165 04D24D6C B85E2CE9 5EF50F24 FB121210 948D25B6 961F4894

The following eight words,  $Y_0$ ,  $Y_1$ ,  $Y_2$ ,  $Y_3$ ,  $Y_4$ ,  $Y_5$ ,  $Y_6$  and  $Y_7$ , represent the output of the final iteration of the round-function.

$Y_0 = 6A09E667 \cup 506E3058 = BA7816BF$   
 $Y_1 = BB67AE85 \cup D39A2165 = 8F01CFEA$   
 $Y_2 = 3C6EF372 \cup 04D24D6C = 414140DE$   
 $Y_3 = A54FF53A \cup B85E2CE9 = 5DAE2223$   
 $Y_4 = 510E527F \cup 5EF50F24 = B00361A3$   
 $Y_5 = 9B05688C \cup FB121210 = 96177A9C$   
 $Y_6 = 1F83D9AB \cup 948D25B6 = B410FF61$   
 $Y_7 = 5BE0CD19 \cup 961F4894 = F20015AD$

The hash value is the following 256-bit string.

BA7816BF 8F01CFEA 414140DE 5DAE2223 B00361A3 96177A9C B410FF61 F20015AD

#### B.5.4 Example 4

In this example, the data string is the 14-byte string consisting of the ASCII-coded version of

“message digest”

The hash value is the following 256-bit string.

F7846F55 CF23E14E EBEAB5B4 E1550CAD 5B509E33 48FBC4EF A3A1413D 393CB650

#### B.5.5 Example 5

In this example, the data string is the 26-byte string consisting of the ASCII-coded version of

“abcdefghijklmnopqrstuvwxyz”

The hash value is the following 256-bit string.

71C480DF 93D6AE2F 1EFAD144 7C66C952 5E316218 CF51FC8D 9ED832F2 DAF18B73

#### B.5.6 Example 6

In this example, the data string is the 62-byte string consisting of the ASCII-coded version of

“ABCDEFGHIJKLMNOPQRSTUVWXYZabcdefghijklmnopqrstuvwxyz0123456789”

The hash value is the following 256-bit string.

DB4BFCBD 4DA0CD85 A60C3C37 D3FBD880 5C77F15F C6B1FDFF 614EE0A7 C8FDB4C0

### B.5.7 Example 7

In this example, the data string is the 80-byte string consisting of the ASCII-coded version of eight repetitions of

“1234567890”

The hash-code is the following 256-bit string.

F371BC4A 311F2B00 9EEF952D D83CA80E 2B60026C 8E935592 D0F9C308 453C813E

### B.5.8 Example 8

In this example, the data string is the 56-byte string consisting of the ASCII-coded version of

“abcdbcdecdefdefgefghfghighijhijkijklklmklmnlmnomnopnopq”

After the padding process, the following two 16-word blocks are derived from the data string.

61626364 62636465 63646566 64656667 65666768 66676869 6768696A 68696A6B  
696A6B6C 6A6B6C6D 6B6C6D6E 6C6D6E6F 6D6E6F70 6E6F7071 80000000 00000000  
  
00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000  
00000000 00000000 00000000 00000000 00000000 00000000 00000000 000001C0

The following are (hexadecimal representations of) the successive values of the variables  $X_0$ ,  $X_1$ ,  $X_2$ ,  $X_3$ ,  $X_4$ ,  $X_5$ ,  $X_6$  and  $X_7$  in the first block process.

INIT: 6A09E667 BB67AE85 3C6EF372 A54FF53A 510E527F 9B05688C 1F83D9AB 5BE0CD19  
0 5D6AEBB1 6A09E667 BB67AE85 3C6EF372 FA2A4606 510E527F 9B05688C 1F83D9AB  
1 2F2D5FCF 5D6AEBB1 6A09E667 BB67AE85 4EB1CFCE FA2A4606 510E527F 9B05688C  
2 97651825 2F2D5FCF 5D6AEBB1 6A09E667 62D5C49E 4EB1CFCE FA2A4606 510E527F  
3 4A8D64D5 97651825 2F2D5FCF 5D6AEBB1 6494841B 62D5C49E 4EB1CFCE FA2A4606  
4 F921C212 4A8D64D5 97651825 2F2D5FCF 05C4F88A 6494841B 62D5C49E 4EB1CFCE  
5 55C8EF48 F921C212 4A8D64D5 97651825 7FF91C94 05C4F88A 6494841B 62D5C49E  
6 485835B7 55C8EF48 F921C212 4A8D64D5 39A5B2CA 7FF91C94 05C4F88A 6494841B  
7 D237E6DB 485835B7 55C8EF48 F921C212 A401D211 39A5B2CA 7FF91C94 05C4F88A  
8 359F2BCE D237E6DB 485835B7 55C8EF48 C09FFEC4 A401D211 39A5B2CA 7FF91C94  
9 3A474B2B 359F2BCE D237E6DB 485835B7 9037B3B8 C09FFEC4 A401D211 39A5B2CA  
10 B8E2B4CB 3A474B2B 359F2BCE D237E6DB 443ED29E 9037B3B8 C09FFEC4 A401D211  
11 1762215C B8E2B4CB 3A474B2B 359F2BCE EE1C97A8 443ED29E 9037B3B8 C09FFEC4  
12 101A4861 1762215C B8E2B4CB 3A474B2B 839A0FC9 EE1C97A8 443ED29E 9037B3B8  
13 D68E6457 101A4861 1762215C B8E2B4CB 9243F8AF 839A0FC9 EE1C97A8 443ED29E  
14 DD16CBB3 D68E6457 101A4861 1762215C 9162ADED 9243F8AF 839A0FC9 EE1C97A8  
15 C3486194 DD16CBB3 D68E6457 101A4861 1496A54F 9162ADED 9243F8AF 839A0FC9  
16 B9DCACB1 C3486194 DD16CBB3 D68E6457 D4F64250 1496A54F 9162ADED 9243F8AF  
17 046A193E B9DCACB1 C3486194 DD16CBB3 885370B6 D4F64250 1496A54F 9162ADED  
18 F402F058 046A193E B9DCACB1 C3486194 6F433549 885370B6 D4F64250 1496A54F  
19 2139187B F402F058 046A193E B9DCACB1 7C304206 6F433549 885370B6 D4F64250  
20 D70AC17D 2139187B F402F058 046A193E 7CC6B262 7C304206 6F433549 885370B6  
21 1B2B66B8 D70AC17D 2139187B F402F058 D560B028 7CC6B262 7C304206 6F433549  
22 AE2E2D4F 1B2B66B8 D70AC17D 2139187B F074FC95 D560B028 7CC6B262 7C304206  
23 59FCE6B9 AE2E2D4F 1B2B66B8 D70AC17D A2C7D51D F074FC95 D560B028 7CC6B262

24 4A885065 59FCE6B9 AE2E2D4F 1B2B66B8 763597FB A2C7D51D F074FC95 D560B028  
 25 573221DA 4A885065 59FCE6B9 AE2E2D4F 36E74EB4 763597FB A2C7D51D F074FC95  
 26 128661DA 573221DA 4A885065 59FCE6B9 1162D575 36E74EB4 763597FB A2C7D51D  
 27 73F858AF 128661DA 573221DA 4A885065 E77C797F 1162D575 36E74EB4 763597FB  
 28 74BCF468 73F858AF 128661DA 573221DA 72ABAECD E77C797F 1162D575 36E74EB4  
 29 DF7151A0 74BCF468 73F858AF 128661DA 7629C961 72ABAECD E77C797F 1162D575  
 30 EB43F3ED DF7151A0 74BCF468 73F858AF 0635D880 7629C961 72ABAECD E77C797F  
 31 5581AB07 EB43F3ED DF7151A0 74BCF468 DF980085 0635D880 7629C961 72ABAECD  
 32 9FC905C8 5581AB07 EB43F3ED DF7151A0 A94D2AF1 DF980085 0635D880 7629C961  
 33 9CE5A62F 9FC905C8 5581AB07 EB43F3ED 6EF3B6BD A94D2AF1 DF980085 0635D880  
 34 1DF8E885 9CE5A62F 9FC905C8 5581AB07 2A9E048E 6EF3B6BD A94D2AF1 DF980085  
 35 0786DCE8 1DF8E885 9CE5A62F 9FC905C8 DE2A21D1 2A9E048E 6EF3B6BD A94D2AF1  
 36 2C55D3A6 0786DCE8 1DF8E885 9CE5A62F B067C1AF DE2A21D1 2A9E048E 6EF3B6BD  
 37 A985B4BE 2C55D3A6 0786DCE8 1DF8E885 F72BF353 B067C1AF DE2A21D1 2A9E048E  
 38 91AC9D5D A985B4BE 2C55D3A6 0786DCE8 68D8D590 F72BF353 B067C1AF DE2A21D1  
 39 7E4D30B8 91AC9D5D A985B4BE 2C55D3A6 9F5B9B6D 68D8D590 F72BF353 B067C1AF  
 40 7E056794 7E4D30B8 91AC9D5D A985B4BE 423B26C0 9F5B9B6D 68D8D590 F72BF353  
 41 508A16AB 7E056794 7E4D30B8 91AC9D5D 45459D97 423B26C0 9F5B9B6D 68D8D590  
 42 B62C7013 508A16AB 7E056794 7E4D30B8 80A92A00 45459D97 423B26C0 9F5B9B6D  
 43 167361DE B62C7013 508A16AB 7E056794 41DD3844 80A92A00 45459D97 423B26C0  
 44 DE71E2F2 167361DE B62C7013 508A16AB FF61C636 41DD3844 80A92A00 45459D97  
 45 18F0D19D DE71E2F2 167361DE B62C7013 6B88472C FF61C636 41DD3844 80A92A00  
 46 165BE9CD 18F0D19D DE71E2F2 167361DE A483F080 6B88472C FF61C636 41DD3844  
 47 13D82741 165BE9CD 18F0D19D DE71E2F2 A7802A4D A483F080 6B88472C FF61C636  
 48 017B9D99 13D82741 165BE9CD 18F0D19D AEB10B60 A7802A4D A483F080 6B88472C  
 49 543C99A1 017B9D99 13D82741 165BE9CD 16F134B6 AEB10B60 A7802A4D A483F080  
 50 758CA97A 543C99A1 017B9D99 13D82741 100CF2EA 16F134B6 AEB10B60 A7802A4D  
 51 81C1CDE0 758CA97A 543C99A1 017B9D99 5C47EB7B 100CF2EA 16F134B6 AEB10B60  
 52 B8D55619 81C1CDE0 758CA97A 543C99A1 1C806A61 5C47EB7B 100CF2EA 16F134B6  
 53 1D6DE87A B8D55619 81C1CDE0 758CA97A 3443BED4 1C806A61 5C47EB7B 100CF2EA  
 54 F907B313 1D6DE87A B8D55619 81C1CDE0 61A41711 3443BED4 1C806A61 5C47EB7B  
 55 9E57C4A0 F907B313 1D6DE87A B8D55619 EEC13548 61A41711 3443BED4 1C806A61  
 56 71629856 9E57C4A0 F907B313 1D6DE87A 2F6C8C4E EEC13548 61A41711 3443BED4  
 57 7C015A2C 71629856 9E57C4A0 F907B313 CB9D3DD0 2F6C8C4E EEC13548 61A41711  
 58 921FCCB6 7C015A2C 71629856 9E57C4A0 43D8A034 CB9D3DD0 2F6C8C4E EEC13548  
 59 E18F259A 921FCCB6 7C015A2C 71629856 51E15869 43D8A034 CB9D3DD0 2F6C8C4E  
 60 BCFCE922 E18F259A 921FCCB6 7C015A2C 962D8621 51E15869 43D8A034 CB9D3DD0  
 61 F6F443F8 BCFCE922 E18F259A 921FCCB6 ACC75916 962D8621 51E15869 43D8A034  
 62 86126910 F6F443F8 BCFCE922 E18F259A 2FC08F85 ACC75916 962D8621 51E15869  
 63 1BDC6F6F 86126910 F6F443F8 BCFCE922 25D2430A 2FC08F85 ACC75916 962D8621

The following eight words,  $Y_0$ ,  $Y_1$ ,  $Y_2$ ,  $Y_3$ ,  $Y_4$ ,  $Y_5$ ,  $Y_6$  and  $Y_7$ , represent the output of the round-function in the first block process.

$Y_0 = 6A09E667 \cup 1BDC6F6F = 85E655D6$   
 $Y_1 = BB67AE85 \cup 86126910 = 417A1795$   
 $Y_2 = 3C6EF372 \cup F6F443F8 = 3363376A$   
 $Y_3 = A54FF53A \cup BCFCE922 = 624CDE5C$   
 $Y_4 = 510E527F \cup 25D2430A = 76E09589$   
 $Y_5 = 9B05688C \cup 2FC08F85 = CAC5F811$   
 $Y_6 = 1F83D9AB \cup ACC75916 = CC4B32C1$   
 $Y_7 = 5BE0CD19 \cup 962D8621 = F20E533A$

The following are (hexadecimal representations of) the successive values of the variables  $Y_0$ ,  $Y_1$ ,  $Y_2$ ,  $Y_3$ ,  $Y_4$ ,  $Y_5$ ,  $Y_6$  and  $Y_7$  in the second block process.

INIT: 85E655D6 417A1795 3363376A 624CDE5C 76E09589 CAC5F811 CC4B32C1 F20E533A

|    |          |          |          |          |          |          |          |          |
|----|----------|----------|----------|----------|----------|----------|----------|----------|
| 0  | 7C20C838 | 85E655D6 | 417A1795 | 3363376A | 4670AE6E | 76E09589 | CAC5F811 | CC4B32C1 |
| 1  | 7C3C0F86 | 7C20C838 | 85E655D6 | 417A1795 | 8C51BE64 | 4670AE6E | 76E09589 | CAC5F811 |
| 2  | FD1EEBDC | 7C3C0F86 | 7C20C838 | 85E655D6 | AF71B9EA | 8C51BE64 | 4670AE6E | 76E09589 |
| 3  | F268FAA9 | FD1EEBDC | 7C3C0F86 | 7C20C838 | E20362EF | AF71B9EA | 8C51BE64 | 4670AE6E |
| 4  | 185A5D79 | F268FAA9 | FD1EEBDC | 7C3C0F86 | 8DFF3001 | E20362EF | AF71B9EA | 8C51BE64 |
| 5  | 3EEB6C06 | 185A5D79 | F268FAA9 | FD1EEBDC | FE20CDA6 | 8DFF3001 | E20362EF | AF71B9EA |
| 6  | 89BBA3F1 | 3EEB6C06 | 185A5D79 | F268FAA9 | 0A34DF03 | FE20CDA6 | 8DFF3001 | E20362EF |
| 7  | BF9A93A0 | 89BBA3F1 | 3EEB6C06 | 185A5D79 | 059ABDD1 | 0A34DF03 | FE20CDA6 | 8DFF3001 |
| 8  | 2C096744 | BF9A93A0 | 89BBA3F1 | 3EEB6C06 | ABFA465B | 059ABDD1 | 0A34DF03 | FE20CDA6 |
| 9  | 2D964E86 | 2C096744 | BF9A93A0 | 89BBA3F1 | AA27ED82 | ABFA465B | 059ABDD1 | 0A34DF03 |
| 10 | 5B35025B | 2D964E86 | 2C096744 | BF9A93A0 | 10E77723 | AA27ED82 | ABFA465B | 059ABDD1 |
| 11 | 5EB4EC40 | 5B35025B | 2D964E86 | 2C096744 | E11B4548 | 10E77723 | AA27ED82 | ABFA465B |
| 12 | 35EE996D | 5EB4EC40 | 5B35025B | 2D964E86 | 5C24E2A2 | E11B4548 | 10E77723 | AA27ED82 |
| 13 | D74080FA | 35EE996D | 5EB4EC40 | 5B35025B | 68AA893F | 5C24E2A2 | E11B4548 | 10E77723 |
| 14 | 0CEA5CBC | D74080FA | 35EE996D | 5EB4EC40 | 60356548 | 68AA893F | 5C24E2A2 | E11B4548 |
| 15 | 16A8CC79 | 0CEA5CBC | D74080FA | 35EE996D | 0FCB1F6F | 60356548 | 68AA893F | 5C24E2A2 |
| 16 | F16F634E | 16A8CC79 | 0CEA5CBC | D74080FA | 8B21CDC1 | 0FCB1F6F | 60356548 | 68AA893F |
| 17 | 23DCB6C2 | F16F634E | 16A8CC79 | 0CEA5CBC | CA9182D3 | 8B21CDC1 | 0FCB1F6F | 60356548 |
| 18 | DCFF40FD | 23DCB6C2 | F16F634E | 16A8CC79 | 69BF7B95 | CA9182D3 | 8B21CDC1 | 0FCB1F6F |
| 19 | 76F1A2BC | DCFF40FD | 23DCB6C2 | F16F634E | 0DC84BB1 | 69BF7B95 | CA9182D3 | 8B21CDC1 |
| 20 | 20AAD899 | 76F1A2BC | DCFF40FD | 23DCB6C2 | CC4769F2 | 0DC84BB1 | 69BF7B95 | CA9182D3 |
| 21 | D44DC81A | 20AAD899 | 76F1A2BC | DCFF40FD | 5BACE62D | CC4769F2 | 0DC84BB1 | 69BF7B95 |
| 22 | F13AE55B | D44DC81A | 20AAD899 | 76F1A2BC | 966AA287 | 5BACE62D | CC4769F2 | 0DC84BB1 |
| 23 | A4195B91 | F13AE55B | D44DC81A | 20AAD899 | EDDBD6ED | 966AA287 | 5BACE62D | CC4769F2 |
| 24 | 4984FA79 | A4195B91 | F13AE55B | D44DC81A | A530D939 | EDDBD6ED | 966AA287 | 5BACE62D |
| 25 | AA6CB982 | 4984FA79 | A4195B91 | F13AE55B | 0B5EEEE4 | A530D939 | EDDBD6ED | 966AA287 |
| 26 | 9450FBBC | AA6CB982 | 4984FA79 | A4195B91 | 09166DDA | 0B5EEEE4 | A530D939 | EDDBD6ED |
| 27 | 0D936BAB | 9450FBBC | AA6CB982 | 4984FA79 | 6E495D4B | 09166DDA | 0B5EEEE4 | A530D939 |
| 28 | D958B529 | 0D936BAB | 9450FBBC | AA6CB982 | C2FA99B1 | 6E495D4B | 09166DDA | 0B5EEEE4 |
| 29 | 1CFA5EB0 | D958B529 | 0D936BAB | 9450FBBC | 6C49DB9F | C2FA99B1 | 6E495D4B | 09166DDA |
| 30 | 02EF3A5F | 1CFA5EB0 | D958B529 | 0D936BAB | 5DA10665 | 6C49DB9F | C2FA99B1 | 6E495D4B |
| 31 | B0EAB1C5 | 02EF3A5F | 1CFA5EB0 | D958B529 | F6D93952 | 5DA10665 | 6C49DB9F | C2FA99B1 |
| 32 | 0BFBA73C | B0EAB1C5 | 02EF3A5F | 1CFA5EB0 | 8B99E3A9 | F6D93952 | 5DA10665 | 6C49DB9F |
| 33 | 4BD1DF96 | 0BFBA73C | B0EAB1C5 | 02EF3A5F | 905E44AC | 8B99E3A9 | F6D93952 | 5DA10665 |
| 34 | 9907F1B6 | 4BD1DF96 | 0BFBA73C | B0EAB1C5 | 66C3043D | 905E44AC | 8B99E3A9 | F6D93952 |
| 35 | ECDE4E0D | 9907F1B6 | 4BD1DF96 | 0BFBA73C | 5DC119E6 | 66C3043D | 905E44AC | 8B99E3A9 |



36 2F11C939 ECDE4E0D 9907F1B6 4BD1DF96 FED4CE1D 5DC119E6 66C3043D 905E44AC  
 37 D949682B 2F11C939 ECDE4E0D 9907F1B6 32D99008 FED4CE1D 5DC119E6 66C3043D  
 38 ADCA7A96 D949682B 2F11C939 ECDE4E0D C6CCE4FF 32D99008 FED4CE1D 5DC119E6  
 39 221B8A5A ADCA7A96 D949682B 2F11C939 0B82C5EB C6CCE4FF 32D99008 FED4CE1D  
 40 12D97845 221B8A5A ADCA7A96 D949682B E4213CA2 0B82C5EB C6CCE4FF 32D99008  
 41 2C794876 12D97845 221B8A5A ADCA7A96 FF6759BA E4213CA2 0B82C5EB C6CCE4FF  
 42 8300FCA2 2C794876 12D97845 221B8A5A E0E3457C FF6759BA E4213CA2 0B82C5EB  
 43 F2AD6322 8300FCA2 2C794876 12D97845 CC48C7F3 E0E3457C FF6759BA E4213CA2  
 44 0F154E11 F2AD6322 8300FCA2 2C794876 6F9517CB CC48C7F3 E0E3457C FF6759BA  
 45 104A7DB4 0F154E11 F2AD6322 8300FCA2 5348E8F6 6F9517CB CC48C7F3 E0E3457C  
 46 0B3303A7 104A7DB4 0F154E11 F2AD6322 BBE1C39A 5348E8F6 6F9517CB CC48C7F3  
 47 D7354D5B 0B3303A7 104A7DB4 0F154E11 AAD55B6B BBE1C39A 5348E8F6 6F9517CB  
 48 B736D7A6 D7354D5B 0B3303A7 104A7DB4 68F25260 AAD55B6B BBE1C39A 5348E8F6  
 49 2748E5EC B736D7A6 D7354D5B 0B3303A7 D4B58576 68F25260 AAD55B6B BBE1C39A  
 50 D8AABCF9 2748E5EC B736D7A6 D7354D5B 27844711 D4B58576 68F25260 AAD55B6B  
 51 1A6BCF6A D8AABCF9 2748E5EC B736D7A6 FF5E99D0 27844711 D4B58576 68F25260  
 52 4ECA6FA0 1A6BCF6A D8AABCF9 2748E5EC 989ED071 FF5E99D0 27844711 D4B58576  
 53 EC02560A 4ECA6FA0 1A6BCF6A D8AABCF9 7151DF8E 989ED071 FF5E99D0 27844711  
 54 D9F0C115 EC02560A 4ECA6FA0 1A6BCF6A 624150C4 7151DF8E 989ED071 FF5E99D0  
 55 92952710 D9F0C115 EC02560A 4ECA6FA0 226806D6 624150C4 7151DF8E 989ED071  
 56 20D4D0E4 92952710 D9F0C115 EC02560A 4E515A4D 226806D6 624150C4 7151DF8E  
 57 4348EB1F 20D4D0E4 92952710 D9F0C115 C21EDDF9 4E515A4D 226806D6 624150C4  
 58 286FE5F0 4348EB1F 20D4D0E4 92952710 54076664 C21EDDF9 4E515A4D 226806D6  
 59 1C4CDD9 286FE5F0 4348EB1F 20D4D0E4 F487A853 54076664 C21EDDF9 4E515A4D  
 60 A9F181DD 1C4CDD9 286FE5F0 4348EB1F 27CCB387 F487A853 54076664 C21EDDF9  
 61 B25CEF29 A9F181DD 1C4CDD9 286FE5F0 2AA1BB13 27CCB387 F487A853 54076664  
 62 908C2123 B25CEF29 A9F181DD 1C4CDD9 9A392956 2AA1BB13 27CCB387 F487A853  
 63 9EA7148B 908C2123 B25CEF29 A9F181DD 2C5C4ED0 9A392956 2AA1BB13 27CCB387

The following eight words,  $Y_0$ ,  $Y_1$ ,  $Y_2$ ,  $Y_3$ ,  $Y_4$ ,  $Y_5$ ,  $Y_6$  and  $Y_7$ , represent the output of the final iteration of the round-function.

$Y_0 = 85E655D6 \oplus 9EA7148B = 248D6A61$   
 $Y_1 = 417A1795 \oplus 908C2123 = D20638B8$   
 $Y_2 = 3363376A \oplus B25CEF29 = E5C02693$   
 $Y_3 = 624CDE5C \oplus A9F181DD = 0C3E6039$   
 $Y_4 = 76E09589 \oplus 2C5C4ED0 = A33CE459$   
 $Y_5 = CAC5F811 \oplus 9A392956 = 64FF2167$   
 $Y_6 = CC4B32C1 \oplus 2AA1BB13 = F6ECEDD4$   
 $Y_7 = F20E533A \oplus 27CCB387 = 19DB06C1$

The hash value for this message is

248D6A61 D20638B8 E5C02693 0C3E6039 A33CE459 64FF2167 F6ECEDD4 19DB06C1

### B.5.9 Example 9

In this example, the data string is the 1 000 000-byte string consisting of the ASCII-coded version of “a” repeated  $10^6$  times.

The hash-code is the following 256-bit string.

CDC76E5C 9914FB92 81A1C7E2 84D73E67 F1809A48 A497200E 046D39CC C7112CD0



**B.5.10 Example 10**

In this example, the data string is the 112-byte string consisting of the ASCII-coded version of

“abcdefghijklmnopqrstuvwxyz  
hijklmnopqrstuvwxyz”

(with no line break after the first n).

The hash-code is the following 256-bit string.

CF5B16A7 78AF8380 036CE59E 7B049237 0B249B11 E8F07A51 AFAC4503 7AFEE9D1

**B.5.11 Example 11**

In this example, the data string is the 32-byte string consisting of the ASCII-coded version of

“abcdefghijklmnopqrstuvwxyz”

The hash-code is the following 256-bit string.

B09CBD26 3B043F00 0C5BEFCA A40BC2F5 5A4785E0 24E5DBE7 49B56061 EAFB65E9

**B.6 Dedicated Hash-Function 5 (SHA-512)****B.6.1 Example 1**

In this example, the data string is the empty string, i.e. the string of length zero.

The hash-code is the following 512-bit string.

CF83E1357EEFB8BD F1542850D66D8007 D620E4050B5715DC 83F4A921D36CE9CE  
47D0D13C5D85F2B0 FF8318D2877EEC2F 63B931BD47417A81 A538327AF927DA3E

**B.6.2 Example 2**

In this example, the data string consists of a single byte, namely the ASCII-coded version of the letter “a”.

The hash-code is the following 512-bit string.

1F40FC92DA241694 750979EE6CF582F2 D5D7D28E18335DE0 5ABC54D0560E0F53  
02860C652BF08D56 0252AA5E74210546 F369FBBBCE8C12CF C7957B2652FE9A75

**B.6.3 Example 3**

In this example, the data string is the 3-byte string consisting of the ASCII-coded version of “abc”. This is equivalent to the bit string “01100001 01100010 01100011”.

After the padding process, the single 16-word block derived from the data string is as follows.

61626380 00000000 00000000 00000000 00000000 00000000 00000000 00000000  
00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000  
00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000  
00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000018

The following are (hexadecimal representations of) the successive values of the variables  $X_0$ ,  $X_1$ ,  $X_2$ ,  $X_3$ ,  $X_4$ ,  $X_5$ ,  $X_6$  and  $X_7$ .

INIT: 6A09E667F3BCC908 BB67AE8584CAA73B 3C6EF372FE94F82B A54FF53A5F1D36F1  
 510E527FADE682D1 9B05688C2B3E6C1F 1F83D9ABFB41BD6B 5BE0CD19137E2179  
 0 F6AFCEB8BCFCDDF5 6A09E667F3BCC908 BB67AE8584CAA73B 3C6EF372FE94F82B  
 58CB02347AB51F91 510E527FADE682D1 9B05688C2B3E6C1F 1F83D9ABFB41BD6B  
 1 1320F8C9FB872CC0 F6AFCEB8BCFCDDF5 6A09E667F3BCC908 BB67AE8584CAA73B  
 C3D4EBFD48650FFA 58CB02347AB51F91 510E527FADE682D1 9B05688C2B3E6C1F  
 2 EBCFFC07203D91F3 1320F8C9FB872CC0 F6AFCEB8BCFCDDF5 6A09E667F3BCC908  
 DFA9B239F2697812 C3D4EBFD48650FFA 58CB02347AB51F91 510E527FADE682D1  
 3 5A83CB3E80050E82 EBCFFC07203D91F3 1320F8C9FB872CC0 F6AFCEB8BCFCDDF5  
 0B47B4BB1928990E DFA9B239F2697812 C3D4EBFD48650FFA 58CB02347AB51F91  
 4 B680953951604860 5A83CB3E80050E82 EBCFFC07203D91F3 1320F8C9FB872CC0  
 745ACA4A342ED2E2 0B47B4BB1928990E DFA9B239F2697812 C3D4EBFD48650FFA  
 5 AF573B02403E89CD B680953951604860 5A83CB3E80050E82 EBCFFC07203D91F3  
 96F60209B6DC35BA 745ACA4A342ED2E2 0B47B4BB1928990E DFA9B239F2697812  
 6 C4875B0C7ABC076B AF573B02403E89CD B680953951604860 5A83CB3E80050E82  
 5A6C781F54DCC00C 96F60209B6DC35BA 745ACA4A342ED2E2 0B47B4BB1928990E  
 7 8093D195E0054FA3 C4875B0C7ABC076B AF573B02403E89CD B680953951604860  
 86F67263A0F0EC0A 5A6C781F54DCC00C 96F60209B6DC35BA 745ACA4A342ED2E2  
 8 F1ECA5544CB89225 8093D195E0054FA3 C4875B0C7ABC076B AF573B02403E89CD  
 D0403C398FC40002 86F67263A0F0EC0A 5A6C781F54DCC00C 96F60209B6DC35BA  
 9 81782D4A5DB48F03 F1ECA5544CB89225 8093D195E0054FA3 C4875B0C7ABC076B  
 00091F460BE46C52 D0403C398FC40002 86F67263A0F0EC0A 5A6C781F54DCC00C  
 10 69854C4AA0F25B59 81782D4A5DB48F03 F1ECA5544CB89225 8093D195E0054FA3  
 D375471BDE1BA3F4 00091F460BE46C52 D0403C398FC40002 86F67263A0F0EC0A  
 11 DB0A9963F80C2EAA 69854C4AA0F25B59 81782D4A5DB48F03 F1ECA5544CB89225  
 475975B91A7A462C D375471BDE1BA3F4 00091F460BE46C52 D0403C398FC40002  
 12 5E41214388186C14 DB0A9963F80C2EAA 69854C4AA0F25B59 81782D4A5DB48F03  
 CDF3BFF2883FC9D9 475975B91A7A462C D375471BDE1BA3F4 00091F460BE46C52  
 13 44249631255D2CA0 5E41214388186C14 DB0A9963F80C2EAA 69854C4AA0F25B59  
 860ACF9EFFBA6F61 CDF3BFF2883FC9D9 475975B91A7A462C D375471BDE1BA3F4  
 14 FA967EED85A08028 44249631255D2CA0 5E41214388186C14 DB0A9963F80C2EAA  
 874BFE5F6AAE9F2F 860ACF9EFFBA6F61 CDF3BFF2883FC9D9 475975B91A7A462C  
 15 0AE07C86B1181C75 FA967EED85A08028 44249631255D2CA0 5E41214388186C14  
 A77B7C035DD4C161 874BFE5F6AAE9F2F 860ACF9EFFBA6F61 CDF3BFF2883FC9D9  
 16 CAF81A425D800537 0AE07C86B1181C75 FA967EED85A08028 44249631255D2CA0  
 2DEECC6B39D64D78 A77B7C035DD4C161 874BFE5F6AAE9F2F 860ACF9EFFBA6F61  
 17 4725BE249AD19E6B CAF81A425D800537 0AE07C86B1181C75 FA967EED85A08028  
 F47E8353F8047455 2DEECC6B39D64D78 A77B7C035DD4C161 874BFE5F6AAE9F2F  
 18 3C4B4104168E3EDB 4725BE249AD19E6B CAF81A425D800537 0AE07C86B1181C75  
 29695FD88D81DBD0 F47E8353F8047455 2DEECC6B39D64D78 A77B7C035DD4C161  
 19 9A3FB4D38AB6CF06 3C4B4104168E3EDB 4725BE249AD19E6B CAF81A425D800537  
 F14998DD5F70767E 29695FD88D81DBD0 F47E8353F8047455 2DEECC6B39D64D78  
 20 8DC5AE65569D3855 9A3FB4D38AB6CF06 3C4B4104168E3EDB 4725BE249AD19E6B  
 4BB9E66D1145BFDC F14998DD5F70767E 29695FD88D81DBD0 F47E8353F8047455  
 21 DA34D6673D452DCF 8DC5AE65569D3855 9A3FB4D38AB6CF06 3C4B4104168E3EDB  
 8E30FF09AD488753 4BB9E66D1145BFDC F14998DD5F70767E 29695FD88D81DBD0  
 22 3E2644567B709A78 DA34D6673D452DCF 8DC5AE65569D3855 9A3FB4D38AB6CF06

0AC2B11DA8F571C6 8E30FF09AD488753 4BB9E66D1145BFDC F14998DD5F70767E  
 23 4F6877B58FE55484 3E2644567B709A78 DA34D6673D452DCF 8DC5AE65569D3855  
 C66005F87DB55233 0AC2B11DA8F571C6 8E30FF09AD488753 4BB9E66D1145BFDC  
 24 9AFF71163FA3A940 4F6877B58FE55484 3E2644567B709A78 DA34D6673D452DCF  
 D3ECF13769180E6F C66005F87DB55233 0AC2B11DA8F571C6 8E30FF09AD488753  
 25 0BC5F791F8E6816B 9AFF71163FA3A940 4F6877B58FE55484 3E2644567B709A78  
 6DDF1FD7EDCCE336 D3ECF13769180E6F C66005F87DB55233 0AC2B11DA8F571C6  
 26 884C3BC27BC4F941 0BC5F791F8E6816B 9AFF71163FA3A940 4F6877B58FE55484  
 E6E48C9A8E948365 6DDF1FD7EDCCE336 D3ECF13769180E6F C66005F87DB55233  
 27 EAB4A9E5771B8D09 884C3BC27BC4F941 0BC5F791F8E6816B 9AFF71163FA3A940  
 09068A4E255A0DAC E6E48C9A8E948365 6DDF1FD7EDCCE336 D3ECF13769180E6F  
 28 E62349090F47D30A EAB4A9E5771B8D09 884C3BC27BC4F941 0BC5F791F8E6816B  
 0FCDF99710F21584 09068A4E255A0DAC E6E48C9A8E948365 6DDF1FD7EDCCE336  
 29 74BF40F869094C63 E62349090F47D30A EAB4A9E5771B8D09 884C3BC27BC4F941  
 F0AEC2FE1437F085 0FCDF99710F21584 09068A4E255A0DAC E6E48C9A8E948365  
 30 4C4FBBB75F1873A6 74BF40F869094C63 E62349090F47D30A EAB4A9E5771B8D09  
 73E025D91B9EFA3 F0AEC2FE1437F085 0FCDF99710F21584 09068A4E255A0DAC  
 31 FF4D3F1F0D46A736 4C4FBBB75F1873A6 74BF40F869094C63 E62349090F47D30A  
 3CD388E119E8162E 73E025D91B9EFA3 F0AEC2FE1437F085 0FCDF99710F21584  
 32 A0509015CA08C8D4 FF4D3F1F0D46A736 4C4FBBB75F1873A6 74BF40F869094C63  
 E1034573654A106F 3CD388E119E8162E 73E025D91B9EFA3 F0AEC2FE1437F085  
 33 60D4E6995ED91FE6 A0509015CA08C8D4 FF4D3F1F0D46A736 4C4FBBB75F1873A6  
 EFABBD8BF47C041A E1034573654A106F 3CD388E119E8162E 73E025D91B9EFA3  
 34 2C59EC7743632621 60D4E6995ED91FE6 A0509015CA08C8D4 FF4D3F1F0D46A736  
 0FBAE670FA780FD3 EFABBD8BF47C041A E1034573654A106F 3CD388E119E8162E  
 35 1A081AFC59FDBC2C 2C59EC7743632621 60D4E6995ED91FE6 A0509015CA08C8D4  
 F098082F502B44CD 0FBAE670FA780FD3 EFABBD8BF47C041A E1034573654A106F  
 36 88DF85B0BBE77514 1A081AFC59FDBC2C 2C59EC7743632621 60D4E6995ED91FE6  
 8FBFD0162BBF4675 F098082F502B44CD 0FBAE670FA780FD3 EFABBD8BF47C041A  
 37 002BB8E4CD989567 88DF85B0BBE77514 1A081AFC59FDBC2C 2C59EC7743632621  
 66ADCFA249AC7BBD 8FBFD0162BBF4675 F098082F502B44CD 0FBAE670FA780FD3  
 38 B3BB8542B3376DE5 002BB8E4CD989567 88DF85B0BBE77514 1A081AFC59FDBC2C  
 B49596C20FEBA7DE 66ADCFA249AC7BBD 8FBFD0162BBF4675 F098082F502B44CD  
 39 8E01E125B855D225 B3BB8542B3376DE5 002BB8E4CD989567 88DF85B0BBE77514  
 0C710A47BA6A567B B49596C20FEBA7DE 66ADCFA249AC7BBD 8FBFD0162BBF4675  
 40 B01521DD6A6BE12C 8E01E125B855D225 B3BB8542B3376DE5 002BB8E4CD989567  
 169008B3A4BB170B 0C710A47BA6A567B B49596C20FEBA7DE 66ADCFA249AC7BBD  
 41 E96F89DD48CBD851 B01521DD6A6BE12C 8E01E125B855D225 B3BB8542B3376DE5  
 F0996439E7B50CB1 169008B3A4BB170B 0C710A47BA6A567B B49596C20FEBA7DE  
 42 BC05BA8DE5D3C480 E96F89DD48CBD851 B01521DD6A6BE12C 8E01E125B855D225  
 639CB938E14DC190 F0996439E7B50CB1 169008B3A4BB170B 0C710A47BA6A567B  
 43 35D7E7F41DEFBBD5 BC05BA8DE5D3C480 E96F89DD48CBD851 B01521DD6A6BE12C  
 CC5100997F5710F2 639CB938E14DC190 F0996439E7B50CB1 169008B3A4BB170B  
 44 C47C9D5C7EA8A234 35D7E7F41DEFBBD5 BC05BA8DE5D3C480 E96F89DD48CBD851  
 858D832AE0E8911C CC5100997F5710F2 639CB938E14DC190 F0996439E7B50CB1  
 45 021FBADBABAB5AC6 C47C9D5C7EA8A234 35D7E7F41DEFBBD5 BC05BA8DE5D3C480  
 E95C2A57572D64D9 858D832AE0E8911C CC5100997F5710F2 639CB938E14DC190  
 46 F61E672694DE2D67 021FBADBABAB5AC6 C47C9D5C7EA8A234 35D7E7F41DEFBBD5  
 C6BC35740D8DAA9A E95C2A57572D64D9 858D832AE0E8911C CC5100997F5710F2  
 47 6B69FC1BB482FEAC F61E672694DE2D67 021FBADBABAB5AC6 C47C9D5C7EA8A234

35264334C03AC8AD C6BC35740D8DAA9A E95C2A57572D64D9 858D832AE0E8911C  
48 571F323D96B3A047 6B69FC1BB482FEAC F61E672694DE2D67 021FBADBABAB5AC6  
271580ED6C3E5650 35264334C03AC8AD C6BC35740D8DAA9A E95C2A57572D64D9  
49 CA9BD862C5050918 571F323D96B3A047 6B69FC1BB482FEAC F61E672694DE2D67  
DFE091DAB182E645 271580ED6C3E5650 35264334C03AC8AD C6BC35740D8DAA9A  
50 813A43DD2C502043 CA9BD862C5050918 571F323D96B3A047 6B69FC1BB482FEAC  
07A0D8EF821C5E1A DFE091DAB182E645 271580ED6C3E5650 35264334C03AC8AD  
51 D43F83727325DD77 813A43DD2C502043 CA9BD862C5050918 571F323D96B3A047  
483F80A82EAE23E 07A0D8EF821C5E1A DFE091DAB182E645 271580ED6C3E5650  
52 03DF11B32D42E203 D43F83727325DD77 813A43DD2C502043 CA9BD862C5050918  
504F94E40591CFFA 483F80A82EAE23E 07A0D8EF821C5E1A DFE091DAB182E645  
53 D63F68037DDF06AA 03DF11B32D42E203 D43F83727325DD77 813A43DD2C502043  
A6781EFE1AA1CE02 504F94E40591CFFA 483F80A82EAE23E 07A0D8EF821C5E1A  
54 F650857B5BABDA4D D63F68037DDF06AA 03DF11B32D42E203 D43F83727325DD77  
9CCFB31A86DF0F86 A6781EFE1AA1CE02 504F94E40591CFFA 483F80A82EAE23E  
55 63B460E42748817E F650857B5BABDA4D D63F68037DDF06AA 03DF11B32D42E203  
C6B4DD2A9931C509 9CCFB31A86DF0F86 A6781EFE1AA1CE02 504F94E40591CFFA  
56 7A52912943D52B05 63B460E42748817E F650857B5BABDA4D D63F68037DDF06AA  
D2E89BBD91E00BE0 C6B4DD2A9931C509 9CCFB31A86DF0F86 A6781EFE1AA1CE02  
57 4B81C3AEC976EA4B 7A52912943D52B05 63B460E42748817E F650857B5BABDA4D  
70505988124351AC D2E89BBD91E00BE0 C6B4DD2A9931C509 9CCFB31A86DF0F86  
58 581ECB3355DCD9B8 4B81C3AEC976EA4B 7A52912943D52B05 63B460E42748817E  
6A3C9B0F71C8BF36 70505988124351AC D2E89BBD91E00BE0 C6B4DD2A9931C509  
59 2C074484EF1EAC8C 581ECB3355DCD9B8 4B81C3AEC976EA4B 7A52912943D52B05  
4797CDE4ED370692 6A3C9B0F71C8BF36 70505988124351AC D2E89BBD91E00BE0  
60 3857DFD2FC37D3BA 2C074484EF1EAC8C 581ECB3355DCD9B8 4B81C3AEC976EA4B  
A6AF4E9C9F807E51 4797CDE4ED370692 6A3C9B0F71C8BF36 70505988124351AC  
61 CFCD928C5424E2B6 3857DFD2FC37D3BA 2C074484EF1EAC8C 581ECB3355DCD9B8  
09AEE5BDA1644DE5 A6AF4E9C9F807E51 4797CDE4ED370692 6A3C9B0F71C8BF36  
62 A81DEDBB9F19E643 CFCD928C5424E2B6 3857DFD2FC37D3BA 2C074484EF1EAC8C  
84058865D60A05FA 09AEE5BDA1644DE5 A6AF4E9C9F807E51 4797CDE4ED370692  
63 AB44E86276478D85 A81DEDBB9F19E643 CFCD928C5424E2B6 3857DFD2FC37D3BA  
CD881EE59CA6BC53 84058865D60A05FA 09AEE5BDA1644DE5 A6AF4E9C9F807E51  
64 5A806D7E9821A501 AB44E86276478D85 A81DEDBB9F19E643 CFCD928C5424E2B6  
AA84B086688A5C45 CD881EE59CA6BC53 84058865D60A05FA 09AEE5BDA1644DE5  
65 EEB9C21BB0102598 5A806D7E9821A501 AB44E86276478D85 A81DEDBB9F19E643  
3B5FED0D6A1F96E1 AA84B086688A5C45 CD881EE59CA6BC53 84058865D60A05FA  
66 46C4210AB2CC155D EEB9C21BB0102598 5A806D7E9821A501 AB44E86276478D85  
29FAB5A7BFF53366 3B5FED0D6A1F96E1 AA84B086688A5C45 CD881EE59CA6BC53  
67 54BA35CF56A0340E 46C4210AB2CC155D EEB9C21BB0102598 5A806D7E9821A501  
1C66F46D95690BCF 29FAB5A7BFF53366 3B5FED0D6A1F96E1 AA84B086688A5C45  
68 181839D609C79748 54BA35CF56A0340E 46C4210AB2CC155D EEB9C21BB0102598  
0ADA78BA2D446140 1C66F46D95690BCF 29FAB5A7BFF53366 3B5FED0D6A1F96E1  
69 FB6AAAE5D0B6A447 181839D609C79748 54BA35CF56A0340E 46C4210AB2CC155D  
E3711CB6564D112D 0ADA78BA2D446140 1C66F46D95690BCF 29FAB5A7BFF53366  
70 7652C579CB60F19C FB6AAAE5D0B6A447 181839D609C79748 54BA35CF56A0340E  
AFF62C9665FF80FA E3711CB6564D112D 0ADA78BA2D446140 1C66F46D95690BCF  
71 F15E9664B2803575 7652C579CB60F19C FB6AAAE5D0B6A447 181839D609C79748  
947C3DFAFEE570EF AFF62C9665FF80FA E3711CB6564D112D 0ADA78BA2D446140  
72 358406D165AEE9AB F15E9664B2803575 7652C579CB60F19C FB6AAAE5D0B6A447

8C7B5FD91A794CA0 947C3DFAFEE570EF AFF62C9665FF80FA E3711CB6564D112D  
 73 20878DCD29CDFAF5 358406D165AEE9AB F15E9664B2803575 7652C579CB60F19C  
 054D3536539948D0 8C7B5FD91A794CA0 947C3DFAFEE570EF AFF62C9665FF80FA  
 74 33D48DABB5521DE2 20878DCD29CDFAF5 358406D165AEE9AB F15E9664B2803575  
 2BA18245B50DE4CF 054D3536539948D0 8C7B5FD91A794CA0 947C3DFAFEE570EF  
 75 C8960E6BE864B916 33D48DABB5521DE2 20878DCD29CDFAF5 358406D165AEE9AB  
 995019A6FF3BA3DE 2BA18245B50DE4CF 054D3536539948D0 8C7B5FD91A794CA0  
 76 654EF9ABEC389CA9 C8960E6BE864B916 33D48DABB5521DE2 20878DCD29CDFAF5  
 CEB9FC3691CE8326 995019A6FF3BA3DE 2BA18245B50DE4CF 054D3536539948D0  
 77 D67806DB8B148677 654EF9ABEC389CA9 C8960E6BE864B916 33D48DABB5521DE2  
 25C96A7768FB2AA3 CEB9FC3691CE8326 995019A6FF3BA3DE 2BA18245B50DE4CF  
 78 10D9C4C4295599F6 D67806DB8B148677 654EF9ABEC389CA9 C8960E6BE864B916  
 9BB4D39778C07F9E 25C96A7768FB2AA3 CEB9FC3691CE8326 995019A6FF3BA3DE  
 79 73A54F399FA4B1B2 10D9C4C4295599F6 D67806DB8B148677 654EF9ABEC389CA9  
 D08446AA79693ED7 9BB4D39778C07F9E 25C96A7768FB2AA3 CEB9FC3691CE8326

The following eight words,  $Y_0$ ,  $Y_1$ ,  $Y_2$ ,  $Y_3$ ,  $Y_4$ ,  $Y_5$ ,  $Y_6$  and  $Y_7$ , represent the output of the final iteration of the round-function.

$Y_0 = 6A09E667F3BCC908 \cup 73A54F399FA4B1B2 = DDAF35A193617ABA$   
 $Y_1 = BB67AE8584CAA73B \cup 10D9C4C4295599F6 = CC417349AE204131$   
 $Y_2 = 3C6EF372FE94F82B \cup D67806DB8B148677 = 12E6FA4E89A97EA2$   
 $Y_3 = A54FF53A5F1D36F1 \cup 654EF9ABEC389CA9 = 0A9EEEE64B55D39A$   
 $Y_4 = 510E527FADE682D1 \cup D08446AA79693ED7 = 2192992A274FC1A8$   
 $Y_5 = 9B05688C2B3E6C1F \cup 9BB4D39778C07F9E = 36BA3C23A3FEEBBD$   
 $Y_6 = 1F83D9ABFB41BD6B \cup 25C96A7768FB2AA3 = 454D4423643CE80E$   
 $Y_7 = 5BE0CD19137E2179 \cup CEB9FC3691CE8326 = 2A9AC94FA54CA49F$

The hash value is the following 512-bit string.

DDAF35A193617ABA CC417349AE204131 12E6FA4E89A97EA2 0A9EEEE64B55D39A  
 2192992A274FC1A8 36BA3C23A3FEEBBD 454D4423643CE80E 2A9AC94FA54CA49F

#### B.6.4 Example 4

In this example, the data string is the 14-byte string consisting of the ASCII-coded version of

“message digest”

The hash-code is the following 512-bit string.

107DBF389D9E9F71 A3A95F6C055B9251 BC5268C2BE16D6C1 3492EA45B0199F33  
 09E16455AB1E9611 8E8A905D5597B720 38DDB372A8982604 6DE66687BB420E7C

#### B.6.5 Example 5

In this example, the data string is the 26-byte string consisting of the ASCII-coded version of

“abcdefghijklmnopqrstuvwxyz”

The hash-code is the following 512-bit string.

4DBFF86CC2CA1BAE 1E16468A05CB9881 C97F1753BCE36190 34898FAA1AABE429  
 955A1BF8EC483D74 21FE3C1646613A59 ED5441FB0F321389 F77F48A879C7B1F1

### B.6.6 Example 6

In this example, the data string is the 62-byte string consisting of the ASCII-coded version of

“ABCDEFGHIJKLMNOPQRSTUVWXYZabcdefghijklmnopqrstuvwxyz0123456789”

The hash-code is the following 512-bit string.

1E07BE23C26A86EA 37EA810C8EC78093 52515A970E9253C2 6F536CFC7A9996C4  
5C8370583E0A78FA 4A90041D71A4CEAB 7423F19C71B9D5A3 E01249F0BEBD5894

### B.6.7 Example 7

In this example, the data string is the 80-byte string consisting of the ASCII-coded version of eight repetitions of

“1234567890”

The hash-code is the following 512-bit string.

72EC1EF1124A45B0 47E8B7C75A932195 135BB61DE24EC0D1 914042246E0AEC3A  
2354E093D76F3048 B456764346900CB1 30D2A4FD5DD16ABB 5E30BCB850DEE843

### B.6.8 Example 8

In this example, the data string is the 56-byte string consisting of the ASCII-coded version of

“abcd**bc**decdefdefgfgfghfghighijhijkijklklmklmnlmnomnopnopq”

The hash-code is the following 512-bit string.

204A8FC6DDA82F0A 0CED7BEB8E08A416 57C16EF468B228A8 279BE331A703C335  
96FD15C13B1B07F9 AA1D3BEA57789CA0 31AD85C7A71DD703 54EC631238CA3445

### B.6.9 Example 9

In this example, the data string is the 1 000 000-byte string consisting of the ASCII-coded version of “a” repeated  $10^6$  times.

The hash-code is the following 512-bit string.

E718483D0CE76964 4E2E42C7BC15B463 8E1F98B13B204428 5632A803AFA973EB  
DE0FF244877EA60A 4CB0432CE577C31B EB009C5C2C49AA2E 4EADB217AD8CC09B

### B.6.10 Example 10

In this example, the data string is the 112-byte string consisting of the ASCII-coded version of

“abcdefghijklmnopqrstuvwxyz  
abcdefghijklmnopqrstuvwxyz”

(with no line break after the first n).

After the padding process, the following two 16-word blocks are derived from the data string.

```

61626364 65666768 62636465 66676869 63646566 6768696A 64656667 68696A6B
65666768 696A6B6C 66676869 6A6B6C6D 6768696A 6B6C6D6E 68696A6B 6C6D6E6F
696A6B6C 6D6E6F70 6A6B6C6D 6E6F7071 6B6C6D6E 6F707172 6C6D6E6F 70717273
6D6E6F70 71727374 6E6F7071 72737475 80000000 00000000 00000000 00000000

00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000080

```

The following are (hexadecimal representations of) the successive values of the variables  $X_0$ ,  $X_1$ ,  $X_2$ ,  $X_3$ ,  $X_4$ ,  $X_5$ ,  $X_6$  and  $X_7$  in the first block process.

```

INIT: 6A09E667F3BCC908 BB67AE8584CAA73B 3C6EF372FE94F82B A54FF53A5F1D36F1
      510E527FADE682D1 9B05688C2B3E6C1F 1F83D9ABFB41BD6B 5BE0CD19137E2179
0  F6AFCE9D2263455D 6A09E667F3BCC908 BB67AE8584CAA73B 3C6EF372FE94F82B
      58CB0218E01B86F9 510E527FADE682D1 9B05688C2B3E6C1F 1F83D9ABFB41BD6B
1  0B7056A534AE5F62 F6AFCE9D2263455D 6A09E667F3BCC908 BB67AE8584CAA73B
      F8C7198FE39E4C8C 58CB0218E01B86F9 510E527FADE682D1 9B05688C2B3E6C1F
2  2CA82233760C9942 0B7056A534AE5F62 F6AFCE9D2263455D 6A09E667F3BCC908
      303ECCCCD65953DE F8C7198FE39E4C8C 58CB0218E01B86F9 510E527FADE682D1
3  A023F17CE52CDA7B 2CA82233760C9942 0B7056A534AE5F62 F6AFCE9D2263455D
      FFDEE5EEDCC9CA42 303ECCCCD65953DE F8C7198FE39E4C8C 58CB0218E01B86F9
4  8F0A67D9D591A1A7 A023F17CE52CDA7B 2CA82233760C9942 0B7056A534AE5F62
      CB4CFBB166505F2F FFDEE5EEDCC9CA42 303ECCCCD65953DE F8C7198FE39E4C8C
5  B466267371ACC493 8F0A67D9D591A1A7 A023F17CE52CDA7B 2CA82233760C9942
      73D6C84C54D399EE CB4CFBB166505F2F FFDEE5EEDCC9CA42 303ECCCCD65953DE
6  658269F1A312FCCD B466267371ACC493 8F0A67D9D591A1A7 A023F17CE52CDA7B
      CDC40314975FB275 73D6C84C54D399EE CB4CFBB166505F2F FFDEE5EEDCC9CA42
7  65E3519C5B88181B 658269F1A312FCCD B466267371ACC493 8F0A67D9D591A1A7
      A657850AB3970C5A CDC40314975FB275 73D6C84C54D399EE CB4CFBB166505F2F
8  56604FBB4B6393EC 65E3519C5B88181B 658269F1A312FCCD B466267371ACC493
      E8B3BE22FBE64DF7 A657850AB3970C5A CDC40314975FB275 73D6C84C54D399EE
9  C4562769A37D02C0 56604FBB4B6393EC 65E3519C5B88181B 658269F1A312FCCD
      0062E70A1EF705C1 E8B3BE22FBE64DF7 A657850AB3970C5A CDC40314975FB275
10 27C0B4C9186E1736 C4562769A37D02C0 56604FBB4B6393EC 65E3519C5B88181B
      BC9740477A18AE2D 0062E70A1EF705C1 E8B3BE22FBE64DF7 A657850AB3970C5A
11 F17F52FB02F4EB74 27C0B4C9186E1736 C4562769A37D02C0 56604FBB4B6393EC
      BE58522CB9590EE1 BC9740477A18AE2D 0062E70A1EF705C1 E8B3BE22FBE64DF7
12 F2C245AC903D4A35 F17F52FB02F4EB74 27C0B4C9186E1736 C4562769A37D02C0
      49D5FA3A16DCD502 BE58522CB9590EE1 BC9740477A18AE2D 0062E70A1EF705C1
13 9B04175EA8090DAA F2C245AC903D4A35 F17F52FB02F4EB74 27C0B4C9186E1736
      EC9C5E98FF98760D 49D5FA3A16DCD502 BE58522CB9590EE1 BC9740477A18AE2D
14 481B8A6EE5E07031 9B04175EA8090DAA F2C245AC903D4A35 F17F52FB02F4EB74
      E4D35B613A5AC420 EC9C5E98FF98760D 49D5FA3A16DCD502 BE58522CB9590EE1
15 9356AC3EC3E51459 481B8A6EE5E07031 9B04175EA8090DAA F2C245AC903D4A35
      701F17D27582443B E4D35B613A5AC420 EC9C5E98FF98760D 49D5FA3A16DCD502
16 B889ED34ABD7AA37 9356AC3EC3E51459 481B8A6EE5E07031 9B04175EA8090DAA

```



1D05D9BA779A1A78 701F17D27582443B E4D35B613A5AC420 EC9C5E98FF98760D  
17 BF537B1F3EDC7381 B889ED34ABD7AA37 9356AC3EC3E51459 481B8A6EE5E07031  
C362FF9CF932951D 1D05D9BA779A1A78 701F17D27582443B E4D35B613A5AC420  
18 D4E44D54E8242AD8 BF537B1F3EDC7381 B889ED34ABD7AA37 9356AC3EC3E51459  
459E4E6888919F36 C362FF9CF932951D 1D05D9BA779A1A78 701F17D27582443B  
19 05F3FBA454E5DE3D D4E44D54E8242AD8 BF537B1F3EDC7381 B889ED34ABD7AA37  
CAED4B5FA322B984 459E4E6888919F36 C362FF9CF932951D 1D05D9BA779A1A78  
20 CDB73772DC0248BF 05F3FBA454E5DE3D D4E44D54E8242AD8 BF537B1F3EDC7381  
DC8049AFA6ACD502 CAED4B5FA322B984 459E4E6888919F36 C362FF9CF932951D  
21 1D47A3268FF677ED CDB73772DC0248BF 05F3FBA454E5DE3D D4E44D54E8242AD8  
8407818E9B28CC12 DC8049AFA6ACD502 CAED4B5FA322B984 459E4E6888919F36  
22 AF4E23EB622D0DF4 1D47A3268FF677ED CDB73772DC0248BF 05F3FBA454E5DE3D  
64B5AE5424598428 8407818E9B28CC12 DC8049AFA6ACD502 CAED4B5FA322B984  
23 BE50606778DE14A6 AF4E23EB622D0DF4 1D47A3268FF677ED CDB73772DC0248BF  
0A5D727CC92E7ADB 64B5AE5424598428 8407818E9B28CC12 DC8049AFA6ACD502  
24 821E44F6678AC478 BE50606778DE14A6 AF4E23EB622D0DF4 1D47A3268FF677ED  
F367E596D0A038A5 0A5D727CC92E7ADB 64B5AE5424598428 8407818E9B28CC12  
25 0C852B1359A77C18 821E44F6678AC478 BE50606778DE14A6 AF4E23EB622D0DF4  
6DEC8A3396A80C3F F367E596D0A038A5 0A5D727CC92E7ADB 64B5AE5424598428  
26 EBB574FAD4B7A7E4 0C852B1359A77C18 821E44F6678AC478 BE50606778DE14A6  
A241E7EFC1EB6FF9 6DEC8A3396A80C3F F367E596D0A038A5 0A5D727CC92E7ADB  
27 A092821C3CDF08DA EBB574FAD4B7A7E4 0C852B1359A77C18 821E44F6678AC478  
C84E849917A7C08E A241E7EFC1EB6FF9 6DEC8A3396A80C3F F367E596D0A038A5  
28 82BA2E1A2DF2A4F1 A092821C3CDF08DA EBB574FAD4B7A7E4 0C852B1359A77C18  
61845F6924789851 C84E849917A7C08E A241E7EFC1EB6FF9 6DEC8A3396A80C3F  
29 1959AD991C63D06A 82BA2E1A2DF2A4F1 A092821C3CDF08DA EBB574FAD4B7A7E4  
231FAF24910A891A 61845F6924789851 C84E849917A7C08E A241E7EFC1EB6FF9  
30 9B32D4CADC9A625B 1959AD991C63D06A 82BA2E1A2DF2A4F1 A092821C3CDF08DA  
533066919D608799 231FAF24910A891A 61845F6924789851 C84E849917A7C08E  
31 DC55339F4D841965 9B32D4CADC9A625B 1959AD991C63D06A 82BA2E1A2DF2A4F1  
E2517F359998A58D 533066919D608799 231FAF24910A891A 61845F6924789851  
32 FDEBB1283B12514F DC55339F4D841965 9B32D4CADC9A625B 1959AD991C63D06A  
B1989170A183C661 E2517F359998A58D 533066919D608799 231FAF24910A891A  
33 B44C7975A83E3334 FDEBB1283B12514F DC55339F4D841965 9B32D4CADC9A625B  
009AD175B8D588A4 B1989170A183C661 E2517F359998A58D 533066919D608799  
34 0BAC61BFC53D18B7 B44C7975A83E3334 FDEBB1283B12514F DC55339F4D841965  
A7D5416D690557B8 009AD175B8D588A4 B1989170A183C661 E2517F359998A58D  
35 392893C22E75856A 0BAC61BFC53D18B7 B44C7975A83E3334 FDEBB1283B12514F  
7A7C9EB7BC813248 A7D5416D690557B8 009AD175B8D588A4 B1989170A183C661  
36 824408631432E09B 392893C22E75856A 0BAC61BFC53D18B7 B44C7975A83E3334  
5E696A9FDA56D6BF 7A7C9EB7BC813248 A7D5416D690557B8 009AD175B8D588A4  
37 A64162F151A8C1CB 824408631432E09B 392893C22E75856A 0BAC61BFC53D18B7  
0F57062401DC680B 5E696A9FDA56D6BF 7A7C9EB7BC813248 A7D5416D690557B8  
38 922537ABAD1E95A1 A64162F151A8C1CB 824408631432E09B 392893C22E75856A  
4F4C193D435FF721 0F57062401DC680B 5E696A9FDA56D6BF 7A7C9EB7BC813248  
39 B80591F6FBFADCDE 922537ABAD1E95A1 A64162F151A8C1CB 824408631432E09B  
00F4407C0F37237E 4F4C193D435FF721 0F57062401DC680B 5E696A9FDA56D6BF  
40 08F151F4B8D0FA2E B80591F6FBFADCDE 922537ABAD1E95A1 A64162F151A8C1CB  
EC8B96FE402094CD 00F4407C0F37237E 4F4C193D435FF721 0F57062401DC680B  
41 12B5FCC2B68F65C0 08F151F4B8D0FA2E B80591F6FBFADCDE 922537ABAD1E95A1

D688101DFD24A148 EC8B96FE402094CD 00F4407C0F37237E 4F4C193D435FF721  
 42 A71BF5BD64289948 12B5FCC2B68F65C0 08F151F4B8D0FA2E B80591F6FBFADCD E  
 E052BFB7A6945939 D688101DFD24A148 EC8B96FE402094CD 00F4407C0F37237E  
 43 890C2CD670C4AEA3 A71BF5BD64289948 12B5FCC2B68F65C0 08F151F4B8D0FA2E  
 DD13E4EDEEFF00E7 E052BFB7A6945939 D688101DFD24A148 EC8B96FE402094CD  
 44 CA61990B43297FFC 890C2CD670C4AEA3 A71BF5BD64289948 12B5FCC2B68F65C0  
 139AA55C51D9EE5F DD13E4EDEEFF00E7 E052BFB7A6945939 D688101DFD24A148  
 45 7196E8FA538BA4BF CA61990B43297FFC 890C2CD670C4AEA3 A71BF5BD64289948  
 046735513CDD14D3 139AA55C51D9EE5F DD13E4EDEEFF00E7 E052BFB7A6945939  
 46 1F0720944DBEB6A4 7196E8FA538BA4BF CA61990B43297FFC 890C2CD670C4AEA3  
 A41EB7E5A27588E3 046735513CDD14D3 139AA55C51D9EE5F DD13E4EDEEFF00E7  
 47 D6D4F8608B8AB199 1F0720944DBEB6A4 7196E8FA538BA4BF CA61990B43297FFC  
 24B9C216F915DA60 A41EB7E5A27588E3 046735513CDD14D3 139AA55C51D9EE5F  
 48 88761EB67845978E D6D4F8608B8AB199 1F0720944DBEB6A4 7196E8FA538BA4BF  
 9FE22E39448D50ED 24B9C216F915DA60 A41EB7E5A27588E3 046735513CDD14D3  
 49 7D40E6BE47D85702 88761EB67845978E D6D4F8608B8AB199 1F0720944DBEB6A4  
 D9C900E01968C33E 9FE22E39448D50ED 24B9C216F915DA60 A41EB7E5A27588E3  
 50 7D0D988DF5768598 7D40E6BE47D85702 88761EB67845978E D6D4F8608B8AB199  
 2EC2E522A7C7D12C D9C900E01968C33E 9FE22E39448D50ED 24B9C216F915DA60  
 51 48A8B60575B37F31 7D0D988DF5768598 7D40E6BE47D85702 88761EB67845978E  
 7059F9BC8C88A373 2EC2E522A7C7D12C D9C900E01968C33E 9FE22E39448D50ED  
 52 6BC425AF294BBF79 48A8B60575B37F31 7D0D988DF5768598 7D40E6BE47D85702  
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 78 11E3570E06E3B74E C517CBA6A09BB26A C9A8C1E2D063CE94 629C8AE6ECD8AF4B  
 075AABBADE34FD01 E1682BD33C8F8E23 AACD089BFAE8FAF9 5A8FE5919D3CF136  
 79 D90F1B1237B3A561 11E3570E06E3B74E C517CBA6A09BB26A C9A8C1E2D063CE94  
 867983F69D3A3AD1 075AABBADE34FD01 E1682BD33C8F8E23 AACD089BFAE8FAF9

The following eight words,  $Y_0$ ,  $Y_1$ ,  $Y_2$ ,  $Y_3$ ,  $Y_4$ ,  $Y_5$ ,  $Y_6$  and  $Y_7$ , represent the output of the round-function in the first block process.

$Y_0 = 6A09E667F3BCC908 \cup D90F1B1237B3A561 = 4319017A2B706E69$   
 $Y_1 = BB67AE8554CAA73B \cup 11E3570E06E3B74E = CD4B05938BAE5E89$   
 $Y_2 = 3C6EF372FE94F82B \cup C517CBA6A09BB26A = 0186BF199F30AA95$   
 $Y_3 = A54FF53A5F1D36F1 \cup C9A8C1E2D063CE94 = 6EF8B71D2F810585$   
 $Y_4 = 510E527FADE682D1 \cup 867983F69D3A3AD1 = D787D6764B20BDA2$   
 $Y_5 = 9B05688C2B3E6C1F \cup 075AABBADE34FD01 = A260144709736920$   
 $Y_6 = 1F83D9ABFB41BD6B \cup E1682BD33C8F8E23 = 00EC057F37D14B8E$   
 $Y_7 = 5BE0CD19137E2179 \cup AACD089BFAE8FAF9 = 06ADD5B50E671C72$

The following are (hexadecimal representations of) the successive values of the variables  $Y_0$ ,  $Y_1$ ,  $Y_2$ ,  $Y_3$ ,  $Y_4$ ,  $Y_5$ ,  $Y_6$  and  $Y_7$  in the second block process.

INIT: 4319017A2B706E69 CD4B05938BAE5E89 0186BF199F30AA95 6EF8B71D2F810585  
 D787D6764B20BDA2 A260144709736920 00EC057F37D14B8E 06ADD5B50E671C72  
 0 B8FDB92BDFB187E8 4319017A2B706E69 CD4B05938BAE5E89 0186BF199F30AA95  
 1D5F4D5AD031B8E6 D787D6764B20BDA2 A260144709736920 00EC057F37D14B8E  
 1 6EB90718369C5CD7 B8FDB92BDFB187E8 4319017A2B706E69 CD4B05938BAE5E89  
 4B9B4877D987B0FE 1D5F4D5AD031B8E6 D787D6764B20BDA2 A260144709736920  
 2 C83451F2335D5144 6EB90718369C5CD7 B8FDB92BDFB187E8 4319017A2B706E69  
 D6B67350E0781E99 4B9B4877D987B0FE 1D5F4D5AD031B8E6 D787D6764B20BDA2  
 3 28EC1DEB2A9EE6E3 C83451F2335D5144 6EB90718369C5CD7 B8FDB92BDFB187E8  
 25E3136BE5999B8C D6B67350E0781E99 4B9B4877D987B0FE 1D5F4D5AD031B8E6

4 806ABD86C0479E5B 28EC1DEB2A9EE6E3 C83451F2335D5144 6EB90718369C5CD7  
 1B8F7670EAB1CF89 25E3136BE5999B8C D6B67350E0781E99 4B9B4877D987B0FE  
 5 234788F8A54AED38 806ABD86C0479E5B 28EC1DEB2A9EE6E3 C83451F2335D5144  
 4FABE51C67D5D156 1B8F7670EAB1CF89 25E3136BE5999B8C D6B67350E0781E99  
 6 01264F18257B5E2C 234788F8A54AED38 806ABD86C0479E5B 28EC1DEB2A9EE6E3  
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 8 F522574A41B2AAC6 5B14F38104DDE991 01264F18257B5E2C 234788F8A54AED38  
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 9 6EC258B855AFAE5A F522574A41B2AAC6 5B14F38104DDE991 01264F18257B5E2C  
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B27252537A83CF27 9D548440D8E110F2 96BECE755CD203CB F5E402EE21DB8915

60 C1700E250DC6FFED 1CE4F2591812E6AE C25E798E50752535 71A0A998FB48C0FC  
970088839126BDA5 B27252537A83CF27 9D548440D8E110F2 96BECE755CD203CB

61 F8E6924412FD0C64 C1700E250DC6FFED 1CE4F2591812E6AE C25E798E50752535  
D50CF4F73910E3EE 970088839126BDA5 B27252537A83CF27 9D548440D8E110F2

62 D53E0A39EEE47528 F8E6924412FD0C64 C1700E250DC6FFED 1CE4F2591812E6AE  
1B6D7234ACE15D7D D50CF4F73910E3EE 970088839126BDA5 B27252537A83CF27

63 3960545AB926C0D5 D53E0A39EEE47528 F8E6924412FD0C64 C1700E250DC6FFED  
9EABB5618B4FCD13 1B6D7234ACE15D7D D50CF4F73910E3EE 970088839126BDA5

64 B2C164D71ABB92FE 3960545AB926C0D5 D53E0A39EEE47528 F8E6924412FD0C64  
F1736FBBFB6EBE72 9EABB5618B4FCD13 1B6D7234ACE15D7D D50CF4F73910E3EE

65 4D979E985B067E75 B2C164D71ABB92FE 3960545AB926C0D5 D53E0A39EEE47528  
D1FB300F35992350 F1736FBBFB6EBE72 9EABB5618B4FCD13 1B6D7234ACE15D7D

66 59D0238CE137ABD7 4D979E985B067E75 B2C164D71ABB92FE 3960545AB926C0D5  
5F3C64B7546E2CEC D1FB300F35992350 F1736FBBFB6EBE72 9EABB5618B4FCD13

67 BF8D9453B9876B0A 59D0238CE137ABD7 4D979E985B067E75 B2C164D71ABB92FE  
6C27893A31B0E07E 5F3C64B7546E2CEC D1FB300F35992350 F1736FBBFB6EBE72

68 C45DD4A2D2FEA059 BF8D9453B9876B0A 59D0238CE137ABD7 4D979E985B067E75  
48253E21B26D8CF9 6C27893A31B0E07E 5F3C64B7546E2CEC D1FB300F35992350

69 E08471946C17B0B6 C45DD4A2D2FEA059 BF8D9453B9876B0A 59D0238CE137ABD7  
714E2ADF4E23FF24 48253E21B26D8CF9 6C27893A31B0E07E 5F3C64B7546E2CEC

70 B4838C1C28FEE7BC E08471946C17B0B6 C45DD4A2D2FEA059 BF8D9453B9876B0A  
371F12F333F7E5B9 714E2ADF4E23FF24 48253E21B26D8CF9 6C27893A31B0E07E

71 851CF60A77F6E6D1 B4838C1C28FEE7BC E08471946C17B0B6 C45DD4A2D2FEA059  
A2A475DEAC0E8B42 371F12F333F7E5B9 714E2ADF4E23FF24 48253E21B26D8CF9

72 F53D23C50249AF2D 851CF60A77F6E6D1 B4838C1C28FEE7BC E08471946C17B0B6  
1E99CAE9D4CF0409 A2A475DEAC0E8B42 371F12F333F7E5B9 714E2ADF4E23FF24

73 B81E85D427045550 F53D23C50249AF2D 851CF60A77F6E6D1 B4838C1C28FEE7BC  
F5794711FAA60F63 1E99CAE9D4CF0409 A2A475DEAC0E8B42 371F12F333F7E5B9

74 AE70C7D11EA84A83 B81E85D427045550 F53D23C50249AF2D 851CF60A77F6E6D1  
DC0D633411C289B2 F5794711FAA60F63 1E99CAE9D4CF0409 A2A475DEAC0E8B42

75 5C54592E13C76135 AE70C7D11EA84A83 B81E85D427045550 F53D23C50249AF2D  
1620DD5479E94B9B DC0D633411C289B2 F5794711FAA60F63 1E99CAE9D4CF0409

76 03A0F79087078A93 5C54592E13C76135 AE70C7D11EA84A83 B81E85D427045550  
57E90FA678E4CC97 1620DD5479E94B9B DC0D633411C289B2 F5794711FAA60F63

77 8DF0BAAD4C6ED50C 03A0F79087078A93 5C54592E13C76135 AE70C7D11EA84A83  
C6E7246F7F0BDAC6 57E90FA678E4CC97 1620DD5479E94B9B DC0D633411C289B2

78 BFA9F194894DB5B6 8DF0BAAD4C6ED50C 03A0F79087078A93 5C54592E13C76135

90BB8597BB41DA1A C6E7246F7F0BDAC6 57E90FA678E4CC97 1620DD5479E94B9B  
 79 4B7C99FBAF72A571 BFA9F194894DB5B6 8DF0BAAD4C6ED50C 03A0F79087078A93  
 78955227FDE03A42 90BB8597BB41DA1A C6E7246F7F0BDAC6 57E90FA678E4CC97

The following eight words,  $Y_0$ ,  $Y_1$ ,  $Y_2$ ,  $Y_3$ ,  $Y_4$ ,  $Y_5$ ,  $Y_6$  and  $Y_7$ , represent the output of the final iteration of the round-function.

$Y_0$  = 4319017A2B706E69  $\cup$  4B7C99FBAF72A571 = 8E959B75DAE313DA  
 $Y_1$  = CD4B05938BAE5E89  $\cup$  BFA9F194894DB5B6 = 8CF4F72814FC143F  
 $Y_2$  = 0186BF199F30AA95  $\cup$  8DF0BAAD4C6ED50C = 8F7779C6EB9F7FA1  
 $Y_3$  = 6EF8B71D2F810585  $\cup$  03A0F79087078A93 = 7299AEADB6889018  
 $Y_4$  = D787D6764B20BDA2  $\cup$  78955227FDE03A42 = 501D289E4900F7E4  
 $Y_5$  = A260144709736920  $\cup$  90BB8597BB41DA1A = 331B99DEC4B5433A  
 $Y_6$  = 00EC057F37D14B8E  $\cup$  C6E7246F7F0BDAC6 = C7D329EEB6DD2654  
 $Y_7$  = 06ADD5B50E671C72  $\cup$  57E90FA678E4CC97 = 5E96E55B874BE909

The following is the hash value for this message.

8E959B75DAE313DA 8CF4F72814FC143F 8F7779C6EB9F7FA1 7299AEADB6889018  
 501D289E4900F7E4 331B99DEC4B5433A C7D329EEB6DD2654 5E96E55B874BE909

## B.6.11 Example 11

In this example, the data string is the 32-byte string consisting of the ASCII-coded version of

“abcdbcdecdefdefgefghfghighijhjk”

The hash-code is the following 512-bit string.

C50E7A500D4058BF 530EC603B66B032A 989A3E033A340090 DC51086CFD8CB222  
 09027932EA830F9B 6BC09DAFE882F908 38C2C91018245904 828C1232FC0942EB

## B.7 Dedicated Hash-Function 6 (SHA-384)

### B.7.1 Example 1

In this example, the data string is the empty string, i.e. the string of length zero.

The hash-code is the following 384-bit string.

38B060A751AC9638 4CD9327EB1B1E36A 21FDB71114BE0743 4C0CC7BF63F6E1DA  
 274EDEBFE76F65FB D51AD2F14898B95B

### B.7.2 Example 2

In this example, the data string consists of a single byte, namely the ASCII-coded version of the letter “a”.

The hash-code is the following 384-bit string.

54A59B9F22B0B808 80D8427E548B7C23 ABD873486E1F035D CE9CD697E8517503  
 3CAA88E6D57BC35E FAE0B5AFD3145F31

### B.7.3 Example 3

In this example, the data string is the 3-byte string consisting of the ASCII-coded version of “abc”. This is equivalent to the bit string “01100001 01100010 01100011”.



After the padding process, the single 16-word block derived from the data string is as follows.

```
61626380 00000000 00000000 00000000 00000000 00000000 00000000 00000000
00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000018
```

The following are (hexadecimal representations of) the successive values of the variables  $X_0$ ,  $X_1$ ,  $X_2$ ,  $X_3$ ,  $X_4$ ,  $X_5$ ,  $X_6$  and  $X_7$ .

```
INIT: CBBB9D5DC1059ED8 629A292A367CD507 9159015A3070DD17 152FECD8F70E5939
      67332667FFC00B31 8EB44A8768581511 DB0C2E0D64F98FA7 47B5481DBEFA4FA4
0 470994AD30873F88 CBBB9D5DC1059ED8 629A292A367CD507 9159015A3070DD17
  BD03F724BE6075F9 67332667FFC00B31 8EB44A8768581511 DB0C2E0D64F98FA7
1 2E91230306A12AE0 470994AD30873F88 CBBB9D5DC1059ED8 629A292A367CD507
  5E1B4E1695372B9E BD03F724BE6075F9 67332667FFC00B31 8EB44A8768581511
2 EEBE5D379BE707AD 2E91230306A12AE0 470994AD30873F88 CBBB9D5DC1059ED8
  54074A65AEF34336 5E1B4E1695372B9E BD03F724BE6075F9 67332667FFC00B31
3 E308483153E15AD6 EEBE5D379BE707AD 2E91230306A12AE0 470994AD30873F88
  086C5B2D36A89178 54074A65AEF34336 5E1B4E1695372B9E BD03F724BE6075F9
4 3A7A023C593D8479 E308483153E15AD6 EEBE5D379BE707AD 2E91230306A12AE0
  8AA1144850633794 086C5B2D36A89178 54074A65AEF34336 5E1B4E1695372B9E
5 333199A85F92B052 3A7A023C593D8479 E308483153E15AD6 EEBE5D379BE707AD
  7A6316F0EF047CE7 8AA1144850633794 086C5B2D36A89178 54074A65AEF34336
6 76F0741213DD2EF6 333199A85F92B052 3A7A023C593D8479 E308483153E15AD6
  74063CBA385F0675 7A6316F0EF047CE7 8AA1144850633794 086C5B2D36A89178
7 02F2A04D3AAB1629 76F0741213DD2EF6 333199A85F92B052 3A7A023C593D8479
  1688B9BF14980FC0 74063CBA385F0675 7A6316F0EF047CE7 8AA1144850633794
8 73E5B2A1704A0349 02F2A04D3AAB1629 76F0741213DD2EF6 333199A85F92B052
  FD00139F705907D0 1688B9BF14980FC0 74063CBA385F0675 7A6316F0EF047CE7
9 BF3F67BA12882648 73E5B2A1704A0349 02F2A04D3AAB1629 76F0741213DD2EF6
  652E311D4F0A4257 FD00139F705907D0 1688B9BF14980FC0 74063CBA385F0675
10 33254508BB2EA48D BF3F67BA12882648 73E5B2A1704A0349 02F2A04D3AAB1629
  9E18991C4F39F0BA 652E311D4F0A4257 FD00139F705907D0 1688B9BF14980FC0
11 C1FDB2A0205EA0E5 33254508BB2EA48D BF3F67BA12882648 73E5B2A1704A0349
  04732E8BC4044582 9E18991C4F39F0BA 652E311D4F0A4257 FD00139F705907D0
12 185F9FF038A50F39 C1FDB2A0205EA0E5 33254508BB2EA48D BF3F67BA12882648
  8B4ACFC4D2B8AFE6 04732E8BC4044582 9E18991C4F39F0BA 652E311D4F0A4257
13 E5F06744C0D7563A 185F9FF038A50F39 C1FDB2A0205EA0E5 33254508BB2EA48D
  2FA93D1CE9523015 8B4ACFC4D2B8AFE6 04732E8BC4044582 9E18991C4F39F0BA
14 7E32DC0E9F414783 E5F06744C0D7563A 185F9FF038A50F39 C1FDB2A0205EA0E5
  3A9950AAA5E75884 2FA93D1CE9523015 8B4ACFC4D2B8AFE6 04732E8BC4044582
15 1EAB6159AE87EF6D 7E32DC0E9F414783 E5F06744C0D7563A 185F9FF038A50F39
  153B895CFBC436C5 3A9950AAA5E75884 2FA93D1CE9523015 8B4ACFC4D2B8AFE6
16 33EF2CEBBF1739AA 1EAB6159AE87EF6D 7E32DC0E9F414783 E5F06744C0D7563A
  9D1A64BAF1D366AA 153B895CFBC436C5 3A9950AAA5E75884 2FA93D1CE9523015
17 7DF1B65F1B87D6CA 33EF2CEBBF1739AA 1EAB6159AE87EF6D 7E32DC0E9F414783
  5B6E369D36E8E181 9D1A64BAF1D366AA 153B895CFBC436C5 3A9950AAA5E75884
18 63A24014A34BB0F6 7DF1B65F1B87D6CA 33EF2CEBBF1739AA 1EAB6159AE87EF6D
  E13E610EAE680D85 5B6E369D36E8E181 9D1A64BAF1D366AA 153B895CFBC436C5
19 F1AABD313309509B 63A24014A34BB0F6 7DF1B65F1B87D6CA 33EF2CEBBF1739AA
```

674385F0D87DB94F E13E610EAE680D85 5B6E369D36E8E181 9D1A64BAF1D366AA  
20 9BA737AE88A72C64 F1AABD313309509B 63A24014A34BB0F6 7DF1B65F1B87D6CA  
3FC2614C43906C0F 674385F0D87DB94F E13E610EAE680D85 5B6E369D36E8E181  
21 042C2DC9A5BF558A 9BA737AE88A72C64 F1AABD313309509B 63A24014A34BB0F6  
19316BEB88E01F2 3FC2614C43906C0F 674385F0D87DB94F E13E610EAE680D85  
22 7799C75ACC748C0F 042C2DC9A5BF558A 9BA737AE88A72C64 F1AABD313309509B  
A7BBD65BF64F58C8 19316BEB88E01F2 3FC2614C43906C0F 674385F0D87DB94F  
23 CCF99A80F92BF002 7799C75ACC748C0F 042C2DC9A5BF558A 9BA737AE88A72C64  
E52A24FAE4E8FC9B A7BBD65BF64F58C8 19316BEB88E01F2 3FC2614C43906C0F  
24 AE993474363EFE68 CCF99A80F92BF002 7799C75ACC748C0F 042C2DC9A5BF558A  
587F308D58681928 E52A24FAE4E8FC9B A7BBD65BF64F58C8 19316BEB88E01F2  
25 335063D1A2AEC92F AE993474363EFE68 CCF99A80F92BF002 7799C75ACC748C0F  
C2D6D65E38C6EA79 587F308D58681928 E52A24FAE4E8FC9B A7BBD65BF64F58C8  
26 53A78B0CCA01BA37 335063D1A2AEC92F AE993474363EFE68 CCF99A80F92BF002  
3B65A26C3C92C8F3 C2D6D65E38C6EA79 587F308D58681928 E52A24FAE4E8FC9B  
27 AB7FFA529F622930 53A78B0CCA01BA37 335063D1A2AEC92F AE993474363EFE68  
B9D8A2F2762901EA 3B65A26C3C92C8F3 C2D6D65E38C6EA79 587F308D58681928  
28 E428BB43AFE3D63E AB7FFA529F622930 53A78B0CCA01BA37 335063D1A2AEC92F  
6A8527525F898726 B9D8A2F2762901EA 3B65A26C3C92C8F3 C2D6D65E38C6EA79  
29 BBED541A5128088C E428BB43AFE3D63E AB7FFA529F622930 53A78B0CCA01BA37  
7973AADBDE294BE9 6A8527525F898726 B9D8A2F2762901EA 3B65A26C3C92C8F3  
30 4C5C38DF7EC8BAF4 BBED541A5128088C E428BB43AFE3D63E AB7FFA529F622930  
422CEEA0200E9EE4 7973AADBDE294BE9 6A8527525F898726 B9D8A2F2762901EA  
31 4BA456EC244033ED 4C5C38DF7EC8BAF4 BBED541A5128088C E428BB43AFE3D63E  
7CF40857056D86B0 422CEEA0200E9EE4 7973AADBDE294BE9 6A8527525F898726  
32 AA4A6AB2AC5F5DD8 4BA456EC244033ED 4C5C38DF7EC8BAF4 BBED541A5128088C  
AD2B1ECFB5BFC556 7CF40857056D86B0 422CEEA0200E9EE4 7973AADBDE294BE9  
33 9CB941F2CED774B3 AA4A6AB2AC5F5DD8 4BA456EC244033ED 4C5C38DF7EC8BAF4  
029F66C7B4569BF0 AD2B1ECFB5BFC556 7CF40857056D86B0 422CEEA0200E9EE4  
34 39265F358594DE27 9CB941F2CED774B3 AA4A6AB2AC5F5DD8 4BA456EC244033ED  
3F7B1C260C82E54F 029F66C7B4569BF0 AD2B1ECFB5BFC556 7CF40857056D86B0  
35 09CCA487D39B02A1 39265F358594DE27 9CB941F2CED774B3 AA4A6AB2AC5F5DD8  
4A22B37B58A5B1B0 3F7B1C260C82E54F 029F66C7B4569BF0 AD2B1ECFB5BFC556  
36 D48D97CE438CF4F0 09CCA487D39B02A1 39265F358594DE27 9CB941F2CED774B3  
A239E00B8BAA0410 4A22B37B58A5B1B0 3F7B1C260C82E54F 029F66C7B4569BF0  
37 D6F41E25A8B634D6 D48D97CE438CF4F0 09CCA487D39B02A1 39265F358594DE27  
25755CB8179DD0B0 A239E00B8BAA0410 4A22B37B58A5B1B0 3F7B1C260C82E54F  
38 54078334358573B4 D6F41E25A8B634D6 D48D97CE438CF4F0 09CCA487D39B02A1  
0E419FB0802B0EFC 25755CB8179DD0B0 A239E00B8BAA0410 4A22B37B58A5B1B0  
39 DB24F9A03F4FFF6B 54078334358573B4 D6F41E25A8B634D6 D48D97CE438CF4F0  
D30E99B4B394B090 0E419FB0802B0EFC 25755CB8179DD0B0 A239E00B8BAA0410  
40 3604C53A845EFC37 DB24F9A03F4FFF6B 54078334358573B4 D6F41E25A8B634D6  
791B2B4AF7338B99 D30E99B4B394B090 0E419FB0802B0EFC 25755CB8179DD0B0  
41 F41B1C0EEE89BDC6 3604C53A845EFC37 DB24F9A03F4FFF6B 54078334358573B4  
E319B77D9E4E87F9 791B2B4AF7338B99 D30E99B4B394B090 0E419FB0802B0EFC  
42 36644AE374632E3A F41B1C0EEE89BDC6 3604C53A845EFC37 DB24F9A03F4FFF6B  
458250878A3972B2 E319B77D9E4E87F9 791B2B4AF7338B99 D30E99B4B394B090  
43 88806F6AE9FCD65B 36644AE374632E3A F41B1C0EEE89BDC6 3604C53A845EFC37  
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44 51DCAA36995C301D 88806F6AE9FCD65B 36644AE374632E3A F41B1C0EEE89BDC6

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 740E347F24E18FDA E37F778353998050 CFDE2E6EA54FA576 458250878A3972B2  
 46 EB3753F4283F4818 EF5E3885A2F238DF 51DCAA36995C301D 88806F6AE9FCD65B  
 0AE48CF840BB8BE9 740E347F24E18FDA E37F778353998050 CFDE2E6EA54FA576  
 47 A6998D63A5D09E04 EB3753F4283F4818 EF5E3885A2F238DF 51DCAA36995C301D  
 E21095012EE0B72A 0AE48CF840BB8BE9 740E347F24E18FDA E37F778353998050  
 48 D3698FB64DF175B0 A6998D63A5D09E04 EB3753F4283F4818 EF5E3885A2F238DF  
 C2F0B90FFCE80739 E21095012EE0B72A 0AE48CF840BB8BE9 740E347F24E18FDA  
 49 317A3B295B991914 D3698FB64DF175B0 A6998D63A5D09E04 EB3753F4283F4818  
 1CADFF2E6CB5AA4D C2F0B90FFCE80739 E21095012EE0B72A 0AE48CF840BB8BE9  
 50 0941DA08148BA463 317A3B295B991914 D3698FB64DF175B0 A6998D63A5D09E04  
 833EB9A4BB5A073E 1CADFF2E6CB5AA4D C2F0B90FFCE80739 E21095012EE0B72A  
 51 494AC238D68C3D0B 0941DA08148BA463 317A3B295B991914 D3698FB64DF175B0  
 80C8FC138E645028 833EB9A4BB5A073E 1CADFF2E6CB5AA4D C2F0B90FFCE80739  
 52 C87E9168DB9E97DE 494AC238D68C3D0B 0941DA08148BA463 317A3B295B991914  
 65CF7F6A829ACA04 80C8FC138E645028 833EB9A4BB5A073E 1CADFF2E6CB5AA4D  
 53 EDB4448879391DBB C87E9168DB9E97DE 494AC238D68C3D0B 0941DA08148BA463  
 7729C85475DD318F 65CF7F6A829ACA04 80C8FC138E645028 833EB9A4BB5A073E  
 54 073775C2456DC7DB EDB4448879391DBB C87E9168DB9E97DE 494AC238D68C3D0B  
 A9CCA0B6266B1D77 7729C85475DD318F 65CF7F6A829ACA04 80C8FC138E645028  
 55 54DE8857B24AFAF7 073775C2456DC7DB EDB4448879391DBB C87E9168DB9E97DE  
 8DE51CFF2AE4B068 A9CCA0B6266B1D77 7729C85475DD318F 65CF7F6A829ACA04  
 56 8A9CDD80F7F09C05 54DE8857B24AFAF7 073775C2456DC7DB EDB4448879391DBB  
 A60BA5E9EBAEB96A 8DE51CFF2AE4B068 A9CCA0B6266B1D77 7729C85475DD318F  
 57 3EEB22A7524D8D7F 8A9CDD80F7F09C05 54DE8857B24AFAF7 073775C2456DC7DB  
 E2E6830B139DF58F A60BA5E9EBAEB96A 8DE51CFF2AE4B068 A9CCA0B6266B1D77  
 58 0ED77C9CDE8883D3 3EEB22A7524D8D7F 8A9CDD80F7F09C05 54DE8857B24AFAF7  
 38413A2052387A9E E2E6830B139DF58F A60BA5E9EBAEB96A 8DE51CFF2AE4B068  
 59 E64E4135F9D30DBC 0ED77C9CDE8883D3 3EEB22A7524D8D7F 8A9CDD80F7F09C05  
 45B640454C75C349 38413A2052387A9E E2E6830B139DF58F A60BA5E9EBAEB96A  
 60 1CA93A293D544328 E64E4135F9D30DBC 0ED77C9CDE8883D3 3EEB22A7524D8D7F  
 EFBEF83A35C0319E 45B640454C75C349 38413A2052387A9E E2E6830B139DF58F  
 61 3DC764F89E54043A 1CA93A293D544328 E64E4135F9D30DBC 0ED77C9CDE8883D3  
 A57784945550CF94 EFBEF83A35C0319E 45B640454C75C349 38413A2052387A9E  
 62 56FB5883F1C87A05 3DC764F89E54043A 1CA93A293D544328 E64E4135F9D30DBC  
 F5198A41EB80E022 A57784945550CF94 EFBEF83A35C0319E 45B640454C75C349  
 63 24A1124262A331C7 56FB5883F1C87A05 3DC764F89E54043A 1CA93A293D544328  
 06EDACAE6E7B54AD F5198A41EB80E022 A57784945550CF94 EFBEF83A35C0319E  
 64 EB85D19201C89694 24A1124262A331C7 56FB5883F1C87A05 3DC764F89E54043A  
 9CED24983EEC8723 06EDACAE6E7B54AD F5198A41EB80E022 A57784945550CF94  
 65 CC981AB3A59C1DB4 EB85D19201C89694 24A1124262A331C7 56FB5883F1C87A05  
 EAC5516336BC8882 9CED24983EEC8723 06EDACAE6E7B54AD F5198A41EB80E022  
 66 CEEF5D997E148B44 CC981AB3A59C1DB4 EB85D19201C89694 24A1124262A331C7  
 617BBF70BB165212 EAC5516336BC8882 9CED24983EEC8723 06EDACAE6E7B54AD  
 67 689EDF608A8E3F14 CEEF5D997E148B44 CC981AB3A59C1DB4 EB85D19201C89694  
 3280D88472C100FD 617BBF70BB165212 EAC5516336BC8882 9CED24983EEC8723  
 68 1E6E0255AB88079F 689EDF608A8E3F14 CEEF5D997E148B44 CC981AB3A59C1DB4  
 F2001138439902B1 3280D88472C100FD 617BBF70BB165212 EAC5516336BC8882  
 69 8C5D3B7FDAD66E70 1E6E0255AB88079F 689EDF608A8E3F14 CEEF5D997E148B44

```

90D18EC8B69F0345 F2001138439902B1 3280D88472C100FD 617BBF70BB165212
70 32E5ED8655871E9B 8C5D3B7FDAD66E70 1E6E0255AB88079F 689EDF608A8E3F14
51105F6241313777 90D18EC8B69F0345 F2001138439902B1 3280D88472C100FD
71 BCD5061679BE7336 32E5ED8655871E9B 8C5D3B7FDAD66E70 1E6E0255AB88079F
454B99F654443AD0 51105F6241313777 90D18EC8B69F0345 F2001138439902B1
72 E7D913B6678E78EF BCD5061679BE7336 32E5ED8655871E9B 8C5D3B7FDAD66E70
1FF613B5AA63776E 454B99F654443AD0 51105F6241313777 90D18EC8B69F0345
73 E6B8CB8DFA3475AB E7D913B6678E78EF BCD5061679BE7336 32E5ED8655871E9B
2E75F34303D39BB0 1FF613B5AA63776E 454B99F654443AD0 51105F6241313777
74 FDD4A30E168C4AE5 E6B8CB8DFA3475AB E7D913B6678E78EF BCD5061679BE7336
83A35DBE2A64FC26 2E75F34303D39BB0 1FF613B5AA63776E 454B99F654443AD0
75 12AEB6268DFA3E14 FDD4A30E168C4AE5 E6B8CB8DFA3475AB E7D913B6678E78EF
F660943B276786F7 83A35DBE2A64FC26 2E75F34303D39BB0 1FF613B5AA63776E
76 055B73814CF102B4 12AEB6268DFA3E14 FDD4A30E168C4AE5 E6B8CB8DFA3475AB
C4B149710F5D6A71 F660943B276786F7 83A35DBE2A64FC26 2E75F34303D39BB0
77 95D33150DE6DF44C 055B73814CF102B4 12AEB6268DFA3E14 FDD4A30E168C4AE5
C7F7BFF08EBF0D30 C4B149710F5D6A71 F660943B276786F7 83A35DBE2A64FC26
78 5306143F64497B00 95D33150DE6DF44C 055B73814CF102B4 12AEB6268DFA3E14
CA06A219CC701096 C7F7BFF08EBF0D30 C4B149710F5D6A71 F660943B276786F7
79 FF44D7E1849DBFB3 5306143F64497B00 95D33150DE6DF44C 055B73814CF102B4
1952E0C3A227C0F2 CA06A219CC701096 C7F7BFF08EBF0D30 C4B149710F5D6A71

```

The following eight words,  $Y_0$ ,  $Y_1$ ,  $Y_2$ ,  $Y_3$ ,  $Y_4$ ,  $Y_5$ ,  $Y_6$  and  $Y_7$ , represent the output of the final iteration of the round-function.

```

Y0 = CBBB9D5DC1059ED8 ⚡ FF44D7E1849DBFB3 = CB00753F45A35E8B
Y1 = 629A292A367CD507 ⚡ 5306143F64497B00 = B5A03D699AC65007
Y2 = 9159015A3070DD17 ⚡ 95D33150DE6DF44C = 272C32AB0EDED163
Y3 = 152FEC8F70E5939 ⚡ 055B73814CF102B4 = 1A8B605A43FF5BED
Y4 = 67332667FFC00B31 ⚡ 1952E0C3A227C0F2 = 8086072BA1E7CC23
Y5 = 8EB44A8768581511 ⚡ CA06A219CC701096 = 58BAECA134C825A7
Y6 = DB0C2E0D64F98FA7 ⚡ C7F7BFF08EBF0D30 = A303EDFDF3B89CD7
Y7 = 47B5481DBEFA4FA4 ⚡ C4B149710F5D6A71 = 0C66918ECE57BA15

```

The hash value is the following 384-bit string.

```

CB00753F45A35E8B B5A03D699AC65007 272C32AB0EDED163 1A8B605A43FF5BED
8086072BA1E7CC23 58BAECA134C825A7

```

#### B.7.4 Example 4

In this example, the data string is the 14-byte string consisting of the ASCII-coded version of

“message digest”

The hash-code is the following 384-bit string.

```

473ED35167EC1F5D 8E550368A3DB39BE 54639F828868E945 4C239FC8B52E3C61
DBD0D8B4DE1390C2 56DCBB5D5FD99CD5

```

#### B.7.5 Example 5

In this example, the data string is the 26-byte string consisting of the ASCII-coded version of

“abcdefghijklmnopqrstuvwxyz”

The hash-code is the following 384-bit string.

```
FEB67349DF3DB6F5 924815D6C3DC133F 091809213731FE5C 7B5F4999E463479F
F2877F5F2936FA63 BB43784B12F3EBB4
```

### B.7.6 Example 6

In this example, the data string is the 62-byte string consisting of the ASCII-coded version of

“ABCDEFGHJKLMNOPQRSTUVWXYZabcdefghijklmnopqrstuvwxyz0123456789”

The hash-code is the following 384-bit string.

```
1761336E3F7CBFE5 1DEB137F026F89E0 1A448E3B1FAFA640 39C1464EE8732F11
A5341A6F41E0C202 294736ED64DB1A84
```

### B.7.7 Example 7

In this example, the data string is the 80-byte string consisting of the ASCII-coded version of eight repetitions of

“1234567890”

The hash-code is the following 384-bit string.

```
B12932B0627D1C06 0942F54477641556 55BD4DA0C9AFA6DD 9B9EF53129AF1B8F
B0195996D2DE9CA0 2F9D821FFEE67026
```

### B.7.8 Example 8

In this example, the data string is the 56-byte string consisting of the ASCII-coded version of

“abcdcbcdcedefdefgfgfghfghighijhijkijklklmklmnlmnomnopnopq”

The hash-code is the following 384-bit string.

```
3391FDDDFC8DC739 3707A65B1B470939 7CF8B1D162AF05AB FE8F450DE5F36BC6
B0455A8520BC4E6F 5FE95B1FE3C8452B
```

### B.7.9 Example 9

In this example, the data string is the 1 000 000-byte string consisting of the ASCII-coded version of “a” repeated 10<sup>6</sup> times.

The hash-code is the following 384-bit string.

```
9D0E1809716474CB 086E834E310A4A1C ED149E9C00F24852 7972CEC5704C2A5B
07B8B3DC38ECC4EB AE97DDD87F3D8985
```

### B.7.10 Example 10

In this example, the data string is the 112-byte string consisting of the ASCII-coded version of

“abcdefghijklm  
hijklmnoijklmnopijklmnopqijklmnopqrsmnopqrstnoprstu”

(with no line break after the first n).

After the padding process, the following two 16-word blocks are derived from the data string.

```

61626364 65666768 62636465 66676869 63646566 6768696A 64656667 68696A6B
65666768 696A6B6C 66676869 6A6B6C6D 6768696A 6B6C6D6E 68696A6B 6C6D6E6F
696A6B6C 6D6E6F70 6A6B6C6D 6E6F7071 6B6C6D6E 6F707172 6C6D6E6F 70717273
6D6E6F70 71727374 6E6F7071 72737475 80000000 00000000 00000000 00000000

00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000380

```

The following are (hexadecimal representations of) the successive values of the variables  $X_0$ ,  $X_1$ ,  $X_2$ ,  $X_3$ ,  $X_4$ ,  $X_5$ ,  $X_6$  and  $X_7$  in the first block process.

```

INIT: CBBB9D5DC1059ED8 629A292A367CD507 9159015A3070DD17 152FEC8F70E5939
      67332667FFC00B31 8EB44A8768581511 DB0C2E0D64F98FA7 47B5481DBEFA4FA4
0 4709949195EDA6F0 CBBB9D5DC1059ED8 629A292A367CD507 9159015A3070DD17
  BD03F70923C6DD61 67332667FFC00B31 8EB44A8768581511 DB0C2E0D64F98FA7
1 78D3F8BC03A38303 4709949195EDA6F0 CBBB9D5DC1059ED8 629A292A367CD507
  AE067F071CD18A36 BD03F70923C6DD61 67332667FFC00B31 8EB44A8768581511
2 ED59D30BEFF95306 78D3F8BC03A38303 4709949195EDA6F0 CBBB9D5DC1059ED8
  C180C7A74ED5CF1F AE067F071CD18A36 BD03F70923C6DD61 67332667FFC00B31
3 8E7FE2ABA3168F2B ED59D30BEFF95306 78D3F8BC03A38303 4709949195EDA6F0
  D92D19667920B327 C180C7A74ED5CF1F AE067F071CD18A36 BD03F70923C6DD61
4 1174F9B374A9263A 8E7FE2ABA3168F2B ED59D30BEFF95306 78D3F8BC03A38303
  DD371F2D13661C52 D92D19667920B327 C180C7A74ED5CF1F AE067F071CD18A36
5 27AAAFB7FBEF806B 1174F9B374A9263A 8E7FE2ABA3168F2B ED59D30BEFF95306
  21AF3C6430A9AF9C DD371F2D13661C52 D92D19667920B327 C180C7A74ED5CF1F
6 B352D03A0BD34D65 27AAAFB7FBEF806B 1174F9B374A9263A 8E7FE2ABA3168F2B
  69397DE9A30E1473 21AF3C6430A9AF9C DD371F2D13661C52 D92D19667920B327
7 412DB7F990563D7C B352D03A0BD34D65 27AAAFB7FBEF806B 1174F9B374A9263A
  5062FD5924E2B62E 69397DE9A30E1473 21AF3C6430A9AF9C DD371F2D13661C52
8 0F79040546E6EDF7 412DB7F990563D7C B352D03A0BD34D65 27AAAFB7FBEF806B
  6B6C511B25A6BDBC 5062FD5924E2B62E 69397DE9A30E1473 21AF3C6430A9AF9C
9 EBF02410F67B8EE7 0F79040546E6EDF7 412DB7F990563D7C B352D03A0BD34D65
  DAC695B91543AE80 6B6C511B25A6BDBC 5062FD5924E2B62E 69397DE9A30E1473
10 97AA05D89B8DBE6D EBF02410F67B8EE7 0F79040546E6EDF7 412DB7F990563D7C
  83B8B72646C0B598 DAC695B91543AE80 6B6C511B25A6BDBC 5062FD5924E2B62E
11 23D0A36B692118EB 97AA05D89B8DBE6D EBF02410F67B8EE7 0F79040546E6EDF7
  A5F6C5155E221E8C 83B8B72646C0B598 DAC695B91543AE80 6B6C511B25A6BDBC
12 E1041368D2FCA1A2 23D0A36B692118EB 97AA05D89B8DBE6D EBF02410F67B8EE7
  AE01675BFB003180 A5F6C5155E221E8C 83B8B72646C0B598 DAC695B91543AE80
13 45BD6F69EFEC540D E1041368D2FCA1A2 23D0A36B692118EB 97AA05D89B8DBE6D
  C35CC50C1CF7EF98 AE01675BFB003180 A5F6C5155E221E8C 83B8B72646C0B598
14 C237FA23ABB9BC16 45BD6F69EFEC540D E1041368D2FCA1A2 23D0A36B692118EB
  A16C4F134B28923E C35CC50C1CF7EF98 AE01675BFB003180 A5F6C5155E221E8C
15 B4092DF1C0F81853 C237FA23ABB9BC16 45BD6F69EFEC540D E1041368D2FCA1A2
  008178E17FA649F2 A16C4F134B28923E C35CC50C1CF7EF98 AE01675BFB003180
16 21E5C91D11809C13 B4092DF1C0F81853 C237FA23ABB9BC16 45BD6F69EFEC540D

```



A26DFA04ED8C9B63 008178E17FA649F2 A16C4F134B28923E C35CC50C1CF7EF98  
 17 2C957137CD4304A5 21E5C91D11809C13 B4092DF1C0F81853 C237FA23ABB9BC16  
 6BE210614B10949B A26DFA04ED8C9B63 008178E17FA649F2 A16C4F134B28923E  
 18 2180E61AFE322BC7 2C957137CD4304A5 21E5C91D11809C13 B4092DF1C0F81853  
 76396996200065F7 6BE210614B10949B A26DFA04ED8C9B63 008178E17FA649F2  
 19 F2911C11C96E5FF5 2180E61AFE322BC7 2C957137CD4304A5 21E5C91D11809C13  
 1BC2160F4F3711DC 76396996200065F7 6BE210614B10949B A26DFA04ED8C9B63  
 20 5EAB10B19A5143A8 F2911C11C96E5FF5 2180E61AFE322BC7 2C957137CD4304A5  
 98D2B19D201F2BB6 1BC2160F4F3711DC 76396996200065F7 6BE210614B10949B  
 21 29C5348D87CD5590 5EAB10B19A5143A8 F2911C11C96E5FF5 2180E61AFE322BC7  
 4324C8CACCF7753C 98D2B19D201F2BB6 1BC2160F4F3711DC 76396996200065F7  
 22 33C6B4A0166B7C9C 29C5348D87CD5590 5EAB10B19A5143A8 F2911C11C96E5FF5  
 D49CEF5BD2DEC121 4324C8CACCF7753C 98D2B19D201F2BB6 1BC2160F4F3711DC  
 23 1DB4EE606D2A7A96 33C6B4A0166B7C9C 29C5348D87CD5590 5EAB10B19A5143A8  
 B17D15B397521AB3 D49CEF5BD2DEC121 4324C8CACCF7753C 98D2B19D201F2BB6  
 24 5CEF5B2F00142660 1DB4EE606D2A7A96 33C6B4A0166B7C9C 29C5348D87CD5590  
 789E540F22E13932 B17D15B397521AB3 D49CEF5BD2DEC121 4324C8CACCF7753C  
 25 FF74F4A162435903 5CEF5B2F00142660 1DB4EE606D2A7A96 33C6B4A0166B7C9C  
 6C0BE33DCC6E7572 789E540F22E13932 B17D15B397521AB3 D49CEF5BD2DEC121  
 26 41740B736E9676A9 FF74F4A162435903 5CEF5B2F00142660 1DB4EE606D2A7A96  
 D8E401251592DA6C 6C0BE33DCC6E7572 789E540F22E13932 B17D15B397521AB3  
 27 931059FE9279FF1D 41740B736E9676A9 FF74F4A162435903 5CEF5B2F00142660  
 7F31116887EEA596 D8E401251592DA6C 6C0BE33DCC6E7572 789E540F22E13932  
 28 356D08D982E2EAD4 931059FE9279FF1D 41740B736E9676A9 FF74F4A162435903  
 40C28C34B1BBE906 7F31116887EEA596 D8E401251592DA6C 6C0BE33DCC6E7572  
 29 89DC825E7235C74B 356D08D982E2EAD4 931059FE9279FF1D 41740B736E9676A9  
 7A499AE05DA50BF2 40C28C34B1BBE906 7F31116887EEA596 D8E401251592DA6C  
 30 97901F333E662FDC 89DC825E7235C74B 356D08D982E2EAD4 931059FE9279FF1D  
 4472B2E331DDFAB4 7A499AE05DA50BF2 40C28C34B1BBE906 7F31116887EEA596  
 31 69C8F40EB38B6022 97901F333E662FDC 89DC825E7235C74B 356D08D982E2EAD4  
 177589502DD39AA2 4472B2E331DDFAB4 7A499AE05DA50BF2 40C28C34B1BBE906  
 32 4920943FFE52B207 69C8F40EB38B6022 97901F333E662FDC 89DC825E7235C74B  
 6B813A0D0CDF4991 177589502DD39AA2 4472B2E331DDFAB4 7A499AE05DA50BF2  
 33 B4CB0DF332D108AB 4920943FFE52B207 69C8F40EB38B6022 97901F333E662FDC  
 8FE3D28097F18618 6B813A0D0CDF4991 177589502DD39AA2 4472B2E331DDFAB4  
 34 E7748FBF744A5240 B4CB0DF332D108AB 4920943FFE52B207 69C8F40EB38B6022  
 0D7AB03208F1D7A5 8FE3D28097F18618 6B813A0D0CDF4991 177589502DD39AA2  
 35 7416CA18D9E265E0 E7748FBF744A5240 B4CB0DF332D108AB 4920943FFE52B207  
 11200C2D47C082F8 0D7AB03208F1D7A5 8FE3D28097F18618 6B813A0D0CDF4991  
 36 75476F5456E82F9C 7416CA18D9E265E0 E7748FBF744A5240 B4CB0DF332D108AB  
 3024702447F76224 11200C2D47C082F8 0D7AB03208F1D7A5 8FE3D28097F18618  
 37 F638A568B53A2F8F 75476F5456E82F9C 7416CA18D9E265E0 E7748FBF744A5240  
 6217C1C02153302C 3024702447F76224 11200C2D47C082F8 0D7AB03208F1D7A5  
 38 C418F6F90602C79A F638A568B53A2F8F 75476F5456E82F9C 7416CA18D9E265E0  
 87F0901C227ADBB3 6217C1C02153302C 3024702447F76224 11200C2D47C082F8  
 39 4F1F4F21DF3DCF43 C418F6F90602C79A F638A568B53A2F8F 75476F5456E82F9C  
 FB7C63FCDDF4A1C2 87F0901C227ADBB3 6217C1C02153302C 3024702447F76224  
 40 13EB82E4B98D0E67 4F1F4F21DF3DCF43 C418F6F90602C79A F638A568B53A2F8F  
 FB6C0E54D48D4F2D FB7C63FCDDF4A1C2 87F0901C227ADBB3 6217C1C02153302C  
 41 820E75046567BACE 13EB82E4B98D0E67 4F1F4F21DF3DCF43 C418F6F90602C79A



B16A9397472F0123 FB6C0E54D48D4F2D FB7C63FCDDF4A1C2 87F0901C227ADBB3  
 42 741FA5DC290DD02C 820E75046567BACE 13EB82E4B98D0E67 4F1F4F21DF3DCF43  
 ED40C88214823792 B16A9397472F0123 FB6C0E54D48D4F2D FB7C63FCDDF4A1C2  
 43 A4809BF6DA6AA8BD 741FA5DC290DD02C 820E75046567BACE 13EB82E4B98D0E67  
 BEC3D7E88C855194 ED40C88214823792 B16A9397472F0123 FB6C0E54D48D4F2D  
 44 D70B1AA4C800979C A4809BF6DA6AA8BD 741FA5DC290DD02C 820E75046567BACE  
 4962F310BDBD54B0 BEC3D7E88C855194 ED40C88214823792 B16A9397472F0123  
 45 9A195492CFDB4745 D70B1AA4C800979C A4809BF6DA6AA8BD 741FA5DC290DD02C  
 2C82D09CF05CF687 4962F310BDBD54B0 BEC3D7E88C855194 ED40C88214823792  
 46 B7E68364F07F017E 9A195492CFDB4745 D70B1AA4C800979C A4809BF6DA6AA8BD  
 2A1FFB84031B1B6C 2C82D09CF05CF687 4962F310BDBD54B0 BEC3D7E88C855194  
 47 0E574B8E0B35E452 B7E68364F07F017E 9A195492CFDB4745 D70B1AA4C800979C  
 29BDAB29EE472A23 2A1FFB84031B1B6C 2C82D09CF05CF687 4962F310BDBD54B0  
 48 C176009CF82FA842 0E574B8E0B35E452 B7E68364F07F017E 9A195492CFDB4745  
 CCA47FBE31B335F4 29BDAB29EE472A23 2A1FFB84031B1B6C 2C82D09CF05CF687  
 49 5D4F78C7A9BDBED2 C176009CF82FA842 0E574B8E0B35E452 B7E68364F07F017E  
 EAF198615E99FFDC CCA47FBE31B335F4 29BDAB29EE472A23 2A1FFB84031B1B6C  
 50 51AB3BE828D8D13C 5D4F78C7A9BDBED2 C176009CF82FA842 0E574B8E0B35E452  
 BD527CD188FB59AE EAF198615E99FFDC CCA47FBE31B335F4 29BDAB29EE472A23  
 51 4D639EF80D0F6D3E 51AB3BE828D8D13C 5D4F78C7A9BDBED2 C176009CF82FA842  
 B2611B90F90D732F BD527CD188FB59AE EAF198615E99FFDC CCA47FBE31B335F4  
 52 BBA9C9EFE0FBC6C8 4D639EF80D0F6D3E 51AB3BE828D8D13C 5D4F78C7A9BDBED2  
 FC0579337591A2C9 B2611B90F90D732F BD527CD188FB59AE EAF198615E99FFDC  
 53 3405D7CAD2E8A689 BBA9C9EFE0FBC6C8 4D639EF80D0F6D3E 51AB3BE828D8D13C  
 0F6649F64EC8E109 FC0579337591A2C9 B2611B90F90D732F BD527CD188FB59AE  
 54 EA54D908505798B3 3405D7CAD2E8A689 BBA9C9EFE0FBC6C8 4D639EF80D0F6D3E  
 EF48A48999108077 0F6649F64EC8E109 FC0579337591A2C9 B2611B90F90D732F  
 55 BE31D1C0CCC143BC EA54D908505798B3 3405D7CAD2E8A689 BBA9C9EFE0FBC6C8  
 4FC2D4CAD0C91AFC EF48A48999108077 0F6649F64EC8E109 FC0579337591A2C9  
 56 285A76D23F6A0073 BE31D1C0CCC143BC EA54D908505798B3 3405D7CAD2E8A689  
 A730855599B738A3 4FC2D4CAD0C91AFC EF48A48999108077 0F6649F64EC8E109  
 57 A714CEFF14BEBC24 285A76D23F6A0073 BE31D1C0CCC143BC EA54D908505798B3  
 53C581DAE1831D80 A730855599B738A3 4FC2D4CAD0C91AFC EF48A48999108077  
 58 697CA14913A50A26 A714CEFF14BEBC24 285A76D23F6A0073 BE31D1C0CCC143BC  
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 59 3A38FA3775D7007C 697CA14913A50A26 A714CEFF14BEBC24 285A76D23F6A0073  
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 60 44EA14D8E450C844 3A38FA3775D7007C 697CA14913A50A26 A714CEFF14BEBC24  
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 62 6DB5469FA19C0E27 0928B75C925F91E2 44EA14D8E450C844 3A38FA3775D7007C  
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 64 483C64D3FDEBF828 384E3159898A7362 6DB5469FA19C0E27 0928B75C925F91E2  
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 65 C9464988A1939BCF 483C64D3FDEBF828 384E3159898A7362 6DB5469FA19C0E27  
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 66 98BC93BCA795059C C9464988A1939BCF 483C64D3FDEBF828 384E3159898A7362

9E04FB49A5FD91DE E3F3F08AC90F86CD 1A238431921EA75E 55FA3AD1102298A8  
 67 B6FC101AD1D74E20 98BC93BCA795059C C9464988A1939BCF 483C64D3FDEBF828  
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 68 FAC26E6E4DA4705D B6FC101AD1D74E20 98BC93BCA795059C C9464988A1939BCF  
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 69 2A630C58CC27FCAA FAC26E6E4DA4705D B6FC101AD1D74E20 98BC93BCA795059C  
 A2F7F27A3EC25ABA 0D60228AA6E55B6E FD13CD3620F6C1F4 9E04FB49A5FD91DE  
 70 159A02D4FAEE11B4 2A630C58CC27FCAA FAC26E6E4DA4705D B6FC101AD1D74E20  
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 72 D42C3A57CFA78513 9D38BDB9DF22B557 159A02D4FAEE11B4 2A630C58CC27FCAA  
 BB56DEA6A325BA32 DFC37C68AF65F8BC B2860FC55BDEDA6 A2F7F27A3EC25ABA  
 73 ABAB4B0CA75A17C7 D42C3A57CFA78513 9D38BDB9DF22B557 159A02D4FAEE11B4  
 9AC71D1C037A8BBD BB56DEA6A325BA32 DFC37C68AF65F8BC B2860FC55BDEDA6  
 74 500F7B61186F6C2E ABAB4B0CA75A17C7 D42C3A57CFA78513 9D38BDB9DF22B557  
 8347F5736531B3EC 9AC71D1C037A8BBD BB56DEA6A325BA32 DFC37C68AF65F8BC  
 75 4ABE0AF6A67DB2FE 500F7B61186F6C2E ABAB4B0CA75A17C7 D42C3A57CFA78513  
 14E986342DDCED0F 8347F5736531B3EC 9AC71D1C037A8BBD BB56DEA6A325BA32  
 76 E1053FC85F9E56BE 4ABE0AF6A67DB2FE 500F7B61186F6C2E ABAB4B0CA75A17C7  
 4779767CC2EC5321 14E986342DDCED0F 8347F5736531B3EC 9AC71D1C037A8BBD  
 77 7001201948FB3D71 E1053FC85F9E56BE 4ABE0AF6A67DB2FE 500F7B61186F6C2E  
 5CDF6C58FC052572 4779767CC2EC5321 14E986342DDCED0F 8347F5736531B3EC  
 78 88146DA76FF6F23A 7001201948FB3D71 E1053FC85F9E56BE 4ABE0AF6A67DB2FE  
 8901CFFE7A74DB98 5CDF6C58FC052572 4779767CC2EC5321 14E986342DDCED0F  
 79 5EC3802B9ECFEF33 88146DA76FF6F23A 7001201948FB3D71 E1053FC85F9E56BE  
 5F2EEAD69EFB4233 8901CFFE7A74DB98 5CDF6C58FC052572 4779767CC2EC5321

The following eight words,  $Y_0$ ,  $Y_1$ ,  $Y_2$ ,  $Y_3$ ,  $Y_4$ ,  $Y_5$ ,  $Y_6$  and  $Y_7$ , represent the output of the round-function in the first block process.

$Y_0$  = CBBB9D5DC1059ED8  $\cup$  5EC3802B9ECFEF33 = 2A7F1D895FD58E0B  
 $Y_1$  = 629A292A367CD507  $\cup$  88146DA76FF6F23A = EAAE96D1A673C741  
 $Y_2$  = 9159015A3070DD17  $\cup$  7001201948FB3D71 = 015A2173796C1A88  
 $Y_3$  = 152FECDD8F70E5939  $\cup$  E1053FC85F9E56BE = F6352CA156ACAFF7  
 $Y_4$  = 67332667FFC00B31  $\cup$  5F2EEAD69EFB4233 = C662113E9EBB4D64  
 $Y_5$  = 8EB44A8768581511  $\cup$  8901CFFE7A74DB98 = 17B61A85E2CCF0A9  
 $Y_6$  = DB0C2E0D64F98FA7  $\cup$  5CDF6C58FC052572 = 37EB9A6660FEB519  
 $Y_7$  = 47B5481DBEFA4FA4  $\cup$  4779767CC2EC5321 = 8F2EBE9A81E6A2C5

The following are (hexadecimal representations of) the successive values of the variables  $Y_0$ ,  $Y_1$ ,  $Y_2$ ,  $Y_3$ ,  $Y_4$ ,  $Y_5$ ,  $Y_6$  and  $Y_7$  in the second block process.

INIT: 2A7F1D895FD58E0B EAAE96D1A673C741 015A2173796C1A88 F6352CA156ACAFF7  
 C662113E9EBB4D64 17B61A85E2CCF0A9 37EB9A6660FEB519 8F2EBE9A81E6A2C5  
 0 657A3C2CA9639D40 2A7F1D895FD58E0B EAAE96D1A673C741 015A2173796C1A88  
 791F2AD0055FDD62 C662113E9EBB4D64 17B61A85E2CCF0A9 37EB9A6660FEB519  
 1 2A4AD5D9B9FD6D86 657A3C2CA9639D40 2A7F1D895FD58E0B EAAE96D1A673C741  
 DBF2E656B5BE3F14 791F2AD0055FDD62 C662113E9EBB4D64 17B61A85E2CCF0A9  
 2 F0AA6758653D1664 2A4AD5D9B9FD6D86 657A3C2CA9639D40 2A7F1D895FD58E0B  
 6E0466C82F4FD35D DBF2E656B5BE3F14 791F2AD0055FDD62 C662113E9EBB4D64  
 3 43A76F011A73D317 F0AA6758653D1664 2A4AD5D9B9FD6D86 657A3C2CA9639D40  
 1367BD36D15E8B40 6E0466C82F4FD35D DBF2E656B5BE3F14 791F2AD0055FDD62

4 D802C2DFD7CC48F6 43A76F011A73D317 F0AA6758653D1664 2A4AD5D9B9FD6D86  
F73D759B839A2A21 1367BD36D15E8B40 6E0466C82F4FD35D DBF2E656B5BE3F14

5 481208E5E8314602 D802C2DFD7CC48F6 43A76F011A73D317 F0AA6758653D1664  
6B2271A46F14C843 F73D759B839A2A21 1367BD36D15E8B40 6E0466C82F4FD35D

6 AF9F8112DF35CF33 481208E5E8314602 D802C2DFD7CC48F6 43A76F011A73D317  
257F4A7D524D7B0B 6B2271A46F14C843 F73D759B839A2A21 1367BD36D15E8B40

7 6730781342D1131B AF9F8112DF35CF33 481208E5E8314602 D802C2DFD7CC48F6  
81957AD408CEC995 257F4A7D524D7B0B 6B2271A46F14C843 F73D759B839A2A21

8 82E64C677356A82E 6730781342D1131B AF9F8112DF35CF33 481208E5E8314602  
10B62FDCE4EBAA51 81957AD408CEC995 257F4A7D524D7B0B 6B2271A46F14C843

9 203578820A8F27D0 82E64C677356A82E 6730781342D1131B AF9F8112DF35CF33  
9937B3A0CB9248A1 10B62FDCE4EBAA51 81957AD408CEC995 257F4A7D524D7B0B

10 0BAC2A84C29A1E2B 203578820A8F27D0 82E64C677356A82E 6730781342D1131B  
6AD288DAB3DE0D53 9937B3A0CB9248A1 10B62FDCE4EBAA51 81957AD408CEC995

11 DD3FF8A140485C25 0BAC2A84C29A1E2B 203578820A8F27D0 82E64C677356A82E  
3149B728123C465E 6AD288DAB3DE0D53 9937B3A0CB9248A1 10B62FDCE4EBAA51

12 E826239F830C5346 DD3FF8A140485C25 0BAC2A84C29A1E2B 203578820A8F27D0  
4BB7B199C4CED186 3149B728123C465E 6AD288DAB3DE0D53 9937B3A0CB9248A1

13 32215CE49AAE40F8 E826239F830C5346 DD3FF8A140485C25 0BAC2A84C29A1E2B  
9A2872C72D790D49 4BB7B199C4CED186 3149B728123C465E 6AD288DAB3DE0D53

14 859533BAC457F94E 32215CE49AAE40F8 E826239F830C5346 DD3FF8A140485C25  
539F225D25EBEB4C 9A2872C72D790D49 4BB7B199C4CED186 3149B728123C465E

15 A88704D9962849F3 859533BAC457F94E 32215CE49AAE40F8 E826239F830C5346  
63BF0472EF24F7A5 539F225D25EBEB4C 9A2872C72D790D49 4BB7B199C4CED186

16 3AA5C566A6CFAD1C A88704D9962849F3 859533BAC457F94E 32215CE49AAE40F8  
CE23F6380EAD33C2 63BF0472EF24F7A5 539F225D25EBEB4C 9A2872C72D790D49

17 2E9C483A7C08C9C1 3AA5C566A6CFAD1C A88704D9962849F3 859533BAC457F94E  
B033F945F3E6B4A2 CE23F6380EAD33C2 63BF0472EF24F7A5 539F225D25EBEB4C

18 5A68585AE0835231 2E9C483A7C08C9C1 3AA5C566A6CFAD1C A88704D9962849F3  
8A0187A9CE93D875 B033F945F3E6B4A2 CE23F6380EAD33C2 63BF0472EF24F7A5

19 CF9CD481E6407CED 5A68585AE0835231 2E9C483A7C08C9C1 3AA5C566A6CFAD1C  
37A29FA30531BAC7 8A0187A9CE93D875 B033F945F3E6B4A2 CE23F6380EAD33C2

20 3F463F864F6474D9 CF9CD481E6407CED 5A68585AE0835231 2E9C483A7C08C9C1  
0CF45BB3C07E847D 37A29FA30531BAC7 8A0187A9CE93D875 B033F945F3E6B4A2

21 CEA26288DFF931A5 3F463F864F6474D9 CF9CD481E6407CED 5A68585AE0835231  
34F1B5F46BF48A73 0CF45BB3C07E847D 37A29FA30531BAC7 8A0187A9CE93D875

22 89634CD0F4F6C08A CEA26288DFF931A5 3F463F864F6474D9 CF9CD481E6407CED  
3A728A543405A8E4 34F1B5F46BF48A73 0CF45BB3C07E847D 37A29FA30531BAC7

23 625FA38464E5C880 89634CD0F4F6C08A CEA26288DFF931A5 3F463F864F6474D9  
CEE1B47A49B2FC42 3A728A543405A8E4 34F1B5F46BF48A73 0CF45BB3C07E847D

24 7DD21453A15A3B92 625FA38464E5C880 89634CD0F4F6C08A CEA26288DFF931A5  
9308BFA1BE1F800B CEE1B47A49B2FC42 3A728A543405A8E4 34F1B5F46BF48A73

25 3D76277BC8CB0601 7DD21453A15A3B92 625FA38464E5C880 89634CD0F4F6C08A  
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26 C8D904196F5A1F54 3D76277BC8CB0601 7DD21453A15A3B92 625FA38464E5C880  
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27 B033139B58B6E423 C8D904196F5A1F54 3D76277BC8CB0601 7DD21453A15A3B92  
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28 097768182CB65F57 B033139B58B6E423 C8D904196F5A1F54 3D76277BC8CB0601  
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29 3196649AB5F5CC39 097768182CB65F57 B033139B58B6E423 C8D904196F5A1F54  
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30 F78D3D221D16965F 3196649AB5F5CC39 097768182CB65F57 B033139B58B6E423  
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31 F58E9876B4984B51 F78D3D221D16965F 3196649AB5F5CC39 097768182CB65F57  
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32 38FBF0E726E04F78 F58E9876B4984B51 F78D3D221D16965F 3196649AB5F5CC39  
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33 F4BE0B32A57597A2 38FBF0E726E04F78 F58E9876B4984B51 F78D3D221D16965F  
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34 F8A6B3FE2E4F0634 F4BE0B32A57597A2 38FBF0E726E04F78 F58E9876B4984B51  
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35 9BC3871BE8046113 F8A6B3FE2E4F0634 F4BE0B32A57597A2 38FBF0E726E04F78  
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36 F1BD2D46BE619585 9BC3871BE8046113 F8A6B3FE2E4F0634 F4BE0B32A57597A2  
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37 24C84B58D119AFFE F1BD2D46BE619585 9BC3871BE8046113 F8A6B3FE2E4F0634  
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38 EC6D3ABC2B291FD3 24C84B58D119AFFE F1BD2D46BE619585 9BC3871BE8046113  
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39 E266C1F77D5EE90E EC6D3ABC2B291FD3 24C84B58D119AFFE F1BD2D46BE619585  
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41 50FDB7BB2E499A34 5ADBAA463642B570 E266C1F77D5EE90E EC6D3ABC2B291FD3  
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42 06514212BB7FA152 50FDB7BB2E499A34 5ADBAA463642B570 E266C1F77D5EE90E  
466781DB35181ABE 257ED8EA645E933A 83E8F410F859388E D92F34C110296B32

43 673ED5A55FF2B07D 06514212BB7FA152 50FDB7BB2E499A34 5ADBAA463642B570  
BA78F3545E7914F0 466781DB35181ABE 257ED8EA645E933A 83E8F410F859388E

44 125E2E5118393E2B 673ED5A55FF2B07D 06514212BB7FA152 50FDB7BB2E499A34  
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45 07EE813DF5910CEC 125E2E5118393E2B 673ED5A55FF2B07D 06514212BB7FA152  
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46 0A0508F0A1D719C3 07EE813DF5910CEC 125E2E5118393E2B 673ED5A55FF2B07D  
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47 0FC8F3B3EFCB1B96 0A0508F0A1D719C3 07EE813DF5910CEC 125E2E5118393E2B  
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48 02AA5B28199F304A 0FC8F3B3EFCB1B96 0A0508F0A1D719C3 07EE813DF5910CEC  
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49 9223E1B34382F104 02AA5B28199F304A 0FC8F3B3EFCB1B96 0A0508F0A1D719C3  
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50 E01A1E47EE8D5656 9223E1B34382F104 02AA5B28199F304A 0FC8F3B3EFCB1B96  
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51 FA7B17AAD857C2F4 E01A1E47EE8D5656 9223E1B34382F104 02AA5B28199F304A  
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52 0C523B7A3C84AB77 FA7B17AAD857C2F4 E01A1E47EE8D5656 9223E1B34382F104  
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53 C773D8B69DA1FDE2 0C523B7A3C84AB77 FA7B17AAD857C2F4 E01A1E47EE8D5656  
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54 C6B1BC79A4F23679 C773D8B69DA1FDE2 0C523B7A3C84AB77 FA7B17AAD857C2F4  
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55 BEF9BB0FE467FD60 C6B1BC79A4F23679 C773D8B69DA1FDE2 0C523B7A3C84AB77  
1DAB0BD116E434E5 C80BDC57F38A05E4 BE2B0602FC6F8F65 B5E80E871AC0C005

56 8E3DB3E380EC7F22 BEF9BB0FE467FD60 C6B1BC79A4F23679 C773D8B69DA1FDE2  
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57 1003EC42412C7B7D 8E3DB3E380EC7F22 BEF9BB0FE467FD60 C6B1BC79A4F23679  
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58 375FACC76291F85E 1003EC42412C7B7D 8E3DB3E380EC7F22 BEF9BB0FE467FD60  
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59 BD113D92E0354FB9 375FACC76291F85E 1003EC42412C7B7D 8E3DB3E380EC7F22  
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60 2F61D4FD8E36D9D4 BD113D92E0354FB9 375FACC76291F85E 1003EC42412C7B7D  
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61 1B1AD88B92701AE2 2F61D4FD8E36D9D4 BD113D92E0354FB9 375FACC76291F85E  
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62 93D09FC06A19C5DA 1B1AD88B92701AE2 2F61D4FD8E36D9D4 BD113D92E0354FB9  
B765273F571A571E 6FD0C1719BCAC335 E9F21933E1C02948 E66C73DB3FAD397D

63 04BEA2CE99CC3BF6 93D09FC06A19C5DA 1B1AD88B92701AE2 2F61D4FD8E36D9D4  
6AB0E443C2F63714 B765273F571A571E 6FD0C1719BCAC335 E9F21933E1C02948

64 02EBFC0A13492F52 04BEA2CE99CC3BF6 93D09FC06A19C5DA 1B1AD88B92701AE2  
77300C52E05AF415 6AB0E443C2F63714 B765273F571A571E 6FD0C1719BCAC335

65 1BF525ABCE8D6F04 02EBFC0A13492F52 04BEA2CE99CC3BF6 93D09FC06A19C5DA  
8FAF12C33BB371B9 77300C52E05AF415 6AB0E443C2F63714 B765273F571A571E

66 B6A36A3431547328 1BF525ABCE8D6F04 02EBFC0A13492F52 04BEA2CE99CC3BF6  
FA8BB40B4E08100F 8FAF12C33BB371B9 77300C52E05AF415 6AB0E443C2F63714

67 FFDAF83202AF0D72 B6A36A3431547328 1BF525ABCE8D6F04 02EBFC0A13492F52  
8045A82F723A9B4E FA8BB40B4E08100F 8FAF12C33BB371B9 77300C52E05AF415

68 12737373D2985232 FFDAF83202AF0D72 B6A36A3431547328 1BF525ABCE8D6F04  
870DBCE23BAD8988 8045A82F723A9B4E FA8BB40B4E08100F 8FAF12C33BB371B9

69 6189F68162B256B5 12737373D2985232 FFDAF83202AF0D72 B6A36A3431547328  
8C059AF157146580 870DBCE23BAD8988 8045A82F723A9B4E FA8BB40B4E08100F

70 20B0A9A1D21C482D 6189F68162B256B5 12737373D2985232 FFDAF83202AF0D72  
F22B874C96785EC8 8C059AF157146580 870DBCE23BAD8988 8045A82F723A9B4E

71 EF6D863C2127B394 20B0A9A1D21C482D 6189F68162B256B5 12737373D2985232  
B7AEE28337D69DAB F22B874C96785EC8 8C059AF157146580 870DBCE23BAD8988

72 D3EFE8B442689074 EF6D863C2127B394 20B0A9A1D21C482D 6189F68162B256B5  
22491AB9CDECB6B0 B7AEE28337D69DAB F22B874C96785EC8 8C059AF157146580

73 4694354944A9F487 D3EFE8B442689074 EF6D863C2127B394 20B0A9A1D21C482D  
659890A5818D0C50 22491AB9CDECB6B0 B7AEE28337D69DAB F22B874C96785EC8

74 B93C2403773DD08C 4694354944A9F487 D3EFE8B442689074 EF6D863C2127B394  
88C2C2AC52C4F679 659890A5818D0C50 22491AB9CDECB6B0 B7AEE28337D69DAB

75 025848E3AB6B69D3 B93C2403773DD08C 4694354944A9F487 D3EFE8B442689074  
750DA3D4E16A1B64 88C2C2AC52C4F679 659890A5818D0C50 22491AB9CDECB6B0

76 396B53E58D04471B 025848E3AB6B69D3 B93C2403773DD08C 4694354944A9F487  
700486BF252CBA75 750DA3D4E16A1B64 88C2C2AC52C4F679 659890A5818D0C50

77 51B6F9A3C1CEE4A 396B53E58D04471B 025848E3AB6B69D3 B93C2403773DD08C  
E6B3850DE8AE6230 700486BF252CBA75 750DA3D4E16A1B64 88C2C2AC52C4F679

78 526A98F5DC595406 51B6F9A3C1CEE4A 396B53E58D04471B 025848E3AB6B69D3

4F0DCF74AEA76F90 E6B3850DE8AE6230 700486BF252CBA75 750DA3D4E16A1B64  
 79 DEB3EEAA973BB9DD 526A98F5DC595406 51B6F9A3C1CEEB4A 396B53E58D04471B  
 3665B5DBB6C2E055 4F0DCF74AEA76F90 E6B3850DE8AE6230 700486BF252CBA75

The following eight words,  $Y_0$ ,  $Y_1$ ,  $Y_2$ ,  $Y_3$ ,  $Y_4$ ,  $Y_5$ ,  $Y_6$  and  $Y_7$ , represent the output of the final iteration of the round-function.

$Y_0 = 2A7F1D895FD58E0B \cup DEB3EEAA973BB9DD = 09330C33F71147E8$   
 $Y_1 = EAAE96D1A673C741 \cup 526A98F5DC595406 = 3D192FC782CD1B47$   
 $Y_2 = 015A2173796C1A88 \cup 51B6F9A3C1CEEB4A = 53111B173B3B05D2$   
 $Y_3 = F6352CA156ACAFF7 \cup 396B53E58D04471B = 2FA08086E3B0F712$   
 $Y_4 = C662113E9EBB4D64 \cup 3665B5DBB6C2E055 = FCC7C71A557E2DB9$   
 $Y_5 = 17B61A85E2CCF0A9 \cup 4F0DCF74AEA76F90 = 66C3E9FA91746039$   
 $Y_6 = 37EB9A6660FEB519 \cup E6B3850DE8AE6230 = 1E9F1F7449AD1749$   
 $Y_7 = 8F2EBE9A81E6A2C5 \cup 700486BF252CBA75 = FF334559A7135D3A$

The following is the hash value for this message.

09330C33F71147E8 3D192FC782CD1B47 53111B173B3B05D2 2FA08086E3B0F712  
 FCC7C71A557E2DB9 66C3E9FA91746039

### B.7.11 Example 11

In this example, the data string is the 32-byte string consisting of the ASCII-coded version of

“abcdbcdecdefdefgefgfghghijhijk”

The hash-code is the following 384-bit string.

D4CC646A83A55044 DF94814DB93B6062 E656623DB0B9E2DA B8819174589BF0C9  
 D7192B9799E30169 8B97ADAA3D82E20C

## B.8 Dedicated Hash-Function 7 (WHIRLPOOL)

### B.8.1 Example 1

In this example, the data string is the empty string, i.e. the string of length zero.

The hash-code is the following 512-bit string.

19FA61D75522A466 9B44E39C1D2E1726 C530232130D407F8 9AFEE0964997F7A7  
 3E83BE698B288FEB CF88E3E03C4F0757 EA8964E59B63D937 08B138CC42A66EB3

### B.8.2 Example 2

In this example, the data string consists of a single byte, namely the ASCII-coded version of the letter “a”.

The hash-code is the following 512-bit string.

8ACA2602792AEC6F 11A67206531FB7D7 F0DFF59413145E69 73C45001D0087B42  
 D11BC645413AEFF6 3A42391A39145A59 1A92200D560195E5 3B478584FDAE231A

### B.8.3 Example 3

In this example, the data string is the 3-byte string consisting of the ASCII-coded version of “abc”.



After the padding process, the  $8 \times 8$  matrix  $Z'$  derived from the data string is as follows.

```

61 62 63 80 00 00 00 00
00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 18

```

The  $K_0$  matrix (from the initialization value,  $IV$ ) and  $X''$  matrix are as follows.

```

00 00 00 00 00 00 00 00    61 62 63 80 00 00 00 00
00 00 00 00 00 00 00 00    00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00    00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00    00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00    00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00    00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00    00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00    00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00    00 00 00 00 00 00 00 18

```

The following are (hexadecimal representations of) the successive values of the variables  $K_i$  for  $i = 1$  to 10 and  $W'$ .

$i = 1:$

```

30 0B EE C0 AF 90 29 67    0F 34 9A FF 3F F3 2F E0
28 28 28 28 28 28 28 28    EB CD CD 13 CD 26 DE 87
28 28 28 28 28 28 28 28    2D 2C 98 98 5A 98 B4 C2
28 28 28 28 28 28 28 28    89 03 83 8F 8F 06 8F 0C
28 28 28 28 28 28 28 28    00 00 00 00 00 00 00 00
28 28 28 28 28 28 28 28    00 00 00 00 00 00 00 00
28 28 28 28 28 28 28 28    05 14 05 28 11 0A 2D 05
28 28 28 28 28 28 28 28    00 00 00 00 00 00 00 00

```

$i = 2:$

```

3B AB 89 F8 EA D1 AE 24    1D 0D 4C DA 43 F6 B0 98
44 45 45 66 45 E9 CB AF    E4 5E 3F B8 7B C7 AA 10
70 FE A4 A4 C5 A4 B2 89    C3 31 D1 56 FD E7 7B 8F
C5 FA A9 E1 E1 CC E1 A0    68 2F 47 A1 BE 4A 53 39
48 AC C0 5C FC FC B8 FC    B2 A2 B8 2F 20 72 F0 6C
8F F7 0E 26 90 8F 8F 69    03 D9 F4 6C 67 B1 79 72
96 79 14 07 D7 85 79 79    2C 67 87 6E FD 5C 25 F8
F8 A8 F8 68 B8 C8 78 F8    44 E6 4C 70 50 7C D8 26

```



$i = 3$ :

|                         |                         |
|-------------------------|-------------------------|
| D3 19 BF DB 30 46 70 58 | EF ED 35 67 80 8E 8D 63 |
| 29 5B 23 D1 AF CF 37 DB | 2F 03 49 91 5B 18 5C 24 |
| 01 2C 8A C2 8B 95 AC 98 | 77 96 F6 03 BF AA F8 E3 |
| 81 63 9E B1 C0 B2 06 A7 | 0A DC 04 7B 58 5A A5 A1 |
| 44 5E 60 7A B0 B2 09 DB | 47 96 DA 7F 56 E4 CC 29 |
| 73 5B 2C CF BC 8C BC 71 | 20 70 D5 D8 50 01 C8 98 |
| DC 67 09 24 EF ED DD D3 | A7 4C 23 FA F6 81 49 A1 |
| 7B 8D 3B F0 D7 3B 7D 19 | 4A CE 46 7D 7D B0 73 A9 |

 $i = 4$ :

|                         |                         |
|-------------------------|-------------------------|
| 38 BE AA C1 DE 11 65 86 | 95 BD DE 1E CA 0F CA 19 |
| 68 7C F3 D0 4A 87 33 7F | D3 C1 CF 6C A0 2E 41 E8 |
| F3 37 FA DB 98 AD F0 57 | 74 C3 5C 63 15 C5 B9 8A |
| C5 E2 42 58 EE 35 8D BC | 36 F0 4E 42 FE 2D D0 5E |
| 11 09 F0 E8 99 6E 24 7E | 0A 3C 50 76 A1 91 F8 EC |
| 01 C5 D6 ED 10 B0 34 01 | 48 6B C7 3E 61 D2 A4 DC |
| FB C9 52 F1 7B 28 EC D3 | ED B8 F0 C5 2C F0 5C 72 |
| 32 56 DC 0C C7 F1 27 40 | FA 3D 00 D4 FB 9A 66 FF |

 $i = 5$ :

|                         |                         |
|-------------------------|-------------------------|
| AF 25 A5 20 94 9B CF 14 | 06 A6 BA 18 05 54 8D 33 |
| C1 36 26 A9 E3 C4 53 4D | 84 55 FE C4 1F B2 0B 1C |
| E6 0F 7D 86 77 40 F9 E1 | 6E A2 93 49 3F 17 89 B7 |
| 91 5D E6 BB E2 6A 06 29 | 7D 02 C9 A0 52 85 BB EF |
| 96 5A 54 CC 4C FE 5E 8D | AC 55 D7 A9 44 48 89 A9 |
| EE E9 31 CB 62 32 3A A6 | CB DE BE 43 AA 4D B5 A0 |
| B1 7B 59 18 96 84 6A 47 | 60 A6 BA C0 25 D9 4F 8C |
| D4 F0 C9 36 27 59 AF 31 | D7 E4 62 E5 D4 A8 CC C0 |

$i = 6$ :

E2 F9 B5 C0 25 37 0B B0  
 39 2B CB A2 16 84 94 A5  
 60 8A F8 CE FA 34 8C 14  
 7A A5 37 64 41 8C 92 19  
 B3 F3 46 A1 FA 83 3F 89  
 97 49 3F 48 78 02 CF 7C  
 DC AD E8 BA 1E 00 8F 23  
 92 77 4F 49 ED B0 32 3D

DB 1D A8 4A 33 38 4D B3  
 97 4C 8E 1A 3E 51 F3 48  
 47 66 64 C2 33 F5 F2 A9  
 85 FD AA B1 D5 CB C3 6E  
 5D 89 59 F2 E1 F8 71 D4  
 8C 1F B9 78 8C 16 DD 05  
 62 AF 63 5F 6D EE D5 F4  
 D8 5B 74 35 5F 8A 98 47

 $i = 7$ :

75 41 63 82 77 4D FF 2F  
 FF FA 38 D0 55 03 46 00  
 BF 7D 02 49 3E 98 F3 61  
 F4 A8 60 C2 9A E5 CE 0B  
 C8 DF 5A 44 EE 5D 9D 27  
 23 F4 5A 55 04 75 00 A4  
 B0 16 10 12 02 F9 E2 8C  
 AC 30 CD 29 68 33 33 1D

59 3D 86 BD A8 CE 25 E5  
 BB 33 95 78 26 63 7D 82  
 EF 46 1D AE DC AD 0C 3C  
 AF A0 E2 86 5E 8B A3 F9  
 C8 8C 0B 43 27 84 31 F4  
 41 5F 51 64 4E 55 78 C2  
 F4 C7 C3 B5 EE A4 C5 86  
 49 F8 AB 68 4A 4C 96 B7

 $i = 8$ :

03 6B F1 82 68 84 AD 89  
 99 40 C6 62 D8 46 71 63  
 4C 43 3E 17 4B 19 C2 10  
 E2 9C CF D3 4C FF 86 C5  
 21 FF 11 A0 42 DF 26 53  
 1B 8E 00 CB 6C E4 4B 13  
 A6 12 3B F7 A3 47 B7 CE  
 D9 18 90 0E 3B 28 33 CA

9C 0D 38 97 73 B2 E4 35  
 4D 44 89 58 D4 59 27 E8  
 AD 59 2E B0 4C A3 63 32  
 E0 D4 70 F3 83 5A 15 59  
 9A 92 69 8C 76 40 A1 51  
 57 2E 81 EA CB A4 3C 36  
 5D 63 2F A7 36 BE 4B 61  
 40 0F DA CB 8B 9D E3 8A

$i = 9$ :

|                         |                         |
|-------------------------|-------------------------|
| D0 1C 67 7A 0A 9A 2C F9 | 4B F0 5E 9B 46 14 16 D0 |
| 2A 94 2F 53 4A 63 B6 B2 | 72 A8 C1 34 47 13 17 2D |
| 88 42 22 46 FE AC A8 B4 | 17 33 2A 69 FB 34 98 98 |
| 47 4A 5C C7 3D 58 35 59 | 83 B1 EE 37 93 47 EC A0 |
| 74 A6 92 5D A5 5C 6F A1 | 3B 39 67 11 23 35 B5 78 |
| 77 17 E6 8C C4 73 5C 39 | FC 78 3D 1F 9D 2F B6 AE |
| 08 2A 3B 0B 53 EC 1A C6 | 3C F9 38 64 96 9B DE 6C |
| 2A F6 58 EB 81 4D E7 62 | 42 5A D1 47 6C 0C 49 AE |

$i = 10$ :

|                         |                         |
|-------------------------|-------------------------|
| 48 95 48 B6 01 EE BC 3A | 2F 46 2B 24 C6 F4 86 BB |
| A5 0D 6B C6 6B ED 8E 81 | 16 B6 56 2C 73 B4 02 0B |
| E0 CE 3D CF 88 26 5A 75 | F3 04 3E 3A 73 1B CE 72 |
| C2 8C 4A DB C0 F6 9C E9 | 1A E1 B3 03 D9 7E 6D 4C |
| 54 B7 9C D5 7F 71 85 13 | 71 81 EE BD B6 C5 7E 27 |
| 43 41 4B 8A 97 7D 0B 7B | 7D 0E 34 95 71 14 CB D6 |
| 63 19 35 BB DB F6 15 7A | C7 97 FC 9D 95 D8 B5 82 |
| 6A 7A 4E F6 37 01 82 27 | D2 25 29 20 76 D4 EE ED |

The value of  $Y'$  output from the round-function is as follows.

|                         |
|-------------------------|
| 4E 24 48 A4 C6 F4 86 BB |
| 16 B6 56 2C 73 B4 02 0B |
| F3 04 3E 3A 73 1B CE 72 |
| 1A E1 B3 03 D9 7E 6D 4C |
| 71 81 EE BD B6 C5 7E 27 |
| 7D 0E 34 95 71 14 CB D6 |
| C7 97 FC 9D 95 D8 B5 82 |
| D2 25 29 20 76 D4 EE F5 |

The hash-code is the following 512-bit string.

4E2448A4C6F486BB 16B6562C73B4020B F3043E3A731BCE72 1AE1B303D97E6D4C  
7181EEBDB6C57E27 7D0E34957114CBD6 C797FC9D95D8B582 D225292076D4EEF5

#### B.8.4 Example 4

In this example, the data string is the 14-byte string consisting of the ASCII-coded version of

“message digest”

The hash-code is the following 512-bit string.

378C84A4126E2DC6 E56DCC7458377AAC 838D00032230F53C E1F5700C0FFB4D3B  
8421557659EF55C1 06B4B52AC5A4AAA6 92ED920052838F33 62E86DBD37A8903E

### B.8.5 Example 5

In this example, the data string is the 26-byte string consisting of the ASCII-coded version of

“abcdefghijklmnopqrstuvwxyz”

The hash-code is the following 512-bit string.

F1D754662636FFE9 2C82EBB9212A484A 8D38631EAD4238F5 442EE13B8054E41B  
08BF2A9251C30B6A 0B8AAE86177AB4A6 F68F673E7207865D 5D9819A3DBA4EB3B

### B.8.6 Example 6

In this example, the data string is the 62-byte string consisting of the ASCII-coded version of

"ABCDEFGHIJKLMNOPQRSTUVWXYZabcdefghijklmnopqrstuvwxyz0123456789"

The hash-code is the following 512-bit string.

DC37E008CF9EE69B F11F00ED9ABA2690 1DD7C28CDEC066CC 6AF42E40F82F3A1E  
08EBA26629129D8F B7CB57211B9281A6 5517CC879D7B9621 42C65F5A7AF01467

### B.8.7 Example 7

In this example, the data string is the 80-byte string consisting of the ASCII-coded version of eight repetitions of

“1234567890”

The hash-code is the following 512-bit string.

466EF18BABB0154D 25B9D38A6414F5C0 8784372BCCB204D6 549C4AFADB601429  
4D5BD8DF2A6C44E5 38CD047B2681A51A 2C60481E88C5A20B 2C2A80CF3A9A083A

### B.8.8 Example 8

In this example, the data string is the 32-byte string consisting of the ASCII-coded version of

“abcdbcdcdefdefgefghfghighijhijk”

After the padding process, the two  $8 \times 8$  matrices derived from the data string are as follows.

|    |    |    |    |    |    |    |    |  |    |    |    |    |    |    |    |    |
|----|----|----|----|----|----|----|----|--|----|----|----|----|----|----|----|----|
| 61 | 62 | 63 | 64 | 62 | 63 | 64 | 65 |  | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| 63 | 64 | 65 | 66 | 64 | 65 | 66 | 67 |  | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| 65 | 66 | 67 | 68 | 66 | 67 | 68 | 69 |  | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| 67 | 68 | 69 | 6A | 68 | 69 | 6A | 6B |  | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| 80 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |  | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |  | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |  | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |  | 00 | 00 | 00 | 00 | 00 | 00 | 01 | 00 |

The first  $Z'$  matrix is as follows.

```

61 62 63 64 62 63 64 65
63 64 65 66 64 65 66 67
65 66 67 68 66 67 68 69
67 68 69 6A 68 69 6A 6B
80 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00

```

For the first  $Z'$  matrix, the  $K_0$  matrix (from the initialization value,  $IV$ ) and the  $X''$  matrix are as follows.

```

00 00 00 00 00 00 00 00      61 62 63 64 62 63 64 65
00 00 00 00 00 00 00 00      63 64 65 66 64 65 66 67
00 00 00 00 00 00 00 00      65 66 67 68 66 67 68 69
00 00 00 00 00 00 00 00      67 68 69 6A 68 69 6A 6B
00 00 00 00 00 00 00 00      80 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00      00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00      00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00      00 00 00 00 00 00 00 00

```

The following are (hexadecimal representations of) the successive values of the variables  $K_i$  for  $i = 1$  to 10 and  $W'$ .

$i = 1$ :

```

30 0B EE C0 AF 90 29 67      86 B9 56 DD B4 BD 40 C2
28 28 28 28 28 28 28 28      0B 48 C1 2E 83 9C 2E 41
28 28 28 28 28 28 28 28      40 5E 0A ED 5C E9 42 E7
28 28 28 28 28 28 28 28      B2 1E 5B 93 43 07 7C 4D
28 28 28 28 28 28 28 28      19 04 67 A3 57 CF DA ED
28 28 28 28 28 28 28 28      59 36 7D 57 F8 E7 EA 60
28 28 28 28 28 28 28 28      98 D1 1B 6A C6 1C 4B CD
28 28 28 28 28 28 28 28      5E B9 76 56 F3 51 F4 43

```

$i = 2$ :

```

3B AB 89 F8 EA D1 AE 24      10 54 A2 C2 9E 00 80 4F
44 45 45 66 45 E9 CB AF      6B C6 9F 0A 98 41 BA 45
70 FE A4 A4 C5 A4 B2 89      6B 0B DE 38 1B F6 5A 3F
C5 FA A9 E1 E1 CC E1 A0      34 F5 52 E4 38 30 DA 32
48 AC C0 5C FC FC B8 FC      A7 4E 3B C9 F2 58 65 5B
8F F7 0E 26 90 8F 8F 69      2C 84 5C F8 DE BA 57 52
96 79 14 07 D7 85 79 79      0B 0B CB 4F 5F 5F 13 10
F8 A8 F8 68 B8 C8 78 F8      B4 43 90 D6 92 4F 65 12

```

$i = 3$ :

|                         |                         |
|-------------------------|-------------------------|
| D3 19 BF DB 30 46 70 58 | 8F 55 E3 10 51 E9 E7 43 |
| 29 5B 23 D1 AF CF 37 DB | F3 AE 56 A1 2E 86 11 01 |
| 01 2C 8A C2 8B 95 AC 98 | 01 78 57 78 4C 25 EE 95 |
| 81 63 9E B1 C0 B2 06 A7 | 8B 13 D5 66 9A EA A5 53 |
| 44 5E 60 7A B0 B2 09 DB | 55 E0 9A 46 78 79 57 56 |
| 73 5B 2C CF BC 8C BC 71 | E2 3E F3 AF D4 5F 66 62 |
| DC 67 09 24 EF ED DD D3 | 05 E9 CA 43 59 FC 08 53 |
| 7B 8D 3B F0 D7 3B 7D 19 | 6A 11 68 9A 3D 24 86 2C |

 $i = 4$ :

|                         |                         |
|-------------------------|-------------------------|
| 38 BE AA C1 DE 11 65 86 | BD A3 5F AC C8 4B 7B 24 |
| 68 7C F3 D0 4A 87 33 7F | D4 D5 53 36 8A FA 90 C8 |
| F3 37 FA DB 98 AD F0 57 | 7D 9A 3C 52 B5 B9 28 0B |
| C5 E2 42 58 EE 35 8D BC | FE CD D7 48 5D 98 AC 21 |
| 11 09 F0 E8 99 6E 24 7E | F6 D3 E3 F5 A1 C0 68 F0 |
| 01 C5 D6 ED 10 B0 34 01 | D9 77 56 2D F1 C4 3C B6 |
| FB C9 52 F1 7B 28 EC D3 | C2 85 71 D3 B2 94 91 69 |
| 32 56 DC 0C C7 F1 27 40 | E2 B9 81 C5 7C 60 42 23 |

 $i = 5$ :

|                         |                         |
|-------------------------|-------------------------|
| AF 25 A5 20 94 9B CF 14 | 15 03 B3 53 CF 70 04 4D |
| C1 36 26 A9 E3 C4 53 4D | D0 74 26 9B 60 EC 9B 92 |
| E6 0F 7D 86 77 40 F9 E1 | BE 22 90 B3 34 54 C2 84 |
| 91 5D E6 BB E2 6A 06 29 | 20 F3 7D 53 7D D1 C1 BA |
| 96 5A 54 CC 4C FE 5E 8D | 87 0E 9B F5 41 7C 2D 29 |
| BE E9 31 CB 62 32 3A A6 | A8 52 51 52 21 71 D5 9D |
| B1 7B 59 18 96 84 6A 47 | 96 9C 26 6D 4A B9 C6 AB |
| D4 F0 C9 36 27 59 AF 31 | 5A 2B DD 3C D9 8A D1 04 |

$i = 6$ :

|                         |                         |
|-------------------------|-------------------------|
| E2 F9 B5 C0 25 37 0B B0 | B1 44 C5 6B 09 97 59 91 |
| 39 2B CB A2 16 84 94 A5 | CF 0D 2C 26 C0 C7 93 54 |
| 60 8A F8 CE FA 34 8C 14 | 18 D0 BE 9C 7A 35 09 8A |
| 7A A5 37 64 41 8C 92 19 | 32 8B E8 B4 2C B0 10 2A |
| B3 F3 46 A1 FA 83 3F 89 | 02 01 B5 CC 2C 68 E9 9C |
| 97 49 3F 48 78 02 CF 7C | 12 BF E0 28 EB 7D 3F F1 |
| DC AD E8 BA 1E 00 8F 23 | 49 BD 0B 4E 55 81 21 AA |
| 92 77 4F 49 ED B0 32 3D | 35 F4 59 17 F1 5C 49 DF |

 $i = 7$ :

|                         |                         |
|-------------------------|-------------------------|
| 75 41 63 82 77 4D FF 2F | DD D3 6C 6C F0 7A C1 16 |
| FF FA 38 D0 55 03 46 00 | 03 42 87 2D A6 3A 4C F4 |
| BF 7D 02 49 3E 98 F3 61 | 5D C0 C5 7D 6B BC 49 81 |
| F4 A8 60 C2 9A E5 CE 0B | 7C 12 58 40 F0 CD DA 1E |
| C8 DF 5A 44 EE 5D 9D 27 | 46 AD D5 C4 F9 77 40 C7 |
| 23 F4 5A 55 04 75 00 A4 | FF 2E 7D 33 E9 7D 27 BA |
| B0 16 10 12 02 F9 E2 8C | 2C CC DF EF 3A 86 58 08 |
| AC 30 CD 29 68 33 33 1D | FB AC B4 52 D2 63 9C 25 |

 $i = 8$ :

|                         |                         |
|-------------------------|-------------------------|
| 03 6B F1 82 68 84 AD 89 | 7B 3B 3C 7B 2D 73 FF 3C |
| 99 40 C6 62 D8 46 71 63 | 32 7A 01 65 DD 7C 8C 7A |
| 4C 43 3E 17 4B 19 C2 10 | 0F 70 81 E9 7B A3 B6 80 |
| E2 9C CF D3 4C FF 86 C5 | 25 DF D5 33 66 08 A2 55 |
| 21 FF 11 A0 42 DF 26 53 | AB 95 54 FC ED D2 51 92 |
| 1B 8E 00 CB 6C E4 4B 13 | 10 3A 15 9C FE CA CF 6E |
| A6 12 3B F7 A3 47 B7 CE | 38 DA 67 14 8A 69 EB B3 |
| D9 18 90 0E 3B 28 33 CA | 92 2A 69 0B 03 4B 46 69 |



$i = 9$ :

|                         |                         |
|-------------------------|-------------------------|
| D0 1C 67 7A 0A 9A 2C F9 | 56 21 86 2A 9C 0B D3 95 |
| 2A 94 2F 53 4A 63 B6 B2 | D4 5A B8 28 42 F2 59 DC |
| 88 42 22 46 FE AC A8 B4 | B2 55 11 33 27 2D E8 43 |
| 47 4A 5C C7 3D 58 35 59 | B7 2C 18 04 84 19 B2 C7 |
| 74 A6 92 5D A5 5C 6F A1 | 0A DD FF 03 52 91 16 83 |
| 77 17 E6 8C C4 73 5C 39 | 3E A7 8D 11 02 CF E8 C8 |
| 08 2A 3B 0B 53 EC 1A C6 | A1 22 69 ED AD B3 2A B4 |
| 2A F6 58 EB 81 4D E7 62 | BE 53 E9 F0 7C B0 79 E7 |

 $i = 10$ :

|                         |                         |
|-------------------------|-------------------------|
| 48 95 48 B6 01 EE BC 3A | 16 5A 82 D1 23 C3 52 8F |
| A5 0D 6B C6 6B ED 8E 81 | 26 E9 35 9E 6E C5 7A 23 |
| E0 CE 3D CF 88 26 5A 75 | 17 EE A9 FF B7 C7 B4 99 |
| C2 8C 4A DB C0 F6 9C E9 | 71 FD 96 BC 8F 74 63 4E |
| 54 B7 9C D5 7F 71 85 13 | B3 BE 30 9F 01 2A 59 09 |
| 43 41 4B 8A 97 7D 0B 7B | 72 91 14 59 5F 08 6E 76 |
| 63 19 35 BB DB F6 15 7A | 07 18 AF E3 65 BC 09 DE |
| 6A 7A 4E F6 37 01 82 27 | B6 AF A1 80 BC EC 2A 98 |

The value of  $Y'$  output from the round-function for the first  $Z'$  matrix is as follows.

|                         |
|-------------------------|
| 77 38 E1 B5 41 A0 36 EA |
| 45 8D 50 F8 0F A0 1C 44 |
| 72 88 CE 97 D1 A0 DC F0 |
| 16 95 FF D6 E7 1D 09 25 |
| 33 BE 30 9F 01 2A 59 09 |
| 72 91 14 59 5F 08 6E 76 |
| 07 18 AF E3 65 BC 09 DE |
| B6 AF A1 80 BC EC 2A 98 |

The second  $Z'$  matrix is as follows.

|                         |
|-------------------------|
| 00 00 00 00 00 00 00 00 |
| 00 00 00 00 00 00 00 00 |
| 00 00 00 00 00 00 00 00 |
| 00 00 00 00 00 00 00 00 |
| 00 00 00 00 00 00 00 00 |
| 00 00 00 00 00 00 00 00 |
| 00 00 00 00 00 00 00 00 |
| 00 00 00 00 00 00 01 00 |

For the second  $Z'$  matrix, the  $K_0$  matrix and the  $X''$  matrix are as follows.

|                         |                         |
|-------------------------|-------------------------|
| 77 38 E1 B5 41 A0 36 EA | 77 38 E1 B5 41 A0 36 EA |
| 45 8D 50 F8 0F A0 1C 44 | 45 8D 50 F8 0F A0 1C 44 |
| 72 88 CE 97 D1 A0 DC F0 | 72 88 CE 97 D1 A0 DC F0 |
| 16 95 FF D6 E7 1D 09 25 | 16 95 FF D6 E7 1D 09 25 |
| 33 BE 30 9F 01 2A 59 09 | 33 BE 30 9F 01 2A 59 09 |
| 72 91 14 59 5F 08 6E 76 | 72 91 14 59 5F 08 6E 76 |
| 07 18 AF E3 65 BC 09 DE | 07 18 AF E3 65 BC 09 DE |
| B6 AF A1 80 BC EC 2A 98 | B6 AF A1 80 BC EC 2B 98 |

The following are (hexadecimal representations of) the successive values of the variables  $K_i$  for  $i = 1$  to 10 and  $W'$ .

$i = 1:$

|                         |                         |
|-------------------------|-------------------------|
| 1A 78 4D 7D BD 4C 17 E6 | 18 23 C6 E8 87 B8 01 4F |
| 27 31 10 AA 63 C5 9E 25 | 00 00 00 00 00 00 00 00 |
| 7A 2E B7 48 C4 5D E0 23 | 00 00 00 00 00 00 00 00 |
| 6D 0D 61 9F 6C 1D 80 AE | 00 00 00 00 00 00 00 00 |
| 01 A2 D5 6E DB 41 D9 A0 | 00 00 00 00 00 00 00 00 |
| E9 06 4C D1 27 95 FA 86 | 8C 23 05 AF 46 26 23 23 |
| 77 62 31 BC B4 4E C6 01 | 00 00 00 00 00 00 00 00 |
| 6F CD BC 98 10 78 6F EC | 00 00 00 00 00 00 00 00 |

$i = 2:$

|                         |                         |
|-------------------------|-------------------------|
| EB 0F 86 07 40 38 54 4F | DF 8A 74 7E 14 4C 22 D0 |
| 87 EF DC C8 FE 45 3D 83 | 2B 04 B7 AE 74 89 5A 13 |
| 99 0E F5 4E 73 1F C0 EA | 2F FD BC A4 26 03 AD 74 |
| EF E0 05 7F D2 C2 41 39 | 99 67 EA 50 34 08 BD B9 |
| 65 8F 5D 92 3E 9A AF 47 | A8 7B 8E 1A 3B 56 CD 91 |
| A9 1D 1C 13 BD 15 73 41 | 77 59 60 2D DD A2 4A 70 |
| 81 AD 80 BD 88 B3 B3 C3 | 03 43 90 91 2B DE 8E 37 |
| 16 26 63 99 AC 18 5D D0 | 48 6B C0 54 B9 C6 72 C9 |

$i = 3$ :

7A A3 A3 3A 99 FD F6 5E  
 E0 78 67 CD 3E 60 BF A7  
 BC 06 8D 5D 98 70 34 84  
 80 E8 69 7D 44 CF 6B E6  
 7E 35 09 07 AF 76 70 C3  
 3B 7E 15 0D CA 5E A9 0A  
 8D 10 98 19 22 3B FC 57  
 AB DE A9 DD D3 B6 68 14

6B 92 48 05 C3 F4 1A 6D  
 45 20 59 41 0D 59 73 6D  
 AF 72 CF 6A 4B B6 11 F4  
 A2 6D AD C1 12 CC 43 6C  
 95 8F C4 AE 60 94 74 74  
 4B AB 72 C2 3E 2C BC 6D  
 ED BF 23 B0 D6 82 B0 E8  
 C0 4B 32 6B B5 14 B7 BB

 $i = 4$ :

3D 21 15 88 E4 48 75 78  
 47 BF 56 CC 8E D4 63 CA  
 AE F0 D0 31 74 25 3C 4E  
 08 F7 59 13 4F 6D DD 37  
 C9 70 32 87 D8 F2 C1 E8  
 90 E9 2D 7C AB A0 8E A7  
 BF 22 A6 93 C1 6E 34 74  
 58 40 F3 10 BF 03 3C 14

78 5A 13 A3 25 81 79 C9  
 DC 69 90 E0 14 F2 39 AC  
 89 5A 8F 66 7F F9 FC E3  
 3B 5C C5 02 8C 4D 96 0A  
 00 28 03 E7 DA 63 5E F5  
 DA 35 A5 BF B6 AB C7 EA  
 0D 5B 90 B8 88 56 C7 9F  
 65 09 D2 D8 ED DA C6 B1

 $i = 5$ :

AE 58 59 43 80 F4 F6 14  
 14 5C 2E E0 5F B0 8E FD  
 CF B7 1F C1 9A AC 6B 6A  
 92 5C 25 E7 6C 28 7B 6B  
 57 B5 8E 30 FB E4 61 9B  
 38 5D B4 49 F9 44 F8 C9  
 A5 EE 29 38 0C 2D A8 70  
 45 8B FE 5E 05 C3 A6 89

6B 77 9A 58 6E 21 06 C1  
 A7 2D B3 6D 1D AD 9E 3C  
 32 CF E9 10 D3 AD CD EB  
 EE 4B 44 77 56 BC BC 63  
 41 05 39 5E 0B A3 8A 46  
 07 B9 8B 76 67 41 AC BD  
 E9 86 74 54 82 35 6F D9  
 27 FB C9 68 EE 1E C7 57

*i* = 6:

|                         |                         |
|-------------------------|-------------------------|
| B1 F3 E2 33 93 63 14 AC | 53 41 C7 63 02 40 D8 3F |
| DD 80 87 12 BF E5 70 0E | 7F D8 0D FB 5D 97 CF 7A |
| A5 F5 16 A8 2A 82 CC 76 | 52 47 5A 93 4A BC D9 84 |
| 8A F5 DD F3 5F B1 11 57 | 95 47 26 76 78 E9 10 42 |
| 62 34 D3 BC 57 72 C7 DC | E5 BA FB 23 2C 32 7B 6D |
| 8D E2 8A 61 DC 88 CB 1A | 62 CA FA 6D 35 F6 AA 13 |
| 53 35 F7 4C 99 ED 19 26 | 43 BF 3B F2 1B 0D B4 46 |
| 95 01 75 82 F7 A6 F7 2D | BC 1C 9F 38 97 77 17 5B |

*i* = 7:

|                         |                         |
|-------------------------|-------------------------|
| 7E 42 E3 38 39 72 B7 82 | 61 E7 C2 37 B0 E6 F6 2B |
| 79 B2 EA 12 B3 68 75 B0 | 46 FE 01 CA 0E 34 5A 26 |
| D8 8D 5F 05 2F AA 73 D2 | 80 2E F8 49 0D 5F 17 60 |
| 90 FC 91 61 30 BB 7B 5C | 89 D5 48 F0 59 6D 73 E8 |
| 5A 1B F6 C2 20 10 61 23 | 72 D8 71 5E 44 80 9B E3 |
| E5 31 C5 68 BC 4F 85 F8 | 8C 90 07 54 63 6B 77 0D |
| 60 72 0A BA A7 90 27 03 | 63 1B 4E CF D7 C6 5D B5 |
| A7 FD 03 BB E3 E9 CA 19 | 91 92 11 87 0F FE EA AB |

*i* = 8:

|                         |                         |
|-------------------------|-------------------------|
| 12 EF 8A A7 F3 B5 7E F6 | 42 C9 DC 71 10 DA FA 7C |
| E9 59 60 9F 18 84 D3 ED | 02 5B 59 54 A2 45 83 20 |
| 93 3E 12 E9 EA 51 D7 C1 | 53 B6 C4 85 4D C3 52 A5 |
| EF DA 8A 82 CB 14 13 93 | 3B 65 C0 24 87 E8 20 BD |
| 4C F0 7B 81 0D 03 9C F3 | C5 3C E3 C4 9C DE 93 9F |
| 2F 40 9C A8 76 D4 7D A3 | CD 47 4A B3 CB C3 69 1B |
| 32 72 85 CE 7A BD 39 58 | 24 5E FB 0E 45 E6 7A 96 |
| 06 1A CE 00 E7 5F EC B5 | 2B 36 CC A8 8A 64 C1 40 |

$i = 9$ :

|                         |                         |
|-------------------------|-------------------------|
| 7C D9 89 12 FC AB 39 B2 | AC C3 BD D6 26 A6 41 F0 |
| 20 E1 E9 E6 79 8D 5E 4F | E7 D8 5F 60 03 D2 7B F8 |
| 99 70 2C 2A CA E1 07 48 | 3F 48 9A 48 16 88 0E 1D |
| A4 85 C1 1F 74 6C 23 DC | D9 C7 62 1D 42 6F 86 A4 |
| CF C8 1D F4 64 41 C6 1B | AD A6 9F 9A 29 CC 8C 6D |
| 7B 0D 6B 84 2A 58 16 40 | 14 63 22 F6 04 B0 94 F4 |
| 4F 0A 55 C3 38 6A 0C 2D | E9 1D 7D 05 0C A8 44 F4 |
| E6 31 16 BA AE C9 AC EC | A7 B1 5B F5 48 C5 2E F7 |

 $i = 10$ :

|                         |                         |
|-------------------------|-------------------------|
| B4 74 E1 56 96 31 B9 6C | 5D A0 9F 11 4E 31 46 8B |
| 21 A1 B6 33 CC 89 68 1A | B0 5B A0 58 EE C4 53 0C |
| B1 97 25 86 7B 2B 3F 09 | F8 F2 94 C5 0F 4E B9 92 |
| 4C 73 C7 62 93 A8 15 CF | 11 50 9D 2F 6F F4 55 4C |
| 55 15 C0 C0 9A 05 05 16 | 25 03 F8 9C 1A EF E7 12 |
| 23 44 8D 8D D3 5F B3 6E | 09 05 62 60 A1 0D 65 20 |
| 7E 6C 2D 37 12 D0 F3 3E | 94 83 05 43 C8 43 93 38 |
| CE B8 04 F2 8D 9F C9 99 | C2 F4 DA 98 A0 D7 C8 65 |

The value of  $Y'$  output from the round-function for the second  $Z'$  matrix is as follows.

|                         |
|-------------------------|
| 2A 98 7E A4 0F 91 70 61 |
| F5 D6 F0 A0 E4 64 4F 48 |
| 8A 7A 5A 52 DE EE 65 62 |
| 07 C5 62 F9 88 E9 5C 69 |
| 16 BD C8 03 1B C5 BE 1B |
| 7B 94 76 39 FE 05 0B 56 |
| 93 9B AA A0 AD FF 9A E6 |
| 74 5B 7B 18 1C 3B E3 FD |

The hash-code is the following 512-bit string.

2A987EA40F917061 F5D6F0A0E4644F48 8A7A5A52DEEE6562 07C562F988E95C69  
16BDC8031BC5BE1B 7B947639FE050B56 939BAAA0ADFF9AE6 745B7B181C3BE3FD

### B.8.9 Example 9

In this example, the data string is the 1 000 000-byte string consisting of the ASCII-coded version of “a” repeated  $10^6$  times.

The hash-code is the following 512-bit string.

0C99005BEB57EFF5 0A7CF005560DDF5D 29057FD86B20BFD6 2DECA0F1CCEA4AF5  
1FC15490EDDC47AF 32BB2B66C34FF9AD 8C6008AD677F7712 6953B226E4ED8B01

## B.9 Dedicated Hash-Function 8 (SHA-224)

### B.9.1 Example 1

In this example, the data string is the empty string, i.e. the string of length zero.

The hash-code is the following 224-bit string.

D14A028C 2A3A2BC9 476102BB 288234C4 15A2B01F 828EA62A C5B3E42F

### B.9.2 Example 2

In this example, the data string consists of a single byte, namely the ASCII-coded version of the letter “a”.

The hash-code is the following 224-bit string.

ABD37534 C7D9A2EF B9465DE9 31CD7055 FFDB8879 563AE980 78D6D6D5

### B.9.3 Example 3

In this example, the data string is the 3-byte string consisting of the ASCII-coded version of “abc”. This is equivalent to the bit string “01100001 01100010 01100011”.

After the padding process, the single 16-word block derived from the data string is as follows.

61626380 00000000 00000000 00000000 00000000 00000000 00000000 00000000  
00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000018

The following are (hexadecimal representations of) the successive values of the variables  $X_0$ ,  $X_1$ ,  $X_2$ ,  $X_3$ ,  $X_4$ ,  $X_5$ ,  $X_6$  and  $X_7$ .

INIT: C1059ED8 367CD507 3070DD17 F70E5939 FFC00B31 68581511 64F98FA7 BEFA4FA4  
0 0E96B2DA C1059ED8 367CD507 3070DD17 0434225E FFC00B31 68581511 64F98FA7  
1 C20DAB6B 0E96B2DA C1059ED8 367CD507 9CAB416F 0434225E FFC00B31 68581511  
2 AB113B7A C20DAB6B 0E96B2DA C1059ED8 82177FE8 9CAB416F 0434225E FFC00B31  
3 8253CC1A AB113B7A C20DAB6B 0E96B2DA 8346B27D 82177FE8 9CAB416F 0434225E  
4 08A0DC0C 8253CC1A AB113B7A C20DAB6B 05B557DB 8346B27D 82177FE8 9CAB416F  
5 B2CA3A91 08A0DC0C 8253CC1A AB113B7A 898DC7BB 05B557DB 8346B27D 82177FE8  
6 0B6B9023 B2CA3A91 08A0DC0C 8253CC1A A2E49147 898DC7BB 05B557DB 8346B27D  
7 F09D116D 0B6B9023 B2CA3A91 08A0DC0C 7A84120D A2E49147 898DC7BB 05B557DB  
8 ED6FA633 F09D116D 0B6B9023 B2CA3A91 C037FAAD 7A84120D A2E49147 898DC7BB  
9 55E6A367 ED6FA633 F09D116D 0B6B9023 AAE50091 C037FAAD 7A84120D A2E49147  
10 0817E82B 55E6A367 ED6FA633 F09D116D C8C53A2C AAE50091 C037FAAD 7A84120D  
11 17142334 0817E82B 55E6A367 ED6FA633 DD4C7BE9 C8C53A2C AAE50091 C037FAAD  
12 FC4F023E 17142334 0817E82B 55E6A367 87BEA51A DD4C7BE9 C8C53A2C AAE50091  
13 BE316902 FC4F023E 17142334 0817E82B 65141125 87BEA51A DD4C7BE9 C8C53A2C  
14 1D80D178 BE316902 FC4F023E 17142334 4545F53A 65141125 87BEA51A DD4C7BE9  
15 9F341A45 1D80D178 BE316902 FC4F023E 6A61C411 4545F53A 65141125 87BEA51A  
16 0F324DB9 9F341A45 1D80D178 BE316902 06C80D6A 6A61C411 4545F53A 65141125  
17 FFE7012B 0F324DB9 9F341A45 1D80D178 B7B601F4 06C80D6A 6A61C411 4545F53A  
18 62932AB8 FFE7012B 0F324DB9 9F341A45 763B627A B7B601F4 06C80D6A 6A61C411  
19 5207D867 62932AB8 FFE7012B 0F324DB9 7FBBA936 763B627A B7B601F4 06C80D6A  
20 07D55CCB 5207D867 62932AB8 FFE7012B 9BA5A6EA 7FBBA936 763B627A B7B601F4  
21 DECE98A4 07D55CCB 5207D867 62932AB8 293FFB5D 9BA5A6EA 7FBBA936 763B627A

|    |          |          |          |          |          |          |          |          |
|----|----------|----------|----------|----------|----------|----------|----------|----------|
| 22 | E62A812E | DECE98A4 | 07D55CCB | 5207D867 | 28FE0FD9 | 293FFB5D | 9BA5A6EA | 7FBBA936 |
| 23 | 57206FB8 | E62A812E | DECE98A4 | 07D55CCB | C76084EA | 28FE0FD9 | 293FFB5D | 9BA5A6EA |
| 24 | 6A6ABCF0 | 57206FB8 | E62A812E | DECE98A4 | B2614C5E | C76084EA | 28FE0FD9 | 293FFB5D |
| 25 | 937514F0 | 6A6ABCF0 | 57206FB8 | E62A812E | B42EC21C | B2614C5E | C76084EA | 28FE0FD9 |
| 26 | 82AF3FFB | 937514F0 | 6A6ABCF0 | 57206FB8 | BE6F6760 | B42EC21C | B2614C5E | C76084EA |
| 27 | ECA3BCD5 | 82AF3FFB | 937514F0 | 6A6ABCF0 | 1DCCBB10 | BE6F6760 | B42EC21C | B2614C5E |
| 28 | 2D1576C4 | ECA3BCD5 | 82AF3FFB | 937514F0 | 01641929 | 1DCCBB10 | BE6F6760 | B42EC21C |
| 29 | FE3C8658 | 2D1576C4 | ECA3BCD5 | 82AF3FFB | FC4B36C5 | 01641929 | 1DCCBB10 | BE6F6760 |
| 30 | 0D7CCE07 | FE3C8658 | 2D1576C4 | ECA3BCD5 | A4A4A3A4 | FC4B36C5 | 01641929 | 1DCCBB10 |
| 31 | CCE1951D | 0D7CCE07 | FE3C8658 | 2D1576C4 | 4BE9475C | A4A4A3A4 | FC4B36C5 | 01641929 |
| 32 | 09B76257 | CCE1951D | 0D7CCE07 | FE3C8658 | 0CCDD86  | 4BE9475C | A4A4A3A4 | FC4B36C5 |
| 33 | F827767E | 09B76257 | CCE1951D | 0D7CCE07 | DB116DB7 | 0CCDD86  | 4BE9475C | A4A4A3A4 |
| 34 | E4A0BB48 | F827767E | 09B76257 | CCE1951D | 994E2BAC | DB116DB7 | 0CCDD86  | 4BE9475C |
| 35 | D8BB1041 | E4A0BB48 | F827767E | 09B76257 | 5B730ABB | 994E2BAC | DB116DB7 | 0CCDD86  |
| 36 | 2A2E32F4 | D8BB1041 | E4A0BB48 | F827767E | 22E15C59 | 5B730ABB | 994E2BAC | DB116DB7 |
| 37 | 0D275CA8 | 2A2E32F4 | D8BB1041 | E4A0BB48 | F6C39382 | 22E15C59 | 5B730ABB | 994E2BAC |
| 38 | 7902369C | 0D275CA8 | 2A2E32F4 | D8BB1041 | D9F8C2E0 | F6C39382 | 22E15C59 | 5B730ABB |
| 39 | F3C80288 | 7902369C | 0D275CA8 | 2A2E32F4 | 00E3A7BB | D9F8C2E0 | F6C39382 | 22E15C59 |
| 40 | 483BBA4D | F3C80288 | 7902369C | 0D275CA8 | F0A8198C | 00E3A7BB | D9F8C2E0 | F6C39382 |
| 41 | D75D4D26 | 483BBA4D | F3C80288 | 7902369C | FCECD4   | F0A8198C | 00E3A7BB | D9F8C2E0 |
| 42 | 0744B618 | D75D4D26 | 483BBA4D | F3C80288 | 03186FAA | FCECD4   | F0A8198C | 00E3A7BB |
| 43 | 9CCE9F01 | 0744B618 | D75D4D26 | 483BBA4D | A56F6BBF | 03186FAA | FCECD4   | F0A8198C |
| 44 | A3701BD9 | 9CCE9F01 | 0744B618 | D75D4D26 | AF1BEF5F | A56F6BBF | 03186FAA | FCECD4   |
| 45 | 131D4C09 | A3701BD9 | 9CCE9F01 | 0744B618 | ECB77E1B | AF1BEF5F | A56F6BBF | 03186FAA |
| 46 | FB3777D9 | 131D4C09 | A3701BD9 | 9CCE9F01 | 1D601F44 | ECB77E1B | AF1BEF5F | A56F6BBF |
| 47 | 847EA00E | FB3777D9 | 131D4C09 | A3701BD9 | 503A7B95 | 1D601F44 | ECB77E1B | AF1BEF5F |
| 48 | AAA69347 | 847EA00E | FB3777D9 | 131D4C09 | 5EEB9930 | 503A7B95 | 1D601F44 | ECB77E1B |
| 49 | 505CAF28 | AAA69347 | 847EA00E | FB3777D9 | CE695893 | 5EEB9930 | 503A7B95 | 1D601F44 |
| 50 | 675E0B02 | 505CAF28 | AAA69347 | 847EA00E | C22DD75F | CE695893 | 5EEB9930 | 503A7B95 |
| 51 | ABD26099 | 675E0B02 | 505CAF28 | AAA69347 | 1409C3F8 | C22DD75F | CE695893 | 5EEB9930 |
| 52 | 0DF9857A | ABD26099 | 675E0B02 | 505CAF28 | 2D864D9F | 1409C3F8 | C22DD75F | CE695893 |
| 53 | 308B8799 | 0DF9857A | ABD26099 | 675E0B02 | 02524F02 | 2D864D9F | 1409C3F8 | C22DD75F |
| 54 | 909CC059 | 308B8799 | 0DF9857A | ABD26099 | 6F2A444A | 02524F02 | 2D864D9F | 1409C3F8 |
| 55 | 8D25BD94 | 909CC059 | 308B8799 | 0DF9857A | 1273C622 | 6F2A444A | 02524F02 | 2D864D9F |
| 56 | F32141DA | 8D25BD94 | 909CC059 | 308B8799 | 1771ED3F | 1273C622 | 6F2A444A | 02524F02 |
| 57 | 8CE24395 | F32141DA | 8D25BD94 | 909CC059 | F52F66A6 | 1771ED3F | 1273C622 | 6F2A444A |
| 58 | 07BCD846 | 8CE24395 | F32141DA | 8D25BD94 | 149DB547 | F52F66A6 | 1771ED3F | 1273C622 |
| 59 | 622D5E5B | 07BCD846 | 8CE24395 | F32141DA | B6F4C630 | 149DB547 | F52F66A6 | 1771ED3F |
| 60 | C693FC7A | 622D5E5B | 07BCD846 | 8CE24395 | 13DFB889 | B6F4C630 | 149DB547 | F52F66A6 |
| 61 | 55D1C760 | C693FC7A | 622D5E5B | 07BCD846 | 7E730E00 | 13DFB889 | B6F4C630 | 149DB547 |
| 62 | FD89031B | 55D1C760 | C693FC7A | 622D5E5B | 55489EE6 | 7E730E00 | 13DFB889 | B6F4C630 |
| 63 | 6203DE4A | FD89031B | 55D1C760 | C693FC7A | 2AEDB1B3 | 55489EE6 | 7E730E00 | 13DFB889 |



The following eight words,  $Y_0$ ,  $Y_1$ ,  $Y_2$ ,  $Y_3$ ,  $Y_4$ ,  $Y_5$ ,  $Y_6$  and  $Y_7$ , represent the output of the final iteration of the round-function.

```

 $Y_0$  = C1059ED8  $\cup$  6203DE4A = 23097D22
 $Y_1$  = 367CD507  $\cup$  FD89031B = 3405D822
 $Y_2$  = 3070DD17  $\cup$  55D1C760 = 8642A477
 $Y_3$  = F70E5939  $\cup$  C693FC7A = BDA255B3
 $Y_4$  = FFC00B31  $\cup$  2AEDB1B3 = 2AADBCE4
 $Y_5$  = 68581511  $\cup$  55489EE6 = BDA0B3F7
 $Y_6$  = 64F98FA7  $\cup$  7E730E00 = E36C9DA7
 $Y_7$  = BEFA4FA4  $\cup$  13DFB889 = AD25F72D

```

The hash value is the following 224-bit string.

```
23097D22 3405D822 8642A477 BDA255B3 2AADBCE4 BDA0B3F7 E36C9DA7
```

#### B.9.4 Example 4

In this example, the data string is the 14-byte string consisting of the ASCII-coded version of

“message digest”

The hash-code is the following 224-bit string.

```
2CB21C83 AE2F004D E7E81C3C 7019CBCB 65B71AB6 56B22D6D 0C39B8EB
```

#### B.9.5 Example 5

In this example, the data string is the 62-byte string consisting of the ASCII-coded version of

“ABCDEFGHIJKLMNOPQRSTUVWXYZabcdefghijklmnopqrstuvwxyz0123456789”

The hash-code is the following 224-bit string.

```
BFF72B4F CB7D75E5 632900AC 5F90D219 E05E97A7 BDE72E74 0DB393D9
```

#### B.9.6 Example 6

In this example, the data string is the 80-byte string consisting of the ASCII-coded version of eight repetitions of

“1234567890”

The hash-code is the following 224-bit string.

```
B50AECBE 4E9BB0B5 7BC5F3AE 760A8E01 DB24F203 FB3CDCD1 3148046E
```

#### B.9.7 Example 7

In this example, the data string is the 56-byte string consisting of the ASCII-coded version of

“abcdcbcdcedefdefgfhghighijhijkijklklmklmnlmnomnopnopq”

After the padding process, the following two 16-word blocks are derived from the data string.

```

61626364 62636465 63646566 64656667 65666768 66676869 6768696A 68696A6B
696A6B6C 6A6B6C6D 6B6C6D6E 6C6D6E6F 6D6E6F70 6E6F7071 80000000 00000000
00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
00000000 00000000 00000000 00000000 00000000 00000000 00000000 000001C0

```

The following are (hexadecimal representations of) the successive values of the variables  $X_0$ ,  $X_1$ ,  $X_2$ ,  $X_3$ ,  $X_4$ ,  $X_5$ ,  $X_6$  and  $X_7$  in the first block process.

```
INIT: C1059ED8 367CD507 3070DD17 F70E5939 FFC00B31 68581511 64F98FA7 BEFA4FA4
0 0E96B2BE C1059ED8 367CD507 3070DD17 04342242 FFC00B31 68581511 64F98FA7
1 51D17D7B 0E96B2BE C1059ED8 367CD507 2F8EA3D4 04342242 FFC00B31 68581511
2 FF1CBD7F 51D17D7B 0E96B2BE C1059ED8 79A896FA 2F8EA3D4 04342242 FFC00B31
3 24BCC047 FF1CBD7F 51D17D7B 0E96B2BE 1F60795A 79A896FA 2F8EA3D4 04342242
4 7D56A6AC 24BCC047 FF1CBD7F 51D17D7B DE395286 1F60795A 79A896FA 2F8EA3D4
5 745BEB11 7D56A6AC 24BCC047 FF1CBD7F D863D132 DE395286 1F60795A 79A896FA
6 0DD41573 745BEB11 7D56A6AC 24BCC047 2E60D323 D863D132 DE395286 1F60795A
7 9A2541FD 0DD41573 745BEB11 7D56A6AC 08D2B348 2E60D323 D863D132 DE395286
8 3140E909 9A2541FD 0DD41573 745BEB11 95DFD707 08D2B348 2E60D323 D863D132
9 B2954925 3140E909 9A2541FD 0DD41573 05EF5E3D 95DFD707 08D2B348 2E60D323
10 B2A874FB B2954925 3140E909 9A2541FD 9DCAF118 05EF5E3D 95DFD707 08D2B348
11 116CE44D B2A874FB B2954925 3140E909 0E6D566A 9DCAF118 05EF5E3D 95DFD707
12 5FF9349A 116CE44D B2A874FB B2954925 08EB3305 0E6D566A 9DCAF118 05EF5E3D
13 7FA9D65D 5FF9349A 116CE44D B2A874FB 4657CF17 08EB3305 0E6D566A 9DCAF118
14 006B1B16 7FA9D65D 5FF9349A 116CE44D 08D09E8D 4657CF17 08EB3305 0E6D566A
15 B301C98A 006B1B16 7FA9D65D 5FF9349A 6FBFA1D 08D09E8D 4657CF17 08EB3305
16 E623ECC0 B301C98A 006B1B16 7FA9D65D 2B3F859C 6FBFA1D 08D09E8D 4657CF17
17 D9244A78 E623ECC0 B301C98A 006B1B16 E66D8D9C 2B3F859C 6FBFA1D 08D09E8D
18 99C72726 D9244A78 E623ECC0 B301C98A B26A409C E66D8D9C 2B3F859C 6FBFA1D
19 AB0CBED2 99C72726 D9244A78 E623ECC0 010D7C65 B26A409C E66D8D9C 2B3F859C
20 78062878 AB0CBED2 99C72726 D9244A78 5678A949 010D7C65 B26A409C E66D8D9C
21 D7C5C5D5 78062878 AB0CBED2 99C72726 B280360C 5678A949 010D7C65 B26A409C
22 BAD2EE72 D7C5C5D5 78062878 AB0CBED2 0D4CD0C4 B280360C 5678A949 010D7C65
23 BCF47346 BAD2EE72 D7C5C5D5 78062878 D6A19DC8 0D4CD0C4 B280360C 5678A949
24 5ECC417B BCF47346 BAD2EE72 D7C5C5D5 3337A11C D6A19DC8 0D4CD0C4 B280360C
25 E15BFA57 5ECC417B BCF47346 BAD2EE72 0CE15173 3337A11C D6A19DC8 0D4CD0C4
26 FAE6167B E15BFA57 5ECC417B BCF47346 73DBE5C7 0CE15173 3337A11C D6A19DC8
27 991C3F99 FAE6167B E15BFA57 5ECC417B 8602A31F 73DBE5C7 0CE15173 3337A11C
28 7055843B 991C3F99 FAE6167B E15BFA57 EB4DE5F8 8602A31F 73DBE5C7 0CE15173
29 08DCFB6D 7055843B 991C3F99 FAE6167B 4606D126 EB4DE5F8 8602A31F 73DBE5C7
30 2964B340 08DCFB6D 7055843B 991C3F99 213B3E63 4606D126 EB4DE5F8 8602A31F
31 5B3677D0 2964B340 08DCFB6D 7055843B C9689CB0 213B3E63 4606D126 EB4DE5F8
32 1EE0FE7D 5B3677D0 2964B340 08DCFB6D 14318A4D C9689CB0 213B3E63 4606D126
33 6B918D6E 1EE0FE7D 5B3677D0 2964B340 216054A8 14318A4D C9689CB0 213B3E63
34 A6710D0D 6B918D6E 1EE0FE7D 5B3677D0 BC823A58 216054A8 14318A4D C9689CB0
35 5E198FED A6710D0D 6B918D6E 1EE0FE7D C49933FE BC823A58 216054A8 14318A4D
36 136C320A 5E198FED A6710D0D 6B918D6E 75687CCB C49933FE BC823A58 216054A8
37 40EE0C43 136C320A 5E198FED A6710D0D F1C2CAF6 75687CCB C49933FE BC823A58
38 AA96D78C 40EE0C43 136C320A 5E198FED F48B4CEB F1C2CAF6 75687CCB C49933FE
39 27C97B86 AA96D78C 40EE0C43 136C320A B556216A F48B4CEB F1C2CAF6 75687CCB
40 B07BD327 27C97B86 AA96D78C 40EE0C43 30EC2D76 B556216A F48B4CEB F1C2CAF6
41 D88D56BD B07BD327 27C97B86 AA96D78C DC2FA5A4 30EC2D76 B556216A F48B4CEB
42 5C775077 D88D56BD B07BD327 27C97B86 5FAD6DB5 DC2FA5A4 30EC2D76 B556216A
43 1526CCA3 5C775077 D88D56BD B07BD327 DA8A0B1C 5FAD6DB5 DC2FA5A4 30EC2D76
44 C09DDA14 1526CCA3 5C775077 D88D56BD D98EC23A DA8A0B1C 5FAD6DB5 DC2FA5A4
```

```

45 F885E124 C09DDA14 1526CCA3 5C775077 E4F23E41 D98EC23A DA8A0B1C 5FAD6DB5
46 5447F0AD F885E124 C09DDA14 1526CCA3 BFB7497C E4F23E41 D98EC23A DA8A0B1C
47 E6227061 5447F0AD F885E124 C09DDA14 5B09619B BFB7497C E4F23E41 D98EC23A
48 009CEBEA E6227061 5447F0AD F885E124 59ECAB46 5B09619B BFB7497C E4F23E41
49 92B0D169 009CEBEA E6227061 5447F0AD 9A572B85 59ECAB46 5B09619B BFB7497C
50 8D224E54 92B0D169 009CEBEA E6227061 32144602 9A572B85 59ECAB46 5B09619B
51 C1FCAC71 8D224E54 92B0D169 009CEBEA 4E98A8B7 32144602 9A572B85 59ECAB46
52 8E6CE843 C1FCAC71 8D224E54 92B0D169 2C1823BE 4E98A8B7 32144602 9A572B85
53 000F54DE 8E6CE843 C1FCAC71 8D224E54 F32CF2A8 2C1823BE 4E98A8B7 32144602
54 2FE2AF3A 000F54DE 8E6CE843 C1FCAC71 20F763EE F32CF2A8 2C1823BE 4E98A8B7
55 1FD539AF 2FE2AF3A 000F54DE 8E6CE843 5ACDBD62 20F763EE F32CF2A8 2C1823BE
56 7F86644E 1FD539AF 2FE2AF3A 000F54DE 9FC10216 5ACDBD62 20F763EE F32CF2A8
57 0E08DC77 7F86644E 1FD539AF 2FE2AF3A 2A4EA749 9FC10216 5ACDBD62 20F763EE
58 0B9F4851 0E08DC77 7F86644E 1FD539AF 18B1DFB9 2A4EA749 9FC10216 5ACDBD62
59 DBCE97C3 0B9F4851 0E08DC77 7F86644E 6EC6BA5B 18B1DFB9 2A4EA749 9FC10216
60 3CD78FE1 DBCE97C3 0B9F4851 0E08DC77 3E1CA2F1 6EC6BA5B 18B1DFB9 2A4EA749
61 35F4BF1C 3CD78FE1 DBCE97C3 0B9F4851 BA1A8A1B 3E1CA2F1 6EC6BA5B 18B1DFB9
62 86795A7D 35F4BF1C 3CD78FE1 DBCE97C3 2CE11258 BA1A8A1B 3E1CA2F1 6EC6BA5B
63 C14B4785 86795A7D 35F4BF1C 3CD78FE1 1108AC7F 2CE11258 BA1A8A1B 3E1CA2F1

```

The following eight words,  $Y_0$ ,  $Y_1$ ,  $Y_2$ ,  $Y_3$ ,  $Y_4$ ,  $Y_5$ ,  $Y_6$  and  $Y_7$ , represent the output of the round-function in the first block process.

```

 $Y_0 = C1059ED8 \cup C14B4785 = 8250E65D$ 
 $Y_1 = 367CD507 \cup 86795A7D = BCF62F84$ 
 $Y_2 = 3070DD17 \cup 35F4BF1C = 66659C33$ 
 $Y_3 = F70E5939 \cup 3CD78FE1 = 33E5E91A$ 
 $Y_4 = FFC00B31 \cup 1108AC7F = 10C8B7B0$ 
 $Y_5 = 68581511 \cup 2CE11258 = 95392769$ 
 $Y_6 = 64F98FA7 \cup BA1A8A1B = 1F1419C2$ 
 $Y_7 = BEFA4FA4 \cup 3E1CA2F1 = FD16F295$ 

```

The following are (hexadecimal representations of) the successive values of the variables  $Y_0$ ,  $Y_1$ ,  $Y_2$ ,  $Y_3$ ,  $Y_4$ ,  $Y_5$ ,  $Y_6$  and  $Y_7$  in the second block process.

```

INIT: 8250E65D BCF62F84 66659C33 33E5E91A 10C8B7B0 95392769 1F1419C2 FD16F295
0 692E407D 8250E65D BCF62F84 66659C33 E4BE1E69 10C8B7B0 95392769 1F1419C2
1 608D83E1 692E407D 8250E65D BCF62F84 3DDB8CEE E4BE1E69 10C8B7B0 95392769
2 09BFA89F 608D83E1 692E407D 8250E65D F5813490 3DDB8CEE E4BE1E69 10C8B7B0
3 2375FBC5 09BFA89F 608D83E1 692E407D C3E18529 F5813490 3DDB8CEE E4BE1E69
4 717E79E7 2375FBC5 09BFA89F 608D83E1 77D39CCC C3E18529 F5813490 3DDB8CEE
5 A9319748 717E79E7 2375FBC5 09BFA89F FDBB9913 77D39CCC C3E18529 F5813490
6 27A42F04 A9319748 717E79E7 2375FBC5 B999CCE4 FDBB9913 77D39CCC C3E18529
7 3419081E 27A42F04 A9319748 717E79E7 54E69E21 B999CCE4 FDBB9913 77D39CCC
8 0AB393C2 3419081E 27A42F04 A9319748 AD29647E 54E69E21 B999CCE4 FDBB9913
9 006784EB 0AB393C2 3419081E 27A42F04 AFF457E7 AD29647E 54E69E21 B999CCE4
10 ECD5C9DB 006784EB 0AB393C2 3419081E 9AF42A0E AFF457E7 AD29647E 54E69E21
11 4762E8F0 ECD5C9DB 006784EB 0AB393C2 8FB6F3D8 9AF42A0E AFF457E7 AD29647E
12 AF93B2A8 4762E8F0 ECD5C9DB 006784EB 97E63D39 8FB6F3D8 9AF42A0E AFF457E7
13 533C517C AF93B2A8 4762E8F0 ECD5C9DB 7364BAE6 97E63D39 8FB6F3D8 9AF42A0E
14 03C0A51B 533C517C AF93B2A8 4762E8F0 3AFB010D 7364BAE6 97E63D39 8FB6F3D8
15 5FD065BD 03C0A51B 533C517C AF93B2A8 B8E64229 3AFB010D 7364BAE6 97E63D39

```

|    |          |          |          |          |          |          |          |          |
|----|----------|----------|----------|----------|----------|----------|----------|----------|
| 16 | 18B268B5 | 5FD065BD | 03C0A51B | 533C517C | 38EDA38D | B8E64229 | 3AFB010D | 7364BAE6 |
| 17 | B87D63B4 | 18B268B5 | 5FD065BD | 03C0A51B | 25C2C397 | 38EDA38D | B8E64229 | 3AFB010D |
| 18 | B1D846E0 | B87D63B4 | 18B268B5 | 5FD065BD | D674405F | 25C2C397 | 38EDA38D | B8E64229 |
| 19 | 8BA0AED6 | B1D846E0 | B87D63B4 | 18B268B5 | B8109422 | D674405F | 25C2C397 | 38EDA38D |
| 20 | 1485F843 | 8BA0AED6 | B1D846E0 | B87D63B4 | 1C58CD66 | B8109422 | D674405F | 25C2C397 |
| 21 | 238F4CDA | 1485F843 | 8BA0AED6 | B1D846E0 | 39B2EB5F | 1C58CD66 | B8109422 | D674405F |
| 22 | 7031B061 | 238F4CDA | 1485F843 | 8BA0AED6 | 4B8262AD | 39B2EB5F | 1C58CD66 | B8109422 |
| 23 | D4E7EC62 | 7031B061 | 238F4CDA | 1485F843 | 163C3AA0 | 4B8262AD | 39B2EB5F | 1C58CD66 |
| 24 | 66582DF3 | D4E7EC62 | 7031B061 | 238F4CDA | C0976260 | 163C3AA0 | 4B8262AD | 39B2EB5F |
| 25 | DEDB8199 | 66582DF3 | D4E7EC62 | 7031B061 | B73E2DEC | C0976260 | 163C3AA0 | 4B8262AD |
| 26 | F8536917 | DEDB8199 | 66582DF3 | D4E7EC62 | 7C2AF9C4 | B73E2DEC | C0976260 | 163C3AA0 |
| 27 | D7333B8A | F8536917 | DEDB8199 | 66582DF3 | B2B0B71A | 7C2AF9C4 | B73E2DEC | C0976260 |
| 28 | 760847C1 | D7333B8A | F8536917 | DEDB8199 | 5898EFF2 | B2B0B71A | 7C2AF9C4 | B73E2DEC |
| 29 | 7EABC6D7 | 760847C1 | D7333B8A | F8536917 | 24DD3883 | 5898EFF2 | B2B0B71A | 7C2AF9C4 |
| 30 | 90C49624 | 7EABC6D7 | 760847C1 | D7333B8A | CCE25E67 | 24DD3883 | 5898EFF2 | B2B0B71A |
| 31 | 0B876264 | 90C49624 | 7EABC6D7 | 760847C1 | E4E4A53B | CCE25E67 | 24DD3883 | 5898EFF2 |
| 32 | 04CB36C0 | 0B876264 | 90C49624 | 7EABC6D7 | 5403A391 | E4E4A53B | CCE25E67 | 24DD3883 |
| 33 | D58CC34A | 04CB36C0 | 0B876264 | 90C49624 | B78767C3 | 5403A391 | E4E4A53B | CCE25E67 |
| 34 | 0ED14DD7 | D58CC34A | 04CB36C0 | 0B876264 | FDCDC9D9 | B78767C3 | 5403A391 | E4E4A53B |
| 35 | 5A89A942 | 0ED14DD7 | D58CC34A | 04CB36C0 | 790C4A20 | FDCDC9D9 | B78767C3 | 5403A391 |
| 36 | 4D30424C | 5A89A942 | 0ED14DD7 | D58CC34A | F95BF853 | 790C4A20 | FDCDC9D9 | B78767C3 |
| 37 | 47F58C5C | 4D30424C | 5A89A942 | 0ED14DD7 | 0EC9BE3B | F95BF853 | 790C4A20 | FDCDC9D9 |
| 38 | B5AD85D7 | 47F58C5C | 4D30424C | 5A89A942 | CF9F1DBE | 0EC9BE3B | F95BF853 | 790C4A20 |
| 39 | 762FECBC | B5AD85D7 | 47F58C5C | 4D30424C | 15427ED3 | CF9F1DBE | 0EC9BE3B | F95BF853 |
| 40 | 32ABE746 | 762FECBC | B5AD85D7 | 47F58C5C | 4053E12E | 15427ED3 | CF9F1DBE | 0EC9BE3B |
| 41 | 84ADB2A0 | 32ABE746 | 762FECBC | B5AD85D7 | 7CECE4E2 | 4053E12E | 15427ED3 | CF9F1DBE |
| 42 | C6E1C5AF | 84ADB2A0 | 32ABE746 | 762FECBC | 42F9990B | 7CECE4E2 | 4053E12E | 15427ED3 |
| 43 | 35E14BFA | C6E1C5AF | 84ADB2A0 | 32ABE746 | C9965792 | 42F9990B | 7CECE4E2 | 4053E12E |
| 44 | 7410BFD8 | 35E14BFA | C6E1C5AF | 84ADB2A0 | CA54CE51 | C9965792 | 42F9990B | 7CECE4E2 |
| 45 | 3FE9E763 | 7410BFD8 | 35E14BFA | C6E1C5AF | AE7CDB66 | CA54CE51 | C9965792 | 42F9990B |
| 46 | 853C3A00 | 3FE9E763 | 7410BFD8 | 35E14BFA | C2BE054D | AE7CDB66 | CA54CE51 | C9965792 |
| 47 | F7D035E7 | 853C3A00 | 3FE9E763 | 7410BFD8 | F6D59D2C | C2BE054D | AE7CDB66 | CA54CE51 |
| 48 | 20BAE2B8 | F7D035E7 | 853C3A00 | 3FE9E763 | CAB73F06 | F6D59D2C | C2BE054D | AE7CDB66 |
| 49 | AE6BF667 | 20BAE2B8 | F7D035E7 | 853C3A00 | 52384D2F | CAB73F06 | F6D59D2C | C2BE054D |
| 50 | 12E504E5 | AE6BF667 | 20BAE2B8 | F7D035E7 | F9A8377F | 52384D2F | CAB73F06 | F6D59D2C |
| 51 | F3497054 | 12E504E5 | AE6BF667 | 20BAE2B8 | D0AB7CFC | F9A8377F | 52384D2F | CAB73F06 |
| 52 | 9F166CDB | F3497054 | 12E504E5 | AE6BF667 | 71B3459B | D0AB7CFC | F9A8377F | 52384D2F |
| 53 | CCD8FA44 | 9F166CDB | F3497054 | 12E504E5 | 0F557DDD | 71B3459B | D0AB7CFC | F9A8377F |
| 54 | F5E664BD | CCD8FA44 | 9F166CDB | F3497054 | A679A5E9 | 0F557DDD | 71B3459B | D0AB7CFC |
| 55 | D4EA8C7E | F5E664BD | CCD8FA44 | 9F166CDB | 2958CE2A | A679A5E9 | 0F557DDD | 71B3459B |
| 56 | E8C8FEC7 | D4EA8C7E | F5E664BD | CCD8FA44 | 35F6800E | 2958CE2A | A679A5E9 | 0F557DDD |
| 57 | 882ED69E | E8C8FEC7 | D4EA8C7E | F5E664BD | 30267D8E | 35F6800E | 2958CE2A | A679A5E9 |
| 58 | 4EC725F6 | 882ED69E | E8C8FEC7 | D4EA8C7E | CE1D1CE4 | 30267D8E | 35F6800E | 2958CE2A |
| 59 | 5C9CFC69 | 4EC725F6 | 882ED69E | E8C8FEC7 | C8242B92 | CE1D1CE4 | 30267D8E | 35F6800E |
| 60 | C9A31836 | 5C9CFC69 | 4EC725F6 | 882ED69E | 9E40A370 | C8242B92 | CE1D1CE4 | 30267D8E |
| 61 | F754C16E | C9A31836 | 5C9CFC69 | 4EC725F6 | 333E0B63 | 9E40A370 | C8242B92 | CE1D1CE4 |
| 62 | 94314748 | F754C16E | C9A31836 | 5C9CFC69 | 1FBC63B0 | 333E0B63 | 9E40A370 | C8242B92 |
| 63 | F2E7A4B9 | 94314748 | F754C16E | C9A31836 | 9FFD8DAC | 1FBC63B0 | 333E0B63 | 9E40A370 |

The following eight words,  $Y_0$ ,  $Y_1$ ,  $Y_2$ ,  $Y_3$ ,  $Y_4$ ,  $Y_5$ ,  $Y_6$  and  $Y_7$ , represent the output of the final iteration of the round-function.

$Y_0 = 8250E65D \cup F2E7A4B9 = 75388B16$   
 $Y_1 = BCF62F84 \cup 94314748 = 512776CC$   
 $Y_2 = 66659C33 \cup F754C16E = 5DBA5DA1$   
 $Y_3 = 33E5E91A \cup C9A31836 = FD890150$   
 $Y_4 = 10C8B7B0 \cup 9FFD8DAC = B0C6455C$   
 $Y_5 = 95392769 \cup 1FBC63B0 = B4F58B19$   
 $Y_6 = 1F1419C2 \cup 333E0B63 = 52522525$   
 $Y_7 = FD16F295 \cup 9E40A370 = 635651E5$

The hash value is the following 224-bit string.

75388B16 512776CC 5DBA5DA1 FD890150 B0C6455C B4F58B19 52522525

### B.9.8 Example 8

In this example, the data string is the 1 000 000-byte string consisting of the ASCII-coded version of “a” repeated  $10^6$  times.

The hash-code is the following 224-bit string.

20794655 980C91D8 BBB4C1EA 97618A4B F03F425B 1948B2EE 4EE7AD67

### B.9.9 Example 9

In this example, the data string consists of a single bit, namely 0.

The hash-code is the following 224-bit string.

D3FE57CB 76CDD24E 9EB23E7E 15684E03 9C75459B EAAE100F 89712E9D

### B.9.10 Example 10

In this example, the data string consists of a single bit, namely 1.

The hash-code is the following 224-bit string.

0D05096B CA2A4A77 A2B47A05 A59618D0 1174B378 92376135 C1B6E957

### B.9.11 Example 11

In this example, the data string consists of 101 bits, namely 1010101...01.

The hash-code is the following 224-bit string.

2B1D4A34 155C04D7 A51065D6 A4476203 9A38DFFD 73E76B17 B043555C

### B.9.12 Example 12

In this example, the data string consists of 256 octets, namely 00 01 02 03 ... FE FF.

The hash-code is the following 224-bit string.

88702E63 237824C4 EB0D0FCF E41469A4 62493E8B EB2A75BB E5981734

### B.9.13 Example 13

In this example, the data string is the  $H_0$  consists of 224 0 bits. For  $i = 1$  to 100 let  $H_i$  be the hash-code of  $H_{i-1}$ .

The hash-code  $H_{100}$  is the following 224-bit string.

A0884CC1 A335042B FE452BF4 6777ED20 217A3472 81DC389E 7B1FBFEE

## B.10 Dedicated Hash-Function 9 (SHA-512/224)

### B.10.1 Example 1

In this example, the input message is “abc”. The padded one block input (1 024 bits) is

$Z[0] = 6162638000000000$   
 $Z[1] = 0000000000000000$   
 $Z[2] = 0000000000000000$   
 $Z[3] = 0000000000000000$   
 $Z[4] = 0000000000000000$   
 $Z[5] = 0000000000000000$   
 $Z[6] = 0000000000000000$   
 $Z[7] = 0000000000000000$   
 $Z[8] = 0000000000000000$   
 $Z[9] = 0000000000000000$   
 $Z[10] = 0000000000000000$   
 $Z[11] = 0000000000000000$   
 $Z[12] = 0000000000000000$   
 $Z[13] = 0000000000000000$   
 $Z[14] = 0000000000000000$   
 $Z[15] = 0000000000000018$

The following are (hexadecimal representations of) the successive values of the variables  $X_0, X_1, X_2, X_3, X_4, X_5, X_6$  and  $X_7$  in each round.

$t=0$ : 9F8617B9DCE5AAD2 8C3D37C819544DA2 73E1996689DCD4D6 1DFAB7AE32FF9C82  
 E606D304F5742303 0F6D2B697BD44DA8 77E36F7304C48942 3F9D85A86A1D36C8  
 $t=1$ : 39EEF9EA0D97D0E7 9F8617B9DCE5AAD2 8C3D37C819544DA2 73E1996689DCD4D6  
 ED6A8CE6AC02AE3B E606D304F5742303 0F6D2B697BD44DA8 77E36F7304C48942  
 $t=2$ : 9F956BCC32F99C4B 39EEF9EA0D97D0E7 9F8617B9DCE5AAD2 8C3D37C819544DA2  
 E7C4F75F0018AB16 ED6A8CE6AC02AE3B E606D304F5742303 0F6D2B697BD44DA8  
 $t=3$ : 624C8289051D5B40 9F956BCC32F99C4B 39EEF9EA0D97D0E7 9F8617B9DCE5AAD2  
 93C0EDD577EF4338 E7C4F75F0018AB16 ED6A8CE6AC02AE3B E606D304F5742303  
 $t=4$ : 8445DB53436C52F8 624C8289051D5B40 9F956BCC32F99C4B 39EEF9EA0D97D0E7  
 E5662EE45E149450 93C0EDD577EF4338 E7C4F75F0018AB16 ED6A8CE6AC02AE3B  
 $t=5$ : 9873F29F683128C8 8445DB53436C52F8 624C8289051D5B40 9F956BCC32F99C4B  
 0B843D2CDE075711 E5662EE45E149450 93C0EDD577EF4338 E7C4F75F0018AB16  
 $t=6$ : 134D4DD913EC29E7 9873F29F683128C8 8445DB53436C52F8 624C8289051D5B40  
 CACE421FD59538B6 0B843D2CDE075711 E5662EE45E149450 93C0EDD577EF4338  
 $t=7$ : 6A01F4E5758D5A14 134D4DD913EC29E7 9873F29F683128C8 8445DB53436C52F8  
 73EA4F37F91D77F0 CACE421FD59538B6 0B843D2CDE075711 E5662EE45E149450  
 $t=8$ : 0B9D8BDA33530FA3 6A01F4E5758D5A14 134D4DD913EC29E7 9873F29F683128C8  
 A64384D872C70950 73EA4F37F91D77F0 CACE421FD59538B6 0B843D2CDE075711  
 $t=9$ : 2C961F00E387DF1D 0B9D8BDA33530FA3 6A01F4E5758D5A14 134D4DD913EC29E7  
 AC79A3FFDAC317FC A64384D872C70950 73EA4F37F91D77F0 CACE421FD59538B6



t=10: 78953995DD54A904 2C961F00E387DF1D 0B9D8BDA33530FA3 6A01F4E5758D5A14  
 5FF1DE02C59C17E6 AC79A3FFDAC317FC A64384D872C70950 73EA4F37F91D77F0  
 t=11: 82A6A4ED5164390E 78953995DD54A904 2C961F00E387DF1D 0B9D8BDA33530FA3  
 3A6E6AED341206D2 5FF1DE02C59C17E6 AC79A3FFDAC317FC A64384D872C70950  
 t=12: 6528AFE0F531B8D9 82A6A4ED5164390E 78953995DD54A904 2C961F00E387DF1D  
 AF77A75BBF7964C9 3A6E6AED341206D2 5FF1DE02C59C17E6 AC79A3FFDAC317FC  
 t=13: 206C69B0295CAE2F 6528AFE0F531B8D9 82A6A4ED5164390E 78953995DD54A904  
 3CA059F97E654F98 AF77A75BBF7964C9 3A6E6AED341206D2 5FF1DE02C59C17E6  
 t=14: DB71F51BE96E76D1 206C69B0295CAE2F 6528AFE0F531B8D9 82A6A4ED5164390E  
 340B10ABC4B10E09 3CA059F97E654F98 AF77A75BBF7964C9 3A6E6AED341206D2  
 t=15: A69AF3FA50F71091 DB71F51BE96E76D1 206C69B0295CAE2F 6528AFE0F531B8D9  
 6C6A7EF25668BBB4 340B10ABC4B10E09 3CA059F97E654F98 AF77A75BBF7964C9  
 t=16: F57D3A111596E3F7 A69AF3FA50F71091 DB71F51BE96E76D1 206C69B0295CAE2F  
 483FD5187E05AF83 6C6A7EF25668BBB4 340B10ABC4B10E09 3CA059F97E654F98  
 t=17: 37F983BB8545A2F2 F57D3A111596E3F7 A69AF3FA50F71091 DB71F51BE96E76D1  
 22CB500B1745C86F 483FD5187E05AF83 6C6A7EF25668BBB4 340B10ABC4B10E09  
 t=18: 6AB7291DC27CE806 37F983BB8545A2F2 F57D3A111596E3F7 A69AF3FA50F71091  
 CC2D9DA4800A1393 22CB500B1745C86F 483FD5187E05AF83 6C6A7EF25668BBB4  
 t=19: 8E50B25D469759C2 6AB7291DC27CE806 37F983BB8545A2F2 F57D3A111596E3F7  
 50193786D52F5194 CC2D9DA4800A1393 22CB500B1745C86F 483FD5187E05AF83  
 t=20: 3041190F76AD53DF 8E50B25D469759C2 6AB7291DC27CE806 37F983BB8545A2F2  
 746F4B17026AA6ED 50193786D52F5194 CC2D9DA4800A1393 22CB500B1745C86F  
 t=21: D37D93454B59A769 3041190F76AD53DF 8E50B25D469759C2 6AB7291DC27CE806  
 3792AA4013809C0F 746F4B17026AA6ED 50193786D52F5194 CC2D9DA4800A1393  
 t=22: 28E37AB968D3F5E5 D37D93454B59A769 3041190F76AD53DF 8E50B25D469759C2  
 936E64805412DE7D 3792AA4013809C0F 746F4B17026AA6ED 50193786D52F5194  
 t=23: 05799053E5D280FD 28E37AB968D3F5E5 D37D93454B59A769 3041190F76AD53DF  
 BD8F22E3B3312F05 936E64805412DE7D 3792AA4013809C0F 746F4B17026AA6ED  
 t=24: A24BC13A743FCBCE 05799053E5D280FD 28E37AB968D3F5E5 D37D93454B59A769  
 CD7C3D09944BE7B6 BD8F22E3B3312F05 936E64805412DE7D 3792AA4013809C0F  
 t=25: 1EABC1C5C3A2CDEA A24BC13A743FCBCE 05799053E5D280FD 28E37AB968D3F5E5  
 27A2534198BE3EFB CD7C3D09944BE7B6 BD8F22E3B3312F05 936E64805412DE7D  
 t=26: 471543A4179B22FE 1EABC1C5C3A2CDEA A24BC13A743FCBCE 05799053E5D280FD  
 A849D4C8E1909347 27A2534198BE3EFB CD7C3D09944BE7B6 BD8F22E3B3312F05  
 t=27: 887298E1C82038F7 471543A4179B22FE 1EABC1C5C3A2CDEA A24BC13A743FCBCE  
 536496733A17ADD7 A849D4C8E1909347 27A2534198BE3EFB CD7C3D09944BE7B6  
 t=28: 42FE965258B7E0EC 887298E1C82038F7 471543A4179B22FE 1EABC1C5C3A2CDEA  
 A37AD4727F2FB6A7 536496733A17ADD7 A849D4C8E1909347 27A2534198BE3EFB  
 t=29: B251E1018FD0C473 42FE965258B7E0EC 887298E1C82038F7 471543A4179B22FE  
 D4A476A812ED33C2 A37AD4727F2FB6A7 536496733A17ADD7 A849D4C8E1909347  
 t=30: DDDD91CB1FDBFD41 B251E1018FD0C473 42FE965258B7E0EC 887298E1C82038F7  
 04986D7E3FD773AE D4A476A812ED33C2 A37AD4727F2FB6A7 536496733A17ADD7  
 t=31: 4AA9D15BECE3FB9F DDDD91CB1FDBFD41 B251E1018FD0C473 42FE965258B7E0EC  
 53C83C436C1A8C55 04986D7E3FD773AE D4A476A812ED33C2 A37AD4727F2FB6A7  
 t=32: 063BE3A3BA1F925C 4AA9D15BECE3FB9F DDDD91CB1FDBFD41 B251E1018FD0C473  
 EB8227C63C6143AB 53C83C436C1A8C55 04986D7E3FD773AE D4A476A812ED33C2  
 t=33: 0BA0D71206B4CE72 063BE3A3BA1F925C 4AA9D15BECE3FB9F DDDD91CB1FDBFD41  
 672DE7D3FD6CE274 EB8227C63C6143AB 53C83C436C1A8C55 04986D7E3FD773AE  
 t=34: 344234B9E239CFBD 0BA0D71206B4CE72 063BE3A3BA1F925C 4AA9D15BECE3FB9F  
 38893650766BED56 672DE7D3FD6CE274 EB8227C63C6143AB 53C83C436C1A8C55



t=35: 8C098B89A7906A73 344234B9E239CFBD 0BA0D71206B4CE72 063BE3A3BA1F925C  
 A7B9698E7EDB54BD 38893650766BED56 672DE7D3FD6CE274 EB8227C63C6143AB  
 t=36: C5A836CC05300A0C 8C098B89A7906A73 344234B9E239CFBD 0BA0D71206B4CE72  
 BC35E565541C0486 A7B9698E7EDB54BD 38893650766BED56 672DE7D3FD6CE274  
 t=37: CDFE2808D45E7924 C5A836CC05300A0C 8C098B89A7906A73 344234B9E239CFBD  
 8B500635C180CC3B BC35E565541C0486 A7B9698E7EDB54BD 38893650766BED56  
 t=38: EDC87E1B480C8A77 CDFE2808D45E7924 C5A836CC05300A0C 8C098B89A7906A73  
 F309D755002EF931 8B500635C180CC3B BC35E565541C0486 A7B9698E7EDB54BD  
 t=39: 13D3A842A45159E7 EDC87E1B480C8A77 CDFE2808D45E7924 C5A836CC05300A0C  
 6D9958CC3F974B68 F309D755002EF931 8B500635C180CC3B BC35E565541C0486  
 t=40: 17AA585EACBB1D8C 13D3A842A45159E7 EDC87E1B480C8A77 CDFE2808D45E7924  
 A62EFC64B5A504C7 6D9958CC3F974B68 F309D755002EF931 8B500635C180CC3B  
 t=41: 7BCD6230B77F244A 17AA585EACBB1D8C 13D3A842A45159E7 EDC87E1B480C8A77  
 543AA84578643C3A A62EFC64B5A504C7 6D9958CC3F974B68 F309D755002EF931  
 t=42: BE63D26279808C58 7BCD6230B77F244A 17AA585EACBB1D8C 13D3A842A45159E7  
 5D1D742D663F17BE 543AA84578643C3A A62EFC64B5A504C7 6D9958CC3F974B68  
 t=43: C6F1FBBEDEA32F8E BE63D26279808C58 7BCD6230B77F244A 17AA585EACBB1D8C  
 D83E6A094C606812 5D1D742D663F17BE 543AA84578643C3A A62EFC64B5A504C7  
 t=44: 6346F580DD1CEC37 C6F1FBBEDEA32F8E BE63D26279808C58 7BCD6230B77F244A  
 5BE7E65BC706B684 D83E6A094C606812 5D1D742D663F17BE 543AA84578643C3A  
 t=45: 0C618B0042ADC22E 6346F580DD1CEC37 C6F1FBBEDEA32F8E BE63D26279808C58  
 BA9737EA9A33D1D4 5BE7E65BC706B684 D83E6A094C606812 5D1D742D663F17BE  
 t=46: BF9E3A882B0B4301 0C618B0042ADC22E 6346F580DD1CEC37 C6F1FBBEDEA32F8E  
 FCAE077AACC5CF59 BA9737EA9A33D1D4 5BE7E65BC706B684 D83E6A094C606812  
 t=47: 586A3D84D04FD482 BF9E3A882B0B4301 0C618B0042ADC22E 6346F580DD1CEC37  
 45F48765CE6A2794 FCAE077AACC5CF59 BA9737EA9A33D1D4 5BE7E65BC706B684  
 t=48: 5B2A6269DAF95602 586A3D84D04FD482 BF9E3A882B0B4301 0C618B0042ADC22E  
 68B8F9BE61FCFCE0 45F48765CE6A2794 FCAE077AACC5CF59 BA9737EA9A33D1D4  
 t=49: 5CF5F4502BB65B08 5B2A6269DAF95602 586A3D84D04FD482 BF9E3A882B0B4301  
 038E7DBE733DDC71 68B8F9BE61FCFCE0 45F48765CE6A2794 FCAE077AACC5CF59  
 t=50: DBB34340CCBA2D51 5CF5F4502BB65B08 5B2A6269DAF95602 586A3D84D04FD482  
 3107BE9653EA4652 038E7DBE733DDC71 68B8F9BE61FCFCE0 45F48765CE6A2794  
 t=51: 903B6E3D2CFDFA75 DBB34340CCBA2D51 5CF5F4502BB65B08 5B2A6269DAF95602  
 13DD1F6DC423ED9D 3107BE9653EA4652 038E7DBE733DDC71 68B8F9BE61FCFCE0  
 t=52: 22F68588F55C8E62 903B6E3D2CFDFA75 DBB34340CCBA2D51 5CF5F4502BB65B08  
 A6B45F7216FF1A92 13DD1F6DC423ED9D 3107BE9653EA4652 038E7DBE733DDC71  
 t=53: AF6B1C8DFE414C86 22F68588F55C8E62 903B6E3D2CFDFA75 DBB34340CCBA2D51  
 00384D2ED96AE437 A6B45F7216FF1A92 13DD1F6DC423ED9D 3107BE9653EA4652  
 t=54: BDCB5AC728279AB9 AF6B1C8DFE414C86 22F68588F55C8E62 903B6E3D2CFDFA75  
 768B77A7A84E1FDF 00384D2ED96AE437 A6B45F7216FF1A92 13DD1F6DC423ED9D  
 t=55: AAB7B27B1CE5D524 BDCB5AC728279AB9 AF6B1C8DFE414C86 22F68588F55C8E62  
 C4E802298CE15481 768B77A7A84E1FDF 00384D2ED96AE437 A6B45F7216FF1A92  
 t=56: 983A35EE537826F0 AAB7B27B1CE5D524 BDCB5AC728279AB9 AF6B1C8DFE414C86  
 0BE7B3FE43EB3463 C4E802298CE15481 768B77A7A84E1FDF 00384D2ED96AE437  
 t=57: C2C9007B1BE9CF4D 983A35EE537826F0 AAB7B27B1CE5D524 BDCB5AC728279AB9  
 397E5321BD27DD2E 0BE7B3FE43EB3463 C4E802298CE15481 768B77A7A84E1FDF  
 t=58: 1A0FCFF62C67E0A5 C2C9007B1BE9CF4D 983A35EE537826F0 AAB7B27B1CE5D524  
 BECEA5B070FDDE4B 397E5321BD27DD2E 0BE7B3FE43EB3463 C4E802298CE15481  
 t=59: E7D763B06CC2AC34 1A0FCFF62C67E0A5 C2C9007B1BE9CF4D 983A35EE537826F0  
 5744D273C1F38773 BECEA5B070FDDE4B 397E5321BD27DD2E 0BE7B3FE43EB3463

t=60: 486F4BADA8CB4D96 E7D763B06CC2AC34 1A0FCFF62C67E0A5 C2C9007B1BE9CF4D  
 6616508EA2133B34 5744D273C1F38773 BECEA5B070FDDE4B 397E5321BD27DD2E  
 t=61: DC6770B956F0F055 486F4BADA8CB4D96 E7D763B06CC2AC34 1A0FCFF62C67E0A5  
 970988E60D971C48 6616508EA2133B34 5744D273C1F38773 BECEA5B070FDDE4B  
 t=62: 5F7CE563832894E8 DC6770B956F0F055 486F4BADA8CB4D96 E7D763B06CC2AC34  
 650678F827F7701F 970988E60D971C48 6616508EA2133B34 5744D273C1F38773  
 t=63: C32DC022E5937D1B 5F7CE563832894E8 DC6770B956F0F055 486F4BADA8CB4D96  
 395087939EBDBDD1 650678F827F7701F 970988E60D971C48 6616508EA2133B34  
 t=64: FEE659ED0008B0EE C32DC022E5937D1B 5F7CE563832894E8 DC6770B956F0F055  
 C24F9D75EB91E085 395087939EBDBDD1 650678F827F7701F 970988E60D971C48  
 t=65: A732EB36834C074A FEE659ED0008B0EE C32DC022E5937D1B 5F7CE563832894E8  
 09A466D6CD127E9D C24F9D75EB91E085 395087939EBDBDD1 650678F827F7701F  
 t=66: 5B1682F0AF0FF6A6 A732EB36834C074A FEE659ED0008B0EE C32DC022E5937D1B  
 DA56B1B76183E9D1 09A466D6CD127E9D C24F9D75EB91E085 395087939EBDBDD1  
 t=67: A71757CE29CD6B61 5B1682F0AF0FF6A6 A732EB36834C074A FEE659ED0008B0EE  
 30ABC3DB21388EDB DA56B1B76183E9D1 09A466D6CD127E9D C24F9D75EB91E085  
 t=68: 8202AB6393E0A6D7 A71757CE29CD6B61 5B1682F0AF0FF6A6 A732EB36834C074A  
 4EDBCB450C9D68A5 30ABC3DB21388EDB DA56B1B76183E9D1 09A466D6CD127E9D  
 t=69: 6508770A9E741395 8202AB6393E0A6D7 A71757CE29CD6B61 5B1682F0AF0FF6A6  
 6B4F58DE06441A41 4EDBCB450C9D68A5 30ABC3DB21388EDB DA56B1B76183E9D1  
 t=70: F7C52916A6830F3F 6508770A9E741395 8202AB6393E0A6D7 A71757CE29CD6B61  
 55F85F28969F648B 6B4F58DE06441A41 4EDBCB450C9D68A5 30ABC3DB21388EDB  
 t=71: 061595A1758E4E5C F7C52916A6830F3F 6508770A9E741395 8202AB6393E0A6D7  
 D94F8C3E0A2F60A9 55F85F28969F648B 6B4F58DE06441A41 4EDBCB450C9D68A5  
 t=72: D5368734187EECCB 061595A1758E4E5C F7C52916A6830F3F 6508770A9E741395  
 A8C792C91D097031 D94F8C3E0A2F60A9 55F85F28969F648B 6B4F58DE06441A41  
 t=73: F338848E621D9D09 D5368734187EECCB 061595A1758E4E5C F7C52916A6830F3F  
 9769EC0E9A73A2BD A8C792C91D097031 D94F8C3E0A2F60A9 55F85F28969F648B  
 t=74: 86A48D31E4F7A2E6 F338848E621D9D09 D5368734187EECCB 061595A1758E4E5C  
 019AA3BCBEBBCD10 9769EC0E9A73A2BD A8C792C91D097031 D94F8C3E0A2F60A9  
 t=75: 8DFF4C4DDF36D9E2 86A48D31E4F7A2E6 F338848E621D9D09 D5368734187EECCB  
 67523326ED58C22B 019AA3BCBEBBCD10 9769EC0E9A73A2BD A8C792C91D097031  
 t=76: D6EB4F969D4CF40A 8DFF4C4DDF36D9E2 86A48D31E4F7A2E6 F338848E621D9D09  
 054704D916035D9D 67523326ED58C22B 019AA3BCBEBBCD10 9769EC0E9A73A2BD  
 t=77: F03D357829EF4D22 D6EB4F969D4CF40A 8DFF4C4DDF36D9E2 86A48D31E4F7A2E6  
 FDDF88A8DFF1FD36 054704D916035D9D 67523326ED58C22B 019AA3BCBEBBCD10  
 t=78: 66CCDBC9BC2B6E0C F03D357829EF4D22 D6EB4F969D4CF40A 8DFF4C4DDF36D9E2  
 B3953BA10977D31A FDDF88A8DFF1FD36 054704D916035D9D 67523326ED58C22B  
 t=79: B9F6EF4757271CB2 66CCDBC9BC2B6E0C F03D357829EF4D22 D6EB4F969D4CF40A  
 12446E230B3B76AC B3953BA10977D31A FDDF88A8DFF1FD36 054704D916035D9D

The output is

$Y_0 = 8C3D37C819544DA2 \oplus B9F6EF4757271CB2 = 4634270F707B6A54$   
 $Y_1 = 73E1996689DCD4D6 \oplus 66CCDBC9BC2B6E0C = DAAE7530460842E2$   
 $Y_2 = 1DFAB7AE32FF9C82 \oplus F03D357829EF4D22 = 0E37ED265CEEE9A4$   
 $Y_3 = 679DD514582F9FCF \oplus D6EB4F969D4CF40A = 3E8924AAF57C93D9$   
 $Y_4 = 0F6D2B697BD44DA8 \oplus 12446E230B3B76AC = 21B1998C870FC454$   
 $Y_5 = 77E36F7304C48942 \oplus B3953BA10977D31A = 2B78AB140E3C5C5C$   
 $Y_6 = 3F9D85A86A1D36C8 \oplus FDDF88A8DFF1FD36 = 3D7D0E514A0F33FE$   
 $Y_7 = 1112E6AD91D692A1 \oplus 054704D916035D9D = 1659EB86A7D9F03E$

The message digest is

4634270F 707B6A54 DAAE7530 460842E2 0E37ED26 5CEEE9A4 3E8924AA

### B.10.2 Example 2

In this example, the input message is

“abcdefghijklmnoijklmnopqklmnopqrlmnopqrsmnopqrstu”

The padded message consists of two blocks.

The first block input (1 024 bits) is

$Z[0] = 6162636465666768$   
 $Z[1] = 6263646566676869$   
 $Z[2] = 636465666768696A$   
 $Z[3] = 6465666768696A6B$   
 $Z[4] = 65666768696A6B6C$   
 $Z[5] = 666768696A6B6C6D$   
 $Z[6] = 6768696A6B6C6D6E$   
 $Z[7] = 68696A6B6C6D6E6F$   
 $Z[8] = 696A6B6C6D6E6F70$   
 $Z[9] = 6A6B6C6D6E6F7071$   
 $Z[10] = 6B6C6D6E6F707172$   
 $Z[11] = 6C6D6E6F70717273$   
 $Z[12] = 6D6E6F7071727374$   
 $Z[13] = 6E6F707172737475$   
 $Z[14] = 8000000000000000$   
 $Z[15] = 0000000000000000$

The following are (hexadecimal representations of) the successive values of the variables  $X_0, X_1, X_2, X_3, X_4, X_5, X_6$  and  $X_7$  in each round when the first block is processed.

$t=0$ : 9F86179E424C123A 8C3D37C819544DA2 73E1996689DCD4D6 1DFAB7AE32FF9C82  
 E606D2E95ADA8A6B 0F6D2B697BD44DA8 77E36F7304C48942 3F9D85A86A1D36C8  
 $t=1$ : 533141CB525091B9 9F86179E424C123A 8C3D37C819544DA2 73E1996689DCD4D6  
 48B022A85133E95D E606D2E95ADA8A6B 0F6D2B697BD44DA8 77E36F7304C48942  
 $t=2$ : E9CF7C4D67D20354 533141CB525091B9 9F86179E424C123A 8C3D37C819544DA2  
 57425F1189DC982C 48B022A85133E95D E606D2E95ADA8A6B 0F6D2B697BD44DA8  
 $t=3$ : A5ADFE61082B9ABD E9CF7C4D67D20354 533141CB525091B9 9F86179E424C123A  
 9848CEBCCFD84FEA 57425F1189DC982C 48B022A85133E95D E606D2E95ADA8A6B  
 $t=4$ : 2C3C2C5ED8EBD26D A5ADFE61082B9ABD E9CF7C4D67D20354 533141CB525091B9  
 E771AD738FE58E76 9848CEBCCFD84FEA 57425F1189DC982C 48B022A85133E95D  
 $t=5$ : AFB0D44C82DFF225 2C3C2C5ED8EBD26D A5ADFE61082B9ABD E9CF7C4D67D20354  
 CFFE93DD39AF3ABF E771AD738FE58E76 9848CEBCCFD84FEA 57425F1189DC982C  
 $t=6$ : 353191AF8D65DEE9 AFB0D44C82DFF225 2C3C2C5ED8EBD26D A5ADFE61082B9ABD  
 DCF6B078908DFF9D CFFE93DD39AF3ABF E771AD738FE58E76 9848CEBCCFD84FEA  
 $t=7$ : F0ED5E552EE187D9 353191AF8D65DEE9 AFB0D44C82DFF225 2C3C2C5ED8EBD26D  
 FF4C75D2E1DE3279 DCF6B078908DFF9D CFFE93DD39AF3ABF E771AD738FE58E76  
 $t=8$ : 779397867FBA1360 F0ED5E552EE187D9 353191AF8D65DEE9 AFB0D44C82DFF225

DE20103108B0A669 FF4C75D2E1DE3279 DCF6B078908DFF9D CFFE93DD39AF3ABF  
 t=9: B2DFC180C2685A63 779397867FBA1360 F0ED5E552EE187D9 353191AF8D65DEE9  
 842E374C7133F9F6 DE20103108B0A669 FF4C75D2E1DE3279 DCF6B078908DFF9D  
 t=10: 360F5422F09700EC B2DFC180C2685A63 779397867FBA1360 F0ED5E552EE187D9  
 60C5AE3708E67485 842E374C7133F9F6 DE20103108B0A669 FF4C75D2E1DE3279  
 t=11: DAEFF6A462386C20 360F5422F09700EC B2DFC180C2685A63 779397867FBA1360  
 A4889E7CE945580A 60C5AE3708E67485 842E374C7133F9F6 DE20103108B0A669  
 t=12: 0DECA4759C7E00AD DAEFF6A462386C20 360F5422F09700EC B2DFC180C2685A63  
 5EE3BD7D600E83AB A4889E7CE945580A 60C5AE3708E67485 842E374C7133F9F6  
 t=13: 13B00ED20E90DAC9 0DECA4759C7E00AD DAEFF6A462386C20 360F5422F09700EC  
 5BD8653319107D74 5EE3BD7D600E83AB A4889E7CE945580A 60C5AE3708E67485  
 t=14: D904C89042A3AD4D 13B00ED20E90DAC9 0DECA4759C7E00AD DAEFF6A462386C20  
 2472BA283736D707 5BD8653319107D74 5EE3BD7D600E83AB A4889E7CE945580A  
 t=15: F2787EC95BF1F813 D904C89042A3AD4D 13B00ED20E90DAC9 0DECA4759C7E00AD  
 99AC6FC931B828B5 2472BA283736D707 5BD8653319107D74 5EE3BD7D600E83AB  
 t=16: C73C91546E687207 F2787EC95BF1F813 D904C89042A3AD4D 13B00ED20E90DAC9  
 86A4CA2DC3377691 99AC6FC931B828B5 2472BA283736D707 5BD8653319107D74  
 t=17: 4F773C1E20EF1984 C73C91546E687207 F2787EC95BF1F813 D904C89042A3AD4D  
 3A2886065715B415 86A4CA2DC3377691 99AC6FC931B828B5 2472BA283736D707  
 t=18: 90DE39FF4862F8DE 4F773C1E20EF1984 C73C91546E687207 F2787EC95BF1F813  
 E7DB461C33EC4D87 3A2886065715B415 86A4CA2DC3377691 99AC6FC931B828B5  
 t=19: 9889961BC5B9B080 90DE39FF4862F8DE 4F773C1E20EF1984 C73C91546E687207  
 18DBE557A44B8215 E7DB461C33EC4D87 3A2886065715B415 86A4CA2DC3377691  
 t=20: 00BE5FE77AEEF04D 9889961BC5B9B080 90DE39FF4862F8DE 4F773C1E20EF1984  
 919D9DD3F8E192BA 18DBE557A44B8215 E7DB461C33EC4D87 3A2886065715B415  
 t=21: 4916899865BA519B 00BE5FE77AEEF04D 9889961BC5B9B080 90DE39FF4862F8DE  
 494E40936BF36522 919D9DD3F8E192BA 18DBE557A44B8215 E7DB461C33EC4D87  
 t=22: 2FD4751621FAA436 4916899865BA519B 00BE5FE77AEEF04D 9889961BC5B9B080  
 461316088EE39598 494E40936BF36522 919D9DD3F8E192BA 18DBE557A44B8215  
 t=23: A895267A751BBB51 2FD4751621FAA436 4916899865BA519B 00BE5FE77AEEF04D  
 7BF13FD8BDEC96E5 461316088EE39598 494E40936BF36522 919D9DD3F8E192BA  
 t=24: 413510E472DEBCAB A895267A751BBB51 2FD4751621FAA436 4916899865BA519B  
 E047DEF947ECF770 7BF13FD8BDEC96E5 461316088EE39598 494E40936BF36522  
 t=25: 0D9BD60E7ECF0CA0 413510E472DEBCAB A895267A751BBB51 2FD4751621FAA436  
 33635248DD1081A9 E047DEF947ECF770 7BF13FD8BDEC96E5 461316088EE39598  
 t=26: 2B6939189B6398BD 0D9BD60E7ECF0CA0 413510E472DEBCAB A895267A751BBB51  
 E1EA008EABDDDD8A 33635248DD1081A9 E047DEF947ECF770 7BF13FD8BDEC96E5  
 t=27: 88C8D5C8FDF31407 2B6939189B6398BD 0D9BD60E7ECF0CA0 413510E472DEBCAB  
 864D416A722024F2 E1EA008EABDDDD8A 33635248DD1081A9 E047DEF947ECF770  
 t=28: C48C3778FBDC16E5 88C8D5C8FDF31407 2B6939189B6398BD 0D9BD60E7ECF0CA0  
 8A4110030D28BE95 864D416A722024F2 E1EA008EABDDDD8A 33635248DD1081A9  
 t=29: D9F2AED6553533CF C48C3778FBDC16E5 88C8D5C8FDF31407 2B6939189B6398BD  
 EC047BC2E5A7C98B 8A4110030D28BE95 864D416A722024F2 E1EA008EABDDDD8A  
 t=30: 9C7DF3E0118B2A03 D9F2AED6553533CF C48C3778FBDC16E5 88C8D5C8FDF31407  
 946A5AB5B814086C EC047BC2E5A7C98B 8A4110030D28BE95 864D416A722024F2  
 t=31: 2642E04B9FC242CC 9C7DF3E0118B2A03 D9F2AED6553533CF C48C3778FBDC16E5  
 F51B8137241F6AEE 946A5AB5B814086C EC047BC2E5A7C98B 8A4110030D28BE95  
 t=32: 9EE2EDA5DE6A4BBF 2642E04B9FC242CC 9C7DF3E0118B2A03 D9F2AED6553533CF  
 3A110967CED1066A F51B8137241F6AEE 946A5AB5B814086C EC047BC2E5A7C98B  
 t=33: 96DD4E3F9F4ECB4B 9EE2EDA5DE6A4BBF 2642E04B9FC242CC 9C7DF3E0118B2A03

F7EA1DB2DE0E0F9C 3A110967CED1066A F51B8137241F6AEE 946A5AB5B814086C  
 t=34: 0A6F2F765D8F08D4 96DD4E3F9F4ECB4B 9EE2EDA5DE6A4BBF 2642E04B9FC242CC  
 A4289B29B081DC1E F7EA1DB2DE0E0F9C 3A110967CED1066A F51B8137241F6AEE  
 t=35: 7696BAE1D69A401A 0A6F2F765D8F08D4 96DD4E3F9F4ECB4B 9EE2EDA5DE6A4BBF  
 5AC1DA918A905421 A4289B29B081DC1E F7EA1DB2DE0E0F9C 3A110967CED1066A  
 t=36: 90B4206FAB7D0530 7696BAE1D69A401A 0A6F2F765D8F08D4 96DD4E3F9F4ECB4B  
 39083A7BEA35DAC5 5AC1DA918A905421 A4289B29B081DC1E F7EA1DB2DE0E0F9C  
 t=37: 071FA5F764C98E5F 90B4206FAB7D0530 7696BAE1D69A401A 0A6F2F765D8F08D4  
 08ECE17FD62AF2F9 39083A7BEA35DAC5 5AC1DA918A905421 A4289B29B081DC1E  
 t=38: CE0FCC34AD8DA36C 071FA5F764C98E5F 90B4206FAB7D0530 7696BAE1D69A401A  
 4685454816101EE6 08ECE17FD62AF2F9 39083A7BEA35DAC5 5AC1DA918A905421  
 t=39: FB78ADD4117E0D4C CE0FCC34AD8DA36C 071FA5F764C98E5F 90B4206FAB7D0530  
 510D7EED2F67960B 4685454816101EE6 08ECE17FD62AF2F9 39083A7BEA35DAC5  
 t=40: 595A8250371D868B FB78ADD4117E0D4C CE0FCC34AD8DA36C 071FA5F764C98E5F  
 5F514945AC2AF500 510D7EED2F67960B 4685454816101EE6 08ECE17FD62AF2F9  
 t=41: F1DC306C639EFB88 595A8250371D868B FB78ADD4117E0D4C CE0FCC34AD8DA36C  
 413017F53DFED208 5F514945AC2AF500 510D7EED2F67960B 4685454816101EE6  
 t=42: 275D96E89981CFE3 F1DC306C639EFB88 595A8250371D868B FB78ADD4117E0D4C  
 0245872EE399310A 413017F53DFED208 5F514945AC2AF500 510D7EED2F67960B  
 t=43: 5BFB82DA35571E11 275D96E89981CFE3 F1DC306C639EFB88 595A8250371D868B  
 76C80FF098F6ABB4 0245872EE399310A 413017F53DFED208 5F514945AC2AF500  
 t=44: E58F44F1BD431603 5BFB82DA35571E11 275D96E89981CFE3 F1DC306C639EFB88  
 5EBDABABF6D782FD 76C80FF098F6ABB4 0245872EE399310A 413017F53DFED208  
 t=45: 53B71BC37D03FACE E58F44F1BD431603 5BFB82DA35571E11 275D96E89981CFE3  
 8598A1A47D0357A5 5EBDABABF6D782FD 76C80FF098F6ABB4 0245872EE399310A  
 t=46: 345AE4AA187437E1 53B71BC37D03FACE E58F44F1BD431603 5BFB82DA35571E11  
 7E74231C4177D4D1 8598A1A47D0357A5 5EBDABABF6D782FD 76C80FF098F6ABB4  
 t=47: 626CEEE8A84D84E0 345AE4AA187437E1 53B71BC37D03FACE E58F44F1BD431603  
 F35A915AD59125EC 7E74231C4177D4D1 8598A1A47D0357A5 5EBDABABF6D782FD  
 t=48: C46DD1206FE63A9F 626CEEE8A84D84E0 345AE4AA187437E1 53B71BC37D03FACE  
 B7E272EFF6528CD5 F35A915AD59125EC 7E74231C4177D4D1 8598A1A47D0357A5  
 t=49: A6190DF4A1B0F666 C46DD1206FE63A9F 626CEEE8A84D84E0 345AE4AA187437E1  
 F01D59E16E01FC67 B7E272EFF6528CD5 F35A915AD59125EC 7E74231C4177D4D1  
 t=50: D1EA1DDDE4EF669B A6190DF4A1B0F666 C46DD1206FE63A9F 626CEEE8A84D84E0  
 45B6FA884E24396A F01D59E16E01FC67 B7E272EFF6528CD5 F35A915AD59125EC  
 t=51: 9F33EE7183AED669 D1EA1DDDE4EF669B A6190DF4A1B0F666 C46DD1206FE63A9F  
 B133508E689D5618 45B6FA884E24396A F01D59E16E01FC67 B7E272EFF6528CD5  
 t=52: B13ECBE9C5AB549B 9F33EE7183AED669 D1EA1DDDE4EF669B A6190DF4A1B0F666  
 257000654C161D77 B133508E689D5618 45B6FA884E24396A F01D59E16E01FC67  
 t=53: 372E19656F4C71F6 B13ECBE9C5AB549B 9F33EE7183AED669 D1EA1DDDE4EF669B  
 53B78D2B828C9FD0 257000654C161D77 B133508E689D5618 45B6FA884E24396A  
 t=54: AE694575918CF0FA 372E19656F4C71F6 B13ECBE9C5AB549B 9F33EE7183AED669  
 6349FBF49B89B65D 53B78D2B828C9FD0 257000654C161D77 B133508E689D5618  
 t=55: 617B509949F118FD AE694575918CF0FA 372E19656F4C71F6 B13ECBE9C5AB549B  
 B1F1CB2F4FC0A9DE 6349FBF49B89B65D 53B78D2B828C9FD0 257000654C161D77  
 t=56: 22C244C694B15B1C 617B509949F118FD AE694575918CF0FA 372E19656F4C71F6  
 AC9793625B6713A6 B1F1CB2F4FC0A9DE 6349FBF49B89B65D 53B78D2B828C9FD0  
 t=57: 3311FB1C405F0D0F 22C244C694B15B1C 617B509949F118FD AE694575918CF0FA  
 E4C449F90128CC38 AC9793625B6713A6 B1F1CB2F4FC0A9DE 6349FBF49B89B65D  
 t=58: 594961E04CE3A122 3311FB1C405F0D0F 22C244C694B15B1C 617B509949F118FD

B6F7A90EB9C18C0A E4C449F90128CC38 AC9793625B6713A6 B1F1CB2F4FC0A9DE  
 t=59: 0A392F484AF8A380 594961E04CE3A122 3311FB1C405F0D0F 22C244C694B15B1C  
 1AD7E0EE097FDEB0 B6F7A90EB9C18C0A E4C449F90128CC38 AC9793625B6713A6  
 t=60: E146E2A7C1A65C6B 0A392F484AF8A380 594961E04CE3A122 3311FB1C405F0D0F  
 BB4DDA7E6C53497D 1AD7E0EE097FDEB0 B6F7A90EB9C18C0A E4C449F90128CC38  
 t=61: 529AB3BCA586375B E146E2A7C1A65C6B 0A392F484AF8A380 594961E04CE3A122  
 96D42DDC61058438 BB4DDA7E6C53497D 1AD7E0EE097FDEB0 B6F7A90EB9C18C0A  
 t=62: 70A7E4A859B8B382 529AB3BCA586375B E146E2A7C1A65C6B 0A392F484AF8A380  
 7F8CAECE994D7B17 96D42DDC61058438 BB4DDA7E6C53497D 1AD7E0EE097FDEB0  
 t=63: 1F5F60BBFE7CCCE7 70A7E4A859B8B382 529AB3BCA586375B E146E2A7C1A65C6B  
 DBBB47B6F5183CB6 7F8CAECE994D7B17 96D42DDC61058438 BB4DDA7E6C53497D  
 t=64: 9D537AF704E642F0 1F5F60BBFE7CCCE7 70A7E4A859B8B382 529AB3BCA586375B  
 BC4B7813CCB07A48 DBBB47B6F5183CB6 7F8CAECE994D7B17 96D42DDC61058438  
 t=65: 0F178025C27E422C 9D537AF704E642F0 1F5F60BBFE7CCCE7 70A7E4A859B8B382  
 E3065FF6F7ADDF6D BC4B7813CCB07A48 DBBB47B6F5183CB6 7F8CAECE994D7B17  
 t=66: A93AA5F85D1BCDEA 0F178025C27E422C 9D537AF704E642F0 1F5F60BBFE7CCCE7  
 DD8BDB1945B27133 E3065FF6F7ADDF6D BC4B7813CCB07A48 DBBB47B6F5183CB6  
 t=67: B93B21F8AEB8F329 A93AA5F85D1BCDEA 0F178025C27E422C 9D537AF704E642F0  
 1546C7737C00F978 DD8BDB1945B27133 E3065FF6F7ADDF6D BC4B7813CCB07A48  
 t=68: CF675521103494C7 B93B21F8AEB8F329 A93AA5F85D1BCDEA 0F178025C27E422C  
 9202AE67985172D8 1546C7737C00F978 DD8BDB1945B27133 E3065FF6F7ADDF6D  
 t=69: 6BD1BCB0F69DEAB9 CF675521103494C7 B93B21F8AEB8F329 A93AA5F85D1BCDEA  
 CC4A167A12B10D07 9202AE67985172D8 1546C7737C00F978 DD8BDB1945B27133  
 t=70: 36FB6D38EC7A9F8F 6BD1BCB0F69DEAB9 CF675521103494C7 B93B21F8AEB8F329  
 BF2DF292FDA17376 A167CC4A12B10D07 9202AE67985172D8 1546C7737C00F978  
 t=71: B45C8408593C88F6 36FB6D38EC7A9F8F 6BD1BCB0F69DEAB9 CF675521103494C7  
 70347EA05752DF76 BF2DF292FDA17376 A167CC4A12B10D07 9202AE67985172D8  
 t=72: 0CA25CCF6FF6180E B45C8408593C88F6 36FB6D38EC7A9F8F 6BD1BCB0F69DEAB9  
 0FFA31707E364987 70347EA05752DF76 BF2DF292FDA17376 A167CC4A12B10D07  
 t=73: D49316BE5F130748 0CA25CCF6FF6180E B45C8408593C88F6 36FB6D38EC7A9F8F  
 51269C93931E39F7 0FFA31707E364987 70347EA05752DF76 BF2DF292FDA17376  
 t=74: 896EE1FEC0F16E4B D49316BE5F130748 0CA25CCF6FF6180E B45C8408593C88F6  
 118DA75760797D25 51269C93931E39F7 0FFA31707E364987 70347EA05752DF76  
 t=75: 22007C194C5B05AD 896EE1FEC0F16E4B D49316BE5F130748 0CA25CCF6FF6180E  
 070F4D2C71FD0609 118DA75760797D25 51269C93931E39F7 0FFA31707E364987  
 t=76: ED4C5451ED5670B7 22007C194C5B05AD 896EE1FEC0F16E4B D49316BE5F130748  
 D5AE0EB0DE35A312 070F4D2C71FD0609 118DA75760797D25 51269C93931E39F7  
 t=77: F61D35F056C47639 ED4C5451ED5670B7 22007C194C5B05AD 896EE1FEC0F16E4B  
 137B9CA2A9375030 D5AE0EB0DE35A312 070F4D2C71FD0609 118DA75760797D25  
 t=78: EC01C4BFEACC2519 F61D35F056C47639 ED4C5451ED5670B7 22007C194C5B05AD  
 F6083B6FEFAEF695 137B9CA2A9375030 D5AE0EB0DE35A312 070F4D2C71FD0609  
 t=79: 09C993659E2DEF45 EC01C4BFEACC2519 F61D35F056C47639 ED4C5451ED5670B7  
 1617F9FA73004761 F6083B6FEFAEF695 137B9CA2A9375030 D5AE0EB0DE35A312



The output after processing the first block is

```

Y0 = 8C3D37C819544DA2 ⊕ 09C993659E2DEF45 = 9606CB2DB7823CE7
Y1 = 73E1996689DCD4D6 ⊕ EC01C4BFEACC2519 = 5FE35E2674A8F9EF
Y2 = 1DFAB7AE32FF9C82 ⊕ F61D35F056C47639 = 1417ED9E89C412BB
Y3 = 679DD514582F9FCF ⊕ ED4C5451ED5670B7 = 54EA296645861086
Y4 = 0F6D2B697BD44DA8 ⊕ 1617F9FA73004761 = 25852563EED49509
Y5 = 77E36F7304C48942 ⊕ F6083B6FEFAEF695 = 6DEBAAE2F4737FD7
Y6 = 3F9D85A86A1D36C8 ⊕ 137B9CA2A9375030 = 5319224B135486F8
Y7 = 1112E6AD91D692A1 ⊕ D5AE0EB0DE35A312 = E6C0F55E700C35B3

```

The second block input (1 024 bits) is

```

Z[ 0] = 0000000000000000
Z[ 1] = 0000000000000000
Z[ 2] = 0000000000000000
Z[ 3] = 0000000000000000
Z[ 4] = 0000000000000000
Z[ 5] = 0000000000000000
Z[ 6] = 0000000000000000
Z[ 7] = 0000000000000000
Z[ 8] = 0000000000000000
Z[ 9] = 0000000000000000
Z[10] = 0000000000000000
Z[11] = 0000000000000000
Z[12] = 0000000000000000
Z[13] = 0000000000000000
Z[14] = 0000000000000000
Z[15] = 0000000000000380

```

The following are (hexadecimal representations of) the successive values of the variables  $X_0, X_1, X_2, X_3, X_4, X_5, X_6$  and  $X_7$  in each round when the second block is processed.

```

t= 0: C62A1109950BC4B0 9606CB2DB7823CE7 5FE35E2674A8F9EF 1417ED9E89C412BB
      B6602607DA508EC1 25852563EED49509 6DEBAAE2F4737FD7 5319224B135486F8
t= 1: 4A2EB8F6FF304F81 C62A1109950BC4B0 9606CB2DB7823CE7 5FE35E2674A8F9EF
      614F9DBEA0C1A45C B6602607DA508EC1 25852563EED49509 6DEBAAE2F4737FD7
t= 2: D708ED5418B1A603 4A2EB8F6FF304F81 C62A1109950BC4B0 9606CB2DB7823CE7
      CF8726E0E363D72E 614F9DBEA0C1A45C B6602607DA508EC1 25852563EED49509
t= 3: 44D5660E0E213AA5 D708ED5418B1A603 4A2EB8F6FF304F81 C62A1109950BC4B0
      EF8A0CF5A58EB13D CF8726E0E363D72E 614F9DBEA0C1A45C B6602607DA508EC1
t= 4: 957D13471214C5F4 44D5660E0E213AA5 D708ED5418B1A603 4A2EB8F6FF304F81
      981291723204C874 EF8A0CF5A58EB13D CF8726E0E363D72E 614F9DBEA0C1A45C
t= 5: 76E8C9D1C9DD8AB8 957D13471214C5F4 44D5660E0E213AA5 D708ED5418B1A603
      7FCCD3C31337A90E 981291723204C874 EF8A0CF5A58EB13D CF8726E0E363D72E
t= 6: 4B16F79453BE3727 76E8C9D1C9DD8AB8 957D13471214C5F4 44D5660E0E213AA5
      80E62F655E7ED37B 7FCCD3C31337A90E 981291723204C874 EF8A0CF5A58EB13D
t= 7: 5E63338FBE9889D9 4B16F79453BE3727 76E8C9D1C9DD8AB8 957D13471214C5F4
      441041F54BE0537B 80E62F655E7ED37B 7FCCD3C31337A90E 981291723204C874
t= 8: C7338364B83DF9C6 5E63338FBE9889D9 4B16F79453BE3727 76E8C9D1C9DD8AB8
      E4FA1425EB9F0182 441041F54BE0537B 80E62F655E7ED37B 7FCCD3C31337A90E
t= 9: 5ED78CF2D7AD0133 C7338364B83DF9C6 5E63338FBE9889D9 4B16F79453BE3727

```



21EC095197532090 E4FA1425EB9F0182 441041F54BE0537B 80E62F655E7ED37B  
 t=10: 75C6A9870347B569 5ED78CF2D7AD0133 C7338364B83DF9C6 5E63338FBE9889D9  
 37D613B93BD7DFB5 21EC095197532090 E4FA1425EB9F0182 441041F54BE0537B  
 t=11: 2330FC9F6CEAC437 75C6A9870347B569 5ED78CF2D7AD0133 C7338364B83DF9C6  
 2F1071A0C464DD6B 37D613B93BD7DFB5 21EC095197532090 E4FA1425EB9F0182  
 t=12: B56EA6063E644DAF 2330FC9F6CEAC437 75C6A9870347B569 5ED78CF2D7AD0133  
 D97C54DC192D2B1A 2F1071A0C464DD6B 37D613B93BD7DFB5 21EC095197532090  
 t=13: F60601BFD3CE4BA2 B56EA6063E644DAF 2330FC9F6CEAC437 75C6A9870347B569  
 B9D5E11F983972F8 D97C54DC192D2B1A 2F1071A0C464DD6B 37D613B93BD7DFB5  
 t=14: FA6E99A8556DF258 F60601BFD3CE4BA2 B56EA6063E644DAF 2330FC9F6CEAC437  
 015DEA3F41B9C289 B9D5E11F983972F8 D97C54DC192D2B1A 2F1071A0C464DD6B  
 t=15: 38E5F661C3F1191B FA6E99A8556DF258 F60601BFD3CE4BA2 B56EA6063E644DAF  
 5279EE55AFE8AFCC 015DEA3F41B9C289 B9D5E11F983972F8 D97C54DC192D2B1A  
 t=16: ACDC1A5C38C85CD5 38E5F661C3F1191B FA6E99A8556DF258 F60601BFD3CE4BA2  
 DB79F8F12D277F02 5279EE55AFE8AFCC 015DEA3F41B9C289 B9D5E11F983972F8  
 t=17: 4B9240C9BA6F1B53 ACDC1A5C38C85CD5 38E5F661C3F1191B FA6E99A8556DF258  
 4DE55D4B2EA4F33C DB79F8F12D277F02 5279EE55AFE8AFCC 015DEA3F41B9C289  
 t=18: 4635F911BF4C6D0D 4B9240C9BA6F1B53 ACDC1A5C38C85CD5 38E5F661C3F1191B  
 BCB192998C798DEA 4DE55D4B2EA4F33C DB79F8F12D277F02 5279EE55AFE8AFCC  
 t=19: E586156D13060B8C 4635F911BF4C6D0D 4B9240C9BA6F1B53 ACDC1A5C38C85CD5  
 176C6027F44C42A5 BCB192998C798DEA 4DE55D4B2EA4F33C DB79F8F12D277F02  
 t=20: 65E9087A1372B7EE E586156D13060B8C 4635F911BF4C6D0D 4B9240C9BA6F1B53  
 1CA79B5218212A16 176C6027F44C42A5 BCB192998C798DEA 4DE55D4B2EA4F33C  
 t=21: 61D617FF18A51FA7 65E9087A1372B7EE E586156D13060B8C 4635F911BF4C6D0D  
 FFF208DDA4ACF3BF 1CA79B5218212A16 176C6027F44C42A5 BCB192998C798DEA  
 t=22: EAE30855B7D727BF 61D617FF18A51FA7 65E9087A1372B7EE E586156D13060B8C  
 1908F447D8261EFD FFF208DDA4ACF3BF 1CA79B5218212A16 176C6027F44C42A5  
 t=23: E17F4AA3CA31951F EAE30855B7D727BF 61D617FF18A51FA7 65E9087A1372B7EE  
 A93A3B339DE2E79E 1908F447D8261EFD FFF208DDA4ACF3BF 1CA79B5218212A16  
 t=24: CBDA7FD5D72B0448 E17F4AA3CA31951F EAE30855B7D727BF 61D617FF18A51FA7  
 39CB25C47F7F1E76 A93A3B339DE2E79E 1908F447D8261EFD FFF208DDA4ACF3BF  
 t=25: 875B7C8BD1FC6FFF CBDA7FD5D72B0448 E17F4AA3CA31951F EAE30855B7D727BF  
 5061761EF4A7B430 39CB25C47F7F1E76 A93A3B339DE2E79E 1908F447D8261EFD  
 t=26: 7493EB03CB083DCB 875B7C8BD1FC6FFF CBDA7FD5D72B0448 E17F4AA3CA31951F  
 A00157FD4436BEC5 5061761EF4A7B430 39CB25C47F7F1E76 A93A3B339DE2E79E  
 t=27: A2194EB42A179534 7493EB03CB083DCB 875B7C8BD1FC6FFF CBDA7FD5D72B0448  
 75E556161E2D8F5E A00157FD4436BEC5 5061761EF4A7B430 39CB25C47F7F1E76  
 t=28: 50120D72503F50A3 A2194EB42A179534 7493EB03CB083DCB 875B7C8BD1FC6FFF  
 B2288596FBF78C7A 75E556161E2D8F5E A00157FD4436BEC5 5061761EF4A7B430  
 t=29: 9388C45EF9BEDABA 50120D72503F50A3 A2194EB42A179534 7493EB03CB083DCB  
 377650FBEE17C4B3 B2288596FBF78C7A 75E556161E2D8F5E A00157FD4436BEC5  
 t=30: FA0D8AF6122631D1 9388C45EF9BEDABA 50120D72503F50A3 A2194EB42A179534  
 4417C8D07BA5397A 377650FBEE17C4B3 B2288596FBF78C7A 75E556161E2D8F5E  
 t=31: 9E234A4F427D2B06 FA0D8AF6122631D1 9388C45EF9BEDABA 50120D72503F50A3  
 23652F849EA698BE 4417C8D07BA5397A 377650FBEE17C4B3 B2288596FBF78C7A  
 t=32: 8D9DC47628B2D452 9E234A4F427D2B06 FA0D8AF6122631D1 9388C45EF9BEDABA  
 D9DD068BDE33B870 23652F849EA698BE 4417C8D07BA5397A 377650FBEE17C4B3  
 t=33: DBC5AB3931DBA353 8D9DC47628B2D452 9E234A4F427D2B06 FA0D8AF6122631D1  
 E3F00F8D49C43EC4 D9DD068BDE33B870 23652F849EA698BE 4417C8D07BA5397A  
 t=34: 90BBFAFE9E70D4DE DBC5AB3931DBA353 8D9DC47628B2D452 9E234A4F427D2B06

C79450C5A27F1152 E3F00F8D49C43EC4 D9DD068BDE33B870 23652F849EA698BE  
 t=35: 0176074A50D737DC 90BBFAFE9E70D4DE DBC5AB3931DBA353 8D9DC47628B2D452  
 484DCDA447B167ED C79450C5A27F1152 E3F00F8D49C43EC4 D9DD068BDE33B870  
 t=36: 8A31589736A222D9 0176074A50D737DC 90BBFAFE9E70D4DE DBC5AB3931DBA353  
 77F0533A9F4225D4 484DCDA447B167ED C79450C5A27F1152 E3F00F8D49C43EC4  
 t=37: DB9603572C370B39 8A31589736A222D9 0176074A50D737DC 90BBFAFE9E70D4DE  
 AD407246D492B9C9 77F0533A9F4225D4 484DCDA447B167ED C79450C5A27F1152  
 t=38: A0BC2200492231A3 DB9603572C370B39 8A31589736A222D9 0176074A50D737DC  
 001CFA61F6A94907 AD407246D492B9C9 77F0533A9F4225D4 484DCDA447B167ED  
 t=39: D17150907EDA767B A0BC2200492231A3 DB9603572C370B39 8A31589736A222D9  
 C7398391FEE339DE 001CFA61F6A94907 AD407246D492B9C9 77F0533A9F4225D4  
 t=40: A3312953448FA7E1 D17150907EDA767B A0BC2200492231A3 DB9603572C370B39  
 88C2310AFA13D7FD C7398391FEE339DE 001CFA61F6A94907 AD407246D492B9C9  
 t=41: A1974BE1E531F375 A3312953448FA7E1 D17150907EDA767B A0BC2200492231A3  
 9CABA67B2C460999 88C2310AFA13D7FD C7398391FEE339DE 001CFA61F6A94907  
 t=42: 34BFABB3D67367DF A1974BE1E531F375 A3312953448FA7E1 D17150907EDA767B  
 4AB15B8120A75FA0 9CABA67B2C460999 88C2310AFA13D7FD C7398391FEE339DE  
 t=43: 47FB83EA0B09CFDF 34BFABB3D67367DF A1974BE1E531F375 A3312953448FA7E1  
 82AF65BB8CF42FDF 4AB15B8120A75FA0 9CABA67B2C460999 88C2310AFA13D7FD  
 t=44: BE123C3EE4765CED 47FB83EA0B09CFDF 34BFABB3D67367DF A1974BE1E531F375  
 553B3C12510AF392 82AF65BB8CF42FDF 4AB15B8120A75FA0 9CABA67B2C460999  
 t=45: 1BBD79A592A8BD47 BE123C3EE4765CED 47FB83EA0B09CFDF 34BFABB3D67367DF  
 02E864735B8BF844 553B3C12510AF392 82AF65BB8CF42FDF 4AB15B8120A75FA0  
 t=46: 0A8B7BECB393BFA4 1BBD79A592A8BD47 BE123C3EE4765CED 47FB83EA0B09CFDF  
 1A8B439714CE8AF1 02E864735B8BF844 553B3C12510AF392 82AF65BB8CF42FDF  
 t=47: 9510DFC044C38B79 0A8B7BECB393BFA4 1BBD79A592A8BD47 BE123C3EE4765CED  
 F5B8B726BB1A26AC 1A8B439714CE8AF1 02E864735B8BF844 553B3C12510AF392  
 t=48: 20C6FF36AAF2AFE6 9510DFC044C38B79 0A8B7BECB393BFA4 1BBD79A592A8BD47  
 E5BDED3F35816323 F5B8B726BB1A26AC 1A8B439714CE8AF1 02E864735B8BF844  
 t=49: 7FA16F7BA5EBE14C 20C6FF36AAF2AFE6 9510DFC044C38B79 0A8B7BECB393BFA4  
 321838784DA12D56 E5BDED3F35816323 F5B8B726BB1A26AC 1A8B439714CE8AF1  
 t=50: D2B84B6F18380735 7FA16F7BA5EBE14C 20C6FF36AAF2AFE6 9510DFC044C38B79  
 67338C92A9E62CB3 321838784DA12D56 E5BDED3F35816323 F5B8B726BB1A26AC  
 t=51: 9201269A2C54F51E D2B84B6F18380735 7FA16F7BA5EBE14C 20C6FF36AAF2AFE6  
 18B3943C938E0477 67338C92A9E62CB3 321838784DA12D56 E5BDED3F35816323  
 t=52: E5AA7485C1241AA4 9201269A2C54F51E D2B84B6F18380735 7FA16F7BA5EBE14C  
 B9CD3EFC85E7C325 18B3943C938E0477 67338C92A9E62CB3 321838784DA12D56  
 t=53: 5E3B46494F487A51 E5AA7485C1241AA4 9201269A2C54F51E D2B84B6F18380735  
 A1A96A63C2F9C2D5 B9CD3EFC85E7C325 18B3943C938E0477 67338C92A9E62CB3  
 t=54: 30F07AE985818A3F 5E3B46494F487A51 E5AA7485C1241AA4 9201269A2C54F51E  
 F7B2345A39EE53D6 A1A96A63C2F9C2D5 B9CD3EFC85E7C325 18B3943C938E0477  
 t=55: D5441CF2BBBF4247 30F07AE985818A3F 5E3B46494F487A51 E5AA7485C1241AA4  
 08170A5A65B9CC59 F7B2345A39EE53D6 A1A96A63C2F9C2D5 B9CD3EFC85E7C325  
 t=56: A028FDCCD5B3CD6C D5441CF2BBBF4247 30F07AE985818A3F 5E3B46494F487A51  
 40F68900D8945D8B 08170A5A65B9CC59 F7B2345A39EE53D6 A1A96A63C2F9C2D5  
 t=57: A7EC8B6433605C8D A028FDCCD5B3CD6C D5441CF2BBBF4247 30F07AE985818A3F  
 5DCC12B8F92F5A2A 40F68900D8945D8B 08170A5A65B9CC59 F7B2345A39EE53D6  
 t=58: E7440592C375CD18 A7EC8B6433605C8D A028FDCCD5B3CD6C D5441CF2BBBF4247  
 800CC35788C7BD7E 5DCC12B8F92F5A2A 40F68900D8945D8B 08170A5A65B9CC59  
 t=59: 8CFEBA0AA271D1E8 E7440592C375CD18 A7EC8B6433605C8D A028FDCCD5B3CD6C

18CEFFE60E5F76E0 800CC35788C7BD7E 5DCC12B8F92F5A2A 40F68900D8945D8B  
 t=60: 47B9D567B722FB37 8CFEBA0AA271D1E8 E7440592C375CD18 A7EC8B6433605C8D  
 A530BEE0AB96F7BF 18CEFFE60E5F76E0 800CC35788C7BD7E 5DCC12B8F92F5A2A  
 t=61: A3C575002D2A90C4 47B9D567B722FB37 8CFEBA0AA271D1E8 E7440592C375CD18  
 332C2311F81CC391 A530BEE0AB96F7BF 18CEFFE60E5F76E0 800CC35788C7BD7E  
 t=62: F96FCB96DEB9E494 A3C575002D2A90C4 47B9D567B722FB37 8CFEBA0AA271D1E8  
 7EFBDECC5D2B5820 332C2311F81CC391 A530BEE0AB96F7BF 18CEFFE60E5F76E0  
 t=63: F363C8EC7B1A0888 F96FCB96DEB9E494 A3C575002D2A90C4 47B9D567B722FB37  
 2AE76A4CDD0B55BD 7EFBDECC5D2B5820 332C2311F81CC391 A530BEE0AB96F7BF  
 t=64: B80FA4876347AD57 F363C8EC7B1A0888 F96FCB96DEB9E494 A3C575002D2A90C4  
 94D171AE802D6C9D 2AE76A4CDD0B55BD 7EFBDECC5D2B5820 332C2311F81CC391  
 t=65: 96345101E32B060F B80FA4876347AD57 F363C8EC7B1A0888 F96FCB96DEB9E494  
 5E1C4C06D3B02C21 94D171AE802D6C9D 2AE76A4CDD0B55BD 7EFBDECC5D2B5820  
 t=66: 35C874D072FDC82C 96345101E32B060F B80FA4876347AD57 F363C8EC7B1A0888  
 3353886B54C833B5 5E1C4C06D3B02C21 94D171AE802D6C9D 2AE76A4CDD0B55BD  
 t=67: 401E4175643FC458 35C874D072FDC82C 96345101E32B060F B80FA4876347AD57  
 EBEF8A88724B7FF7 3353886B54C833B5 5E1C4C06D3B02C21 94D171AE802D6C9D  
 t=68: D58E109317C90113 401E4175643FC458 35C874D072FDC82C 96345101E32B060F  
 894598AE776D2ED5 EBEF8A88724B7FF7 3353886B54C833B5 5E1C4C06D3B02C21  
 t=69: 68A4AA1333AEA536 D58E109317C90113 401E4175643FC458 35C874D072FDC82C  
 09FCE6C815B259F9 894598AE776D2ED5 EBEF8A88724B7FF7 3353886B54C833B5  
 t=70: 8A0D8C01F5588CC1 68A4AA1333AEA536 D58E109317C90113 401E4175643FC458  
 AEE1595DB3F40CF8 09FCE6C815B259F9 894598AE776D2ED5 EBEF8A88724B7FF7  
 t=71: 6F485B267B52813E 8A0D8C01F5588CC1 68A4AA1333AEA536 D58E109317C90113  
 BBA5B657667A087C AEE1595DB3F40CF8 09FCE6C815B259F9 894598AE776D2ED5  
 t=72: CBF0FF8A3EB56D59 6F485B267B52813E 8A0D8C01F5588CC1 68A4AA1333AEA536  
 D0686F6ECF9AB51E BBA5B657667A087C AEE1595DB3F40CF8 09FCE6C815B259F9  
 t=73: AD1D1893EE86E3B6 CBF0FF8A3EB56D59 6F485B267B52813E 8A0D8C01F5588CC1  
 D9F1FF942480D4D5 D0686F6ECF9AB51E BBA5B657667A087C AEE1595DB3F40CF8  
 t=74: 1443D9D1606FF323 AD1D1893EE86E3B6 CBF0FF8A3EB56D59 6F485B267B52813E  
 7AE67C10BF64A97B D9F1FF942480D4D5 D0686F6ECF9AB51E BBA5B657667A087C  
 t=75: 9F07271D479F94DC 1443D9D1606FF323 AD1D1893EE86E3B6 CBF0FF8A3EB56D59  
 84D997908D444616 7AE67C10BF64A97B D9F1FF942480D4D5 D0686F6ECF9AB51E  
 t=76: 137D219301D78C4D 9F07271D479F94DC 1443D9D1606FF323 AD1D1893EE86E3B6  
 2FD56FB46B6F4F93 84D997908D444616 7AE67C10BF64A97B D9F1FF942480D4D5  
 t=77: 21BE76D4C61FFBB7 137D219301D78C4D 9F07271D479F94DC 1443D9D1606FF323  
 BC85E4FC899BA009 2FD56FB46B6F4F93 84D997908D444616 7AE67C10BF64A97B  
 t=78: D09E343D96634B44 21BE76D4C61FFBB7 137D219301D78C4D 9F07271D479F94DC  
 D7AE6C10F1681576 BC85E4FC899BA009 2FD56FB46B6F4F93 84D997908D444616  
 t=79: 8DF7FA8DDD53CE3C D09E343D96634B44 21BE76D4C61FFBB7 137D219301D78C4D  
 A2C04D0AEA35A515 D7AE6C10F1681576 BC85E4FC899BA009 2FD56FB46B6F4F93

The output after processing the second block is

$Y_0 = 9606CB2DB7823CE7 \cup 8DF7FA8DDD53CE3C = 23FEC5BB94D60B23$   
 $Y_1 = 5FE35E2674A8F9EF \cup D09E343D96634B44 = 308192640B0C4533$   
 $Y_2 = 1417ED9E89C412BB \cup 21BE76D4C61FFBB7 = 35D664734FE40E72$   
 $Y_3 = 54EA296645861086 \cup 137D219301D78C4D = 68674AF9475D9CD3$   
 $Y_4 = 25852563EED49509 \cup A2C04D0AEA35A515 = C845726ED90A3A1E$   
 $Y_5 = 6DEBAAE2F4737FD7 \cup D7AE6C10F1681576 = 459A16F3E5DB954D$   
 $Y_6 = 5319224B135486F8 \cup BC85E4FC899BA009 = 0F9F07479CF02701$   
 $Y_7 = E6C0F55E700C35B3 \cup 2FD56FB46B6F4F93 = 16966512DB7B8546$

The message digest is

23FEC5BB 94D60B23 30819264 0B0C4533 35D66473 4FE40E72 68674AF9

## B.11 Dedicated Hash-Function 10 (SHA-512/256)

### B.11.1 Example 1

In this example, the input message is “abc”. The padded one block input (1 024 bits) is

$Z[0] = 6162638000000000$   
 $Z[1] = 0000000000000000$   
 $Z[2] = 0000000000000000$   
 $Z[3] = 0000000000000000$   
 $Z[4] = 0000000000000000$   
 $Z[5] = 0000000000000000$   
 $Z[6] = 0000000000000000$   
 $Z[7] = 0000000000000000$   
 $Z[8] = 0000000000000000$   
 $Z[9] = 0000000000000000$   
 $Z[10] = 0000000000000000$   
 $Z[11] = 0000000000000000$   
 $Z[12] = 0000000000000000$   
 $Z[13] = 0000000000000000$   
 $Z[14] = 0000000000000000$   
 $Z[15] = 0000000000000018$

The following are (hexadecimal representations of) the successive values of the variables  $X_0, X_1, X_2, X_3, X_4, X_5, X_6$  and  $X_7$  in each round.

$t=0$ : 9A2F6D11C39458FE 22312194FC2BF72C 9F555FA3C84C64C2 2393B86B6F53B151  
 3908D19FBCAF1B12 96283EE2A88EFFE3 BE5E1E2553863992 2B0199FC2C85B8AA  
 $t=1$ : 9C465A16F85EBD68 9A2F6D11C39458FE 22312194FC2BF72C 9F555FA3C84C64C2  
 BB7CF388A65CA549 3908D19FBCAF1B12 96283EE2A88EFFE3 BE5E1E2553863992  
 $t=2$ : D983D31C6CEA97C9 9C465A16F85EBD68 9A2F6D11C39458FE 22312194FC2BF72C  
 C8A505020ACB43C1 BB7CF388A65CA549 3908D19FBCAF1B12 96283EE2A88EFFE3  
 $t=3$ : 1D4E8897FCFF509E D983D31C6CEA97C9 9C465A16F85EBD68 9A2F6D11C39458FE  
 BA2E42D7925DE73B C8A505020ACB43C1 BB7CF388A65CA549 3908D19FBCAF1B12  
 $t=4$ : 47376B4548F81A5F 1D4E8897FCFF509E D983D31C6CEA97C9 9C465A16F85EBD68  
 24ECDAD8A00C274A BA2E42D7925DE73B C8A505020ACB43C1 BB7CF388A65CA549  
 $t=5$ : AA7B88556927CE7D 47376B4548F81A5F 1D4E8897FCFF509E D983D31C6CEA97C9  
 928BC3FFD85778B3 24ECDAD8A00C274A BA2E42D7925DE73B C8A505020ACB43C1  
 $t=6$ : B906B3DF822CF7C1 AA7B88556927CE7D 47376B4548F81A5F 1D4E8897FCFF509E  
 2023A2CD4FA5A4D8 928BC3FFD85778B3 24ECDAD8A00C274A BA2E42D7925DE73B  
 $t=7$ : 2F839A3929F48358 B906B3DF822CF7C1 AA7B88556927CE7D 47376B4548F81A5F  
 245A5F77616E5931 2023A2CD4FA5A4D8 928BC3FFD85778B3 24ECDAD8A00C274A  
 $t=8$ : 4B1B0E41FB81C46C 2F839A3929F48358 B906B3DF822CF7C1 AA7B88556927CE7D  
 3FE7E2D7D7CED54A 245A5F77616E5931 2023A2CD4FA5A4D8 928BC3FFD85778B3  
 $t=9$ : C4F1C71E65B18C15 4B1B0E41FB81C46C 2F839A3929F48358 B906B3DF822CF7C1  
 FF5E80C2A75481B7 3FE7E2D7D7CED54A 245A5F77616E5931 2023A2CD4FA5A4D8

t=10: 19D100CB5E1A3438 C4F1C71E65B18C15 4B1B0E41FB81C46C 2F839A3929F48358  
 8484655060EBC3EE FF5E80C2A75481B7 3FE7E2D7D7CED54A 245A5F77616E5931  
 t=11: 7AAB2807D4F3F022 19D100CB5E1A3438 C4F1C71E65B18C15 4B1B0E41FB81C46C  
 BFC3C10D93FF00B8 8484655060EBC3EE FF5E80C2A75481B7 3FE7E2D7D7CED54A  
 t=12: C9E2CB6D5D017BA7 7AAB2807D4F3F022 19D100CB5E1A3438 C4F1C71E65B18C15  
 0662BFD092E26FB7 BFC3C10D93FF00B8 8484655060EBC3EE FF5E80C2A75481B7  
 t=13: 8C4D8B98E0672988 C9E2CB6D5D017BA7 7AAB2807D4F3F022 19D100CB5E1A3438  
 996E6405C63D83E3 0662BFD092E26FB7 BFC3C10D93FF00B8 8484655060EBC3EE  
 t=14: 8D70D5EBDEA6724A 8C4D8B98E0672988 C9E2CB6D5D017BA7 7AAB2807D4F3F022  
 CEAAAEFF7189EC61 996E6405C63D83E3 0662BFD092E26FB7 BFC3C10D93FF00B8  
 t=15: 1EC6365704280063 8D70D5EBDEA6724A 8C4D8B98E0672988 C9E2CB6D5D017BA7  
 419C9D961BA8EA8F CEAAAEFF7189EC61 996E6405C63D83E3 0662BFD092E26FB7  
 t=16: 3AA569FFD0244EC4 1EC6365704280063 8D70D5EBDEA6724A 8C4D8B98E0672988  
 4AC147677B104598 419C9D961BA8EA8F CEAAAEFF7189EC61 996E6405C63D83E3  
 t=17: 2B6738209B26B728 3AA569FFD0244EC4 1EC6365704280063 8D70D5EBDEA6724A  
 8EE2964A7ADF0F1D 4AC147677B104598 419C9D961BA8EA8F CEAAAEFF7189EC61  
 t=18: 1FE6F882B4543504 2B6738209B26B728 3AA569FFD0244EC4 1EC6365704280063  
 9CDC03D015DA1E7D 8EE2964A7ADF0F1D 4AC147677B104598 419C9D961BA8EA8F  
 t=19: 73F4F92021784BB1 1FE6F882B4543504 2B6738209B26B728 3AA569FFD0244EC4  
 6994C169A3D21916 9CDC03D015DA1E7D 8EE2964A7ADF0F1D 4AC147677B104598  
 t=20: 4E8CA806D9319A74 73F4F92021784BB1 1FE6F882B4543504 2B6738209B26B728  
 EDB2C079F68C6C60 6994C169A3D21916 9CDC03D015DA1E7D 8EE2964A7ADF0F1D  
 t=21: 73214592D44C971F 4E8CA806D9319A74 73F4F92021784BB1 1FE6F882B4543504  
 15BBE2C3AA0E7FD7 EDB2C079F68C6C60 6994C169A3D21916 9CDC03D015DA1E7D  
 t=22: C56EBA713AEEA98F 73214592D44C971F 4E8CA806D9319A74 73F4F92021784BB1  
 9D3DFCD24D8FF89C 15BBE2C3AA0E7FD7 EDB2C079F68C6C60 6994C169A3D21916  
 t=23: 77F4BC54FFD4166B C56EBA713AEEA98F 73214592D44C971F 4E8CA806D9319A74  
 A2981D9590A4F202 9D3DFCD24D8FF89C 15BBE2C3AA0E7FD7 EDB2C079F68C6C60  
 t=24: B380E5F84D5DD65C 77F4BC54FFD4166B C56EBA713AEEA98F 73214592D44C971F  
 1F5D06ACB369D69F A2981D9590A4F202 9D3DFCD24D8FF89C 15BBE2C3AA0E7FD7  
 t=25: D8F368221281F96A B380E5F84D5DD65C 77F4BC54FFD4166B C56EBA713AEEA98F  
 1E1F4553B9689309 1F5D06ACB369D69F A2981D9590A4F202 9D3DFCD24D8FF89C  
 t=26: 73CE37ED59FC4595 D8F368221281F96A B380E5F84D5DD65C 77F4BC54FFD4166B  
 5CB11AE8485959C1 1E1F4553B9689309 1F5D06ACB369D69F A2981D9590A4F202  
 t=27: 2B79283E450B25D2 73CE37ED59FC4595 D8F368221281F96A B380E5F84D5DD65C  
 9CA2CDF1A009F7A0 5CB11AE8485959C1 1E1F4553B9689309 1F5D06ACB369D69F  
 t=28: 7C8479834A5D5E1C 2B79283E450B25D2 73CE37ED59FC4595 D8F368221281F96A  
 F68FB52FAD1792EB 9CA2CDF1A009F7A0 5CB11AE8485959C1 1E1F4553B9689309  
 t=29: 5623A1ED63ACFE9C 7C8479834A5D5E1C 2B79283E450B25D2 73CE37ED59FC4595  
 4174C3633D3223CB F68FB52FAD1792EB 9CA2CDF1A009F7A0 5CB11AE8485959C1  
 t=30: E0639E0746A1C4B9 5623A1ED63ACFE9C 7C8479834A5D5E1C 2B79283E450B25D2  
 1D2D1CA60E71D9C4 4174C3633D3223CB F68FB52FAD1792EB 9CA2CDF1A009F7A0  
 t=31: 0ECE8CB912DE792B E0639E0746A1C4B9 5623A1ED63ACFE9C 7C8479834A5D5E1C  
 10EA82370759FF98 1D2D1CA60E71D9C4 4174C3633D3223CB F68FB52FAD1792EB  
 t=32: 1011563D5CA6F21D 0ECE8CB912DE792B E0639E0746A1C4B9 5623A1ED63ACFE9C  
 2ABC930AEB105DDA 10EA82370759FF98 1D2D1CA60E71D9C4 4174C3633D3223CB  
 t=33: 001128D308744A0E 1011563D5CA6F21D 0ECE8CB912DE792B E0639E0746A1C4B9  
 6DF15BD09649437B 2ABC930AEB105DDA 10EA82370759FF98 1D2D1CA60E71D9C4  
 t=34: 785B23CDC94E4D47 001128D308744A0E 1011563D5CA6F21D 0ECE8CB912DE792B  
 75645A2459E2B29C 6DF15BD09649437B 2ABC930AEB105DDA 10EA82370759FF98

t=35: 431A6F9571320866 785B23CDC94E4D47 001128D308744A0E 1011563D5CA6F21D  
 C4B1FDB46655F51A 75645A2459E2B29C 6DF15BD09649437B 2ABC930AEB105DDA  
 t=36: D9E89BCB3B3616FE 431A6F9571320866 785B23CDC94E4D47 001128D308744A0E  
 445065C5E0806A68 C4B1FDB46655F51A 75645A2459E2B29C 6DF15BD09649437B  
 t=37: 4C5C5085AFB86C02 D9E89BCB3B3616FE 431A6F9571320866 785B23CDC94E4D47  
 0738C70B69B65E34 445065C5E0806A68 C4B1FDB46655F51A 75645A2459E2B29C  
 t=38: 49F49406AA9C7915 4C5C5085AFB86C02 D9E89BCB3B3616FE 431A6F9571320866  
 DDBFB052E66E151C 0738C70B69B65E34 445065C5E0806A68 C4B1FDB46655F51A  
 t=39: D53B182812347708 49F49406AA9C7915 4C5C5085AFB86C02 D9E89BCB3B3616FE  
 C0233F51F0027715 DDBFB052E66E151C 0738C70B69B65E34 445065C5E0806A68  
 t=40: 6204009DBFD8D0DB D53B182812347708 49F49406AA9C7915 4C5C5085AFB86C02  
 768286C2D8FD381E C0233F51F0027715 DDBFB052E66E151C 0738C70B69B65E34  
 t=41: AF3049C09D76ABCE 6204009DBFD8D0DB D53B182812347708 49F49406AA9C7915  
 11540218448DA4BA 768286C2D8FD381E C0233F51F0027715 DDBFB052E66E151C  
 t=42: 6F48A93A6216BDFA AF3049C09D76ABCE 6204009DBFD8D0DB D53B182812347708  
 60FF3969A7A7545B 11540218448DA4BA 768286C2D8FD381E C0233F51F0027715  
 t=43: 163B797CD24C6D2E 6F48A93A6216BDFA AF3049C09D76ABCE 6204009DBFD8D0DB  
 AF4C2A6889A401A2 60FF3969A7A7545B 11540218448DA4BA 768286C2D8FD381E  
 t=44: 75B6F991523D6EBD 163B797CD24C6D2E 6F48A93A6216BDFA AF3049C09D76ABCE  
 BE913F4585AA524A AF4C2A6889A401A2 60FF3969A7A7545B 11540218448DA4BA  
 t=45: 807232323213D257 75B6F991523D6EBD 163B797CD24C6D2E 6F48A93A6216BDFA  
 6269B8150084C5E5 BE913F4585AA524A AF4C2A6889A401A2 60FF3969A7A7545B  
 t=46: 5A93EC3C573AB27A 807232323213D257 75B6F991523D6EBD 163B797CD24C6D2E  
 EBCC25FD1EF4B66A 6269B8150084C5E5 BE913F4585AA524A AF4C2A6889A401A2  
 t=47: 96F715647C35010B 5A93EC3C573AB27A 807232323213D257 75B6F991523D6EBD  
 3DB3985131165CA8 EBCC25FD1EF4B66A 6269B8150084C5E5 BE913F4585AA524A  
 t=48: A493F38FA8BD1B7A 96F715647C35010B 5A93EC3C573AB27A 807232323213D257  
 72B27DF2E6E57AA8 3DB3985131165CA8 EBCC25FD1EF4B66A 6269B8150084C5E5  
 t=49: D379E2742808F23F A493F38FA8BD1B7A 96F715647C35010B 5A93EC3C573AB27A  
 3EA89437C88CCD1E 72B27DF2E6E57AA8 3DB3985131165CA8 EBCC25FD1EF4B66A  
 t=50: 8C0C28392DFEEDF0 D379E2742808F23F A493F38FA8BD1B7A 96F715647C35010B  
 ECCF127AA015E2F4 3EA89437C88CCD1E 72B27DF2E6E57AA8 3DB3985131165CA8  
 t=51: 1D5955ABCFCADF0 8C0C28392DFEEDF0 D379E2742808F23F A493F38FA8BD1B7A  
 496BCDAFE07B21B5 ECCF127AA015E2F4 3EA89437C88CCD1E 72B27DF2E6E57AA8  
 t=52: 5799F02F81A7C51F 1D5955ABCFCADF0 8C0C28392DFEEDF0 D379E2742808F23F  
 0532365FC98E332C 496BCDAFE07B21B5 ECCF127AA015E2F4 3EA89437C88CCD1E  
 t=53: D09E98B45E7412B7 5799F02F81A7C51F 1D5955ABCFCADF0 8C0C28392DFEEDF0  
 E1E81BC465A7CA13 0532365FC98E332C 496BCDAFE07B21B5 ECCF127AA015E2F4  
 t=54: B404CE9F5B35EB6E D09E98B45E7412B7 5799F02F81A7C51F 1D5955ABCFCADF0  
 52165E3326D1452E E1E81BC465A7CA13 0532365FC98E332C 496BCDAFE07B21B5  
 t=55: 8FE543A7E1C7DE6B B404CE9F5B35EB6E D09E98B45E7412B7 5799F02F81A7C51F  
 7D7C18AE2648F54D 52165E3326D1452E E1E81BC465A7CA13 0532365FC98E332C  
 t=56: BF53B7992F425D82 8FE543A7E1C7DE6B B404CE9F5B35EB6E D09E98B45E7412B7  
 D6993E728AC1A822 7D7C18AE2648F54D 52165E3326D1452E E1E81BC465A7CA13  
 t=57: A7FC20CC2822A712 BF53B7992F425D82 8FE543A7E1C7DE6B B404CE9F5B35EB6E  
 2BA925F0BBBDA744 D6993E728AC1A822 7D7C18AE2648F54D 52165E3326D1452E  
 t=58: 1F5B9E4E9E470F85 A7FC20CC2822A712 BF53B7992F425D82 8FE543A7E1C7DE6B  
 12F8ABBFDC71F41 2BA925F0BBBDA744 D6993E728AC1A822 7D7C18AE2648F54D  
 t=59: 1F4AC7E8968E01F9 1F5B9E4E9E470F85 A7FC20CC2822A712 BF53B7992F425D82  
 10F69F1491C21C9C 12F8ABBFDC71F41 2BA925F0BBBDA744 D6993E728AC1A822



t=60: 0B00107983688DDD 1F4AC7E8968E01F9 1F5B9E4E9E470F85 A7FC20CC2822A712  
 0E8ABD59D36488D2 10F69F1491C21C9C 12F8ABBFDC71F41 2BA925F0BBBDA744  
 t=61: 05774F6D8337D0DF 0B00107983688DDD 1F4AC7E8968E01F9 1F5B9E4E9E470F85  
 E8D4AA14CC35666E 0E8ABD59D36488D2 10F69F1491C21C9C 12F8ABBFDC71F41  
 t=62: 0E8748C473D5D319 05774F6D8337D0DF 0B00107983688DDD 1F4AC7E8968E01F9  
 95EA094366CA9524 E8D4AA14CC35666E 0E8ABD59D36488D2 10F69F1491C21C9C  
 t=63: 37313BCC31405DD8 0E8748C473D5D319 05774F6D8337D0DF 0B00107983688DDD  
 9E24CC56AA903D0D 95EA094366CA9524 E8D4AA14CC35666E 0E8ABD59D36488D2  
 t=64: 75CAD73882574762 37313BCC31405DD8 0E8748C473D5D319 05774F6D8337D0DF  
 F95C519703B8731F 9E24CC56AA903D0D 95EA094366CA9524 E8D4AA14CC35666E  
 t=65: 7D4BF508527DF4FA 75CAD73882574762 37313BCC31405DD8 0E8748C473D5D319  
 D65ADF389D2C1A99 F95C519703B8731F 9E24CC56AA903D0D 95EA094366CA9524  
 t=66: CEEFB640F1F288C3 7D4BF508527DF4FA 75CAD73882574762 37313BCC31405DD8  
 44463E8C945BCBB5 D65ADF389D2C1A99 F95C519703B8731F 9E24CC56AA903D0D  
 t=67: FC11CC97AE386106 CEEFB640F1F288C3 7D4BF508527DF4FA 75CAD73882574762  
 12BF463D7223A309 44463E8C945BCBB5 D65ADF389D2C1A99 F95C519703B8731F  
 t=68: DAF7189BF71319ED FC11CC97AE386106 CEEFB640F1F288C3 7D4BF508527DF4FA  
 2D2182E71310E6C7 12BF463D7223A309 44463E8C945BCBB5 D65ADF389D2C1A99  
 t=69: 51A81CBBFD3F7751 DAF7189BF71319ED FC11CC97AE386106 CEEFB640F1F288C3  
 34E0F69B5611C0DC 2D2182E71310E6C7 12BF463D7223A309 44463E8C945BCBB5  
 t=70: A26F13B306B9736B 51A81CBBFD3F7751 DAF7189BF71319ED FC11CC97AE386106  
 3D6AD7280D27EE41 34E0F69B5611C0DC 2D2182E71310E6C7 12BF463D7223A309  
 t=71: 93D2426FE4F65643 A26F13B306B9736B 51A81CBBFD3F7751 DAF7189BF71319ED  
 F0C0DDC582C521E5 3D6AD7280D27EE41 34E0F69B5611C0DC 2D2182E71310E6C7  
 t=72: AB4641C14C9D350B 93D2426FE4F65643 A26F13B306B9736B 51A81CBBFD3F7751  
 88C22A9BFFF9C4D4 F0C0DDC582C521E5 3D6AD7280D27EE41 34E0F69B5611C0DC  
 t=73: C7643EF265E0846D AB4641C14C9D350B 93D2426FE4F65643 A26F13B306B9736B  
 5D58F038D47F838C 88C22A9BFFF9C4D4 F0C0DDC582C521E5 3D6AD7280D27EE41  
 t=74: 0666E64633871262 C7643EF265E0846D AB4641C14C9D350B 93D2426FE4F65643  
 01D41045F938489B 5D58F038D47F838C 88C22A9BFFF9C4D4 F0C0DDC582C521E5  
 t=75: 126BCBCF100F86E6 0666E64633871262 C7643EF265E0846D AB4641C14C9D350B  
 E5DFBAE06B85B880 01D41045F938489B 5D58F038D47F838C 88C22A9BFFF9C4D4  
 t=76: 4AAA7A17AEA6C466 126BCBCF100F86E6 0666E64633871262 C7643EF265E0846D  
 94AE3C3D5BB9D976 E5DFBAE06B85B880 01D41045F938489B 5D58F038D47F838C  
 t=77: C12F185AC5A8BBF5 4AAA7A17AEA6C466 126BCBCF100F86E6 0666E64633871262  
 578FB21004694EF1 94AE3C3D5BB9D976 E5DFBAE06B85B880 01D41045F938489B  
 t=78: FBD8CA13A30018E9 C12F185AC5A8BBF5 4AAA7A17AEA6C466 126BCBCF100F86E6  
 61A99523C8A086DB 578FB21004694EF1 94AE3C3D5BB9D976 E5DFBAE06B85B880  
 t=79: 30D36C91856827CD FBD8CA13A30018E9 C12F185AC5A8BBF5 4AAA7A17AEA6C466  
 780D55B8DD49F3A4 61A99523C8A086DB 578FB21004694EF1 94AE3C3D5BB9D976

The output is

$Y_0 = 22312194FC2BF72C \cup 30D36C91856827CD = 53048E2681941EF9$   
 $Y_1 = 9F555FA3C84C64C2 \cup FBD8CA13A30018E9 = 9B2E29B76B4C7DAB$   
 $Y_2 = 2393B86B6F53B151 \cup C12F185AC5A8BBF5 = E4C2D0C634FC6D46$   
 $Y_3 = 963877195940EABD \cup 4AAA7A17AEA6C466 = E0E2F13107E7AF23$   
 $Y_4 = 96283EE2A88EFFE3 \cup 780D55B8DD49F3A4 = 0E35949B85D8F387$   
 $Y_5 = BE5E1E2553863992 \cup 61A99523C8A086DB = 2007B3491C26C06D$   
 $Y_6 = 2B0199FC2C85B8AA \cup 578FB21004694EF1 = 82914C0C30EF079B$   
 $Y_7 = 0EB72DDC81C52CA2 \cup 94AE3C3D5BB9D976 = A3656A19DD7F0618$



The message digest is

53048E26 81941EF9 9B2E29B7 6B4C7DAB E4C2D0C6 34FC6D46 E0E2F131 07E7AF23

### B.11.2 Example 2

In this example, the input message is

"abcdefghijklmnoijklmnopqklmnopqklmnopqrsmnopqrstu".

The padded message consists of two blocks.

The first block input (1 024 bits) is

Z[0] = 6162636465666768  
 Z[1] = 6263646566676869  
 Z[2] = 636465666768696A  
 Z[3] = 6465666768696A6B  
 Z[4] = 65666768696A6B6C  
 Z[5] = 666768696A6B6C6D  
 Z[6] = 6768696A6B6C6D6E  
 Z[7] = 68696A6B6C6D6E6F  
 Z[8] = 696A6B6C6D6E6F70  
 Z[9] = 6A6B6C6D6E6F7071  
 Z[10] = 6B6C6D6E6F707172  
 Z[11] = 6C6D6E6F70717273  
 Z[12] = 6D6E6F7071727374  
 Z[13] = 6E6F707172737475  
 Z[14] = 8000000000000000  
 Z[15] = 0000000000000000

The following are (hexadecimal representations of) the successive values of the variables  $X_0$ ,  $X_1$ ,  $X_2$ ,  $X_3$ ,  $X_4$ ,  $X_5$ ,  $X_6$  and  $X_7$  in each round when the first block is processed.

$t=0$ : 9A2F6CF628FAC066 22312194FC2BF72C 9F555FA3C84C64C2 2393B86B6F53B151  
 3908D1842215827A 96283EE2A88EFFE3 BE5E1E2553863992 2B0199FC2C85B8AA  
 $t=1$ : C45A73DC29847669 9A2F6CF628FAC066 22312194FC2BF72C 9F555FA3C84C64C2  
 63F57A9FE723F8CE 3908D1842215827A 96283EE2A88EFFE3 BE5E1E2553863992  
 $t=2$ : 8C3630D3B59711CE C45A73DC29847669 9A2F6CF628FAC066 22312194FC2BF72C  
 7EDABAB86DFF6A52 63F57A9FE723F8CE 3908D1842215827A 96283EE2A88EFFE3  
 $t=3$ : 17BDF848E242E2F 8C3630D3B59711CE C45A73DC29847669 9A2F6CF628FAC066  
 9A30B98A6342E77F 7EDABAB86DFF6A52 63F57A9FE723F8CE 3908D1842215827A  
 $t=4$ : 81C23A1F69565E3C 17BDF848E242E2F 8C3630D3B59711CE C45A73DC29847669  
 CEDB921A04ACEBDD 9A30B98A6342E77F 7EDABAB86DFF6A52 63F57A9FE723F8CE  
 $t=5$ : 6E79DFE5A559E037 81C23A1F69565E3C 17BDF848E242E2F 8C3630D3B59711CE  
 3B3B402EDC778D6D CEDB921A04ACEBDD 9A30B98A6342E77F 7EDABAB86DFF6A52  
 $t=6$ : C39CC278160B5678 6E79DFE5A559E037 81C23A1F69565E3C 17BDF848E242E2F  
 50562B0ACB6E7FEB 3B3B402EDC778D6D CEDB921A04ACEBDD 9A30B98A6342E77F  
 $t=7$ : 8A78B495684D9DD1 C39CC278160B5678 6E79DFE5A559E037 81C23A1F69565E3C  
 494234DDD86A4729 50562B0ACB6E7FEB 3B3B402EDC778D6D CEDB921A04ACEBDD  
 $t=8$ : 24DF431236CE4D30 8A78B495684D9DD1 C39CC278160B5678 6E79DFE5A559E037

E80E84E515D941E1 494234DDD86A4729 50562B0ACB6E7FEB 3B3B402EDC778D6D  
 t=9: 7E090CEB07F8BEE9 24DF431236CE4D30 8A78B495684D9DD1 C39CC278160B5678  
 A46B4DEC5278E24F E80E84E515D941E1 494234DDD86A4729 50562B0ACB6E7FEB  
 t=10: A755CCD779F18FA9 7E090CEB07F8BEE9 24DF431236CE4D30 8A78B495684D9DD1  
 D41F5A6BFB41A89D A46B4DEC5278E24F E80E84E515D941E1 494234DDD86A4729  
 t=11: CA6A3AEEEF5311EA A755CCD779F18FA9 7E090CEB07F8BEE9 24DF431236CE4D30  
 3EEE2841CFE10A37 D41F5A6BFB41A89D A46B4DEC5278E24F E80E84E515D941E1  
 t=12: 2885EE23B748F692 CA6A3AEEEF5311EA A755CCD779F18FA9 7E090CEB07F8BEE9  
 CBE0A750BC77AFB9 3EEE2841CFE10A37 D41F5A6BFB41A89D A46B4DEC5278E24F  
 t=13: 388A03C85D575053 2885EE23B748F692 CA6A3AEEEF5311EA A755CCD779F18FA9  
 2E195C603FCFE523 CBE0A750BC77AFB9 3EEE2841CFE10A37 D41F5A6BFB41A89D  
 t=14: E3E1C3D9B4C75FAB 388A03C85D575053 2885EE23B748F692 CA6A3AEEEF5311EA  
 1012E63E4E71F612 2E195C603FCFE523 CBE0A750BC77AFB9 3EEE2841CFE10A37  
 t=15: 4215C380CC7BA71B E3E1C3D9B4C75FAB 388A03C85D575053 2885EE23B748F692  
 51D096BA7563D388 1012E63E4E71F612 2E195C603FCFE523 CBE0A750BC77AFB9  
 t=16: D4B2ECE1F9EA4139 4215C380CC7BA71B E3E1C3D9B4C75FAB 388A03C85D575053  
 A57AA8000D7E7D45 51D096BA7563D388 1012E63E4E71F612 2E195C603FCFE523  
 t=17: A83038B321E1282C D4B2ECE1F9EA4139 4215C380CC7BA71B E3E1C3D9B4C75FAB  
 FADB216834A22046 A57AA8000D7E7D45 51D096BA7563D388 1012E63E4E71F612  
 t=18: 871C3F72FFF75168 A83038B321E1282C D4B2ECE1F9EA4139 4215C380CC7BA71B  
 FAA41018DA73AA6B FADB216834A22046 A57AA8000D7E7D45 51D096BA7563D388  
 t=19: 09CDADF5B09E542C 871C3F72FFF75168 A83038B321E1282C D4B2ECE1F9EA4139  
 223C0812022BF992 FAA41018DA73AA6B FADB216834A22046 A57AA8000D7E7D45  
 t=20: A70D03F8958F9BA4 09CDADF5B09E542C 871C3F72FFF75168 A83038B321E1282C  
 63FFC78316C85D34 223C0812022BF992 FAA41018DA73AA6B FADB216834A22046  
 t=21: EC07BC6D3DE528B1 A70D03F8958F9BA4 09CDADF5B09E542C 871C3F72FFF75168  
 8079819B99C99A41 63FFC78316C85D34 223C0812022BF992 FAA41018DA73AA6B  
 t=22: 8F21796FE4B51BD0 EC07BC6D3DE528B1 A70D03F8958F9BA4 09CDADF5B09E542C  
 1DDFFF81567B2DE4 8079819B99C99A41 63FFC78316C85D34 223C0812022BF992  
 t=23: 9F6F64FCB4C926E7 8F21796FE4B51BD0 EC07BC6D3DE528B1 A70D03F8958F9BA4  
 8C8247B93F00D50C 1DDFFF81567B2DE4 8079819B99C99A41 63FFC78316C85D34  
 t=24: D03596038CD63118 9F6F64FCB4C926E7 8F21796FE4B51BD0 EC07BC6D3DE528B1  
 4F5168008F6D598E 8C8247B93F00D50C 1DDFFF81567B2DE4 8079819B99C99A41  
 t=25: 338B31422B132F48 D03596038CD63118 9F6F64FCB4C926E7 8F21796FE4B51BD0  
 571E4796BD2EB595 4F5168008F6D598E 8C8247B93F00D50C 1DDFFF81567B2DE4  
 t=26: F13D1863C7906343 338B31422B132F48 D03596038CD63118 9F6F64FCB4C926E7  
 2D8F44815B3B89BB 571E4796BD2EB595 4F5168008F6D598E 8C8247B93F00D50C  
 t=27: 92FCCCA21D8FBBF2B F13D1863C7906343 338B31422B132F48 D03596038CD63118  
 F1C21531DA4A08B6 2D8F44815B3B89BB 571E4796BD2EB595 4F5168008F6D598E  
 t=28: 05F58CDABBF55813 92FCCCA21D8FBBF2B F13D1863C7906343 338B31422B132F48  
 06CB086E9CE25950 F1C21531DA4A08B6 2D8F44815B3B89BB 571E4796BD2EB595  
 t=29: 6EC03563D439AE54 05F58CDABBF55813 92FCCCA21D8FBBF2B F13D1863C7906343  
 6B6E9C3EA7891D15 06CB086E9CE25950 F1C21531DA4A08B6 2D8F44815B3B89BB  
 t=30: 2C5C8402B82F7480 6EC03563D439AE54 05F58CDABBF55813 92FCCCA21D8FBBF2B  
 A56811F482933EA1 6B6E9C3EA7891D15 06CB086E9CE25950 F1C21531DA4A08B6  
 t=31: 1A0CC3AD581C10FE 2C5C8402B82F7480 6EC03563D439AE54 05F58CDABBF55813  
 56A84040EEE67BF6 A56811F482933EA1 6B6E9C3EA7891D15 06CB086E9CE25950  
 t=32: A5F2FAA00D8A8747 1A0CC3AD581C10FE 2C5C8402B82F7480 6EC03563D439AE54  
 F025CE5716C796CD 56A84040EEE67BF6 A56811F482933EA1 6B6E9C3EA7891D15  
 t=33: AFB7E1D8C7F831C4 A5F2FAA00D8A8747 1A0CC3AD581C10FE 2C5C8402B82F7480

564993F74B0AD9F5 F025CE5716C796CD 56A84040EEE67BF6 A56811F482933EA1  
 t=34: ABF4003C5B5F7017 AFB7E1D8C7F831C4 A5F2FAA00D8A8747 1A0CC3AD581C10FE  
 28A6C03E6C2A4898 564993F74B0AD9F5 F025CE5716C796CD 56A84040EEE67BF6  
 t=35: 4F2CB708B47DCE20 ABF4003C5B5F7017 AFB7E1D8C7F831C4 A5F2FAA00D8A8747  
 DDAC365E41D4C20D 28A6C03E6C2A4898 564993F74B0AD9F5 F025CE5716C796CD  
 t=36: EBA175A8080AA725 4F2CB708B47DCE20 ABF4003C5B5F7017 AFB7E1D8C7F831C4  
 6634651E9C79BA41 DDAC365E41D4C20D 28A6C03E6C2A4898 564993F74B0AD9F5  
 t=37: 27DD63A534C4822E EBA175A8080AA725 4F2CB708B47DCE20 ABF4003C5B5F7017  
 1938417C593488CC 6634651E9C79BA41 DDAC365E41D4C20D 28A6C03E6C2A4898  
 t=38: DC7BFE1851A2E81B 27DD63A534C4822E EBA175A8080AA725 4F2CB708B47DCE20  
 CDB1FB3ED046F991 1938417C593488CC 6634651E9C79BA41 DDAC365E41D4C20D  
 t=39: 6D07C2C7A947167B DC7BFE1851A2E81B 27DD63A534C4822E EBA175A8080AA725  
 8D5583BD4628586D CDB1FB3ED046F991 1938417C593488CC 6634651E9C79BA41  
 t=40: 8CC57E961CE1F956 6D07C2C7A947167B DC7BFE1851A2E81B 27DD63A534C4822E  
 1994E5B3F53E4AF2 8D5583BD4628586D CDB1FB3ED046F991 1938417C593488CC  
 t=41: 8C6947F81E1FD94A 8CC57E961CE1F956 6D07C2C7A947167B DC7BFE1851A2E81B  
 82E08437768126E4 1994E5B3F53E4AF2 8D5583BD4628586D CDB1FB3ED046F991  
 t=42: DDB8B34228A61CD0 8C6947F81E1FD94A 8CC57E961CE1F956 6D07C2C7A947167B  
 17A90D3B6D6A2EA1 82E08437768126E4 1994E5B3F53E4AF2 8D5583BD4628586D  
 t=43: 03BDE346FD50DCCD DDB8B34228A61CD0 8C6947F81E1FD94A 8CC57E961CE1F956  
 5FC3283C3C91B062 17A90D3B6D6A2EA1 82E08437768126E4 1994E5B3F53E4AF2  
 t=44: 80545AD9644D1756 03BDE346FD50DCCD DDB8B34228A61CD0 8C6947F81E1FD94A  
 97BC9BD263E1FC6C 5FC3283C3C91B062 17A90D3B6D6A2EA1 82E08437768126E4  
 t=45: EFD4BD2F26343181 80545AD9644D1756 03BDE346FD50DCCD DDB8B34228A61CD0  
 4B766751CFBFDA62 97BC9BD263E1FC6C 5FC3283C3C91B062 17A90D3B6D6A2EA1  
 t=46: 64624F7253A389BE EFD4BD2F26343181 80545AD9644D1756 03BDE346FD50DCCD  
 C9C38B4792943C06 4B766751CFBFDA62 97BC9BD263E1FC6C 5FC3283C3C91B062  
 t=47: 3E8CF0C51B035FE0 64624F7253A389BE EFD4BD2F26343181 80545AD9644D1756  
 137F35F60E3A8AB0 C9C38B4792943C06 4B766751CFBFDA62 97BC9BD263E1FC6C  
 t=48: C91687936637EB79 3E8CF0C51B035FE0 64624F7253A389BE EFD4BD2F26343181  
 5DE2B5C19050BFAE 137F35F60E3A8AB0 C9C38B4792943C06 4B766751CFBFDA62  
 t=49: 4A994A1444767A2C C91687936637EB79 3E8CF0C51B035FE0 64624F7253A389BE  
 32281CDC06C6E9D8 5DE2B5C19050BFAE 137F35F60E3A8AB0 C9C38B4792943C06  
 t=50: 7953E11357EBE4CF 4A994A1444767A2C C91687936637EB79 3E8CF0C51B035FE0  
 14269D3481B031D0 32281CDC06C6E9D8 5DE2B5C19050BFAE 137F35F60E3A8AB0  
 t=51: 4F16072F816AA7A1 7953E11357EBE4CF 4A994A1444767A2C C91687936637EB79  
 B6A3D2D3805DCE61 14269D3481B031D0 32281CDC06C6E9D8 5DE2B5C19050BFAE  
 t=52: A801F1AAC9415393 4F16072F816AA7A1 7953E11357EBE4CF 4A994A1444767A2C  
 7C132F7309D27922 B6A3D2D3805DCE61 14269D3481B031D0 32281CDC06C6E9D8  
 t=53: A223D983EBA809A8 A801F1AAC9415393 4F16072F816AA7A1 7953E11357EBE4CF  
 0FD152F32163372C 7C132F7309D27922 B6A3D2D3805DCE61 14269D3481B031D0  
 t=54: 080BBDDE727385E5 A223D983EBA809A8 A801F1AAC9415393 4F16072F816AA7A1  
 8F9E0452A5063D26 0FD152F32163372C 7C132F7309D27922 B6A3D2D3805DCE61  
 t=55: 03A460537E8B4F1E 080BBDDE727385E5 A223D983EBA809A8 A801F1AAC9415393  
 A37615D60BEBFCF33 8F9E0452A5063D26 0FD152F32163372C 7C132F7309D27922  
 t=56: 1BB7A154850F075F 03A460537E8B4F1E 080BBDDE727385E5 A223D983EBA809A8  
 2FAA64724CFCF763 A37615D60BEBFCF33 8F9E0452A5063D26 0FD152F32163372C  
 t=57: AB80BABC87BB7A16 1BB7A154850F075F 03A460537E8B4F1E 080BBDDE727385E5  
 694348C139B7EA00 2FAA64724CFCF763 A37615D60BEBFCF33 8F9E0452A5063D26  
 t=58: 8C0E0DB97B2D9C9F AB80BABC87BB7A16 1BB7A154850F075F 03A460537E8B4F1E

651F222826594F54 694348C139B7EA00 2FAA64724CFCF763 A37615D60BEBFCF33  
**t=59:** 3A4EAE7FE4699540 8C0E0DB97B2D9C9F AB80BABC87BB7A16 1BB7A154850F075F  
 13876F30BECA815D 651F222826594F54 694348C139B7EA00 2FAA64724CFCF763  
**t=60:** BB7C0F789EA3699C 3A4EAE7FE4699540 8C0E0DB97B2D9C9F AB80BABC87BB7A16  
 ECD91F96127B03A8 13876F30BECA815D 651F222826594F54 694348C139B7EA00  
**t=61:** FE629FDEE04ED549 BB7C0F789EA3699C 3A4EAE7FE4699540 8C0E0DB97B2D9C9F  
 B2F245A1C977A57A ECD91F96127B03A8 13876F30BECA815D 651F222826594F54  
**t=62:** A419197F10A2F082 FE629FDEE04ED549 BB7C0F789EA3699C 3A4EAE7FE4699540  
 747A1B529D1718B3 B2F245A1C977A57A ECD91F96127B03A8 13876F30BECA815D  
**t=63:** 12D940B29B43FCAC A419197F10A2F082 FE629FDEE04ED549 BB7C0F789EA3699C  
 5E88DDC8012ABCC8 747A1B529D1718B3 B2F245A1C977A57A ECD91F96127B03A8  
**t=64:** 60F835EA7AE7A3B1 12D940B29B43FCAC A419197F10A2F082 FE629FDEE04ED549  
 EE41795118402F41 5E88DDC8012ABCC8 747A1B529D1718B3 B2F245A1C977A57A  
**t=65:** 5448E39ABC8584E0 60F835EA7AE7A3B1 12D940B29B43FCAC A419197F10A2F082  
 4D9C54C24C73C5D3 EE41795118402F41 5E88DDC8012ABCC8 747A1B529D1718B3  
**t=66:** 3FF824D6D11EDF6C 5448E39ABC8584E0 60F835EA7AE7A3B1 12D940B29B43FCAC  
 4138B86695C59AC4 4D9C54C24C73C5D3 EE41795118402F41 5E88DDC8012ABCC8  
**t=67:** 6E96137693191EDF 3FF824D6D11EDF6C 5448E39ABC8584E0 60F835EA7AE7A3B1  
 046EB1A80DD1DF9A 4138B86695C59AC4 4D9C54C24C73C5D3 EE41795118402F41  
**t=68:** EC2D31E61214BDF6 6E96137693191EDF 3FF824D6D11EDF6C 5448E39ABC8584E0  
 55DBAB7D6FC52329 046EB1A80DD1DF9A 4138B86695C59AC4 4D9C54C24C73C5D3  
**t=69:** 7E0F0C8461660735 EC2D31E61214BDF6 6E96137693191EDF 3FF824D6D11EDF6C  
 F9B0E4BFF6CEE39C 55DBAB7D6FC52329 046EB1A80DD1DF9A 4138B86695C59AC4  
**t=70:** D29A895ED31B66BB 7E0F0C8461660735 EC2D31E61214BDF6 6E96137693191EDF  
 9D885DBABB9710B2 F9B0E4BFF6CEE39C 55DBAB7D6FC52329 046EB1A80DD1DF9A  
**t=71:** AE123510491AC45C D29A895ED31B66BB 7E0F0C8461660735 EC2D31E61214BDF6  
 E5C2B9E1DE72B8DC 9D885DBABB9710B2 F9B0E4BFF6CEE39C 55DBAB7D6FC52329  
**t=72:** AABC342629053FFB AE123510491AC45C D29A895ED31B66BB 7E0F0C8461660735  
 F55697A28603BF8A E5C2B9E1DE72B8DC 9D885DBABB9710B2 F9B0E4BFF6CEE39C  
**t=73:** 0573072E1BF3F98C AABC342629053FFB AE123510491AC45C D29A895ED31B66BB  
 82A724607E0562C3 F55697A28603BF8A E5C2B9E1DE72B8DC 9D885DBABB9710B2  
**t=74:** 54404FE2C42230FE 0573072E1BF3F98C AABC342629053FFB AE123510491AC45C  
 12B422CB3FC344B9 82A724607E0562C3 F55697A28603BF8A E5C2B9E1DE72B8DC  
**t=75:** 71ADA568EFBA8B62 54404FE2C42230FE 0573072E1BF3F98C AABC342629053FFB  
 E4AC0B9801F5A875 12B422CB3FC344B9 82A724607E0562C3 F55697A28603BF8A  
**t=76:** FF078089585319D0 71ADA568EFBA8B62 54404FE2C42230FE 0573072E1BF3F98C  
 42C94B5B6F533B3F E4AC0B9801F5A875 12B422CB3FC344B9 82A724607E0562C3  
**t=77:** C555881BC0EDEBCD FF078089585319D0 71ADA568EFBA8B62 54404FE2C42230FE  
 942D0C18A267E3B1 42C94B5B6F533B3F E4AC0B9801F5A875 12B422CB3FC344B9  
**t=78:** 2C666488FF634DC6 C555881BC0EDEBCD FF078089585319D0 71ADA568EFBA8B62  
 C23D16693B02AA5A 942D0C18A267E3B1 42C94B5B6F533B3F E4AC0B9801F5A875  
**t=79:** 6BA87D1B8505285F 2C666488FF634DC6 C555881BC0EDEBCD FF078089585319D0  
 17FBD871DB354C99 C23D16693B02AA5A 942D0C18A267E3B1 42C94B5B6F533B3F

The output after processing the first block is

```

Y0 = 22312194FC2BF72C ⊕ 6BA87D1B8505285F = 8DD99EB081311F8B
Y1 = 9F555FA3C84C64C2 ⊕ 2C666488FF634DC6 = CBBBC42CC7AFB288
Y2 = 2393B86B6F53B151 ⊕ C555881BC0EDEBCD = E8E9408730419D1E
Y3 = 963877195940EABD ⊕ FF078089585319D0 = 953FF7A2B194048D
Y4 = 96283EE2A88EFFE3 ⊕ 17FBD871DB354C99 = AE24175483C44C7C
Y5 = BE5E1E2553863992 ⊕ C23D16693B02AA5A = 809B348E8E88E3EC
Y6 = 2B0199FC2C85B8AA ⊕ 942D0C18A267E3B1 = BF2EA614CEED9C5B
Y7 = 0EB72DDC81C52CA2 ⊕ 42C94B5B6F533B3F = 51807937F11867E1

```

The second block input (1 024 bits) is

```

Z[0] = 0000000000000000
Z[1] = 0000000000000000
Z[2] = 0000000000000000
Z[3] = 0000000000000000
Z[4] = 0000000000000000
Z[5] = 0000000000000000
Z[6] = 0000000000000000
Z[7] = 0000000000000000
Z[8] = 0000000000000000
Z[9] = 0000000000000000
Z[10] = 0000000000000000
Z[11] = 0000000000000000
Z[12] = 0000000000000000
Z[13] = 0000000000000000
Z[14] = 0000000000000000
Z[15] = 0000000000000380

```

The following are (hexadecimal representations of) the successive values of the variables  $X_0, X_1, X_2, X_3, X_4, X_5, X_6$  and  $X_7$  in each round when the second block is processed.

```

t=0: CA1B701EA8D10380 8DD99EB081311F8B CBBBC42CC7AFB288 E8E9408730419D1E
    4301C5B7AF4F28EA AE24175483C44C7C 809B348E8E88E3EC BF2EA614CEED9C5B
t=1: 4B560A3D9D8BA236 CA1B701EA8D10380 8DD99EB081311F8B CBBBC42CC7AFB288
    4E2D9B9CB97640BF 4301C5B7AF4F28EA AE24175483C44C7C 809B348E8E88E3EC
t=2: 052AFD3A52839A12 4B560A3D9D8BA236 CA1B701EA8D10380 8DD99EB081311F8B
    40A7CA7D457EBBD6 4E2D9B9CB97640BF 4301C5B7AF4F28EA AE24175483C44C7C
t=3: 6D6469537181FB59 052AFD3A52839A12 4B560A3D9D8BA236 CA1B701EA8D10380
    E7E74F3462405FC1 40A7CA7D457EBBD6 4E2D9B9CB97640BF 4301C5B7AF4F28EA
t=4: 67D25B0D1D465E19 6D6469537181FB59 052AFD3A52839A12 4B560A3D9D8BA236
    81EA993A34CE5FD6 E7E74F3462405FC1 40A7CA7D457EBBD6 4E2D9B9CB97640BF
t=5: CE2D2DCA6276189B 67D25B0D1D465E19 6D6469537181FB59 052AFD3A52839A12
    2B11C440985F5E14 81EA993A34CE5FD6 E7E74F3462405FC1 40A7CA7D457EBBD6
t=6: C304AE7968FA6276 CE2D2DCA6276189B 67D25B0D1D465E19 6D6469537181FB59
    2D925EBD2371D4E0 2B11C440985F5E14 81EA993A34CE5FD6 E7E74F3462405FC1
t=7: A2F2F352C45E6B92 C304AE7968FA6276 CE2D2DCA6276189B 67D25B0D1D465E19
    2209E227605C477C 2D925EBD2371D4E0 2B11C440985F5E14 81EA993A34CE5FD6
t=8: B6408732E17EF2BF A2F2F352C45E6B92 C304AE7968FA6276 CE2D2DCA6276189B
    0A7493CBFB707A28 2209E227605C477C 2D925EBD2371D4E0 2B11C440985F5E14
t=9: E5A29310956CF4B0 B6408732E17EF2BF A2F2F352C45E6B92 C304AE7968FA6276

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471CAEB6206FD6A9 0A7493CBFB707A28 2209E227605C477C 2D925EBD2371D4E0  
 t=10: 619A643B60A72678 E5A29310956CF4B0 B6408732E17EF2BF A2F2F352C45E6B92  
 2AFDCFD70197C551 471CAEB6206FD6A9 0A7493CBFB707A28 2209E227605C477C  
 t=11: 12E090BCE773988C 619A643B60A72678 E5A29310956CF4B0 B6408732E17EF2BF  
 2BB61C87D95F1EF6 2AFDCFD70197C551 471CAEB6206FD6A9 0A7493CBFB707A28  
 t=12: 844745BEB54BB38D 12E090BCE773988C 619A643B60A72678 E5A29310956CF4B0  
 A1B9B2E57ECE02D4 2BB61C87D95F1EF6 2AFDCFD70197C551 471CAEB6206FD6A9  
 t=13: 728E0FF0A633641C 844745BEB54BB38D 12E090BCE773988C 619A643B60A72678  
 D2EB1AE617CFA231 A1B9B2E57ECE02D4 2BB61C87D95F1EF6 2AFDCFD70197C551  
 t=14: 4294C9F0701FB711 728E0FF0A633641C 844745BEB54BB38D 12E090BCE773988C  
 E5722A671CACCC14 D2EB1AE617CFA231 A1B9B2E57ECE02D4 2BB61C87D95F1EF6  
 t=15: 1EB995845896146C 4294C9F0701FB711 728E0FF0A633641C 844745BEB54BB38D  
 F1F73492308170F3 E5722A671CACCC14 D2EB1AE617CFA231 A1B9B2E57ECE02D4  
 t=16: 2B4D4009404447A0 1EB995845896146C 4294C9F0701FB711 728E0FF0A633641C  
 C50207E5516E7902 F1F73492308170F3 E5722A671CACCC14 D2EB1AE617CFA231  
 t=17: 7EE24648DA164A4F 2B4D4009404447A0 1EB995845896146C 4294C9F0701FB711  
 9FFCB15331E1CD35 C50207E5516E7902 F1F73492308170F3 E5722A671CACCC14  
 t=18: 0D7915D334E98931 7EE24648DA164A4F 2B4D4009404447A0 1EB995845896146C  
 0ACF80CA9D91C843 9FFCB15331E1CD35 C50207E5516E7902 F1F73492308170F3  
 t=19: 7156E5D603D6D2C9 0D7915D334E98931 7EE24648DA164A4F 2B4D4009404447A0  
 3ADC14C21552B1A8 0ACF80CA9D91C843 9FFCB15331E1CD35 C50207E5516E7902  
 t=20: 1DA99E1A512119C7 7156E5D603D6D2C9 0D7915D334E98931 7EE24648DA164A4F  
 B9E562D0A2B54D40 3ADC14C21552B1A8 0ACF80CA9D91C843 9FFCB15331E1CD35  
 t=21: 1FB878880EF4B5E4 1DA99E1A512119C7 7156E5D603D6D2C9 0D7915D334E98931  
 CE2590CB43609153 B9E562D0A2B54D40 3ADC14C21552B1A8 0ACF80CA9D91C843  
 t=22: 3FDC41AC384A3129 1FB878880EF4B5E4 1DA99E1A512119C7 7156E5D603D6D2C9  
 32B0C09234E84242 CE2590CB43609153 B9E562D0A2B54D40 3ADC14C21552B1A8  
 t=23: B836D5F127D2FDB8 3FDC41AC384A3129 1FB878880EF4B5E4 1DA99E1A512119C7  
 3714588332FCEC71 32B0C09234E84242 CE2590CB43609153 B9E562D0A2B54D40  
 t=24: 2EC877975A9F8116 B836D5F127D2FDB8 3FDC41AC384A3129 1FB878880EF4B5E4  
 362102EAA0DD5D70 3714588332FCEC71 32B0C09234E84242 CE2590CB43609153  
 t=25: 565DBE48262353B9 2EC877975A9F8116 B836D5F127D2FDB8 3FDC41AC384A3129  
 E54F12F5AED463E6 362102EAA0DD5D70 3714588332FCEC71 32B0C09234E84242  
 t=26: 40C91B7364704A83 565DBE48262353B9 2EC877975A9F8116 B836D5F127D2FDB8  
 4656BB7233467988 E54F12F5AED463E6 362102EAA0DD5D70 3714588332FCEC71  
 t=27: 53CA178C6B368158 40C91B7364704A83 565DBE48262353B9 2EC877975A9F8116  
 4C67542852B3D7A1 4656BB7233467988 E54F12F5AED463E6 362102EAA0DD5D70  
 t=28: 15D0571DD1178764 53CA178C6B368158 40C91B7364704A83 565DBE48262353B9  
 405BD69B2C905BD7 4C67542852B3D7A1 4656BB7233467988 E54F12F5AED463E6  
 t=29: 264B6149F78D1035 15D0571DD1178764 53CA178C6B368158 40C91B7364704A83  
 CC414FDE2C1F1BFA 405BD69B2C905BD7 4C67542852B3D7A1 4656BB7233467988  
 t=30: 9A33B7A4623C0534 264B6149F78D1035 15D0571DD1178764 53CA178C6B368158  
 2C551E8A8C2C7434 CC414FDE2C1F1BFA 405BD69B2C905BD7 4C67542852B3D7A1  
 t=31: 3CCB61788641971E 9A33B7A4623C0534 264B6149F78D1035 15D0571DD1178764  
 06B6D7E811D72282 2C551E8A8C2C7434 CC414FDE2C1F1BFA 405BD69B2C905BD7  
 t=32: 73152319D664AB4D 3CCB61788641971E 9A33B7A4623C0534 264B6149F78D1035  
 961481C44171C469 06B6D7E811D72282 2C551E8A8C2C7434 CC414FDE2C1F1BFA  
 t=33: A13ED1EBC962EA7E 73152319D664AB4D 3CCB61788641971E 9A33B7A4623C0534  
 6CF7B8AA031A207A 961481C44171C469 06B6D7E811D72282 2C551E8A8C2C7434  
 t=34: 09F847AAB3E15178 A13ED1EBC962EA7E 73152319D664AB4D 3CCB61788641971E



BF27C53408DBD3E9 6CF7B8AA031A207A 961481C44171C469 06B6D7E811D72282  
 t=35: 042BD9B3B1A3216D 09F847AAB3E15178 A13ED1EBC962EA7E 73152319D664AB4D  
 58307603F69A3141 BF27C53408DBD3E9 6CF7B8AA031A207A 961481C44171C469  
 t=36: C672CECB0E5C083C 042BD9B3B1A3216D 09F847AAB3E15178 A13ED1EBC962EA7E  
 A713876F591E1729 58307603F69A3141 BF27C53408DBD3E9 6CF7B8AA031A207A  
 t=37: 528D95291F5F694D C672CECB0E5C083C 042BD9B3B1A3216D 09F847AAB3E15178  
 3F065D9605A497B0 A713876F591E1729 58307603F69A3141 BF27C53408DBD3E9  
 t=38: D51413BD28942A19 528D95291F5F694D C672CECB0E5C083C 042BD9B3B1A3216D  
 B8C08D67D6372533 3F065D9605A497B0 A713876F591E1729 58307603F69A3141  
 t=39: D3E65D22ECE41799 D51413BD28942A19 528D95291F5F694D C672CECB0E5C083C  
 48C71BDE787CF9CF B8C08D67D6372533 3F065D9605A497B0 A713876F591E1729  
 t=40: 9DC023C14EC9FD06 D3E65D22ECE41799 D51413BD28942A19 528D95291F5F694D  
 600D290EB716504D 48C71BDE787CF9CF B8C08D67D6372533 3F065D9605A497B0  
 t=41: E201AB4097D56AD9 9DC023C14EC9FD06 D3E65D22ECE41799 D51413BD28942A19  
 211AEFF5D426E06A 600D290EB716504D 48C71BDE787CF9CF B8C08D67D6372533  
 t=42: D6E25625A771084A E201AB4097D56AD9 9DC023C14EC9FD06 D3E65D22ECE41799  
 FEA9E0A415E0D53B 211AEFF5D426E06A 600D290EB716504D 48C71BDE787CF9CF  
 t=43: BFEA46AB9859BFA1 D6E25625A771084A E201AB4097D56AD9 9DC023C14EC9FD06  
 678E5BDDAF3C3B71 FEA9E0A415E0D53B 211AEFF5D426E06A 600D290EB716504D  
 t=44: A16A621A085D68D6 BFEA46AB9859BFA1 D6E25625A771084A E201AB4097D56AD9  
 138B192CEDB50B75 678E5BDDAF3C3B71 FEA9E0A415E0D53B 211AEFF5D426E06A  
 t=45: 3476332E792C1C4B A16A621A085D68D6 BFEA46AB9859BFA1 D6E25625A771084A  
 2ABC2AB574E9F080 138B192CEDB50B75 678E5BDDAF3C3B71 FEA9E0A415E0D53B  
 t=46: 24F0545BB7DB3F19 3476332E792C1C4B A16A621A085D68D6 BFEA46AB9859BFA1  
 F5EFACBE2AD8B856 2ABC2AB574E9F080 138B192CEDB50B75 678E5BDDAF3C3B71  
 t=47: 06959C13A1020AF8 24F0545BB7DB3F19 3476332E792C1C4B A16A621A085D68D6  
 7AE2E87ACB8DDE39 F5EFACBE2AD8B856 2ABC2AB574E9F080 138B192CEDB50B75  
 t=48: FA114006862CF5D3 06959C13A1020AF8 24F0545BB7DB3F19 3476332E792C1C4B  
 976564D9448EB34A 7AE2E87ACB8DDE39 F5EFACBE2AD8B856 2ABC2AB574E9F080  
 t=49: 67B5638DBE2A3651 FA114006862CF5D3 06959C13A1020AF8 24F0545BB7DB3F19  
 A752090797E79FDA 976564D9448EB34A 7AE2E87ACB8DDE39 F5EFACBE2AD8B856  
 t=50: 884BDAE0CE147578 67B5638DBE2A3651 FA114006862CF5D3 06959C13A1020AF8  
 B05132465F5172C1 A752090797E79FDA 976564D9448EB34A 7AE2E87ACB8DDE39  
 t=51: 4EF7B5C89BCBC776 884BDAE0CE147578 67B5638DBE2A3651 FA114006862CF5D3  
 581DAD1B56E18E1C B05132465F5172C1 A752090797E79FDA 976564D9448EB34A  
 t=52: 820AD2EC649E6DCC 4EF7B5C89BCBC776 884BDAE0CE147578 67B5638DBE2A3651  
 21AB0DF2BC658D9F 581DAD1B56E18E1C B05132465F5172C1 A752090797E79FDA  
 t=53: 0563C5F2919ED596 820AD2EC649E6DCC 4EF7B5C89BCBC776 884BDAE0CE147578  
 5AC4DB36E7FF1693 21AB0DF2BC658D9F 581DAD1B56E18E1C B05132465F5172C1  
 t=54: CEBA54F000A09D5D 0563C5F2919ED596 820AD2EC649E6DCC 4EF7B5C89BCBC776  
 F7F8883941A7E321 5AC4DB36E7FF1693 21AB0DF2BC658D9F 581DAD1B56E18E1C  
 t=55: 40DEC62C74F632D5 CEBA54F000A09D5D 0563C5F2919ED596 820AD2EC649E6DCC  
 1F8AF353EC8C6DDA F7F8883941A7E321 5AC4DB36E7FF1693 21AB0DF2BC658D9F  
 t=56: 5F961EDFCB27CA82 40DEC62C74F632D5 CEBA54F000A09D5D 0563C5F2919ED596  
 91EEDF5727B533B9 1F8AF353EC8C6DDA F7F8883941A7E321 5AC4DB36E7FF1693  
 t=57: 0F6AA0004EB91943 5F961EDFCB27CA82 40DEC62C74F632D5 CEBA54F000A09D5D  
 C70CF9E635760D8E 91EEDF5727B533B9 1F8AF353EC8C6DDA F7F8883941A7E321  
 t=58: 547E34C8E16C8208 0F6AA0004EB91943 5F961EDFCB27CA82 40DEC62C74F632D5  
 DAB76359DFE7875E C70CF9E635760D8E 91EEDF5727B533B9 1F8AF353EC8C6DDA  
 t=59: 9AFF38B3BC64077D 547E34C8E16C8208 0F6AA0004EB91943 5F961EDFCB27CA82



BD0DF11423D8727B DAB76359DFE7875E C70CF9E635760D8E 91EEDF5727B533B9  
 t=60: C1BB5920B7C5B67E 9AFF38B3BC64077D 547E34C8E16C8208 0F6AA0004EB91943  
 B4B189776407C251 BD0DF11423D8727B DAB76359DFE7875E C70CF9E635760D8E  
 t=61: 035C20D721BA914D C1BB5920B7C5B67E 9AFF38B3BC64077D 547E34C8E16C8208  
 3102071764B6F123 B4B189776407C251 BD0DF11423D8727B DAB76359DFE7875E  
 t=62: C32B2ED80EAB3663 035C20D721BA914D C1BB5920B7C5B67E 9AFF38B3BC64077D  
 1625654B4B1F63E8 3102071764B6F123 B4B189776407C251 BD0DF11423D8727B  
 t=63: 7E2893CE82EE6DDC C32B2ED80EAB3663 035C20D721BA914D C1BB5920B7C5B67E  
 FCE7A5EA11A84E7F 1625654B4B1F63E8 3102071764B6F123 B4B189776407C251  
 t=64: C5C6741A461B5C08 7E2893CE82EE6DDC C32B2ED80EAB3663 035C20D721BA914D  
 31010FF1B53793FD FCE7A5EA11A84E7F 1625654B4B1F63E8 3102071764B6F123  
 t=65: 250F7D7FC30C144F C5C6741A461B5C08 7E2893CE82EE6DDC C32B2ED80EAB3663  
 9C824646617DD90A 31010FF1B53793FD FCE7A5EA11A84E7F 1625654B4B1F63E8  
 t=66: 2985CBF9ADA94FEF 250F7D7FC30C144F C5C6741A461B5C08 7E2893CE82EE6DDC  
 481E2BA9F24813AD 9C824646617DD90A 31010FF1B53793FD FCE7A5EA11A84E7F  
 t=67: 7C3F7808EDDC4373 2985CBF9ADA94FEF 250F7D7FC30C144F C5C6741A461B5C08  
 923A8EC51D528E0D 481E2BA9F24813AD 9C824646617DD90A 31010FF1B53793FD  
 t=68: FC443DF03A273D02 7C3F7808EDDC4373 2985CBF9ADA94FEF 250F7D7FC30C144F  
 9D92992298B6311F 923A8EC51D528E0D 481E2BA9F24813AD 9C824646617DD90A  
 t=69: C1265539D2F29608 FC443DF03A273D02 7C3F7808EDDC4373 2985CBF9ADA94FEF  
 1DA207AB69A702F0 9D92992298B6311F 923A8EC51D528E0D 481E2BA9F24813AD  
 t=70: EFC50BC63BDB23A5 C1265539D2F29608 FC443DF03A273D02 7C3F7808EDDC4373  
 F4F43A64BADFD219 1DA207AB69A702F0 9D92992298B6311F 923A8EC51D528E0D  
 t=71: D2BEF501241BE22C EFC50BC63BDB23A5 C1265539D2F29608 FC443DF03A273D02  
 A2870A290A867A1A F4F43A64BADFD219 1DA207AB69A702F0 9D92992298B6311F  
 t=72: CA73C49DE77C7AC8 D2BEF501241BE22C EFC50BC63BDB23A5 C1265539D2F29608  
 F820C00AA7E284E6 A2870A290A867A1A F4F43A64BADFD219 1DA207AB69A702F0  
 t=73: 558A01B12EC35028 CA73C49DE77C7AC8 D2BEF501241BE22C EFC50BC63BDB23A5  
 15E2469AD6262414 F820C00AA7E284E6 A2870A290A867A1A F4F43A64BADFD219  
 t=74: 370DAFCBF2D25DA8 558A01B12EC35028 CA73C49DE77C7AC8 D2BEF501241BE22C  
 8E3FA5D1EAE87FA8 15E2469AD6262414 F820C00AA7E284E6 A2870A290A867A1A  
 t=75: B6FDAC1E04495875 370DAFCBF2D25DA8 558A01B12EC35028 CA73C49DE77C7AC8  
 EC3C3233141B55E7 8E3FA5D1EAE87FA8 15E2469AD6262414 F820C00AA7E284E6  
 t=76: DAAAD0BF300751AD B6FDAC1E04495875 370DAFCBF2D25DA8 558A01B12EC35028  
 7401A3CB07B8228E EC3C3233141B55E7 8E3FA5D1EAE87FA8 15E2469AD6262414  
 t=77: 7CE25CB7C7FD48F6 DAAAD0BF300751AD B6FDAC1E04495875 370DAFCBF2D25DA8  
 69A9F1B43ECA54F4 7401A3CB07B8228E EC3C3233141B55E7 8E3FA5D1EAE87FA8  
 t=78: 751E755B4A6D7F36 7CE25CB7C7FD48F6 DAAAD0BF300751AD B6FDAC1E04495875  
 CB9D209C7B0DEB01 69A9F1B43ECA54F4 7401A3CB07B8228E EC3C3233141B55E7  
 t=79: AB4F42D47A55716D 751E755B4A6D7F36 7CE25CB7C7FD48F6 DAAAD0BF300751AD  
 22CA23DE9BE67C24 CB9D209C7B0DEB01 69A9F1B43ECA54F4 7401A3CB07B8228E

The output after processing the second block is

Y<sub>0</sub> = 8DD99EB081311F8B ⊕ AB4F42D47A55716D = 3928E184FB8690F8  
 Y<sub>1</sub> = CBBBC42CC7AFB288 ⊕ 751E755B4A6D7F36 = 40DA3988121D31BE  
 Y<sub>2</sub> = E8E9408730419D1E ⊕ 7CE25CB7C7FD48F6 = 65CB9D3EF83EE614  
 Y<sub>3</sub> = 953FF7A2B194048D ⊕ DAAAD0BF300751AD = 6FEAC861E19B563A  
 Y<sub>4</sub> = AE24175483C44C7C ⊕ 22CA23DE9BE67C24 = D0EE3B331FAAC8A0  
 Y<sub>5</sub> = 809B348E8E88E3EC ⊕ CB9D209C7B0DEB01 = 4C38552B0996CEED  
 Y<sub>6</sub> = BF2EA614CEED9C5B ⊕ 69A9F1B43ECA54F4 = 28D897C90DB7F14F  
 Y<sub>7</sub> = 51807937F11867E1 ⊕ 7401A3CB07B8228E = C5821D02F8D08A6F



**Iteration 1**

$K_1 = \text{B383FC2ECED4A574B383FC2ECED4A574B383FC2ECED4A574B383FC2ECED4A574}$   
 $X[K_1](m) = \text{B2B1CD1EF7EC924286B7CF1CFFE49C4C84B5C91AFDE694448ABBCB18FBE09646}$   
 $82B3C516F9E2904080B1CD1EF7EC924286B7CF1CFFE49C4C84B5C91AFDE69444,$   
 $SX[K_1](m) = 4645D95FC0BEEC2C432F8914B62D4EFD3E5E37F14B097AEAD67DE417C220B048}$   
 $2492AC996667E0EBDF45D95FC0BEEC2C432F8914B62D4EFD3E5E37F14B097AEA,$   
 $PSX[K_1](m) = 46433ED624DF433E452F5E7D92452F5ED98937E4ACD989375F14F117995F14F1}$   
 $C0B64BC266C0B64BBE2D092067BE2D09EC4E7AB0E0EC4E7A2CFDEA48EB2CFDEA,$   
 $LPSX[K_1](m) = \text{E60059D4D8E0758024C73F6F3183653F56579189602AE4C21E7953EBC0E212A0}$   
 $\text{CE78A8DF475C2FD4FC43FC4B71C01E35BE465FB20DAD2CF690CDF65028121BB9},$   
 $K_1 \oplus C_1 = 028BA7F4D01E7F9D5848D3AF0EB1D96B9CE98A6DE0917562C2CD44A3BB516E88}$   
 $\text{F8FF1CBF5CB3CC7511C1D6266AB47661B6F5881802A0E8576E0399773C72E073},$   
 $S(K_1 \oplus C_1) = \text{DDF644E6E15F5733BFF249410445536F4E9BD69E200F3596B3D9FA737D70A1D7}$   
 $\text{D1B6143B9C9288357758F8EF78278AA155F4D717DDA7CB12B211E87E7F19203D},$   
 $PS(K_1 \oplus C_1) = \text{DDBF4EB3D17755B2F6F29BD9B658F4114449D6EA14F8D7E8E6419E733BEF177E}$   
 $\text{E104207D9C78DD7F5F450F709227A719575335A1888ACB20336F96D735A1123D},$   
 $LPS(K_1 \oplus C_1) = \text{D0B00807642FD78F13F2C3EBC774E80DE0E902D23AEF2EE9A73D010807DAE9C1}$   
 $\text{88BE14F0B2DA27973569CD2BA051301036F728BD1D7EEC33F4D18AF70C46CF1E}.$

**Iteration 2**

$K_2 = \text{D0B00807642FD78F13F2C3EBC774E80DE0E902D23AEF2EE9A73D010807DAE9C1}$   
 $\text{88BE14F0B2DA27973569CD2BA051301036F728BD1D7EEC33F4D18AF70C46CF1E},$   
 $LPSX[K_2]LPSX[K_1](m) = 18E77571E703D19548075C574CE5E50E0480C9C5B9F21D45611AB86CF32}$   
 $\text{E352AD91854EA7DF8F863D46333673F62FF2D3EFAE1CD966F8E2A74CE49902799AAD4}.$

**Iteration 3**

$K_3 = 9D4475C7899F2D0BB0E8B7DAC6EF6E6B44ECF66716D3A0F16681105E2D13712A}$   
 $\text{1A9387ECC257930E2D61014A1B5C9FC9E24E7D636EB1607E816DBAF927B8FCA9},$   
 $LPSX[K_3]...LPSX[K_1](m) = 03DC0A9C164D42543CCDB62960D58C17E0B5B805D08A07406ECE679D5F}$   
 $\text{82B70FEA22A7EA56E21814619E8749B308214575489D4D465539852CD4B0CD3829BEF39}.$

**Iteration 4**

$K_4 = 5C283DABA5EC1F233B8C833C48E1C670DAE2E40CC4C3219C73E58856BD96A72F}$   
 $\text{DF9F8055FEF3C004C8CDE3B8BF78F95F3370D0A3D6194AC5782487DEFD83CA0F},$   
 $LPSX[K_4]...LPSX[K_1](m) = \text{DBEE312EA7301B0D6D13E43855E85DB81608C780C43675BC93CFD82C1}$   
 $\text{B4933B3898A35B13E1878ABE119E4DFFB9DE4889738CA74D064CD9EB732078C1FB25E04}.$

**Iteration 5**

$K_5 = 109F33262731F9BD569CBC9317BAA551D4D2964FA18D42C41FAB4E37225292EC}$   
 $\text{2FD97D7493784779046388469AE195C436FA7CBA93F8239CEB5FFC818826470C},$   
 $LPSX[K_5]...LPSX[K_1](m) = 7FB3F15718D90E889F9FB7C38F527BEC861C298AFB9186934A93C9D96AD}$   
 $\text{E20DF109379BB9C1A1FFD0AD81FCE7B45CCD54501E7D127E32874B5D7927B032DE7A1}.$

**Iteration 6**

$K_6 = \text{B32C9B02667911CF8F8A0877BE9A170757E25026CCF41E67C6B5DA70B1B87474}$   
 $\text{3E1135CFBEFE244237555C676C153D99459BC382573AEE2D85D30D99F286C5E7},$   
 $LPSX[K_6]...LPSX[K_1](m) = 95EFA4E104F235824BAE5030FE2D0F170A38DE3C9B8FC6D8FA1A9ADC2945C413389A12}$   
 $\text{1501FA71A65067916B0C06F6B87CE18DE1A2A98E0A64670985F47D73F1}.$



The result of the transformation  $g_0(h, N)$  is

# h = 5C881FD924695CF196C2E4FEC20D14B642026F2A0B1716EBAABB7067D4D597523D2DB69D6D3794622147A14F19A66E7F9037E1D662D34501A8901A5DE7771D7C.

The result of the transformation  $g_0(h, \Sigma)$  is

# h = 486F64C1917879417FEF082B3381A4E211C324F074654C38823A7B76F830AD00FA1FBAE42B1285C0352F227524BC9AB16254288DD6863DCCD5B9F54A1AD0541B.

The hash-code of the message  $M_1$  is the value:

H=486F64C1917879417FEF082B3381A4E211C324F074654C38823A7B76F830AD00FA1FBAE42B1285C0352F227524BC9AB16254288DD6863DCCD5B9F54A1AD0541B.

### B.12.3 Example 2

In this example, the data string is given as a sequence of bytes (in hexadecimal notation):

$M_1 =$  D1 E5 20 E2 E5 F2 F0 E8 2C 20 D1 F2 F0 E8 E1 EE E6 E8 20 E2 ED F3 F6 E8 2C 20 E2 E5  
FE F2 FA 20 F1 20 EC EE F0 FF 20 F1 F2 F0 E5 EB E0 EC E8 20 ED E0 20 F5 F0 E0 E1 F0 FB FF  
20 EF EB FA EA FB 20 C8 E3 EE F0 E5 E2 FB.

Assign the following values to the variables:

$$h := IV = 0512;$$
$$N := 0512;$$
$$\Sigma := 0^{512}.$$

The length of the message is  $L_{M_1} = 576 > 512$ , so a part of this message is initially processed:

```
m := FBEAFAEBEF20FFFBF0E1F0F0F520E0ED20E8ECE0EBE5F0F2F120FFF0EEEC20F1
20FAF2FEE5E2202CE8F6F3E0E220E8E6EEE1E8F0F2D1202CE8F0F2E5E220E5D1.
```

Calculate  $K := LPS(h \oplus N) = LPS(0512)$ .

After the transformation S:

[illegible]

after the transformation  $P$ :

[illegible]

after the transformation  $L$ :

$$K = LPS(h \oplus N) = B383FC2ECED4A574B383FC2ECED4A574B383FC2ECED4A574B383FC2ECED4A574 \\ B383FC2ECED4A574B383FC2ECED4A574B383FC2ECED4A574B383FC2ECED4A574.$$

Then the transformation  $E(K, m)$  is performed:

### Iteration 1

$$\begin{aligned} K_1 &= \text{B383FC2ECED4A574B383FC2ECED4A574B383FC2ECED4A574B383FC2ECED4A574} \\ &\quad \text{B383FC2ECED4A574B383FC2ECED4A574B383FC2ECED4A574B383FC2ECED4A574}, \\ X[K_1](m) &= 486906C521F45A8F43621CDE3BF44599936B10CE2531558642A303DE20388585 \\ &\quad 93790ED02B3685585B750FC32CF44D925D6214DE3C0585585B730ECB2CF440A5, \\ SX[K_1](m) &= \text{F29131AC18E613035196148598E6C8E8DE6FE9E75C840C432C731185F906A8A8} \\ &\quad \text{DE5404E1428FA8BF47354D408BE63AECB79693857F6EA8BF473D04E48BE6EB00}, \end{aligned}$$

$PSX[K_1](m) = \text{F251DE2CDE47B74791966F735435963D3114E911044D9304AC85E785E14085E4}$   
 $18985CF9428B7F8BE6E684068FE66EE613C80CA8A83AA8EB03E843A8BFECBF00,$   
 $LPSX[K_1](m) = 909AA733E1F52321A2FE35BFB8F67E92FBC70EF544709D5739D8FAACA4ACF126}$   
 $E83E273745C25B7B8F4A83A7436F6353753CBBBE492262CD3A868EACE0104AF1,$   
 $K_1 \oplus C_1 = 028BA7F4D01E7F9D5848D3AF0EB1D96B9CE98A6DE0917562C2CD44A3BB516188}$   
 $F8FF1CBF5CB3CC7511C1D6266AB47661B6F5881802A0E8576E0399773C72E073,$   
 $S(K_1 \oplus C_1) = \text{DDF644E6E15F5733BFF249410445536F4E9BD69E200F3596B3D9EA737D70A1D7}$   
 $D1B6143B9C9288357758F8EF78278AA155F4D717DDA7CB12B211E87E7F19203D,$   
 $PS(K_1 \oplus C_1) = \text{DDBF4EB3D17755B2F6F29BD9B658F4114449D6EA14F8D7E8E6419E733BEF177E}$   
 $E104207D9C78DD7F5F450F709227A719575335A1888ACB20336F96D735A1123D,$   
 $LPS(K_1 \oplus C_1) = \text{D0B00807642FD78F13F2C3EBC774E80DE0E902D23AEF2EE9A73D010807DAE9C1}$   
 $88BE14F0B2DA27973569CD2BA051301036F728BD1D7EEC33F4D18AF70C46CF1E.$

## Iteration 2

$K_2 = \text{D0B00807642FD78F13F2C3EBC774E80DE0E902D23AEF2EE9A73D010807DAE9C1}$   
 $88BE14F0B2DA27973569CD2BA051301036F728BD1D7EEC33F4D18AF70C46CF1E,$   
 $LPSX[K_2]LPSX[K_1](m) = 301AADD761D13DF0B473055B14A2F74A45F408022AECADD4D5F19CAB8228883A}$   
 $021AC0B62600A495950C628354FFCE1161C68B7BE7E0C58AF090CE6B45E49F16.$

## Iteration 3

$K_3 = 9D4475C7899F2D0BB0E8B7DAC6EF6E6B44ECF66716D3A0F16681105E2D13712A}$   
 $1A9387ECC257930E2D61014A1B5C9FC9E24E7D636EB1607E816DBAF927B8FCA9,$   
 $LPSX[K_3]...LPSX[K_1](m) = 9B83492B9860A93BCBA1C0D8E0CE59DB04E10500A6AC85D4103304974E78D322}$   
 $59CEFF03FBB353147A9C948786582DF78A34C9BDE3F72B3CA41B9179C2CCEEF3.$

## Iteration 4

$K_4 = 5C283DABA5EC1F233B8C833C48E1C670DAE2E40CC4C3219C73E58856BD96A72F}$   
 $DF9F8055FFE3C004C8CDE3B8BF78F95F3370D0A3D6194AC5782487DEFD83CA0F,$   
 $LPSX[K_4]...LPSX[K_1](m) = E638E0A1677CDEA107EC3402F70698A4038450DAB44AC7A447E10155AA33EF1B}$   
 $DAF8F49DA7B66F3E05815045FBD39C991CB0DC536E09505FD62D3C2CD00B0F57.$

## Iteration 5

$K_5 = 109F33262731F9BD569C9317BAA551D4D2964FA18D42C41FAB4E37225292EC}$   
 $2FD97D7493784779046388469AE195C436FA7CBA93F8239CEB5FFC818826470C,$   
 $LPSX[K_5]...LPSX[K_1](m) = 1C7C8E19B2BF443EB3ADC0C787A52A173821A97BC5A8EFEA58FB8B27861829F6}$   
 $DD5FF9C97865E08C1AC66F47392B578E21266E323A0ACEDEEC3EF0314F517C6.$

## Iteration 6

$K_6 = B32C9B02667911CF8F8A0877BE9A170757E25026CCF41E67C6B5DA70B1B87474}$   
 $3E1135CFBEFE244237555C676C153D99459BC382573AEE2D85D30D99F286C5E7,$   
 $LPSX[K_6]...LPSX[K_1](m) = 48FECFC5B3EB77998FB39BFCCCD128CD42FCCB714221BE1E675A1C6FDDE7E311}$   
 $98B318622412AF7E999A3EFF45E6D61609A7F2AE5C2FF1AB7FF3B37BE7011BA2.$

## Iteration 7

$K_7 = 8A13C1B195FD0886AC49989E7D84B08BC7B00E4F3F62765ECE6050FCBABDC234}$   
 $6C8207594714E8E9C9C7AAD694EDC922D6B01E17285EB7E61502E634559E32F1,$   
 $LPSX[K_7]...LPSX[K_1](m) = A48F8D781C2C5BE417AE644CC2E15A9F01FCEAD3232E5BD53F18A5AB875CCE1B}$   
 $8A1A400CF48521C7CE27FB1E94452FB54DE23118F53B364EE633170A62F5A8A9.$

## Iteration 8

$K_8 = 52CEC3B11448BB8617D0DDFBC926F2E88730CB9179D6DECEA5ACBFFD323EC376}$   
 $4C47F7A9E13BB1DB56C342034773023D617FF01CC546728E71DFF8DE5D128CAC,$   
 $LPSX[K_8]...LPSX[K_1](m) = E8A31B2E34BD2AE21B0ECF29CC4C37C75C4D11D9B82852517515C23E81E906A4}$   
 $51B72779C3087141F1A15AB57F96D7DA6C7EE38ED25BEFBDEF631216356FF59C.$





The variables  $N$  and  $\Sigma$  change their values to:

```
N = 000000000000000000000000000000000000000000000000000000000000000000000000  
000000000000000000000000000000000000000000000000000000000000000000000240,  
 $\Sigma$  = FBFAFABEF20FFBF0E1E0F0F520E0ED20E8ECE0EBE5F0F2F120FFF0EEEC20F1  
20FAF2FEE5E2202CE8F6F3EDE220E8E6EEE1E8F0F2D1202EE4D3D8D6D104ADF1.
```

The result of the transformation  $g_0(h, N)$  is

**h** = 4DEB6649FFA5CAF4163D9D3F9967FBBD6EB3DA68F916B6A09F41F2518B81292B703DC5D74E1ACE5BCD3458AF43BB456E837326088F2B5DF14BF83997A0B1AD8D.

The result of the transformation  $g_0(h, \Sigma)$  is

# h = 28FBC9BADA033B1460642BDCDD90C3FB3E56C497CCD0F62B8A2AD4935E85F037613966DE4EE00531AE60F3B5A47F8DAE06915D5F2F194996FCABF2622E6881E.

The hash-code of the message  $M_2$  is the value:

H = 28FBC9BADA033B1460642BDCDB90C3FB3E56C497CCD0F62B8A2AD4935E85F037613966DE4EE00531AE60F3B5A47F8DAE06915D5F2F194996FCABF2622E6881E.

### B.13 Dedicated Hash-Function 12 (STREEBOG-256)

### B.13.1 General

The binary words are expressed in hexadecimal notation. The  $4n$ -bit word is given in the form  $a_{n-1}, \dots, a_0$ , where  $a_i \in \mathbb{F}_{16}$ ,  $i = 0, \dots, n-1$  is  $\text{Vec}_4(a_{n-1}) \parallel \dots \parallel \text{Vec}_4(a_0)$ .

It should be noted that in this set of examples all data strings treated in right-to-left order. Byte ordering convention holds.

### B.13.2 Example 1

In this example, the data string is given as a sequence of bytes (in hexadecimal notation):

$M_1 =$  30 31 32 33 34 35 36 37 38 39 30 31 32 33 34 35 36 37 38 39 30 31 32 33 34 35 36 37  
 38 39 30 31 32 33 34 35 36 37 38 39 30 31 32 33 34 35 36 37 38 39 30 31 32 33 34 35 36 37  
 38 39 30 31 32

Assign the following values to the variables:

$$h := IV = (000\ 000\ 01)^{64};$$
$$N := 0512;$$
$$\Sigma := 0^{512}.$$

The length of the message is  $L_{M_1} = 504 < 512$ , so the incomplete block is padded:

$$m := 0132313039383736353433323130393837363534333231303938373635343332$$
  

$$3130393837363534333231303938373635343332313039383736353433323130.$$

Calculate  $K := LPS(h \oplus N) = LPS[(000\ 000\ 01)^{64}]$ .

After the transformation  $S$ :

$$S(h \oplus N) =$$



## Iteration 6

$K_6 = \text{F05772AE2CE7F025156C9A7FBCC6B8FDF1E735D613946E32922994E52820FFEA}$   
 $62615D907EB0551AD170990A86602088AF98C83C22CDB0E2BE297C13C0F7A156,$

$LPSX[K_6] \dots LPSX[K_1](m) = 1BC204BF9506EE9B86BBCF82D254A112AEA6910B6DB3805E399CB718D1B33199$   
 $64459516967CEE4E648E8CFBF81F56DC8DA6811C469091BE5123E6A1D5E28C73.$

## Iteration 7

$K_7 = 5AD144C362546E4E46B3E7688829FBB77453E9C3211974330B2B8D0E6BE2B5AC$   
 $C89EB6B35167F159B7B005A43E5959A651A9B18CFC8E4098FCF03D9B81CFBB8D,$

$LPSX[K_7] \dots LPSX[K_1](m) = \text{F30D791ED78BDEE819022A3D78182242124EFCDD54E203F23FB2DC7F94338FF9}$   
 $55A5AFC15FFEF03165263C4FDB36933AA982016471FBAC9419F892551E9E568B.$

## Iteration 8

$K_8 = 6A6CEC9A1BA20A8DB64FA840B934352B518C638ED530122A83332FE0B8EFDAC9$   
 $018287E5A9F509C78D6C746ADCD5426FB0A0AD5790DFB73FC1F191A539016DAA,$

$LPSX[K_8] \dots LPSX[K_1](m) = 1FC20F1E91A1801A4293D3F3AA9E91560FCC3810BB15F3EE9741C9B87452519F$   
 $67CB9145519884A24DE6DB736A5CB1430DA7458E5E51B80BE5204BA5E2800177.$

## Iteration 9

$K_9 = 99217036737AA9B38A8D6643F705BD51F351531F948F0FC5E35FA35FEE9DD8BD$   
 $BB4C9D580A224E9CD82E0E2069FC49ED367D5F94374435382B8FB6A8F5DD0409,$

$LPSX[K_9] \dots LPSX[K_1](m) = 1A52F09D1E81515A36171E0B1A2809C50359BED90F2E78CBD89B7D4AFA6D0466$   
 $55C96BDAE6EE97055CC7E857267C2CCF28C8F5DD95ED58A9A68C12663BB28967.$

## Iteration 10

$K_{10} = 906763C0FC89FA1AE69288D8EC9E9DDA9A7630E8BFD6C3FED703C35D2E62AEAF$   
 $F0B35D80A7317A7F76F83022F2526791CA8FDF678FCB337BD74FE5393CCB05D2,$

$LPSX[K_{10}] \dots LPSX[K_1](m) = 764043744A0A93687E65ABA8CFC25EC8714FB8E1BDC9AE2271E7205EAAA577C1$   
 $B3B83E7325E50A19BD2D56B061B5DE39235C9C9FD95E071A1A291A5F24E8C774.$

## Iteration 11

$K_{11} = 88CE996C63618E6404A5C8E03EE433854E2AE3EEE68991BBBFF3C29D38DADB6E$   
 $D6A1DAE9A6DC6DDF52CE34AF272F96D3159C8C624C3FE6E13D695C0BFC89ADD5,$

$LPSX[K_{11}] \dots LPSX[K_1](m) = 9B1CE8FF26B445CB288C0AECFC84658EEA91DBDF14828BF70110A5C9BD146CD9$   
 $646350CFF4E90E7B63C5CC325E9B441081935F282D4648D9584F71860538F03B.$

## Iteration 12

$K_{12} = 3E0A281EA9BD46063EEC550100576F3A506AA168CF82915776B978FCCAA32F38$   
 $B55F30C79982CA45628E8365D8798477E75A49C68199112A1D7B5A0F7655F2DB,$

$LPSX[K_{12}] \dots LPSX[K_1](m) = 133AECEDE251EB81914B8BA48DCBC0B8A6FC63A292CC49043C3D3346B3F0829$   
 $A9CB71ECFF25ED2A91BDCF8F649907C110CB76FF2E43100CDD4BA8A147A572F5.$

## Iteration 13

$K_{13} = \text{F0B273409EB31AEBE432FBAE1867212262C848422B6A92F93F6CBAB54ED18B83}$   
 $14B21CFFC51E3FA319FF433E76EF6ADB0EF9F5E03C907FA1FCF9ECA06500BF03,$

$LPSX[K_{13}] \dots LPSX[K_1](m) = \text{E3889D8E40960453FD26431450BB9D29E8A78E78024656697CAF698125EE83AA}$   
 $BD796D133A3BD28988428CB112766D1A1E32831F12D36FAD21B2440122A5CDF6.$

The result of the transformation  $g_N(h, m)$  is

$h = \text{E3BBADB7F8AF3264C9137127608AA510DE90BA4D3075665844965FB611DBB199}$   
 $8D48552A0C0CE6BCBA71BC802A4F5B2D2A07B12C22E25794178570341096FDC7.$

The variables  $N$  and  $\Sigma$  change their values to:

[illegible]

The result of the transformation  $g_0(h, N)$  is

$h = 70F22BADA4CFE18A6A56EC4B3F328CD40DB8E1BF8A9D5F711D5EFAB11191279D715AAB7648D07EDDBF87DC79C80516E6FFCBCF5678B0AC29EA00FA85C8173CC6.$

The result of the transformation  $g_0(h, \Sigma)$  is

# h = 00557BE5E584FD52A449B16B0251D05D27F94AB76CBAA6DA890B59D8EF1E159D2088E482E2ACF564E0E9795A51E4DD261F3F667985A2FCC40AC8631FAC41709A.

The hash-code of the message  $M_1$  is the value:

$H = 00557BE5E584FD52A449B16B0251D05D27F94AB76CBAA6DA890B59D8EF1E159D.$

### B.13.3 Example 2

In this example, the data string is given as a sequence of bytes (in hexadecimal notation):

$M_2 =$  D1 E5 20 E2 E5 F2 F0 E8 2C 20 D1 F2 F0 E8 E1 EE E6 E8 20 E2 ED F3 F6 E8 2C 20 E2 E5  
FE F2 FA 20 F1 20 EC EE F0 FF 20 F1 F2 F0 E5 EB E0 EC E8 20 ED E0 20 F5 F0 E0 E1 F0 FB FF  
20 EF EB FA EA FB 20 C8 E3 EE F0 E5 E2 FB.

Assign the following values to the variables:

$$h := IV = (000\ 000\ 01)^{64};$$
$$N := 0512;$$
$$\Sigma := 0512.$$

The length of the message is  $L_{M_2} = 576 > 512$ , so a part of this message is initially processed

```
m := FBEAFAFBFF20FFFBF0E1E0F0F520E0ED20E8ECE0EBE5F0F2F120FFF0EEEC20F1
20FAF2EEE5E2202CE8F6F3EDE220E8E6EEE1E8F0F2D1202CE8F0F2E5E220E5D1.
```

Calculate  $K := LPS(h \oplus N) = LPS((000\ 000\ 01)^{64})$ .

After the transformation  $S$ :

$S(h \oplus N) =$

after the transformation  $P$ :

$$PS(h \oplus N) =$$

after the transformation  $L$ :

$$K = LPS(h \oplus N) = 23C5EE40B07B5F1523C5EE40B07B5F1523C5EE40B07B5F1523C5EE40B07B5F15$$
  

$$23C5EE40B07B5F1523C5EE40B07B5F1523C5EE40B07B5F1523C5EE40B07B5F15.$$

Then the transformation  $E(K, m)$  is performed:

## Iteration 2

### Iteration 3

### Iteration 4

### Iteration 5

### Iteration 6

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The length of the rest of the message is less than 512, so the incomplete block is padded:

[illegible]

The result of the transformation  $g_N(h, m)$  is

**h** = A69049E7BD076AB775BC2873AF26F098C538B17E39A5C027D532F0A2B3B56426  
C96B285FA297B9D39AE6AFD8B9001D97BB718A65FCC53C41B4EBF4991A617227.

The variables  $N$  and  $\Sigma$  change their values to:

`N = 000000000000000000000000000000000000000000000000000000000000000000000000  
0000000000000000000000000000000000000000000000000000000000000000000000000240,  
Σ = FBEAFAEBEF20FFBF0E1E0F0F520E0ED20E8ECE0EBE5F0F2F120FFF0EEEC20F1  
20FAF2FE5E2202CE8F6F3EDE220E8E6EEE1E8F0F2D1202EE4D3D8D6D104ADF1`

The result of the transformation  $g_0(h, N)$  is

# h = AEE3BD55EA6F387BCF28C6DCBDBBFB3DDACC67DCC13DBD8D548C6BF808111D4B75B8E74D2AFAE960835AE6A5F03575559C9FD839783FFCD5CF99BD61566B4818.

The result of the transformation  $g_0(h, \Sigma)$  is

# h = 508F7E553C06501D749A66FC28C6CAC0B005746D97537FA85D9E40904EFED29D C345E53D7F84875D5068E4EB743F0793D673F09741F9578471FB2598CB35C230.

The hash-code of the message  $M_2$  is the value:

$H = 508F7E553C06501D749A66FC28C6CAC0B005746D97537FA85D9E40904EFED29D.$

### B.14 Dedicated Hash-Function 13 (SHA3-224)

NOTE 1 Data is presented in three different ways: bit strings, byte strings and  $w$ -length words (for the lanes).

**NOTE 2** Bit strings are the sequence of bits from left to right.

NOTE 3 Byte strings are the bytes from left to right and the bits within the byte are right to left.

NOTE 4 Words are the integer representation of the values in the lanes.

The message as bit string

(empty message)





Round #0

After  $\theta$

```

06 00 00 00 00 00 00 00 07 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 80
0C 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
07 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 80 0C 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 07 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 80
0C 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
07 00 00 00 00 00 00 00 00 00 00 00 00 00 00 80
00 00 00 00 00 00 00 80 0C 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 07 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 80
0C 00 00 00 00 00 00 00 00

```

After  $p$

```

06 00 00 00 00 00 00 00 0E 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 60 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 70 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 40 00 00 00 C0 00 00 00 00 00
00 00 00 00 00 00 00 00 00 1C 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 01 00 00 00 00 00
00 00 00 00 00 06 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 E0 00 00 00 40 00 00 00 00 00 00
00 00 10 00 00 00 00 00 00 0C 00 00 00 00 00 00
00 00 00 00 00 00 00 00 1C 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 80 00
00 00 03 00 00 00 00 00 00

```

After  $\pi$ 

```

06 00 00 00 00 00 00 00 00 00 00 00 00 00 70 00 00
00 00 00 00 00 00 00 00 00 00 00 10 00 00 00 00 00
00 00 03 00 00 00 00 00 00 00 00 00 08 00 00 00 00
00 00 C0 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 E0 00 00 00 00 00 00 00 00 00 00 00
0E 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 01 00 00 00 00 00 00 0C 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 60 00 00 00 00
00 00 00 00 00 00 00 00 00 00 1C 00 00 00 00 00 00
00 40 00 00 00 00 00 00 00 00 00 00 00 00 00 80 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 40 00
00 00 00 00 00 06 00 00 00 00 00 00 00 00 00 00 00
1C 00 00 00 00 00 00 00 00

```

After  $\chi$ 

```

06 00 00 00 00 00 00 00 00 00 10 00 00 70 00 00
00 00 03 00 00 00 00 00 06 00 10 00 00 00 00 00
00 00 03 00 00 70 00 00 00 00 00 08 00 00 00 00
00 00 C0 00 00 E0 00 00 00 00 00 00 00 00 00 00
00 00 00 08 00 E0 00 00 00 00 C0 00 00 00 00 00
0E 00 00 01 00 00 00 00 00 0C 00 00 00 00 00 00
00 00 00 01 00 00 00 00 0E 0C 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 1C 00 60 00 00 00 00
00 40 00 00 00 00 00 00 1C 00 00 00 00 00 80 00
00 40 00 60 00 00 00 00 00 00 00 00 00 00 80 00
00 00 00 00 00 06 00 00 00 00 00 00 00 00 40 00
1C 00 00 00 00 06 00 00 00 00 00 00 00 00 00 00
1C 00 00 00 00 00 00 40 00

```

After  $\iota$ 

```

07 00 00 00 00 00 00 00 00 00 10 00 00 70 00 00
00 00 03 00 00 00 00 00 06 00 10 00 00 00 00 00
00 00 03 00 00 70 00 00 00 00 00 08 00 00 00 00
00 00 C0 00 00 E0 00 00 00 00 00 00 00 00 00 00
00 00 00 08 00 E0 00 00 00 00 C0 00 00 00 00 00
0E 00 00 01 00 00 00 00 00 0C 00 00 00 00 00 00
00 00 00 01 00 00 00 00 0E 0C 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 1C 00 60 00 00 00 00
00 40 00 00 00 00 00 00 00 1C 00 00 00 00 00 80 00
00 40 00 60 00 00 00 00 00 00 00 00 00 00 80 00
00 00 00 00 00 06 00 00 00 00 00 00 00 00 40 00
1C 00 00 00 00 06 00 00 00 00 00 00 00 00 00 00
1C 00 00 00 00 00 00 40 00

```

(Skip rounds 1 to 22)

Round #23

After  $\theta$

23 DE E9 70 36 66 D5 23 91 03 C3 F1 B6 6B 93 28  
 69 4D 53 70 6B BA E5 B1 E5 9D C2 7E 0A 05 AD B2  
 50 64 AE 08 3D B0 14 9C FB 89 A8 CE 9E BA 03 4F  
 0F BB 2E E3 5E 01 F0 E2 4A AC FA E8 B0 11 19 00  
 D8 15 A2 68 94 D3 D6 73 A3 57 6E 6C B4 F0 14 5C  
 8B F5 47 AE E7 26 8B 54 6E E4 99 A0 C5 07 C8 83  
 C1 F7 03 8E 6F 5D 36 A1 B7 B6 AD B9 10 2D E1 37  
 A8 AD D4 4D DA BD 72 32 08 CF 7B 7F 6E A0 15 01  
 51 8F EB C7 1E C0 B6 08 CF 77 B8 E7 0C BA 43 70  
 BB 4E AB 4F 60 CA 82 5E 26 37 0A 73 AA C9 00 D9  
 57 78 B9 E1 BC E9 EB 13 B9 98 DD 5A FB B1 60 18  
 E9 0E 7E AC F3 3F F8 6C 5A 92 4F 9E FF FD 74 FF  
 FD BB E9 E8 C4 A0 D4 D6

After  $\rho$

23 DE E9 70 36 66 D5 23 22 07 86 E3 6D D7 26 51  
 5A D3 14 DC 9A 6E 79 6C 50 D0 2A 5B DE 29 EC A7  
 81 A5 E0 84 22 73 45 E8 EC A9 3B F0 B4 9F 88 EA  
 32 EE 15 00 2F FE B0 EB 80 12 AB 3E 3A 6C 44 06  
 0A 51 34 CA 69 EB 39 EC 4F C1 35 7A E5 C6 46 0B  
 5A AC 3F 72 3D 37 59 A4 0F BA 91 67 82 16 1F 20  
 70 7C EB B2 09 0D BE 1F 5A C2 6F 6E 6D 5B 73 21  
 26 ED 5E 39 19 D4 56 EA FE DC 40 2B 02 10 9E F7  
 FD D8 03 D8 16 21 EA 71 21 B8 E7 3B DC 73 06 DD  
 59 D0 6B D7 69 F5 09 4C D9 26 37 0A 73 AA C9 00  
 AF 4F 5C E1 E5 86 F3 A6 E4 62 76 6B ED C7 82 61  
 DD C1 8F 75 FE 07 9F 2D 92 4F 9E FF FD 74 FF 5A  
 B5 75 FF 6E 3A 3A 31 28

After  $\pi$ 

23 DE E9 70 36 66 D5 23 32 EE 15 00 2F FE B0 EB  
 70 7C EB B2 09 0D BE 1F 59 D0 6B D7 69 F5 09 4C  
 B5 75 FF 6E 3A 3A 31 28 50 D0 2A 5B DE 29 EC A7  
 4F C1 35 7A E5 C6 46 0B 5A AC 3F 72 3D 37 59 A4  
 FD D8 03 D8 16 21 EA 71 DD C1 8F 75 FE 07 9F 2D  
 22 07 86 E3 6D D7 26 51 80 12 AB 3E 3A 6C 44 06  
 5A C2 6F 6E 6D 5B 73 21 D9 26 37 0A 73 AA C9 00  
 AF 4F 5C E1 E5 86 F3 A6 81 A5 E0 84 22 73 45 E8  
 EC A9 3B F0 B4 9F 88 EA 0F BA 91 67 82 16 1F 20  
 21 B8 E7 3B DC 73 06 DD 92 4F 9E FF FD 74 FF 5A  
 5A D3 14 DC 9A 6E 79 6C 0A 51 34 CA 69 EB 39 EC  
 26 ED 5E 39 19 D4 56 EA FE DC 40 2B 02 10 9E F7  
 E4 62 76 6B ED C7 82 61

After  $\chi$ 

63 CE 03 C2 36 67 DB 37 3B 6E 15 45 4F 0E B1 AB  
 D4 59 7F 9A 1B 07 8E 3F 5B 5A 6B C7 6D B1 CD 4F  
 A5 55 EB 6E 33 A2 11 E0 40 FC 20 5B C6 18 F5 03  
 EA 91 35 F2 E7 C6 E4 5A 5A AD B3 57 D5 31 4C A8  
 FD C8 23 D2 16 09 8A F3 D2 C0 9A 55 DF C1 9D 25  
 78 C7 C2 A3 28 C4 15 70 01 36 BB 3E 28 CC CC 06  
 7C 8B 27 8F E9 5F 41 87 D9 26 B5 08 7B FB CD 51  
 2F 5F 75 FD F7 AE B3 A0 82 B7 60 83 20 73 52 E8  
 CC A9 5D E8 E8 FE 88 37 9D FD 89 A3 A3 12 E6 22  
 20 18 87 3B DE 70 06 7D FE 47 85 8F 69 F8 77 58  
 7E 7F 5E ED 8A 7A 3F 6E D2 41 34 C8 6B EB B1 F9  
 26 CF 68 79 F4 13 56 EA E4 4D 40 BF 10 38 E7 FB  
 E4 62 56 69 8C 46 82 E1

After  $\iota$ 

6B 4E 03 42 36 67 DB B7 3B 6E 15 45 4F 0E B1 AB  
 D4 59 7F 9A 1B 07 8E 3F 5B 5A 6B C7 6D B1 CD 4F  
 A5 55 EB 6E 33 A2 11 E0 40 FC 20 5B C6 18 F5 03  
 EA 91 35 F2 E7 C6 E4 5A 5A AD B3 57 D5 31 4C A8  
 FD C8 23 D2 16 09 8A F3 D2 C0 9A 55 DF C1 9D 25  
 78 C7 C2 A3 28 C4 15 70 01 36 BB 3E 28 CC CC 06  
 7C 8B 27 8F E9 5F 41 87 D9 26 B5 08 7B FB CD 51  
 2F 5F 75 FD F7 AE B3 A0 82 B7 60 83 20 73 52 E8  
 CC A9 5D E8 E8 FE 88 37 9D FD 89 A3 A3 12 E6 22  
 20 18 87 3B DE 70 06 7D FE 47 85 8F 69 F8 77 58  
 7E 7F 5E ED 8A 7A 3F 6E D2 41 34 C8 6B EB B1 F9  
 26 CF 68 79 F4 13 56 EA E4 4D 40 BF 10 38 E7 FB  
 E4 62 56 69 8C 46 82 E1

After permutation

```

6B 4E 03 42 36 67 DB B7 3B 6E 15 45 4F 0E B1 AB
D4 59 7F 9A 1B 07 8E 3F 5B 5A 6B C7 6D B1 CD 4F
A5 55 EB 6E 33 A2 11 E0 40 FC 20 5B C6 18 F5 03
EA 91 35 F2 E7 C6 E4 5A 5A AD B3 57 D5 31 4C A8
FD C8 23 D2 16 09 8A F3 D2 C0 9A 55 DF C1 9D 25
78 C7 C2 A3 28 C4 15 70 01 36 BB 3E 28 CC CC 06
7C 8B 27 8F E9 5F 41 87 D9 26 B5 08 7B FB CD 51
2F 5F 75 FD F7 AE B3 A0 82 B7 60 83 20 73 52 E8
CC A9 5D E8 E8 FE 88 37 9D FD 89 A3 A3 12 E6 22
20 18 87 3B DE 70 06 7D FE 47 85 8F 69 F8 77 58
7E 7F 5E ED 8A 7A 3F 6E D2 41 34 C8 6B EB B1 F9
26 CF 68 79 F4 13 56 EA E4 4D 40 BF 10 38 E7 FB
E4 62 56 69 8C 46 82 E1

```

State (as lanes of integers)

```

[0, 0] = B7DB673642034E6B
[1, 0] = ABB10E4F45156E3B
[2, 0] = 3F8E071B9A7F59D4
[3, 0] = 4FCDB16DC76B5A5B
[4, 0] = E011A2336EEB55A5
[0, 1] = 03F518C65B20FC40
[1, 1] = 5AE4C6E7F23591EA
[2, 1] = A84C31D557B3AD5A
[3, 1] = F38A0916D223C8FD
[4, 1] = 259DC1DF559AC0D2
[0, 2] = 7015C428A3C2C778
[1, 2] = 06CCCC283EBB3601
[2, 2] = 87415FE98F278B7C
[3, 2] = 51CDFB7B08B526D9
[4, 2] = A0B3AEF7FD755F2F
[0, 3] = E85273208360B782
[1, 3] = 3788FEE8E85DA9CC
[2, 3] = 22E612A3A389FD9D
[3, 3] = 7D0670DE3B871820
[4, 3] = 5877F8698F8547FE
[0, 4] = 6E3F7A8AED5E7F7E
[1, 4] = F9B1EB6BC83441D2
[2, 4] = EA5613F47968CF26
[3, 4] = FBE73810BF404DE4
[4, 4] = E182468C695662E4

```

The hash value is

```

6B 4E 03 42 36 67 DB B7 3B 6E 15 45 4F 0E B1 AB
D4 59 7F 9A 1B 07 8E 3F 5B 5A 6B C7

```

The message as bit string

1 1 0 0 1

XORed state (in bytes)

```
D3 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 80
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
```

XORed state (as lanes of integers)

```
[0,0] = 0000000000000000D3
[1,0] = 000000000000000000
[2,0] = 000000000000000000
[3,0] = 000000000000000000
[4,0] = 000000000000000000
[0,1] = 000000000000000000
[1,1] = 000000000000000000
[2,1] = 000000000000000000
[3,1] = 000000000000000000
[4,1] = 000000000000000000
[0,2] = 000000000000000000
[1,2] = 000000000000000000
[2,2] = 000000000000000000
[3,2] = 000000000000000000
[4,2] = 000000000000000000
[0,3] = 000000000000000000
[1,3] = 000000000000000000
[2,3] = 800000000000000000
[3,3] = 000000000000000000
[4,3] = 000000000000000000
[0,4] = 000000000000000000
[1,4] = 000000000000000000
[2,4] = 000000000000000000
[3,4] = 000000000000000000
[4,4] = 000000000000000000
```

Round #0



After  $\theta$ 

```

D3 00 00 00 00 00 00 00 00 D2 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 80
A6 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00
D2 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 80 A6 01 00 00 00 00 00 00
00 00 00 00 00 00 00 00 D2 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 80
A6 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00
D2 00 00 00 00 00 00 00 00 00 00 00 00 00 00 80
00 00 00 00 00 00 00 80 A6 01 00 00 00 00 00 00
00 00 00 00 00 00 00 00 D2 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 80
A6 01 00 00 00 00 00 00

```

After  $\rho$ 

```

D3 00 00 00 00 00 00 00 00 A4 01 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 08 00 00 00 00
00 00 00 30 0D 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 20 0D 00 00 00 00 00 00 00 00 00
00 00 00 00 00 40 00 00 00 60 1A 00 00 00 00 00
00 00 00 00 00 00 00 00 00 48 03 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 01 00 00 00 00
00 00 00 00 00 D3 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 40 1A 00 00 40 00 00 00 00 00 00
00 00 10 00 00 00 00 00 00 A6 01 00 00 00 00 00
00 00 00 00 00 00 00 00 48 03 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 80 00
00 80 69 00 00 00 00 00

```

After  $\pi$ 

```

D3 00 00 00 00 00 00 00 00 00 00 00 00 20 0D 00
00 00 00 00 00 00 00 00 00 00 10 00 00 00 00 00
00 80 69 00 00 00 00 00 00 00 00 08 00 00 00 00
00 00 60 1A 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 40 1A 00 00 00 00 00 00 00 00 00
A4 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 01 00 00 00 00 00 A6 01 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 30 0D 00 00 00
00 00 00 00 00 00 00 00 00 48 03 00 00 00 00 00
00 40 00 00 00 00 00 00 00 00 00 00 00 80 00
00 00 00 00 00 00 00 00 00 00 00 00 00 40 00
00 00 00 00 00 D3 00 00 00 00 00 00 00 00 00 00
48 03 00 00 00 00 00 00

```

After  $\chi$

```

D3 00 00 00 00 00 00 00 00 00 00 10 00 00 20 0D 00
00 80 69 00 00 00 00 00 D3 00 10 00 00 00 00 00
00 80 69 00 00 20 0D 00 00 00 00 08 00 00 00 00
00 00 60 1A 00 40 1A 00 00 00 00 00 00 00 00 00
00 00 00 08 00 40 1A 00 00 00 60 12 00 00 00 00
A4 01 00 01 00 00 00 00 00 A6 01 00 00 00 00 00
00 00 00 01 00 00 00 00 A4 A7 01 00 00 00 00 00
00 00 00 00 00 00 00 00 00 48 03 30 0D 00 00 00
00 00 00 00 00 00 00 00 00 48 03 00 00 00 80 00
00 40 00 30 0D 00 00 00 00 00 00 00 00 00 80 00
00 00 00 00 00 D3 00 00 00 00 00 00 00 00 40 00
48 03 00 00 00 D3 00 00 00 00 00 00 00 00 00 00
48 03 00 00 00 00 00 40 00

```

After  $\iota$

```

D2 00 00 00 00 00 00 00 00 00 00 10 00 00 20 0D 00
00 80 69 00 00 00 00 00 D3 00 10 00 00 00 00 00
00 80 69 00 00 20 0D 00 00 00 00 08 00 00 00 00
00 00 60 1A 00 40 1A 00 00 00 00 00 00 00 00 00
00 00 00 08 00 40 1A 00 00 00 60 12 00 00 00 00
A4 01 00 01 00 00 00 00 00 A6 01 00 00 00 00 00
00 00 00 01 00 00 00 00 A4 A7 01 00 00 00 00 00
00 00 00 00 00 00 00 00 00 48 03 30 0D 00 00 00
00 00 00 00 00 00 00 00 00 48 03 00 00 00 80 00
00 40 00 30 0D 00 00 00 00 00 00 00 00 00 80 00
00 00 00 00 00 D3 00 00 00 00 00 00 00 00 40 00
48 03 00 00 00 D3 00 00 00 00 00 00 00 00 00 00
48 03 00 00 00 00 00 40 00

```

(Skip rounds 1 to 22)

Round #23

After  $\theta$ 

F1 B2 6C 63 94 B2 D4 96 0E 77 89 20 45 67 B5 7C  
 54 76 53 B2 CE 42 7B 45 AE 9C D3 5B 7D 3F CF AE  
 5B 7D 43 7B 5E D3 9D 8C F4 DB 13 5D 1B 41 E2 B6  
 46 CE 85 7D 63 60 CC 3C C5 13 00 F1 9C 26 46 A3  
 68 C9 F4 D7 8F 18 5A 2D 03 51 B3 76 FE 9A 0E 6D  
 BF 8F A8 FD 7F D7 11 34 54 ED D4 9D 1F 53 45 90  
 69 AC C0 01 37 37 47 30 30 86 B5 81 65 DB E4 45  
 E0 E7 D6 4F 28 A3 E0 80 07 AA 7C B5 8D 7A 33 8F  
 71 1B 55 70 8B 4C 36 EA 61 D3 13 EE B4 F3 C5 41  
 40 86 6C 78 8D CD 22 A5 C3 9C 81 D4 B3 0A 5F AE  
 1E 60 28 D1 E3 5A FD A4 F7 A3 3B 46 53 BE 04 26  
 26 27 89 FB B3 CA 06 B9 A2 E1 6E 85 C6 1E BB 54  
 7A 50 60 9F 7C 51 80 37

After  $p$ 

F1 B2 6C 63 94 B2 D4 96 1C EE 12 41 8A CE 6A F9  
 95 DD 94 AC B3 D0 5E 11 F7 F3 EC EA CA 39 BD D5  
 9A EE 64 DC EA 1B DA F3 B5 11 24 6E 4B BF 3D D1  
 D8 37 06 C6 CC 63 E4 5C 68 F1 04 40 3C A7 89 D1  
 64 FA EB 47 0C AD 16 B4 E9 D0 36 10 35 6B E7 AF  
 F9 7D 44 ED FF BB 8E A0 41 52 B5 53 77 7E 4C 15  
 0E B8 B9 39 82 49 63 05 E6 C9 8B 60 0C 6B 03 CB  
 27 94 51 70 40 F0 73 EB 6A 1B F5 66 1E 0F 54 F9  
 0A 6E 91 C9 46 3D 6E A3 E2 A0 B0 E9 09 77 DA F9  
 59 A4 14 C8 90 0D AF B1 AE C3 9C 81 D4 B3 0A 5F  
 F5 93 7A 80 A1 44 8F 6B DC 8F EE 18 4D F9 12 98  
 E4 24 71 7F 56 D9 20 D7 E1 6E 85 C6 1E BB 54 A2  
 E0 8D 1E 14 D8 27 5F 14

After  $\pi$ 

F1 B2 6C 63 94 B2 D4 96 D8 37 06 C6 CC 63 E4 5C  
 0E B8 B9 39 82 49 63 05 59 A4 14 C8 90 0D AF B1  
 E0 8D 1E 14 D8 27 5F 14 F7 F3 EC EA CA 39 BD D5  
 E9 D0 36 10 35 6B E7 AF F9 7D 44 ED FF BB 8E A0  
 0A 6E 91 C9 46 3D 6E A3 E4 24 71 7F 56 D9 20 D7  
 1C EE 12 41 8A CE 6A F9 68 F1 04 40 3C A7 89 D1  
 B6 C9 8B 60 0C 6B 03 CB AE C3 9C 81 D4 B3 0A 5F  
 F5 93 7A 80 A1 44 8F 6B 9A EE 64 DC EA 1B DA F3  
 B5 11 24 6E 4B BF 3D D1 41 52 B5 53 77 7E 4C 15  
 E2 A0 B0 E9 09 77 DA F9 E1 6E 85 C6 1E BB 54 A2  
 95 DD 94 AC B3 D0 5E 11 64 FA EB 47 0C AD 16 B4  
 27 94 51 70 40 F0 73 EB 6A 1B F5 66 1E 0F 54 F9  
 DC 8F EE 18 4D F9 12 98

After  $\chi$

```
F7 3A D5 5A 96 BA D7 97 89 33 02 06 DC 67 68 EC
AE B1 B3 2D CA 6B 33 01 48 96 74 AB 94 9D 2F 33
E8 88 1C 90 90 66 7F 5C E7 DE AC 07 00 A9 B5 D5
EB D2 A7 10 35 6F 87 AC 1D 7D 24 DB EF 7B 8E F4
19 BD 1D 49 CE 1D F3 A3 EC 24 63 6F 63 9B 62 FD
8A E6 99 61 8A 86 68 F3 60 F3 10 C1 EC 37 81 C5
E7 D9 E9 60 2D 2F 86 EB A6 AF 9C C0 DE 39 6A CF
95 82 7E 80 95 65 0E 6B DA AC F5 CD DE 5B 9A F7
17 B1 24 C6 43 BE AF 39 40 1C B0 55 61 F6 48 17
F8 20 D0 F1 E9 77 50 A8 C4 7F 85 E4 1F 1F 71 A2
96 D9 84 9C F3 80 3F 5A 2C F1 4F 41 12 A2 12 A4
B3 10 5B 68 01 00 71 EB 6B 4B E5 C2 AC 0F 18 F8
BC AD 85 5B 41 D4 12 3C
```

After  $\iota$

```
FF BA D5 DA 96 BA D7 17 89 33 02 06 DC 67 68 EC
AE B1 B3 2D CA 6B 33 01 48 96 74 AB 94 9D 2F 33
E8 88 1C 90 90 66 7F 5C E7 DE AC 07 00 A9 B5 D5
EB D2 A7 10 35 6F 87 AC 1D 7D 24 DB EF 7B 8E F4
19 BD 1D 49 CE 1D F3 A3 EC 24 63 6F 63 9B 62 FD
8A E6 99 61 8A 86 68 F3 60 F3 10 C1 EC 37 81 C5
E7 D9 E9 60 2D 2F 86 EB A6 AF 9C C0 DE 39 6A CF
95 82 7E 80 95 65 0E 6B DA AC F5 CD DE 5B 9A F7
17 B1 24 C6 43 BE AF 39 40 1C B0 55 61 F6 48 17
F8 20 D0 F1 E9 77 50 A8 C4 7F 85 E4 1F 1F 71 A2
96 D9 84 9C F3 80 3F 5A 2C F1 4F 41 12 A2 12 A4
B3 10 5B 68 01 00 71 EB 6B 4B E5 C2 AC 0F 18 F8
BC AD 85 5B 41 D4 12 3C
```

After permutation

```
FF BA D5 DA 96 BA D7 17 89 33 02 06 DC 67 68 EC
AE B1 B3 2D CA 6B 33 01 48 96 74 AB 94 9D 2F 33
E8 88 1C 90 90 66 7F 5C E7 DE AC 07 00 A9 B5 D5
EB D2 A7 10 35 6F 87 AC 1D 7D 24 DB EF 7B 8E F4
19 BD 1D 49 CE 1D F3 A3 EC 24 63 6F 63 9B 62 FD
8A E6 99 61 8A 86 68 F3 60 F3 10 C1 EC 37 81 C5
E7 D9 E9 60 2D 2F 86 EB A6 AF 9C C0 DE 39 6A CF
95 82 7E 80 95 65 0E 6B DA AC F5 CD DE 5B 9A F7
17 B1 24 C6 43 BE AF 39 40 1C B0 55 61 F6 48 17
F8 20 D0 F1 E9 77 50 A8 C4 7F 85 E4 1F 1F 71 A2
96 D9 84 9C F3 80 3F 5A 2C F1 4F 41 12 A2 12 A4
B3 10 5B 68 01 00 71 EB 6B 4B E5 C2 AC 0F 18 F8
BC AD 85 5B 41 D4 12 3C
```

State (as lanes of integers)

[0, 0] = 17D7BA96DAD5BAFF  
 [1, 0] = EC6867DC06023389  
 [2, 0] = 01336BCA2DB3B1AE  
 [3, 0] = 332F9D94AB749648  
 [4, 0] = 5C7F6690901C88E8  
 [0, 1] = D5B5A90007ACDEE7  
 [1, 1] = AC876F3510A7D2EB  
 [2, 1] = F48E7BEFDB247D1D  
 [3, 1] = A3F31DCE491DBD19  
 [4, 1] = FD629B636F6324EC  
 [0, 2] = F368868A6199E68A  
 [1, 2] = C58137ECC110F360  
 [2, 2] = EB862F2D60E9D9E7  
 [3, 2] = CF6A39DEC09CAFA6  
 [4, 2] = 6B0E6595807E8295  
 [0, 3] = F79A5BDECDF5ACDA  
 [1, 3] = 39AFBE43C624B117  
 [2, 3] = 1748F66155B01C40  
 [3, 3] = A85077E9F1D020F8  
 [4, 3] = A2711F1FE4857FC4  
 [0, 4] = 5A3F80F39C84D996  
 [1, 4] = A412A212414FF12C  
 [2, 4] = EB710001685B10B3  
 [3, 4] = F8180FACC2E54B6B  
 [4, 4] = 3C12D4415B85ADBC

The hash value is

FF BA D5 DA 96 BA D7 17 89 33 02 06 DC 67 68 EC  
 AE B1 B3 2D CA 6B 33 01 48 96 74 AB

The message as bit string

110010100001101011011110100110

## XORed state (in bytes)

[illegible]

## XORed state (as lanes of integers)

```
[0, 0] = 000000001997B5853
[1, 0] = 00000000000000000
[2, 0] = 000000000000000000
[3, 0] = 000000000000000000
[4, 0] = 000000000000000000
[0, 1] = 000000000000000000
[1, 1] = 000000000000000000
[2, 1] = 000000000000000000
[3, 1] = 000000000000000000
[4, 1] = 000000000000000000
[0, 2] = 000000000000000000
[1, 2] = 000000000000000000
[2, 2] = 000000000000000000
[3, 2] = 000000000000000000
[4, 2] = 000000000000000000
[0, 3] = 000000000000000000
[1, 3] = 000000000000000000
[2, 3] = 800000000000000000
[3, 3] = 000000000000000000
[4, 3] = 000000000000000000
[0, 4] = 000000000000000000
[1, 4] = 000000000000000000
[2, 4] = 000000000000000000
[3, 4] = 000000000000000000
[4, 4] = 000000000000000000
```

## Round #0

After  $\theta$ 

```

53 58 7B 99 01 00 00 00 52 58 7B 99 01 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 80
A6 B0 F6 32 03 00 00 00 00 00 00 00 00 00 00
52 58 7B 99 01 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 80 A6 B0 F6 32 03 00 00 00
00 00 00 00 00 00 00 00 52 58 7B 99 01 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 80
A6 B0 F6 32 03 00 00 00 00 00 00 00 00 00 00
52 58 7B 99 01 00 00 00 00 00 00 00 00 80
00 00 00 00 00 00 00 80 A6 B0 F6 32 03 00 00 00
00 00 00 00 00 00 00 00 52 58 7B 99 01 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 80
A6 B0 F6 32 03 00 00 00

```

After  $\rho$ 

```

53 58 7B 99 01 00 00 00 A4 B0 F6 32 03 00 00 00
00 00 00 00 00 00 00 00 00 00 00 08 00 00 00
00 00 00 30 85 B5 97 19 00 00 00 00 00 00 00
97 19 00 00 00 20 85 B5 00 00 00 00 00 00 00
00 00 00 00 00 40 00 00 00 60 0A 6B 2F 33 00
00 00 00 00 00 00 00 00 00 48 61 ED 65 06 00 00
00 00 00 00 00 00 00 00 00 00 00 01 00 00 00
99 01 00 00 00 53 58 7B 00 00 00 00 00 00 00 00
2F 33 00 00 00 40 0A 6B 00 40 00 00 00 00 00 00
00 00 10 00 00 00 00 00 00 A6 B0 F6 32 03 00 00
00 00 00 00 00 00 00 00 48 61 ED 65 06 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 80 00
00 80 29 AC BD CC 00 00

```

After  $\pi$ 

```

53 58 7B 99 01 00 00 00 97 19 00 00 00 20 85 B5
00 00 00 00 00 00 00 00 00 00 10 00 00 00 00
00 80 29 AC BD CC 00 00 00 00 00 08 00 00 00 00
00 00 60 0A 6B 2F 33 00 00 00 00 00 00 00 00
2F 33 00 00 00 40 0A 6B 00 00 00 00 00 00 00
A4 B0 F6 32 03 00 00 00 00 00 00 00 00 00 00
00 00 00 01 00 00 00 00 00 A6 B0 F6 32 03 00 00
00 00 00 00 00 00 00 00 00 00 30 85 B5 97 19
00 00 00 00 00 00 00 00 00 48 61 ED 65 06 00 00
00 40 00 00 00 00 00 00 00 00 00 00 00 80 00
00 00 00 00 00 00 00 00 00 00 00 00 00 40 00
99 01 00 00 00 53 58 7B 00 00 00 00 00 00 00 00
48 61 ED 65 06 00 00 00

```



After  $\chi$

```

53 58 7B 99 01 00 00 00 97 19 10 00 00 20 85 B5
00 80 29 AC BD CC 00 00 53 58 42 11 00 00 00 00
84 81 29 AC BD EC 85 B5 00 00 00 08 00 00 00 00
2F 33 60 0A 6B 6F 39 6B 00 00 00 00 00 00 00 00
2F 33 00 08 00 40 0A 6B 00 00 60 02 6B 2F 33 00
A4 B0 F6 33 03 00 00 00 00 A6 B0 F6 32 03 00 00
00 00 00 01 00 00 00 00 A4 16 46 C4 31 03 00 00
00 00 00 00 00 00 00 00 00 48 61 DD E0 B3 97 19
00 00 00 00 00 00 00 00 00 48 61 ED 65 06 80 00
00 40 00 30 85 B5 17 19 00 00 00 00 00 00 80 00
99 01 00 00 00 53 18 7B 00 00 00 00 00 00 40 00
D1 60 ED 65 06 53 58 7B 00 00 00 00 00 00 00 00
48 61 ED 65 06 00 40 00

```

After  $\iota$

```

52 58 7B 99 01 00 00 00 97 19 10 00 00 20 85 B5
00 80 29 AC BD CC 00 00 53 58 42 11 00 00 00 00
84 81 29 AC BD EC 85 B5 00 00 00 08 00 00 00 00
2F 33 60 0A 6B 6F 39 6B 00 00 00 00 00 00 00 00
2F 33 00 08 00 40 0A 6B 00 00 60 02 6B 2F 33 00
A4 B0 F6 33 03 00 00 00 00 A6 B0 F6 32 03 00 00
00 00 00 01 00 00 00 00 A4 16 46 C4 31 03 00 00
00 00 00 00 00 00 00 00 00 48 61 DD E0 B3 97 19
00 00 00 00 00 00 00 00 00 48 61 ED 65 06 80 00
00 40 00 30 85 B5 17 19 00 00 00 00 00 00 80 00
99 01 00 00 00 53 18 7B 00 00 00 00 00 00 40 00
D1 60 ED 65 06 53 58 7B 00 00 00 00 00 00 00 00
48 61 ED 65 06 00 40 00

```

(Skip rounds 1 to 22)

Round #23

After  $\theta$ 

CE E6 EC 95 C4 F1 D8 BE 89 31 6B F4 37 BB C3 10  
 46 14 61 DF BC 87 EF 0F 7C 55 5A 24 86 54 37 D8  
 E0 AC 13 D8 C4 E5 DC 0C BC DD EA C7 B1 17 C3 F5  
 41 48 C6 E8 05 49 7A 33 D1 C3 AD 43 DF 01 5E E4  
 AF EA B8 23 BA 81 44 F2 56 FF D3 33 B8 A2 FF 0D  
 66 1F C1 21 27 77 E0 C1 ED D6 CD 84 64 57 02 47  
 4F 6C 0F 52 20 B9 70 E3 95 51 E1 60 70 06 90 DD  
 B2 8C 8D 91 20 D9 F9 1D 8A 76 62 3E 60 C1 97 44  
 37 A2 56 38 9C 16 44 AE FD 9C 49 06 FA 9C 97 F4  
 F7 3D FF 14 64 81 29 FA 0C 03 CB 10 7C 02 86 C2  
 E6 06 57 D7 E2 04 71 0E 66 BA 6D 70 70 41 C2 7E  
 40 7A 6A 65 1B F2 98 0C 22 EB 06 C8 20 08 1E B5  
 76 CB 0C 95 A6 57 FB B1

After  $\rho$ 

CE E6 EC 95 C4 F1 D8 BE 12 63 D6 E8 6F 76 87 21  
 11 45 D8 37 EF E1 FB 83 48 75 83 CD 57 A5 45 62  
 2E E7 66 00 67 9D C0 26 1C 7B 31 5C CF DB AD 7E  
 8C 5E 90 A4 37 13 84 64 79 F4 70 EB D0 77 80 17  
 75 DC 11 DD 40 22 F9 57 FA DF 60 F5 3F 3D 83 2B  
 36 FB 08 0E 39 B9 03 0F 1C B5 5B 37 13 92 5D 09  
 90 02 C9 85 1B 7F 62 7B 0C 20 BB 2B A3 C2 C1 E0  
 48 90 EC FC 0E 59 C6 C6 7C C0 82 2F 89 14 ED C4  
 0A 87 D3 82 C8 F5 46 D4 4B FA 7E CE 24 03 7D CE  
 30 45 FF BE E7 9F 82 2C C2 0C 03 CB 10 7C 02 86  
 C4 39 98 1B 5C 5D 8B 13 99 E9 B6 C1 C1 05 09 FB  
 48 4F AD 6C 43 1E 93 01 EB 06 C8 20 08 1E B5 22  
 7E AC DD 32 43 A5 E9 D5

After  $\pi$ 

CE E6 EC 95 C4 F1 D8 BE 8C 5E 90 A4 37 13 84 64  
 90 02 C9 85 1B 7F 62 7B 30 45 FF BE E7 9F 82 2C  
 7E AC DD 32 43 A5 E9 D5 48 75 83 CD 57 A5 45 62  
 FA DF 60 F5 3F 3D 83 2B 36 FB 08 0E 39 B9 03 0F  
 0A 87 D3 82 C8 F5 46 D4 48 4F AD 6C 43 1E 93 01  
 12 63 D6 E8 6F 76 87 21 79 F4 70 EB D0 77 80 17  
 0C 20 BB 2B A3 C2 C1 E0 C2 0C 03 CB 10 7C 02 86  
 C4 39 98 1B 5C 5D 8B 13 2E E7 66 00 67 9D C0 26  
 1C 7B 31 5C CF DB AD 7E 1C B5 5B 37 13 92 5D 09  
 4B FA 7E CE 24 03 7D CE EB 06 C8 20 08 1E B5 22  
 11 45 D8 37 EF E1 FB 83 75 DC 11 DD 40 22 F9 57  
 48 90 EC FC 0E 59 C6 C6 7C C0 82 2F 89 14 ED C4  
 99 E9 B6 C1 C1 05 09 FB

After  $\chi$

```
DE E6 A5 94 CC 9D BA A5 AC 1B A6 9E D3 93 04 60
DE AA C9 85 1B 5F 0B AA B0 07 DF 3B 63 CF 92 06
7E B4 CD 12 70 A7 ED 95 4C 55 8B C7 57 25 45 66
F2 DB B3 75 FF 79 C7 FB 76 B3 24 62 3A B3 92 0E
0A B7 D1 03 DC 54 02 B6 FA C5 CD 5C 6B 06 11 08
16 63 5D E8 4C F6 C6 C1 BB F8 70 2B C0 4B 82 11
08 11 23 3B EF C3 48 F1 D0 4E 45 2B 33 5E 06 A6
AD AD B8 18 CC 5C 8B 05 2E 63 2C 23 77 9D 90 27
5F 31 15 94 EB DA 8D B8 BC B1 DB 17 1B 8E DD 29
4F 1B 58 CE 43 82 3D CA FB 1E D9 7C 80 5C 98 7A
19 45 34 17 E1 B8 FD 03 41 9C 13 DE C1 26 D0 57
C9 B9 D8 3C 4E 58 C6 FD 7C C4 CA 19 A7 F4 1F C4
FD 71 B7 09 C1 07 09 AF
```

After  $\iota$

```
D6 66 A5 14 CC 9D BA 25 AC 1B A6 9E D3 93 04 60
DE AA C9 85 1B 5F 0B AA B0 07 DF 3B 63 CF 92 06
7E B4 CD 12 70 A7 ED 95 4C 55 8B C7 57 25 45 66
F2 DB B3 75 FF 79 C7 FB 76 B3 24 62 3A B3 92 0E
0A B7 D1 03 DC 54 02 B6 FA C5 CD 5C 6B 06 11 08
16 63 5D E8 4C F6 C6 C1 BB F8 70 2B C0 4B 82 11
08 11 23 3B EF C3 48 F1 D0 4E 45 2B 33 5E 06 A6
AD AD B8 18 CC 5C 8B 05 2E 63 2C 23 77 9D 90 27
5F 31 15 94 EB DA 8D B8 BC B1 DB 17 1B 8E DD 29
4F 1B 58 CE 43 82 3D CA FB 1E D9 7C 80 5C 98 7A
19 45 34 17 E1 B8 FD 03 41 9C 13 DE C1 26 D0 57
C9 B9 D8 3C 4E 58 C6 FD 7C C4 CA 19 A7 F4 1F C4
FD 71 B7 09 C1 07 09 AF
```

After permutation

```
D6 66 A5 14 CC 9D BA 25 AC 1B A6 9E D3 93 04 60
DE AA C9 85 1B 5F 0B AA B0 07 DF 3B 63 CF 92 06
7E B4 CD 12 70 A7 ED 95 4C 55 8B C7 57 25 45 66
F2 DB B3 75 FF 79 C7 FB 76 B3 24 62 3A B3 92 0E
0A B7 D1 03 DC 54 02 B6 FA C5 CD 5C 6B 06 11 08
16 63 5D E8 4C F6 C6 C1 BB F8 70 2B C0 4B 82 11
08 11 23 3B EF C3 48 F1 D0 4E 45 2B 33 5E 06 A6
AD AD B8 18 CC 5C 8B 05 2E 63 2C 23 77 9D 90 27
5F 31 15 94 EB DA 8D B8 BC B1 DB 17 1B 8E DD 29
4F 1B 58 CE 43 82 3D CA FB 1E D9 7C 80 5C 98 7A
19 45 34 17 E1 B8 FD 03 41 9C 13 DE C1 26 D0 57
C9 B9 D8 3C 4E 58 C6 FD 7C C4 CA 19 A7 F4 1F C4
FD 71 B7 09 C1 07 09 AF
```

State (as lanes of integers)

[0, 0] = 25BA9DCC14A566D6  
 [1, 0] = 600493D39EA61BAC  
 [2, 0] = AA0B5F1B85C9AADE  
 [3, 0] = 0692CF633BDF07B0  
 [4, 0] = 95EDA77012CDB47E  
 [0, 1] = 66452557C78B554C  
 [1, 1] = FBC779FF75B3DBF2  
 [2, 1] = 0E92B33A6224B376  
 [3, 1] = B60254DC03D1B70A  
 [4, 1] = 0811066B5CCDC5FA  
 [0, 2] = C1C6F64CE85D6316  
 [1, 2] = 11824BC02B70F8BB  
 [2, 2] = F148C3EF3B231108  
 [3, 2] = A6065E332B454ED0  
 [4, 2] = 058B5CCC18B8ADAD  
 [0, 3] = 27909D77232C632E  
 [1, 3] = B88DDAEB9415315F  
 [2, 3] = 29DD8E1B17DBB1BC  
 [3, 3] = CA3D8243CE581B4F  
 [4, 3] = 7A985C807CD91EFB  
 [0, 4] = 03FDB8E117344519  
 [1, 4] = 57D026C1DE139C41  
 [2, 4] = FDC6584E3CD8B9C9  
 [3, 4] = C41FF4A719CAC47C  
 [4, 4] = AF0907C109B771FD

The hash value is

D6 66 A5 14 CC 9D BA 25 AC 1B A6 9E D3 93 04 60  
 DE AA C9 85 1B 5F 0B AA B0 07 DF 3B

## B.15 Dedicated Hash-Function 14 (SHA3-256)

NOTE 1 Data is presented in three different ways: bit strings, byte strings and w-length words (for the lanes).

NOTE 2 Bit strings are the sequence of bits from left to right.

NOTE 3 Byte strings are the bytes from left to right and the bits within the byte are right to left.

NOTE 4 Words are the integer representation of the values in the lanes.

The message as bit string

(empty message)

## XORed state (in bytes)

[illegible]

XORed state (as lanes of integers)

$[0, 0] = 00000000000000000006$   
 $[1, 0] = 00000000000000000000$   
 $[2, 0] = 00000000000000000000$   
 $[3, 0] = 00000000000000000000$   
 $[4, 0] = 00000000000000000000$   
 $[0, 1] = 00000000000000000000$   
 $[1, 1] = 00000000000000000000$   
 $[2, 1] = 00000000000000000000$   
 $[3, 1] = 00000000000000000000$   
 $[4, 1] = 00000000000000000000$   
 $[0, 2] = 00000000000000000000$   
 $[1, 2] = 00000000000000000000$   
 $[2, 2] = 00000000000000000000$   
 $[3, 2] = 00000000000000000000$   
 $[4, 2] = 00000000000000000000$   
 $[0, 3] = 00000000000000000000$   
 $[1, 3] = 80000000000000000000$   
 $[2, 3] = 00000000000000000000$   
 $[3, 3] = 00000000000000000000$   
 $[4, 3] = 00000000000000000000$   
 $[0, 4] = 00000000000000000000$   
 $[1, 4] = 00000000000000000000$   
 $[2, 4] = 00000000000000000000$   
 $[3, 4] = 00000000000000000000$   
 $[4, 4] = 00000000000000000000$

## Round #0

After  $\theta$ 

```

07 00 00 00 00 00 00 00 06 00 00 00 00 00 00 00
00 00 00 00 00 00 00 80 00 00 00 00 00 00 00
0C 00 00 00 00 00 00 00 01 00 00 00 00 00 00
06 00 00 00 00 00 00 00 00 00 00 00 00 00 80
00 00 00 00 00 00 00 00 0C 00 00 00 00 00 00
01 00 00 00 00 00 00 00 06 00 00 00 00 00 00
00 00 00 00 00 00 80 00 00 00 00 00 00 00
0C 00 00 00 00 00 00 00 01 00 00 00 00 00 00
06 00 00 00 00 00 80 00 00 00 00 00 00 80
00 00 00 00 00 00 00 00 0C 00 00 00 00 00 00
01 00 00 00 00 00 00 00 06 00 00 00 00 00 00
00 00 00 00 00 00 80 00 00 00 00 00 00 00
      0C 00 00 00 00 00 00 00

```

After  $\rho$ 

```

07 00 00 00 00 00 00 00 0C 00 00 00 00 00 00
00 00 00 00 00 00 00 20 00 00 00 00 00 00
00 00 00 60 00 00 00 00 00 00 00 00 10 00 00
00 00 00 00 00 60 00 00 20 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00
08 00 00 00 00 00 00 00 18 00 00 00 00 00
00 00 00 00 00 04 00 00 00 00 00 00 00 00
00 00 00 00 00 06 00 00 00 00 00 00 02 00
00 00 00 00 00 D0 00 00 40 00 00 00 00 00
00 00 00 00 00 00 00 00 0C 00 00 00 00 00
00 00 04 00 00 00 00 00 18 00 00 00 00 00
00 00 00 00 00 00 00 10 00 00 00 00 00 00
      00 00 03 00 00 00 00 00

```

After  $\pi$ 

```

07 00 00 00 00 00 00 00 00 00 00 00 60 00 00
00 00 00 00 00 04 00 00 00 00 00 00 00 00
00 00 03 00 00 00 00 00 00 00 00 00 00 00
00 00 C0 00 00 00 00 00 08 00 00 00 00 00
00 00 00 00 00 D0 00 00 00 00 00 00 00 10
0C 00 00 00 00 00 00 00 20 00 00 00 00 00
00 00 00 00 00 00 00 00 00 0C 00 00 00 00
00 00 04 00 00 00 00 00 00 00 60 00 00 00
00 00 00 00 10 00 00 00 00 18 00 00 00 00
00 40 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 20 00 00 00 00 00 00 00
00 00 00 00 00 06 00 00 00 00 00 00 02 00
      18 00 00 00 00 00 00 00

```

After  $\chi$

```

07 00 00 00 00 04 00 00 00 00 00 00 00 60 00 00
00 00 03 00 00 04 00 00 07 00 00 00 00 00 00 00
00 00 03 00 00 60 00 00 08 00 00 00 00 00 00 00
00 00 C0 00 00 D0 00 00 08 00 00 00 00 00 00 10
00 00 00 00 00 D0 00 00 00 00 C0 00 00 00 00 10
0C 00 00 00 00 00 00 00 20 0C 00 00 00 00 00 00
00 00 04 00 00 00 00 00 0C 0C 00 00 00 00 00 00
20 00 04 00 00 00 00 00 00 18 00 60 00 00 00 00
00 40 00 00 10 00 00 00 00 18 00 00 00 00 00 00
00 40 00 60 00 00 00 00 00 00 00 00 10 00 00 00
00 00 00 00 00 06 00 20 00 00 00 00 00 00 00 00
18 00 00 00 00 06 00 00 00 00 00 00 00 02 00 20
18 00 00 00 00 00 00 00 00

```

After  $\iota$

```

06 00 00 00 00 04 00 00 00 00 00 00 00 60 00 00
00 00 03 00 00 04 00 00 07 00 00 00 00 00 00 00
00 00 03 00 00 60 00 00 08 00 00 00 00 00 00 00
00 00 C0 00 00 D0 00 00 08 00 00 00 00 00 00 10
00 00 00 00 00 D0 00 00 00 00 C0 00 00 00 00 10
0C 00 00 00 00 00 00 00 20 0C 00 00 00 00 00 00
00 00 04 00 00 00 00 00 0C 0C 00 00 00 00 00 00
20 00 04 00 00 00 00 00 00 18 00 60 00 00 00 00
00 40 00 00 10 00 00 00 00 18 00 00 00 00 00 00
00 40 00 60 00 00 00 00 00 00 00 00 10 00 00 00
00 00 00 00 00 06 00 20 00 00 00 00 00 00 00 00
18 00 00 00 00 06 00 00 00 00 00 00 00 02 00 20
18 00 00 00 00 00 00 00 00

```

(Skip rounds 1 to 22)

Round #23



After  $\theta$ 

0B 59 CE D1 EF 06 FE FE 38 5F F6 8E 93 9E 40 E5  
 5C 66 DE 34 99 D3 D8 DF 14 D8 1D F8 4A 47 49 28  
 15 4F 96 4D 0E 22 B1 D5 B4 62 AC E5 B1 0B AD 03  
 0A 6D B6 05 78 44 B5 5A 5E 88 06 49 2D E1 CA CF  
 17 B9 7C 0D 52 BF BE CA 53 F7 B5 93 4F 90 44 7B  
 23 24 0F FF BE F7 13 6A 20 81 F5 70 53 F7 98 2E  
 27 5F AB DE 54 A9 1F 3A 59 23 6F 17 94 8D 53 92  
 B1 16 1C B0 07 E9 00 04 A9 4B 50 26 B1 5C D7 A3  
 67 21 C4 76 20 9F C7 C0 55 30 C6 37 91 76 45 95  
 5A 58 E2 7F B2 5A 0C 56 0A C2 D2 F7 03 FC DB 89  
 6B BB A0 28 1A 30 B3 50 AB D5 DE D6 45 89 84 46  
 03 A7 B8 A6 97 C5 08 C3 99 28 E1 5B 2E 90 19 BD  
 FF CE D2 28 CF 8B 0B 98

After  $p$ 

0B 59 CE D1 EF 06 FE FE 71 BE EC 1D 27 3D 81 CA  
 97 99 37 4D E6 34 F6 37 74 94 84 42 81 DD 81 AF  
 10 89 AD AE 78 B2 6C 72 1E BB D0 3A 40 2B C6 5A  
 5B 80 47 54 AB A5 D0 66 B3 17 A2 41 52 4B B8 F2  
 5C BE 06 A9 5F 5F E5 8B 49 B4 37 75 5F 3B F9 04  
 1B 21 79 F8 F7 BD 9F 50 BA 80 04 D6 C3 4D DD 63  
 F5 A6 4A FD D0 39 F9 5A 4B A7 24 B3 46 DE 2E 28  
 D8 83 74 00 82 58 0B 0E 4C 62 B9 AE 47 53 97 A0  
 D8 0E E4 F3 18 F8 2C 84 A2 CA 2A 18 E3 9B 48 BB  
 8B C1 4A 0B 4B FC 4F 56 89 0A C2 D2 F7 03 FC DB  
 CC 42 AD ED 82 A2 68 C0 AD 56 7B 5B 17 25 12 1A  
 E0 14 D7 F4 B2 18 61 78 28 E1 5B 2E 90 19 BD 99  
 02 E6 BF B3 34 CA F3 E2

After  $\pi$ 

0B 59 CE D1 EF 06 FE FE 5B 80 47 54 AB A5 D0 66  
 F5 A6 4A FD D0 39 F9 5A 8B C1 4A 0B 4B FC 4F 56  
 02 E6 BF B3 34 CA F3 E2 74 94 84 42 81 DD 81 AF  
 49 B4 37 75 5F 3B F9 04 1B 21 79 F8 F7 BD 9F 50  
 D8 0E E4 F3 18 F8 2C 84 E0 14 D7 F4 B2 18 61 78  
 71 BE EC 1D 27 3D 81 CA B3 17 A2 41 52 4B B8 F2  
 1B A7 24 B3 46 DE 2E 28 89 0A C2 D2 F7 03 FC DB  
 CC 42 AD ED 82 A2 68 C0 10 89 AD AE 78 B2 6C 72  
 1E BB D0 3A 40 2B C6 5A BA 80 04 D6 C3 4D DD 63  
 A2 CA 2A 18 E3 9B 48 BB 28 E1 5B 2E 90 19 BD 99  
 97 99 37 4D E6 34 F6 37 5C BE 06 A9 5F 5F E5 8B  
 D8 83 74 00 82 58 0B 0E 4C 62 B9 AE 47 53 97 A0  
 AD 56 7B 5B 17 25 12 1A

After  $\chi$

```

AF 7F C6 78 BF 1E D7 E6 51 C1 47 56 A0 61 D6 62
F5 80 FF 4D E4 3B 49 FA 82 D8 0A 4B 80 F8 43 4A
52 66 BE B7 34 6B F3 E2 66 95 CC CA 21 59 87 FF
89 BA B3 76 57 7B D9 80 3B 31 6A FC 55 BD DE 28
CC 8E E4 F1 19 3D AC 03 E9 34 E4 C1 EC 3A 19 78
79 1E E8 AF 23 A9 87 C2 33 1F 60 01 E3 4A 68 21
5F E7 09 9E 46 7E 2E 28 B8 B6 82 C2 D2 1E 7D D1
4E 43 AF AD D2 E0 50 F0 B0 89 A9 6A FB F6 75 53
1E F1 FA 32 60 B9 C6 C2 B2 A1 55 F0 D3 4D 68 63
B2 C2 8E 98 8B 39 08 D9 26 D3 0B 3E 90 10 3F 91
17 98 47 4D 66 34 FC 33 58 DE 8F 07 1A 5C 71 2B
79 97 36 51 92 7C 0B 14 5E EB BD AA A7 43 73 85
E5 70 7B FB 0E 6E 13 92

```

After  $\iota$

```

A7 FF C6 F8 BF 1E D7 66 51 C1 47 56 A0 61 D6 62
F5 80 FF 4D E4 3B 49 FA 82 D8 0A 4B 80 F8 43 4A
52 66 BE B7 34 6B F3 E2 66 95 CC CA 21 59 87 FF
89 BA B3 76 57 7B D9 80 3B 31 6A FC 55 BD DE 28
CC 8E E4 F1 19 3D AC 03 E9 34 E4 C1 EC 3A 19 78
79 1E E8 AF 23 A9 87 C2 33 1F 60 01 E3 4A 68 21
5F E7 09 9E 46 7E 2E 28 B8 B6 82 C2 D2 1E 7D D1
4E 43 AF AD D2 E0 50 F0 B0 89 A9 6A FB F6 75 53
1E F1 FA 32 60 B9 C6 C2 B2 A1 55 F0 D3 4D 68 63
B2 C2 8E 98 8B 39 08 D9 26 D3 0B 3E 90 10 3F 91
17 98 47 4D 66 34 FC 33 58 DE 8F 07 1A 5C 71 2B
79 97 36 51 92 7C 0B 14 5E EB BD AA A7 43 73 85
E5 70 7B FB 0E 6E 13 92

```

After permutation

```

A7 FF C6 F8 BF 1E D7 66 51 C1 47 56 A0 61 D6 62
F5 80 FF 4D E4 3B 49 FA 82 D8 0A 4B 80 F8 43 4A
52 66 BE B7 34 6B F3 E2 66 95 CC CA 21 59 87 FF
89 BA B3 76 57 7B D9 80 3B 31 6A FC 55 BD DE 28
CC 8E E4 F1 19 3D AC 03 E9 34 E4 C1 EC 3A 19 78
79 1E E8 AF 23 A9 87 C2 33 1F 60 01 E3 4A 68 21
5F E7 09 9E 46 7E 2E 28 B8 B6 82 C2 D2 1E 7D D1
4E 43 AF AD D2 E0 50 F0 B0 89 A9 6A FB F6 75 53
1E F1 FA 32 60 B9 C6 C2 B2 A1 55 F0 D3 4D 68 63
B2 C2 8E 98 8B 39 08 D9 26 D3 0B 3E 90 10 3F 91
17 98 47 4D 66 34 FC 33 58 DE 8F 07 1A 5C 71 2B
79 97 36 51 92 7C 0B 14 5E EB BD AA A7 43 73 85
E5 70 7B FB 0E 6E 13 92

```

State (as lanes of integers)

[0, 0] = 66D71EBFF8C6FFA7  
 [1, 0] = 62D661A05647C151  
 [2, 0] = FA493BE44DFF80F5  
 [3, 0] = 4A43F8804B0AD882  
 [4, 0] = E2F36B34B7BE6652  
 [0, 1] = FF875921CACC9566  
 [1, 1] = 80D97B5776B3BA89  
 [2, 1] = 28DEBD55FC6A313B  
 [3, 1] = 03AC3D19F1E48ECC  
 [4, 1] = 78193AECC1E434E9  
 [0, 2] = C287A923AFE81E79  
 [1, 2] = 21684AE301601F33  
 [2, 2] = 282E7E469E09E75F  
 [3, 2] = D17D1ED2C282B6B8  
 [4, 2] = F050E0D2ADAF434E  
 [0, 3] = 5375F6FB6AA989B0  
 [1, 3] = C2C6B96032FAF11E  
 [2, 3] = 63684DD3F055A1B2  
 [3, 3] = D908398B988EC2B2  
 [4, 3] = 913F10903E0BD326  
 [0, 4] = 33FC34664D479817  
 [1, 4] = 2B715C1A078FDE58  
 [2, 4] = 140B7C9251369779  
 [3, 4] = 857343A7AABDEB5E  
 [4, 4] = 92136E0EFB7B70E5

The hash value is

A7 FF C6 F8 ... 80 F8 43 4A

The message as bit string

1 1 0 0 1

## XORed state (in bytes)

|    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| D3 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| 00 | 00 | 00 | 00 | 00 | 00 | 00 | 80 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
|    |    |    |    | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |    |    |    |    |    |

XORed state (as lanes of integers)

```
[0, 0] = 00000000000000000000
[1, 0] = 00000000000000000000
[2, 0] = 00000000000000000000
[3, 0] = 00000000000000000000
[4, 0] = 00000000000000000000
[0, 1] = 00000000000000000000
[1, 1] = 00000000000000000000
[2, 1] = 00000000000000000000
[3, 1] = 00000000000000000000
[4, 1] = 00000000000000000000
[0, 2] = 00000000000000000000
[1, 2] = 00000000000000000000
[2, 2] = 00000000000000000000
[3, 2] = 00000000000000000000
[4, 2] = 00000000000000000000
[0, 3] = 00000000000000000000
[1, 3] = 80000000000000000000
[2, 3] = 00000000000000000000
[3, 3] = 00000000000000000000
[4, 3] = 00000000000000000000
[0, 4] = 00000000000000000000
[1, 4] = 00000000000000000000
[2, 4] = 00000000000000000000
[3, 4] = 00000000000000000000
[4, 4] = 00000000000000000000
```

## Round #0

After  $\theta$ 

```

D2 00 00 00 00 00 00 00 00 D3 00 00 00 00 00 00 00
00 00 00 00 00 00 00 80 00 00 00 00 00 00 00 00
A6 01 00 00 00 00 00 00 01 00 00 00 00 00 00 00
D3 00 00 00 00 00 00 00 00 00 00 00 00 00 00 80
00 00 00 00 00 00 00 00 A6 01 00 00 00 00 00 00
01 00 00 00 00 00 00 00 D3 00 00 00 00 00 00 00
00 00 00 00 00 00 00 80 00 00 00 00 00 00 00 00
A6 01 00 00 00 00 00 00 01 00 00 00 00 00 00 00
D3 00 00 00 00 00 00 80 00 00 00 00 00 00 00 80
00 00 00 00 00 00 00 00 A6 01 00 00 00 00 00 00
01 00 00 00 00 00 00 00 D3 00 00 00 00 00 00 00
00 00 00 00 00 00 00 80 00 00 00 00 00 00 00 00
A6 01 00 00 00 00 00 00

```

After  $\rho$ 

```

D2 00 00 00 00 00 00 00 A6 01 00 00 00 00 00 00
00 00 00 00 00 00 00 20 00 00 00 00 00 00 00 00
00 00 00 30 0D 00 00 00 00 00 00 00 00 10 00 00 00
00 00 00 00 00 30 0D 00 20 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 60 1A 00 00 00 00 00
08 00 00 00 00 00 00 00 00 4C 03 00 00 00 00 00
00 00 00 00 00 04 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 D3 00 00 00 00 00 00 00 02 00 00
00 00 00 00 00 70 1A 00 00 40 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 A6 01 00 00 00 00 00
00 00 04 00 00 00 00 00 4C 03 00 00 00 00 00 00
00 00 00 00 00 00 00 10 00 00 00 00 00 00 00 00
00 80 69 00 00 00 00 00

```

After  $\pi$ 

```

D2 00 00 00 00 00 00 00 00 00 00 00 00 30 0D 00
00 00 00 00 00 04 00 00 00 00 00 00 00 00 00 00
00 80 69 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 60 1A 00 00 00 00 08 00 00 00 00 00 00 00
00 00 00 00 00 70 1A 00 00 00 00 00 00 00 10
A6 01 00 00 00 00 00 00 20 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 A6 01 00 00 00 00 00
00 00 04 00 00 00 00 00 00 00 30 0D 00 00 00
00 00 00 00 10 00 00 00 00 4C 03 00 00 00 00 00
00 40 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 20 00 00 00 00 00 00 00 00
00 00 00 00 00 D3 00 00 00 00 00 00 00 02 00 00
4C 03 00 00 00 00 00 00

```

After  $\chi$

```

D2 00 00 00 00 04 00 00 00 00 00 00 00 00 30 0D 00
00 80 69 00 00 04 00 00 D2 00 00 00 00 00 00 00 00
00 80 69 00 00 30 0D 00 08 00 00 00 00 00 00 00 00
00 00 60 1A 00 70 1A 00 08 00 00 00 00 00 00 00 10
00 00 00 00 00 70 1A 00 00 00 60 1A 00 00 00 00 10
A6 01 00 00 00 00 00 00 20 A6 01 00 00 00 00 00 00
00 00 04 00 00 00 00 00 A6 A7 01 00 00 00 00 00 00
00 00 04 00 00 00 00 00 00 4C 03 30 0D 00 00 00 00
00 00 00 00 10 00 00 00 00 4C 03 00 00 00 00 00 00
00 40 00 30 0D 00 00 00 00 00 00 00 00 10 00 00 00
00 00 00 00 00 D3 00 20 00 00 00 00 00 00 00 00 00
4C 03 00 00 00 D3 00 00 00 00 00 00 00 02 00 20
4C 03 00 00 00 00 00 00 00

```

After  $\iota$

```

D3 00 00 00 00 04 00 00 00 00 00 00 00 00 30 0D 00
00 80 69 00 00 04 00 00 D2 00 00 00 00 00 00 00 00
00 80 69 00 00 30 0D 00 08 00 00 00 00 00 00 00 00
00 00 60 1A 00 70 1A 00 08 00 00 00 00 00 00 00 10
00 00 00 00 00 70 1A 00 00 00 60 1A 00 00 00 00 10
A6 01 00 00 00 00 00 00 20 A6 01 00 00 00 00 00 00
00 00 04 00 00 00 00 00 A6 A7 01 00 00 00 00 00 00
00 00 04 00 00 00 00 00 00 4C 03 30 0D 00 00 00 00
00 00 00 00 10 00 00 00 00 4C 03 00 00 00 00 00 00
00 40 00 30 0D 00 00 00 00 00 00 00 00 10 00 00 00
00 00 00 00 00 D3 00 20 00 00 00 00 00 00 00 00 00
4C 03 00 00 00 D3 00 00 00 00 00 00 00 02 00 20
4C 03 00 00 00 00 00 00 00

```

(Skip rounds 1 to 22)

Round #23

After  $\theta$

7A C0 47 4F 5A 45 7C 12 42 CB B4 2E FF 7C AF 1E  
 F9 70 2C D1 F8 A9 DE FA D1 44 4E E0 1F 81 9D 0C  
 81 AA 52 B4 7E BF C1 1B 0D E4 68 B7 A9 C6 EB B5  
 BC E6 66 DB F3 DF 5A AD 8F B8 18 FD 1A 68 07 B4  
 D9 A1 B5 E4 D2 ED 8D A5 AF 1A 1A 58 DA C4 F4 03  
 C7 78 B0 28 86 98 71 6A C8 4B AC EF E9 A2 D9 8C  
 C8 C6 23 87 6A A6 01 12 06 EF 64 77 5F A0 70 79  
 3F 1F C3 B3 68 88 AE 9A A3 82 63 1C 8B 11 6F BD  
 A9 AD 0F A7 D9 91 1D CD B4 C3 93 CA 5F 50 57 A5  
 3B AD CF FC FB 0D 0D 9A 9A 24 AE D5 6C 72 0C E7  
 A3 2A 29 68 41 8B 00 C9 71 66 43 5D D7 29 F6 23  
 60 99 F4 D9 38 70 BB E1 CE E8 1D 04 91 97 41 0D  
 5A AE 78 3E 56 2D 77 83

After  $p$

7A C0 47 4F 5A 45 7C 12 84 96 69 5D FE F9 5E 3D  
 3E 1C 4B 34 7E AA B7 7E 11 D8 C9 10 4D E4 04 FE  
 FB 0D DE 08 54 95 A2 F5 9B 6A BC 5E DB 40 8E 76  
 B6 3D FF AD D5 CA 6B 6E ED 23 2E 46 BF 06 DA 01  
 D0 5A 72 E9 F6 C6 D2 EC 4C 3F F0 AA A1 81 A5 4D  
 3B C6 83 45 31 C4 8C 53 33 22 2F B1 BE A7 8B 66  
 39 54 33 0D 90 40 36 1E 40 E1 F2 0C DE C9 EE BE  
 59 34 44 57 CD 9F 8F E1 38 16 23 DE 7A 47 05 C7  
 E1 34 3B B2 A3 39 B5 F5 AB 52 DA E1 49 E5 2F A8  
 A1 41 73 A7 F5 99 7F BF E7 9A 24 AE D5 6C 72 0C  
 02 24 8F AA A4 A0 05 2D C4 99 0D 75 5D A7 D8 8F  
 2C 93 3E 1B 07 6E 37 1C E8 1D 04 91 97 41 0D CE  
 DD A0 96 2B 9E 8F 55 CB

After  $\pi$

7A C0 47 4F 5A 45 7C 12 B6 3D FF AD D5 CA 6B 6E  
 39 54 33 0D 90 40 36 1E A1 41 73 A7 F5 99 7F BF  
 DD A0 96 2B 9E 8F 55 CB 11 D8 C9 10 4D E4 04 FE  
 4C 3F F0 AA A1 81 A5 4D 3B C6 83 45 31 C4 8C 53  
 E1 34 3B B2 A3 39 B5 F5 2C 93 3E 1B 07 6E 37 1C  
 84 96 69 5D FE F9 5E 3D ED 23 2E 46 BF 06 DA 01  
 40 E1 F2 0C DE C9 EE BE E7 9A 24 AE D5 6C 72 0C  
 02 24 8F AA A4 A0 05 2D FB 0D DE 08 54 95 A2 F5  
 9B 6A BC 5E DB 40 8E 76 33 22 2F B1 BE A7 8B 66  
 AB 52 DA E1 49 E5 2F A8 E8 1D 04 91 97 41 0D CE  
 3E 1C 4B 34 7E AA B7 7E D0 5A 72 E9 F6 C6 D2 EC  
 59 34 44 57 CD 9F 8F E1 38 16 23 DE 7A 47 05 C7  
 C4 99 0D 75 5D A7 D8 8F



After  $\chi$

```

73 80 47 4F 5A 45 68 02 36 3C BF 0F B0 53 22 CF
65 F4 B7 05 9A 46 36 5E 83 01 32 E3 B5 D9 57 AF
59 9D 2E 8B 1B 05 56 A7 22 18 CA 55 5D A0 0C EC
8C 0F C8 18 23 B8 94 E9 37 45 87 4C 35 82 8E 5B
F0 7C FA B2 EB B9 B5 17 60 B4 0E B1 A7 6F 96 1D
84 56 B9 55 BE 30 7A 83 4A 39 2A E4 BE 22 CA 01
40 C5 79 0C FE 49 EB 9F 63 08 44 FB 8F 35 28 1C
6B 05 89 A8 A5 A6 85 2D DB 0D DD A9 70 32 A3 F5
13 3A 6C 1E 9A 00 AA FE 73 2F 2B A1 28 A7 8B 20
B8 52 00 E9 09 71 8D 99 E8 7F 24 C7 1C 01 01 CC
37 38 4F 22 77 B3 BA 7F F0 58 51 61 C4 86 D2 EA
9D BD 48 76 C8 3F 57 E9 02 12 61 DE 58 4F 22 B7
04 DB 3D BC DD E3 98 0F

```

After  $\iota$

```

7B 00 47 CF 5A 45 68 82 36 3C BF 0F B0 53 22 CF
65 F4 B7 05 9A 46 36 5E 83 01 32 E3 B5 D9 57 AF
59 9D 2E 8B 1B 05 56 A7 22 18 CA 55 5D A0 0C EC
8C 0F C8 18 23 B8 94 E9 37 45 87 4C 35 82 8E 5B
F0 7C FA B2 EB B9 B5 17 60 B4 0E B1 A7 6F 96 1D
84 56 B9 55 BE 30 7A 83 4A 39 2A E4 BE 22 CA 01
40 C5 79 0C FE 49 EB 9F 63 08 44 FB 8F 35 28 1C
6B 05 89 A8 A5 A6 85 2D DB 0D DD A9 70 32 A3 F5
13 3A 6C 1E 9A 00 AA FE 73 2F 2B A1 28 A7 8B 20
B8 52 00 E9 09 71 8D 99 E8 7F 24 C7 1C 01 01 CC
37 38 4F 22 77 B3 BA 7F F0 58 51 61 C4 86 D2 EA
9D BD 48 76 C8 3F 57 E9 02 12 61 DE 58 4F 22 B7
04 DB 3D BC DD E3 98 0F

```

After permutation

```

7B 00 47 CF 5A 45 68 82 36 3C BF 0F B0 53 22 CF
65 F4 B7 05 9A 46 36 5E 83 01 32 E3 B5 D9 57 AF
59 9D 2E 8B 1B 05 56 A7 22 18 CA 55 5D A0 0C EC
8C 0F C8 18 23 B8 94 E9 37 45 87 4C 35 82 8E 5B
F0 7C FA B2 EB B9 B5 17 60 B4 0E B1 A7 6F 96 1D
84 56 B9 55 BE 30 7A 83 4A 39 2A E4 BE 22 CA 01
40 C5 79 0C FE 49 EB 9F 63 08 44 FB 8F 35 28 1C
6B 05 89 A8 A5 A6 85 2D DB 0D DD A9 70 32 A3 F5
13 3A 6C 1E 9A 00 AA FE 73 2F 2B A1 28 A7 8B 20
B8 52 00 E9 09 71 8D 99 E8 7F 24 C7 1C 01 01 CC
37 38 4F 22 77 B3 BA 7F F0 58 51 61 C4 86 D2 EA
9D BD 48 76 C8 3F 57 E9 02 12 61 DE 58 4F 22 B7
04 DB 3D BC DD E3 98 0F

```

State (as lanes of integers)

[0, 0] = 8268455acf47007b  
 [1, 0] = cf2253b00fbf3c36  
 [2, 0] = 5e36469a05b7f465  
 [3, 0] = af57d9b5e3320183  
 [4, 0] = a756051b8b2e9d59  
 [0, 1] = ec0ca05d55ca1822  
 [1, 1] = e994b82318c80f8c  
 [2, 1] = 5b8e82354c874537  
 [3, 1] = 17b5b9ebb2fa7cf0  
 [4, 1] = 1d966fa7b10eb460  
 [0, 2] = 837a30be55b95684  
 [1, 2] = 01ca22bee42a394a  
 [2, 2] = 9feb49fe0c79c540  
 [3, 2] = 1c28358ffb440863  
 [4, 2] = 2d85a6a5a889056b  
 [0, 3] = f5a33270a9dd0ddb  
 [1, 3] = feaa009a1e6c3a13  
 [2, 3] = 208ba728a12b2f73  
 [3, 3] = 998d7109e90052b8  
 [4, 3] = cc01011cc7247fe8  
 [0, 4] = 7fbab377224f3837  
 [1, 4] = ead286c4615158f0  
 [2, 4] = e9573fc87648bd9d  
 [3, 4] = b7224f58de611202  
 [4, 4] = 0f98e3ddbc3ddb04

The hash value is

7B 00 47 CF 5A 45 68 82 36 3C BF 0F B0 53 22 CF  
 65 F4 B7 05 9A 46 36 5E 83 01 32 E3 B5 D9 57 AF

The message as bit string

110010100001101011011110100110

## XORed state (in bytes)

```

53 58 7B 99 01 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 80 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00

```

## XORed state (as lanes of integers)

```

[0,0] = 00000001997B5853
[1,0] = 0000000000000000
[2,0] = 0000000000000000
[3,0] = 0000000000000000
[4,0] = 0000000000000000
[0,1] = 0000000000000000
[1,1] = 0000000000000000
[2,1] = 0000000000000000
[3,1] = 0000000000000000
[4,1] = 0000000000000000
[0,2] = 0000000000000000
[1,2] = 0000000000000000
[2,2] = 0000000000000000
[3,2] = 0000000000000000
[4,2] = 0000000000000000
[0,3] = 0000000000000000
[1,3] = 8000000000000000
[2,3] = 0000000000000000
[3,3] = 0000000000000000
[4,3] = 0000000000000000
[0,4] = 0000000000000000
[1,4] = 0000000000000000
[2,4] = 0000000000000000
[3,4] = 0000000000000000
[4,4] = 0000000000000000

```

## Round #0

After  $\theta$

```

52 58 7B 99 01 00 00 00 53 58 7B 99 01 00 00 00
00 00 00 00 00 00 00 80 00 00 00 00 00 00 00
A6 B0 F6 32 03 00 00 00 01 00 00 00 00 00 00
53 58 7B 99 01 00 00 00 00 00 00 00 00 00 80
00 00 00 00 00 00 00 A6 B0 F6 32 03 00 00 00
01 00 00 00 00 00 00 53 58 7B 99 01 00 00 00
00 00 00 00 00 00 80 00 00 00 00 00 00 00
A6 B0 F6 32 03 00 00 00 01 00 00 00 00 00 00
53 58 7B 99 01 00 00 80 00 00 00 00 00 00 80
00 00 00 00 00 00 00 A6 B0 F6 32 03 00 00 00
01 00 00 00 00 00 00 53 58 7B 99 01 00 00 00
00 00 00 00 00 00 80 00 00 00 00 00 00 00
A6 B0 F6 32 03 00 00 00

```

After  $\rho$

```

52 58 7B 99 01 00 00 00 A6 B0 F6 32 03 00 00 00
00 00 00 00 00 00 20 00 00 00 00 00 00 00 00
00 00 00 30 85 B5 97 19 00 00 00 00 10 00 00 00
97 19 00 00 00 30 85 B5 20 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 60 0A 6B 2F 33 00
08 00 00 00 00 00 00 00 4C 61 ED 65 06 00 00
00 00 00 00 00 04 00 00 00 00 00 00 00 00 00
99 01 00 00 00 53 58 7B 00 00 00 00 00 02 00 00
2F 33 00 00 00 70 0A 6B 00 40 00 00 00 00 00 00
00 00 00 00 00 00 00 00 A6 B0 F6 32 03 00 00
00 00 04 00 00 00 00 00 4C 61 ED 65 06 00 00 00
00 00 00 00 00 00 10 00 00 00 00 00 00 00 00
00 80 29 AC BD CC 00 00

```

After  $\pi$

```

52 58 7B 99 01 00 00 00 97 19 00 00 00 30 85 B5
00 00 00 00 00 04 00 00 00 00 00 00 00 00 00
00 80 29 AC BD CC 00 00 00 00 00 00 00 00 00
00 00 60 0A 6B 2F 33 00 08 00 00 00 00 00 00
2F 33 00 00 00 70 0A 6B 00 00 00 00 00 00 10
A6 B0 F6 32 03 00 00 00 20 00 00 00 00 00 00
00 00 00 00 00 00 00 00 A6 B0 F6 32 03 00 00
00 00 04 00 00 00 00 00 00 00 30 85 B5 97 19
00 00 00 00 10 00 00 00 00 4C 61 ED 65 06 00 00
00 40 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 20 00 00 00 00 00 00 00 00
99 01 00 00 00 53 58 7B 00 00 00 00 00 02 00 00
4C 61 ED 65 06 00 00 00

```

After  $\chi$

```

52 58 7B 99 01 04 00 00 97 19 00 00 00 30 85 B5
00 80 29 AC BD C8 00 00 52 58 52 11 00 00 00 00
85 81 29 AC BD FC 85 B5 08 00 00 00 00 00 00 00
27 33 60 0A 6B 5F 39 6B 08 00 00 00 00 00 00 10
2F 33 00 00 00 70 0A 6B 00 00 60 0A 6B 2F 33 10
A6 B0 F6 32 03 00 00 00 20 A6 B0 F6 32 03 00 00
00 00 04 00 00 00 00 00 A6 16 42 C4 31 03 00 00
00 00 04 00 00 00 00 00 4C 61 DD E0 B3 97 19
00 00 00 00 10 00 00 00 00 4C 61 ED 65 06 00 00
00 40 00 30 85 B5 97 19 00 00 00 00 10 00 00 00
99 01 00 00 00 53 58 5B 00 00 00 00 00 00 00 00
D5 60 ED 65 06 53 58 7B 00 00 00 00 00 02 00 20
4C 61 ED 65 06 00 00 00

```

After  $\iota$

```

53 58 7B 99 01 04 00 00 97 19 00 00 00 30 85 B5
00 80 29 AC BD C8 00 00 52 58 52 11 00 00 00 00
85 81 29 AC BD FC 85 B5 08 00 00 00 00 00 00 00
27 33 60 0A 6B 5F 39 6B 08 00 00 00 00 00 00 10
2F 33 00 00 00 70 0A 6B 00 00 60 0A 6B 2F 33 10
A6 B0 F6 32 03 00 00 00 20 A6 B0 F6 32 03 00 00
00 00 04 00 00 00 00 00 A6 16 42 C4 31 03 00 00
00 00 04 00 00 00 00 00 4C 61 DD E0 B3 97 19
00 00 00 00 10 00 00 00 00 4C 61 ED 65 06 00 00
00 40 00 30 85 B5 97 19 00 00 00 00 10 00 00 00
99 01 00 00 00 53 58 5B 00 00 00 00 00 00 00 00
D5 60 ED 65 06 53 58 7B 00 00 00 00 00 02 00 20
4C 61 ED 65 06 00 00 00

```

(Skip rounds 1 to 22)

Round #23

After  $\theta$ 

E0 A8 3E 4F 51 BC 7A EA 31 43 F5 C3 14 A1 71 39  
 1B 4F 50 1E 76 8B 79 7A F1 34 AF 61 D5 4D 3D 28  
 6A 52 D5 36 62 0A 0C 4E 07 C1 3D 60 17 F4 CB 82  
 7D 49 71 1D A3 AE E4 DC 6D E1 43 3A C0 1C D1 8B  
 55 70 34 6E 5C F3 90 56 39 51 41 B7 2E F6 24 88  
 EF 8A B3 ED 03 39 1B 7B 11 CD A4 A6 A4 A5 C5 F2  
 8C 74 30 BE 27 43 64 F3 EB 76 40 BB 3E 2D 84 0D  
 52 F5 75 CB 70 12 A0 7D DB 7F A6 74 94 69 27 4E  
 C1 7A 29 C4 5D 0B AD 65 C3 DA 16 FE D6 B7 C2 8E  
 E9 88 87 8F 87 3D 4D 17 1F 6E 56 FD F7 52 1B CE  
 D7 77 A3 6C D4 A8 63 74 F3 43 7D FD 59 97 88 63  
 B2 03 94 5E 27 59 2C 9B 91 64 2E 34 F7 7A 29 5F  
 01 98 12 D4 FD 7E 2E 59

After  $p$ 

E0 A8 3E 4F 51 BC 7A EA 62 86 EA 87 29 42 E3 72  
 C6 13 94 87 DD 62 9E DE DD D4 83 12 4F F3 1A 56  
 53 60 70 52 93 AA B6 11 76 41 BF 2C 78 10 DC 03  
 D7 31 EA 4A CE DD 97 14 62 5B F8 90 0E 30 47 F4  
 38 1A 37 AE 79 48 AB 2A 4F 82 98 13 15 74 EB 62  
 7B 57 9C 6D 1F C8 D9 D8 CB 47 34 93 9A 92 96 16  
 F1 3D 19 22 9B 67 A4 83 5A 08 1B D6 ED 80 76 7D  
 65 38 09 D0 3E A9 FA BA E9 28 D3 4E 9C B6 FF 4C  
 85 B8 6B A1 B5 2C 58 2F 61 C7 61 6D 0B 7F EB 5B  
 A7 E9 22 1D F1 F0 F1 B0 CE 1F 6E 56 FD F7 52 1B  
 8E D1 5D DF 8D B2 51 A3 CD 0F F5 F5 67 5D 22 8E  
 76 80 D2 EB 24 8B 65 53 64 2E 34 F7 7A 29 5F 91  
 4B 56 00 A6 04 75 BF 9F

After  $\pi$ 

E0 A8 3E 4F 51 BC 7A EA D7 31 EA 4A CE DD 97 14  
 F1 3D 19 22 9B 67 A4 83 A7 E9 22 1D F1 F0 F1 B0  
 4B 56 00 A6 04 75 BF 9F DD D4 83 12 4F F3 1A 56  
 4F 82 98 13 15 74 EB 62 7B 57 9C 6D 1F C8 D9 D8  
 85 B8 6B A1 B5 2C 58 2F 76 80 D2 EB 24 8B 65 53  
 62 86 EA 87 29 42 E3 72 62 5B F8 90 0E 30 47 F4  
 5A 08 1B D6 ED 80 76 7D CE 1F 6E 56 FD F7 52 1B  
 8E D1 5D DF 8D B2 51 A3 53 60 70 52 93 AA B6 11  
 76 41 BF 2C 78 10 DC 03 CB 47 34 93 9A 92 96 16  
 61 C7 61 6D 0B 7F EB 5B 64 2E 34 F7 7A 29 5F 91  
 C6 13 94 87 DD 62 9E DE 38 1A 37 AE 79 48 AB 2A  
 65 38 09 D0 3E A9 FA BA E9 28 D3 4E 9C B6 FF 4C  
 CD 0F F5 F5 67 5D 22 8E

After  $\chi$

C0 A4 2F 6F 40 9E 5A 69 D1 F1 C8 57 AE 4D C6 24  
 B9 2B 19 80 9F 62 AA 8C 07 41 1C 54 A0 78 B1 D0  
 5C 47 C0 A6 8A 34 3A 8B ED 81 87 7E 45 7B 0A CE  
 CB 2A FB 93 B5 50 EB 45 09 57 0C 27 1F 4B FC 88  
 0C EC 6A B1 FE 5C 42 2B 74 82 CA EA 34 8F 84 73  
 7A 86 E9 C1 C8 C2 D3 7B E6 4C 9C 90 1E 47 47 F6  
 5A C8 0A 5F ED 80 77 DD AE 19 CC 56 DD B7 F0 4B  
 8E 88 4D CF 8B 82 55 27 DA 66 70 C1 11 28 B4 05  
 56 C1 FE 40 79 7D B5 4A CF 6F 20 01 EA 92 82 96  
 72 87 21 6D 8A FD 4B 5B 40 2F BB DB 12 39 17 93  
 83 33 9C D7 DB C3 CE 4E B0 1A E5 A0 F9 5E AE 6E  
 61 3F 2D 61 5D E0 FA 38 EB 38 D3 4C 04 94 63 1C  
 F5 07 D6 DD 47 55 03 AE

After  $\iota$

C8 24 2F EF 40 9E 5A E9 D1 F1 C8 57 AE 4D C6 24  
 B9 2B 19 80 9F 62 AA 8C 07 41 1C 54 A0 78 B1 D0  
 5C 47 C0 A6 8A 34 3A 8B ED 81 87 7E 45 7B 0A CE  
 CB 2A FB 93 B5 50 EB 45 09 57 0C 27 1F 4B FC 88  
 0C EC 6A B1 FE 5C 42 2B 74 82 CA EA 34 8F 84 73  
 7A 86 E9 C1 C8 C2 D3 7B E6 4C 9C 90 1E 47 47 F6  
 5A C8 0A 5F ED 80 77 DD AE 19 CC 56 DD B7 F0 4B  
 8E 88 4D CF 8B 82 55 27 DA 66 70 C1 11 28 B4 05  
 56 C1 FE 40 79 7D B5 4A CF 6F 20 01 EA 92 82 96  
 72 87 21 6D 8A FD 4B 5B 40 2F BB DB 12 39 17 93  
 83 33 9C D7 DB C3 CE 4E B0 1A E5 A0 F9 5E AE 6E  
 61 3F 2D 61 5D E0 FA 38 EB 38 D3 4C 04 94 63 1C  
 F5 07 D6 DD 47 55 03 AE

After permutation

C8 24 2F EF 40 9E 5A E9 D1 F1 C8 57 AE 4D C6 24  
 B9 2B 19 80 9F 62 AA 8C 07 41 1C 54 A0 78 B1 D0  
 5C 47 C0 A6 8A 34 3A 8B ED 81 87 7E 45 7B 0A CE  
 CB 2A FB 93 B5 50 EB 45 09 57 0C 27 1F 4B FC 88  
 0C EC 6A B1 FE 5C 42 2B 74 82 CA EA 34 8F 84 73  
 7A 86 E9 C1 C8 C2 D3 7B E6 4C 9C 90 1E 47 47 F6  
 5A C8 0A 5F ED 80 77 DD AE 19 CC 56 DD B7 F0 4B  
 8E 88 4D CF 8B 82 55 27 DA 66 70 C1 11 28 B4 05  
 56 C1 FE 40 79 7D B5 4A CF 6F 20 01 EA 92 82 96  
 72 87 21 6D 8A FD 4B 5B 40 2F BB DB 12 39 17 93  
 83 33 9C D7 DB C3 CE 4E B0 1A E5 A0 F9 5E AE 6E  
 61 3F 2D 61 5D E0 FA 38 EB 38 D3 4C 04 94 63 1C  
 F5 07 D6 DD 47 55 03 AE

State (as lanes of integers)

[0, 0] = E95A9E40EF2F24C8  
 [1, 0] = 24C64DAE57C8F1D1  
 [2, 0] = 8CAA629F80192BB9  
 [3, 0] = D0B178A0541C4107  
 [4, 0] = 8B3A348AA6C0475C  
 [0, 1] = CE0A7B457E8781ED  
 [1, 1] = 45EB50B593FB2ACB  
 [2, 1] = 88FC4B1F270C5709  
 [3, 1] = 2B425CFEB16AEC0C  
 [4, 1] = 73848F34EACA8274  
 [0, 2] = 7BD3C2C8C1E9867A  
 [1, 2] = F647471E909C4CE6  
 [2, 2] = DD7780ED5F0AC85A  
 [3, 2] = 4BF0B7DD56CC19AE  
 [4, 2] = 2755828BCF4D888E  
 [0, 3] = 05B42811C17066DA  
 [1, 3] = 4AB57D7940FEC156  
 [2, 3] = 968292EA01206FCF  
 [3, 3] = 5B4BFD8A6D218772  
 [4, 3] = 93173912DBB2F40  
 [0, 4] = 4ECEC3DED79C3383  
 [1, 4] = 6EAE5FF9A0E51AB0  
 [2, 4] = 38FAE05D612D3F61  
 [3, 4] = 1C6394044CD338EB  
 [4, 4] = AE035547DDD607F5

The hash value is

C8 24 2E EF 40 9E 5A E9 D1 F1 C8 57 AE 4D C6 24  
 B9 C2 B 19 80 9F 62 AA 8C 07 41 1C 54 A0 78 B1 D0

## B.16 Dedicated Hash-Function 15 (SHA3-384)

NOTE 1 Data is presented in three different ways: bit strings, byte strings and w-length words (for the lanes).

NOTE 2 Bit strings are the sequence of bits from left to right.

NOTE 3 Byte strings are the bytes from left to right and the bits within the byte are right to left.

NOTE 4 Words are the integer representation of the values in the lanes.

The message as bit string

(empty message)



## XORed state (in bytes)

[illegible]

XORed state (as lanes of integers)

$[0, 0] = 00000000000000000000$   
 $[1, 0] = 00000000000000000000$   
 $[2, 0] = 00000000000000000000$   
 $[3, 0] = 00000000000000000000$   
 $[4, 0] = 00000000000000000000$   
 $[0, 1] = 00000000000000000000$   
 $[1, 1] = 00000000000000000000$   
 $[2, 1] = 00000000000000000000$   
 $[3, 1] = 00000000000000000000$   
 $[4, 1] = 00000000000000000000$   
 $[0, 2] = 00000000000000000000$   
 $[1, 2] = 00000000000000000000$   
 $[2, 2] = 80000000000000000000$   
 $[3, 2] = 00000000000000000000$   
 $[4, 2] = 00000000000000000000$   
 $[0, 3] = 00000000000000000000$   
 $[1, 3] = 00000000000000000000$   
 $[2, 3] = 00000000000000000000$   
 $[3, 3] = 00000000000000000000$   
 $[4, 3] = 00000000000000000000$   
 $[0, 4] = 00000000000000000000$   
 $[1, 4] = 00000000000000000000$   
 $[2, 4] = 00000000000000000000$   
 $[3, 4] = 00000000000000000000$   
 $[4, 4] = 00000000000000000000$

## Round #0

After  $\theta$ 

```

06 00 00 00 00 00 00 00 07 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 80
0C 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
07 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 80 0C 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 07 00 00 00 00 00 00 00
00 00 00 00 00 00 00 80 00 00 00 00 00 00 00 80
0C 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
07 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 80 0C 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 07 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 80
0C 00 00 00 00 00 00 00 00

```

After  $\rho$ 

```

06 00 00 00 00 00 00 00 0E 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 08 00 00 00 00
00 00 00 60 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 70 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 40 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 1C 00 00 00 00 00
00 00 00 00 00 04 00 00 00 00 00 01 00 00 00 00
00 00 00 00 00 06 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 E0 00 00 00 00 00 00 00 00 00 00
00 00 10 00 00 00 00 00 00 00 0C 00 00 00 00 00
00 00 00 00 00 00 00 00 00 1C 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 80 00
00 00 03 00 00 00 00 00 00

```

After  $\pi$ 

```

06 00 00 00 00 00 00 00 00 00 00 00 00 70 00 00
00 00 00 00 00 04 00 00 00 00 10 00 00 00 00 00
00 00 03 00 00 00 00 00 00 00 00 08 00 00 00 00
00 00 C0 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 E0 00 00 00 00 00 00 00 00 00 00
0E 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 01 00 00 00 00 00 0C 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 60 00 00 00 00
00 00 00 00 00 00 00 00 00 1C 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 80 00
00 00 00 00 00 00 00 00 00 00 00 00 00 40 00
00 00 00 00 00 06 00 00 00 00 00 00 00 00 00 00
1C 00 00 00 00 00 00 00 00

```

After  $\chi$

```

06 00 00 00 00 04 00 00 00 00 10 00 00 70 00 00
00 00 03 00 00 04 00 00 06 00 10 00 00 00 00 00
00 00 03 00 00 70 00 00 00 00 00 08 00 00 00 00
00 00 C0 00 00 E0 00 00 00 00 00 00 00 00 00 00
00 00 00 08 00 E0 00 00 00 00 C0 00 00 00 00 00
0E 00 00 01 00 00 00 00 00 00 0C 00 00 00 00 00
00 00 00 01 00 00 00 00 00 0E 0C 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 1C 00 60 00 00 00
00 00 00 00 00 00 00 00 00 00 1C 00 00 00 00 80
00 00 00 60 00 00 00 00 00 00 00 00 00 00 80 00
00 00 00 00 00 06 00 00 00 00 00 00 00 00 40 00
1C 00 00 00 00 06 00 00 00 00 00 00 00 00 00 00
      1C 00 00 00 00 00 40 00

```

After  $\iota$

```

07 00 00 00 00 04 00 00 00 00 10 00 00 70 00 00
00 00 03 00 00 04 00 00 06 00 10 00 00 00 00 00
00 00 03 00 00 70 00 00 00 00 00 08 00 00 00 00
00 00 C0 00 00 E0 00 00 00 00 00 00 00 00 00 00
00 00 00 08 00 E0 00 00 00 00 C0 00 00 00 00 00
0E 00 00 01 00 00 00 00 00 00 0C 00 00 00 00 00
00 00 00 01 00 00 00 00 00 0E 0C 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 1C 00 60 00 00 00
00 00 00 00 00 00 00 00 00 00 1C 00 00 00 00 80
00 00 00 60 00 00 00 00 00 00 00 00 00 00 80 00
00 00 00 00 00 06 00 00 00 00 00 00 00 00 40 00
1C 00 00 00 00 06 00 00 00 00 00 00 00 00 00 00
      1C 00 00 00 00 00 40 00

```

(Skip rounds 1 to 22)

Round #23

After  $\theta$

82 C8 A7 F1 04 CC 56 DD 92 34 F3 C3 2B AC A0 86  
 FD C0 AA 7F 37 23 13 EB 5A FF 0D 29 F9 3E 30 DF  
 51 C0 BB 57 F0 50 5B 48 55 32 25 4A 13 39 94 30  
 64 72 91 41 BD 4D AD 46 04 F5 B9 DE 62 D4 EC 57  
 52 CD 17 96 D3 CC BA 6E 29 23 55 9F 09 26 7E 58  
 26 CD F6 AD DD 05 DE DA D1 38 07 60 86 FF EA 16  
 BA 87 E4 70 07 CA 55 D5 35 29 2F D3 CD A8 27 4C  
 DF 50 FE 4B F8 EF B7 98 C5 2A 0F 3F C8 BB 69 92  
 78 76 9E 56 EA AC B2 41 8A B0 9E E9 78 C2 9B C9  
 DF 73 E7 F0 91 CD B4 B6 65 E2 04 F2 F3 CD CE 33  
 5A B2 23 92 C4 CA 6C AB 5F 32 47 49 35 61 6F E7  
 4E A1 F3 54 E7 7C F1 81 A0 45 75 8A E7 D5 D6 5A  
 81 D5 30 29 ED 17 69 97

After  $p$

82 C8 A7 F1 04 CC 56 DD 25 69 E6 87 57 58 41 0D  
 3F B0 EA DF CD C8 C4 7A EF 03 F3 AD F5 DF 90 92  
 87 DA 42 8A 02 DE BD 82 34 91 43 09 53 25 53 A2  
 19 D4 DB D4 6A 44 26 17 15 41 7D AE B7 18 35 FB  
 E6 0B CB 69 66 5D 37 A9 E2 87 95 32 52 F5 99 60  
 36 69 B6 6F ED 2E F0 D6 5B 44 E3 1C 80 19 FE AB  
 87 3B 50 AE AA D6 3D 24 51 4F 98 6A 52 5E A6 9B  
 25 FC F7 5B CC 6F 28 FF 7E 90 77 D3 24 8B 55 1E  
 D3 4A 9D 55 36 08 CF CE CD 64 45 58 CF 74 3C E1  
 99 D6 F6 7B EE 1C 3E B2 33 65 E2 04 F2 F3 CD CE  
 B3 AD 6A C9 8E 48 12 2B 7F C9 1C 25 D5 84 BD 9D  
 29 74 9E EA 9C 2F 3E D0 45 75 8A E7 D5 D6 5A A0  
 DA 65 60 35 4C 4A FB 45

After  $\pi$

82 C8 A7 F1 04 CC 56 DD 19 D4 DB D4 6A 44 26 17  
 87 3B 50 AE AA D6 3D 24 99 D6 F6 7B EE 1C 3E B2  
 DA 65 60 35 4C 4A FB 45 EF 03 F3 AD F5 DF 90 92  
 E2 87 95 32 52 F5 99 60 36 69 B6 6F ED 2E F0 D6  
 D3 4A 9D 55 36 08 CF CE 29 74 9E EA 9C 2F 3E D0  
 25 69 E6 87 57 58 41 0D 15 41 7D AE B7 18 35 FB  
 51 4F 98 6A 52 5E A6 9B 33 65 E2 04 F2 F3 CD CE  
 B3 AD 6A C9 8E 48 12 2B 87 DA 42 8A 02 DE BD 82  
 34 91 43 09 53 25 53 A2 5B 44 E3 1C 80 19 FE AB  
 CD 64 45 58 CF 74 3C E1 45 75 8A E7 D5 D6 5A A0  
 3F B0 EA DF CD C8 C4 7A E6 0B CB 69 66 5D 37 A9  
 25 FC F7 5B CC 6F 28 FF 7E 90 77 D3 24 8B 55 1E  
 7F C9 1C 25 D5 84 BD 9D

After  $\chi$

```

04 E3 A7 DB 84 5E 4F FD 01 10 7D 85 2E 4C 24 85
C5 1A 50 AA AA 94 FC 61 99 5E 71 BB EE 98 3A 2A
C3 71 38 31 26 4A DB 47 FB 6B D1 E0 58 D5 F0 04
23 85 9C 22 40 F5 96 68 1E 5D B4 C5 65 09 C0 C6
15 49 FC 50 57 D8 4F CC 29 F0 9A F8 9E 0F 37 B0
65 67 66 C7 17 1E C3 0D 37 61 1F AA 17 B9 7C BF
D1 C7 90 A3 5E 56 B4 BA 37 25 66 02 A3 E3 8C CA
A3 AD 73 E1 2E 48 26 D9 CC 9E E2 9E 82 C6 11 8B
B0 B1 47 49 1C 41 53 E2 5B 55 69 BB 90 9B BC AB
4F EE 05 50 CD 7C 99 E3 75 74 8B E6 84 F7 18 80
3E 44 DE CD 45 EA CC 2C BC 0B CB E9 46 DD 62 A9
24 B5 FF 7F 1D 6B 80 7E 7E A0 95 09 2C C3 15 7C
      BF C2 1D 05 F7 91 8E 1C

```

After  $\iota$

```

0C 63 A7 5B 84 5E 4F 7D 01 10 7D 85 2E 4C 24 85
C5 1A 50 AA AA 94 FC 61 99 5E 71 BB EE 98 3A 2A
C3 71 38 31 26 4A DB 47 FB 6B D1 E0 58 D5 F0 04
23 85 9C 22 40 F5 96 68 1E 5D B4 C5 65 09 C0 C6
15 49 FC 50 57 D8 4F CC 29 F0 9A F8 9E 0F 37 B0
65 67 66 C7 17 1E C3 0D 37 61 1F AA 17 B9 7C BF
D1 C7 90 A3 5E 56 B4 BA 37 25 66 02 A3 E3 8C CA
A3 AD 73 E1 2E 48 26 D9 CC 9E E2 9E 82 C6 11 8B
B0 B1 47 49 1C 41 53 E2 5B 55 69 BB 90 9B BC AB
4F EE 05 50 CD 7C 99 E3 75 74 8B E6 84 F7 18 80
3E 44 DE CD 45 EA CC 2C BC 0B CB E9 46 DD 62 A9
24 B5 FF 7F 1D 6B 80 7E 7E A0 95 09 2C C3 15 7C
      BF C2 1D 05 F7 91 8E 1C

```

After permutation

```

0C 63 A7 5B 84 5E 4F 7D 01 10 7D 85 2E 4C 24 85
C5 1A 50 AA AA 94 FC 61 99 5E 71 BB EE 98 3A 2A
C3 71 38 31 26 4A DB 47 FB 6B D1 E0 58 D5 F0 04
23 85 9C 22 40 F5 96 68 1E 5D B4 C5 65 09 C0 C6
15 49 FC 50 57 D8 4F CC 29 F0 9A F8 9E 0F 37 B0
65 67 66 C7 17 1E C3 0D 37 61 1F AA 17 B9 7C BF
D1 C7 90 A3 5E 56 B4 BA 37 25 66 02 A3 E3 8C CA
A3 AD 73 E1 2E 48 26 D9 CC 9E E2 9E 82 C6 11 8B
B0 B1 47 49 1C 41 53 E2 5B 55 69 BB 90 9B BC AB
4F EE 05 50 CD 7C 99 E3 75 74 8B E6 84 F7 18 80
3E 44 DE CD 45 EA CC 2C BC 0B CB E9 46 DD 62 A9
24 B5 FF 7F 1D 6B 80 7E 7E A0 95 09 2C C3 15 7C
      BF C2 1D 05 F7 91 8E 1C

```

State (as lanes of integers)

[0, 0] = 7d4f5e845ba7630c  
 [1, 0] = 85244c2e857d1001  
 [2, 0] = 61fc94aaaa501ac5  
 [3, 0] = 2a3a98eebb715e99  
 [4, 0] = 47db4a26313871c3  
 [0, 1] = 04f0d558e0d16bfb  
 [1, 1] = 6896f540229c8523  
 [2, 1] = c6c00965c5b45d1e  
 [3, 1] = cc4fd85750fc4915  
 [4, 1] = b0370f9ef89af029  
 [0, 2] = 0dc31e17c7666765  
 [1, 2] = bf7cb917aa1f6137  
 [2, 2] = bab4565ea390c7d1  
 [3, 2] = ca8ce3a302662537  
 [4, 2] = d926482ee173ada3  
 [0, 3] = 8b11c6829ee29ecc  
 [1, 3] = e253411c4947b1b0  
 [2, 3] = abbc9b90bb69555b  
 [3, 3] = e3997ccd5005ee4f  
 [4, 3] = 8018f784e68b7475  
 [0, 4] = 2cccea45cddde443e  
 [1, 4] = a962dd46e9cb0bbc  
 [2, 4] = 7e806b1d7fffb524  
 [3, 4] = 7c15c32c0995a07e  
 [4, 4] = 1c8e91f7051dc2bf

The hash value is

0C 63 A7 5B 84 5E 4F 7D 01 10 7D 85 2E 4C 24 85  
 C5 1A 50 AA AA 94 FC 61 99 5E 71 BB EE 98 3A 2A  
 C3 71 38 31 26 4A DB 47 FB 6B D1 E0 58 D5 F0 04

The message as bit string

1 1 0 0 1



After  $\theta$ 

```

D3 00 00 00 00 00 00 00 00 D2 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 80
A6 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00
D2 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 80 A6 01 00 00 00 00 00 00
00 00 00 00 00 00 00 00 D2 00 00 00 00 00 00 00
00 00 00 00 00 00 80 00 00 00 00 00 00 00 80
A6 01 00 00 00 00 00 00 00 00 00 00 00 00 00 00
D2 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 80 A6 01 00 00 00 00 00 00 00
00 00 00 00 00 00 00 D2 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 80
A6 01 00 00 00 00 00 00

```

After  $\rho$ 

```

D3 00 00 00 00 00 00 00 A4 01 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 08 00 00 00 00
00 00 00 30 0D 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 20 0D 00 00 00 00 00 00 00 00
00 00 00 00 00 40 00 00 00 60 1A 00 00 00 00
00 00 00 00 00 00 00 00 48 03 00 00 00 00 00
00 00 00 00 00 04 00 00 00 00 01 00 00 00 00
00 00 00 00 00 D3 00 00 00 00 00 00 00 00 00
00 00 00 00 00 40 1A 00 00 00 00 00 00 00 00
00 00 10 00 00 00 00 00 00 A6 01 00 00 00 00
00 00 00 00 00 00 00 00 48 03 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 80 00
00 80 69 00 00 00 00 00

```

After  $\pi$ 

```

D3 00 00 00 00 00 00 00 00 00 00 00 00 20 0D 00
00 00 00 00 00 04 00 00 00 00 10 00 00 00 00
00 80 69 00 00 00 00 00 00 00 00 08 00 00 00
00 00 60 1A 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 40 1A 00 00 00 00 00 00 00 00
A4 01 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 01 00 00 00 00 00 A6 01 00 00 00 00
00 00 00 00 00 00 00 00 00 00 30 0D 00 00
00 00 00 00 00 00 00 00 00 48 03 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 80 00
00 00 00 00 00 00 00 00 00 00 00 00 40 00
00 00 00 00 00 D3 00 00 00 00 00 00 00 00 00
48 03 00 00 00 00 00 00

```



After  $\chi$

```

D3 00 00 00 00 04 00 00 00 00 10 00 00 20 0D 00
00 80 69 00 00 04 00 00 D3 00 10 00 00 00 00 00
00 80 69 00 00 20 0D 00 00 00 00 08 00 00 00 00
00 00 60 1A 00 40 1A 00 00 00 00 00 00 00 00 00
00 00 00 08 00 40 1A 00 00 00 60 12 00 00 00 00
A4 01 00 01 00 00 00 00 00 00 A6 01 00 00 00 00 00
00 00 00 01 00 00 00 00 00 A4 A7 01 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 48 03 30 0D 00 00 00
00 00 00 00 00 00 00 00 00 00 48 03 00 00 00 80 00
00 00 00 30 0D 00 00 00 00 00 00 00 00 00 00 80 00
00 00 00 00 00 D3 00 00 00 00 00 00 00 00 00 40 00
48 03 00 00 00 D3 00 00 00 00 00 00 00 00 00 00 00
48 03 00 00 00 00 00 40 00

```

After  $\iota$

```

D2 00 00 00 00 04 00 00 00 00 10 00 00 20 0D 00
00 80 69 00 00 04 00 00 D3 00 10 00 00 00 00 00
00 80 69 00 00 20 0D 00 00 00 00 08 00 00 00 00
00 00 60 1A 00 40 1A 00 00 00 00 00 00 00 00 00
00 00 00 08 00 40 1A 00 00 00 60 12 00 00 00 00
A4 01 00 01 00 00 00 00 00 00 A6 01 00 00 00 00 00
00 00 00 01 00 00 00 00 00 A4 A7 01 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 48 03 30 0D 00 00 00
00 00 00 00 00 00 00 00 00 00 48 03 00 00 00 80 00
00 00 00 30 0D 00 00 00 00 00 00 00 00 00 00 80 00
00 00 00 00 00 D3 00 00 00 00 00 00 00 00 00 40 00
48 03 00 00 00 D3 00 00 00 00 00 00 00 00 00 00 00
48 03 00 00 00 00 00 40 00

```

(Skip rounds 1 to 22)

Round #23

After  $\theta$

F3 BD 8B A1 99 41 E9 3C 51 E0 3A E1 05 12 12 B9  
 CD FF FD 9E 4D 58 D5 C5 3E D1 C3 D1 E7 7E A2 C7  
 3D 80 9B EE FA E3 24 6B 49 51 2C 0C BF E2 5B 5E  
 13 87 5E A5 D2 06 E9 27 ED 7A F5 BA 16 96 92 10  
 73 95 55 13 68 DA D4 C6 0F 3E 1D 98 6D AA 95 8D  
 B3 BB 77 B4 DA 14 AA A3 AB 8F A5 0D 74 0C E5 FC  
 18 6C 98 39 8D 06 3D DC 75 83 32 99 36 C1 40 1F  
 C6 A3 06 14 D0 38 AE C6 20 F0 90 21 1B 22 F1 AF  
 FF 44 6D 00 E7 E6 88 FD 1B 5B 81 70 0F 98 F2 4F  
 15 58 53 53 83 2A 5F 71 5F DB 3B 44 C6 DD 4D 00  
 27 65 58 D0 56 40 0A 05 7A 42 58 B0 80 31 F5 75  
 E5 AC 7A ED A8 33 5E 6C 41 D9 A9 82 7F A6 A8 6D  
 E7 79 E7 17 2D 2E 46 A5

After  $p$

F3 BD 8B A1 99 41 E9 3C A3 C0 75 C2 0B 24 24 72  
 F3 7F BF 67 13 56 75 71 EE 27 7A EC 13 3D 1C 7D  
 1F 27 59 EB 01 DC 74 D7 F0 2B BE E5 95 14 C5 C2  
 55 2A 6D 90 7E 32 71 E8 44 BB 5E BD AE 85 A5 24  
 CA AA 09 34 6D 6A E3 B9 5A D9 F8 E0 D3 81 D9 A6  
 9D DD BD A3 D5 A6 50 1D F3 AF 3E 96 36 D0 31 94  
 CC 69 34 E8 E1 C6 60 C3 82 81 3E EA 06 65 32 6D  
 0A 68 1C 57 63 E3 51 03 43 36 44 E2 5F 41 E0 21  
 0D E0 DC 1C B1 FF 9F A8 F9 A7 8D AD 40 B8 07 4C  
 E5 2B AE 02 6B 6A 6A 50 00 5F DB 3B 44 C6 DD 4D  
 29 14 9C 94 61 41 5B 01 E9 09 61 C1 02 C6 D4 D7  
 9C 55 AF 1D 75 C6 8B AD D9 A9 82 7F A6 A8 6D 41  
 51 E9 79 DE F9 45 8B 8B

After  $\pi$

F3 BD 8B A1 99 41 E9 3C 55 2A 6D 90 7E 32 71 E8  
 CC 69 34 E8 E1 C6 60 C3 E5 2B AE 02 6B 6A 6A 50  
 51 E9 79 DE F9 45 8B 8B EE 27 7A EC 13 3D 1C 7D  
 5A D9 F8 E0 D3 81 D9 A6 9D DD BD A3 D5 A6 50 1D  
 0D E0 DC 1C B1 FF 9F A8 9C 55 AF 1D 75 C6 8B AD  
 A3 C0 75 C2 0B 24 24 72 44 BB 5E BD AE 85 A5 24  
 82 81 3E EA 06 65 32 6D 00 5F DB 3B 44 C6 DD 4D  
 29 14 9C 94 61 41 5B 01 1F 27 59 EB 01 DC 74 D7  
 F0 2B BE E5 95 14 C5 C2 F3 AF 3E 96 36 D0 31 94  
 F9 A7 8D AD 40 B8 07 4C D9 A9 82 7F A6 A8 6D 41  
 F3 7F BF 67 13 56 75 71 CA AA 09 34 6D 6A E3 B9  
 0A 68 1C 57 63 E3 51 03 43 36 44 E2 5F 41 E0 21  
 E9 09 61 C1 02 C6 D4 D7

After  $\chi$

```

7B FC 9B C9 18 85 E9 3F 74 28 E7 92 74 1A 7B F8
DC A9 65 34 71 C3 E1 48 47 3F 2C 23 6B 6A 0A 64
55 EB 1D CE 9F 77 9B 4B 6B 23 7F EF 17 1B 1C 64
5A F9 B8 FC F3 D8 56 06 0D C8 9E A2 91 A6 50 18
6F C2 8C FC B3 C6 8B F8 8C 8D 2F 1D B5 46 4A 2F
21 C0 55 80 0B 44 36 3B 44 E5 9F AC EE 07 68 24
AB 81 3A 6E 27 64 30 6D 82 9F BA 79 4E E2 F9 3F
6D 2F 96 A9 C5 C0 DA 05 1C A3 59 F9 23 1C 44 C3
F8 2B 3F CC D5 3C C3 8A F3 A7 3C C4 90 D0 59 95
FF A1 D4 2D 41 EC 17 DA 39 A1 24 7B 32 A8 EC 41
F3 3F AB 24 11 D7 65 73 8B BC 49 94 71 6A 43 99
A2 61 3D 56 63 65 45 D5 51 40 DA C4 4E 51 C1 01
E1 89 61 D1 6E EE 56 5F

```

After  $\iota$

```

73 7C 9B 49 18 85 E9 BF 74 28 E7 92 74 1A 7B F8
DC A9 65 34 71 C3 E1 48 47 3F 2C 23 6B 6A 0A 64
55 EB 1D CE 9F 77 9B 4B 6B 23 7F EF 17 1B 1C 64
5A F9 B8 FC F3 D8 56 06 0D C8 9E A2 91 A6 50 18
6F C2 8C FC B3 C6 8B F8 8C 8D 2F 1D B5 46 4A 2F
21 C0 55 80 0B 44 36 3B 44 E5 9F AC EE 07 68 24
AB 81 3A 6E 27 64 30 6D 82 9F BA 79 4E E2 F9 3F
6D 2F 96 A9 C5 C0 DA 05 1C A3 59 F9 23 1C 44 C3
F8 2B 3F CC D5 3C C3 8A F3 A7 3C C4 90 D0 59 95
FF A1 D4 2D 41 EC 17 DA 39 A1 24 7B 32 A8 EC 41
F3 3F AB 24 11 D7 65 73 8B BC 49 94 71 6A 43 99
A2 61 3D 56 63 65 45 D5 51 40 DA C4 4E 51 C1 01
E1 89 61 D1 6E EE 56 5F

```

After permutation

```

73 7C 9B 49 18 85 E9 BF 74 28 E7 92 74 1A 7B F8
DC A9 65 34 71 C3 E1 48 47 3F 2C 23 6B 6A 0A 64
55 EB 1D CE 9F 77 9B 4B 6B 23 7F EF 17 1B 1C 64
5A F9 B8 FC F3 D8 56 06 0D C8 9E A2 91 A6 50 18
6F C2 8C FC B3 C6 8B F8 8C 8D 2F 1D B5 46 4A 2F
21 C0 55 80 0B 44 36 3B 44 E5 9F AC EE 07 68 24
AB 81 3A 6E 27 64 30 6D 82 9F BA 79 4E E2 F9 3F
6D 2F 96 A9 C5 C0 DA 05 1C A3 59 F9 23 1C 44 C3
F8 2B 3F CC D5 3C C3 8A F3 A7 3C C4 90 D0 59 95
FF A1 D4 2D 41 EC 17 DA 39 A1 24 7B 32 A8 EC 41
F3 3F AB 24 11 D7 65 73 8B BC 49 94 71 6A 43 99
A2 61 3D 56 63 65 45 D5 51 40 DA C4 4E 51 C1 01
E1 89 61 D1 6E EE 56 5F

```

State (as lanes of integers)

[0, 0] = BFE98518499B7C73  
 [1, 0] = F87B1A7492E72874  
 [2, 0] = 48E1C3713465A9DC  
 [3, 0] = 640A6A6B232C3F47  
 [4, 0] = 4B9B779FCE1DEB55  
 [0, 1] = 641C1B17EF7F236B  
 [1, 1] = 0656D8F3FCB8F95A  
 [2, 1] = 1850A691A29EC80D  
 [3, 1] = F88BC6B3FC8CC26F  
 [4, 1] = 2F4A46B51D2F8D8C  
 [0, 2] = 3B36440B8055C021  
 [1, 2] = 246807EEAC9FE544  
 [2, 2] = 6D3064276E3A81AB  
 [3, 2] = 3FF9E24E79BA9F82  
 [4, 2] = 05DAC0C5A9962F6D  
 [0, 3] = C3441C23F959A31C  
 [1, 3] = 8AC33CD5CC3F2BF8  
 [2, 3] = 9559D090C43CA7F3  
 [3, 3] = DA17EC412DD4A1FF  
 [4, 3] = 41ECA8327E24A139  
 [0, 4] = 7365D71124AB3FF3  
 [1, 4] = 99436A719449BC8B  
 [2, 4] = D5456563563D61A2  
 [3, 4] = 01C1514EC4DA4051  
 [4, 4] = 5F56EE6ED16189E1

The hash value is

73 7C 9B 49 18 85 E9 BF 74 28 E7 92 74 1A 7B F8  
 DC A9 65 34 71 C3 E1 48 47 3F 2C 23 6B 6A 0A 64  
 55 EB 1D CE 9F 77 9B 4B 6B 23 7F EF 17 1B 1C 64

The message as bit string

110010100001101011011110100110



After  $\theta$ 

```

53 58 7B 99 01 00 00 00 52 58 7B 99 01 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 80
A6 B0 F6 32 03 00 00 00 00 00 00 00 00 00 00
52 58 7B 99 01 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 80 A6 B0 F6 32 03 00 00 00
00 00 00 00 00 00 00 00 52 58 7B 99 01 00 00 00
00 00 00 00 00 00 00 80 00 00 00 00 00 00 80
A6 B0 F6 32 03 00 00 00 00 00 00 00 00 00 00
52 58 7B 99 01 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 80 A6 B0 F6 32 03 00 00 00
00 00 00 00 00 00 00 00 52 58 7B 99 01 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 80
A6 B0 F6 32 03 00 00 00

```

After  $\rho$ 

```

53 58 7B 99 01 00 00 00 A4 B0 F6 32 03 00 00 00
00 00 00 00 00 00 00 00 00 00 00 08 00 00 00
00 00 00 30 85 B5 97 19 00 00 00 00 00 00 00
97 19 00 00 00 20 85 B5 00 00 00 00 00 00 00
00 00 00 00 00 00 40 00 00 00 60 0A 6B 2F 33 00
00 00 00 00 00 00 00 00 00 48 61 ED 65 06 00 00
00 00 00 00 00 04 00 00 00 00 00 01 00 00 00 00
99 01 00 00 00 53 58 7B 00 00 00 00 00 00 00 00
2F 33 00 00 00 40 0A 6B 00 00 00 00 00 00 00 00
00 00 10 00 00 00 00 00 00 A6 B0 F6 32 03 00 00
00 00 00 00 00 00 00 00 48 61 ED 65 06 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 80 00
00 80 29 AC BD CC 00 00

```

After  $\pi$ 

```

53 58 7B 99 01 00 00 00 97 19 00 00 00 20 85 B5
00 00 00 00 00 04 00 00 00 00 10 00 00 00 00 00
00 80 29 AC BD CC 00 00 00 00 00 08 00 00 00 00
00 00 60 0A 6B 2F 33 00 00 00 00 00 00 00 00 00
2F 33 00 00 00 40 0A 6B 00 00 00 00 00 00 00 00
A4 B0 F6 32 03 00 00 00 00 00 00 00 00 00 00 00
00 00 00 01 00 00 00 00 00 A6 B0 F6 32 03 00 00
00 00 00 00 00 00 00 00 00 00 00 30 85 B5 97 19
00 00 00 00 00 00 00 00 00 48 61 ED 65 06 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 80 00
00 00 00 00 00 00 00 00 00 00 00 00 00 40 00
99 01 00 00 00 53 58 7B 00 00 00 00 00 00 00 00
48 61 ED 65 06 00 00 00

```

After  $\chi$

```

53 58 7B 99 01 04 00 00 97 19 10 00 00 20 85 B5
00 80 29 AC BD C8 00 00 53 58 42 11 00 00 00 00
84 81 29 AC BD EC 85 B5 00 00 00 08 00 00 00 00
2F 33 60 0A 6B 6F 39 6B 00 00 00 00 00 00 00 00
2F 33 00 08 00 40 0A 6B 00 00 60 02 6B 2F 33 00
A4 B0 F6 33 03 00 00 00 00 00 A6 B0 F6 32 03 00 00
00 00 00 01 00 00 00 00 00 A4 16 46 C4 31 03 00 00
00 00 00 00 00 00 00 00 00 00 48 61 DD E0 B3 97 19
00 00 00 00 00 00 00 00 00 00 48 61 ED 65 06 80 00
00 00 00 30 85 B5 17 19 00 00 00 00 00 00 80 00
99 01 00 00 00 53 18 7B 00 00 00 00 00 00 40 00
D1 60 ED 65 06 53 58 7B 00 00 00 00 00 00 00 00
48 61 ED 65 06 00 40 00

```

After  $\iota$

```

52 58 7B 99 01 04 00 00 97 19 10 00 00 20 85 B5
00 80 29 AC BD C8 00 00 53 58 42 11 00 00 00 00
84 81 29 AC BD EC 85 B5 00 00 00 08 00 00 00 00
2F 33 60 0A 6B 6F 39 6B 00 00 00 00 00 00 00 00
2F 33 00 08 00 40 0A 6B 00 00 60 02 6B 2F 33 00
A4 B0 F6 33 03 00 00 00 00 00 A6 B0 F6 32 03 00 00
00 00 00 01 00 00 00 00 00 A4 16 46 C4 31 03 00 00
00 00 00 00 00 00 00 00 00 00 48 61 DD E0 B3 97 19
00 00 00 00 00 00 00 00 00 00 48 61 ED 65 06 80 00
00 00 00 30 85 B5 17 19 00 00 00 00 00 00 80 00
99 01 00 00 00 53 18 7B 00 00 00 00 00 00 40 00
D1 60 ED 65 06 53 58 7B 00 00 00 00 00 00 00 00
48 61 ED 65 06 00 40 00

```

(Skip rounds 1 to 22)

Round #23

After  $\theta$

BD 5B 7B D5 BE 03 9E 1B D9 A6 6A 12 CB 04 FC 5D  
D0 76 3F A3 A9 F2 C4 09 73 F7 06 51 68 18 7E FD  
7D 8C 28 76 AE 14 D1 94 95 CB 8C F2 5D 99 24 A7  
1B E0 72 4D 86 3C F3 72 E0 77 86 C1 EB DE 56 02  
53 F2 40 67 99 64 8E 5A 28 C2 52 4C 16 EA 6B E6  
44 FC F9 BA AB 82 C3 68 60 00 F5 9D BB 09 26 A1  
06 97 90 96 D8 D6 D6 25 8F 47 11 DB 72 4C A5 EA  
57 AB F9 4C 32 96 3C C5 31 37 33 94 60 18 D5 F3  
28 B3 7D E1 85 AE 9A 77 97 19 4B 51 B3 40 CB 7E  
FA CB DB 12 56 A0 79 E2 58 E9 9B B9 02 03 F7 B2  
64 6B 36 AE 0D 05 F9 33 A4 B7 F7 90 B3 01 A9 29  
24 A7 43 A9 2D C2 F3 DE 9B 7B E1 63 BA 3D F4 70  
B5 F3 BB A0 09 AC 14 1A

After  $\rho$

BD 5B 7B D5 BE 03 9E 1B B2 4D D5 24 96 09 F8 BB  
B4 DD CF 68 AA 3C 71 02 86 E1 D7 3F 77 6F 10 85  
A5 88 A6 EC 63 44 B1 73 DF 95 49 72 5A B9 CC 28  
D7 64 C8 33 2F B7 01 2E 00 F8 9D 61 F0 BA B7 95  
79 A0 B3 4C 32 47 AD 29 BE 66 8E 22 2C C5 64 A1  
23 E2 CF D7 5D 15 1C 46 84 82 01 D4 77 EE 26 98  
B4 C4 B6 B6 2E 31 B8 84 98 4A D5 1F 8F 22 B6 E5  
26 19 4B 9E E2 AB D5 7C 28 C1 30 AA E7 63 6E 66  
2F BC D0 55 F3 0E 65 B6 65 BF CB 8C A5 A8 59 A0  
34 4F 5C 7F 79 5B C2 0A B2 58 E9 9B B9 02 03 F7  
E4 CF 90 AD D9 B8 36 14 90 DE DE 43 CE 06 A4 A6  
E4 74 28 B5 45 78 DE 9B 7B E1 63 BA 3D F4 70 9B  
85 46 ED FC 2E 68 02 2B

After  $\pi$

BD 5B 7B D5 BE 03 9E 1B D7 64 C8 33 2F B7 01 2E  
B4 C4 B6 B6 2E 31 B8 84 34 4F 5C 7F 79 5B C2 0A  
85 46 ED FC 2E 68 02 2B 86 E1 D7 3F 77 6F 10 85  
BE 66 8E 22 2C C5 64 A1 23 E2 CF D7 5D 15 1C 46  
2F BC D0 55 F3 0E 65 B6 E4 74 28 B5 45 78 DE 9B  
B2 4D D5 24 96 09 F8 BB 00 F8 9D 61 F0 BA B7 95  
98 4A D5 1F 8F 22 B6 E5 B2 58 E9 9B B9 02 03 F7  
E4 CF 90 AD D9 B8 36 14 A5 88 A6 EC 63 44 B1 73  
DF 95 49 72 5A B9 CC 28 84 82 01 D4 77 EE 26 98  
65 BF CB 8C A5 A8 59 A0 7B E1 63 BA 3D F4 70 9B  
B4 DD CF 68 AA 3C 71 02 79 A0 B3 4C 32 47 AD 29  
26 19 4B 9E E2 AB D5 7C 28 C1 30 AA E7 63 6E 66  
90 DE DE 43 CE 06 A4 A6



After  $\chi$

```

9D DB 4D 51 BE 03 26 9B D7 6F 80 7A 7E FD 43 24
35 C4 17 36 28 11 B8 A5 0C 56 4E 7E E9 58 5E 1A
C7 62 6D DE 2F DC 03 0F 87 61 96 EA 26 7F 08 C3
B2 7A 9E 22 8E CF 05 11 E3 A2 E7 77 59 65 86 4F
2D 3D 07 5F C1 09 65 B2 DC 72 20 B5 4D F8 BA BB
2A 4F 95 3A 99 09 F8 DB 22 E8 B5 E1 C0 BA B6 87
DC CD C5 3B CF 9A 82 E5 A0 58 AC 9B BF 03 CB 5C
E4 7F 98 EC B9 0A 31 10 A5 8A A6 68 46 02 93 E3
BE A8 83 7A DA B9 95 08 9E C2 21 E6 6F BA 06 83
E1 B7 4F C8 E7 A8 D8 C0 21 F4 2A A8 25 4D 3C 93
B2 C4 87 FA 6A 94 21 56 71 60 83 6C 37 07 87 2B
B6 07 85 DF EA AF 55 FC 0C C0 31 82 C7 5B 3F 66
D9 FE EE 47 DE 45 28 8F

```

After  $\iota$

```

95 5B 4D D1 BE 03 26 1B D7 6F 80 7A 7E FD 43 24
35 C4 17 36 28 11 B8 A5 0C 56 4E 7E E9 58 5E 1A
C7 62 6D DE 2F DC 03 0F 87 61 96 EA 26 7F 08 C3
B2 7A 9E 22 8E CF 05 11 E3 A2 E7 77 59 65 86 4F
2D 3D 07 5F C1 09 65 B2 DC 72 20 B5 4D F8 BA BB
2A 4F 95 3A 99 09 F8 DB 22 E8 B5 E1 C0 BA B6 87
DC CD C5 3B CF 9A 82 E5 A0 58 AC 9B BF 03 CB 5C
E4 7F 98 EC B9 0A 31 10 A5 8A A6 68 46 02 93 E3
BE A8 83 7A DA B9 95 08 9E C2 21 E6 6F BA 06 83
E1 B7 4F C8 E7 A8 D8 C0 21 F4 2A A8 25 4D 3C 93
B2 C4 87 FA 6A 94 21 56 71 60 83 6C 37 07 87 2B
B6 07 85 DF EA AF 55 FC 0C C0 31 82 C7 5B 3F 66
D9 FE EE 47 DE 45 28 8F

```

After permutation

```

95 5B 4D D1 BE 03 26 1B D7 6F 80 7A 7E FD 43 24
35 C4 17 36 28 11 B8 A5 0C 56 4E 7E E9 58 5E 1A
C7 62 6D DE 2F DC 03 0F 87 61 96 EA 26 7F 08 C3
B2 7A 9E 22 8E CF 05 11 E3 A2 E7 77 59 65 86 4F
2D 3D 07 5F C1 09 65 B2 DC 72 20 B5 4D F8 BA BB
2A 4F 95 3A 99 09 F8 DB 22 E8 B5 E1 C0 BA B6 87
DC CD C5 3B CF 9A 82 E5 A0 58 AC 9B BF 03 CB 5C
E4 7F 98 EC B9 0A 31 10 A5 8A A6 68 46 02 93 E3
BE A8 83 7A DA B9 95 08 9E C2 21 E6 6F BA 06 83
E1 B7 4F C8 E7 A8 D8 C0 21 F4 2A A8 25 4D 3C 93
B2 C4 87 FA 6A 94 21 56 71 60 83 6C 37 07 87 2B
B6 07 85 DF EA AF 55 FC 0C C0 31 82 C7 5B 3F 66
D9 FE EE 47 DE 45 28 8F

```

State (as lanes of integers)

[0, 0] = 1B2603BED14D5B95  
 [1, 0] = 2443FD7E7A806FD7  
 [2, 0] = A5B811283617C435  
 [3, 0] = 1A5E58E97E4E560C  
 [4, 0] = 0F03DC2FDE6D62C7  
 [0, 1] = C3087F26EA966187  
 [1, 1] = 1105CF8E229E7AB2  
 [2, 1] = 4F86655977E7A2E3  
 [3, 1] = B26509C15F073D2D  
 [4, 1] = BBBAF84DB52072DC  
 [0, 2] = DBF809993A954F2A  
 [1, 2] = 87B6BAC0E1B5E822  
 [2, 2] = E5829ACF3BC5CDDC  
 [3, 2] = 5CCB03BF9BAC58A0  
 [4, 2] = 10310AB9EC987FE4  
 [0, 3] = E393024668A68AA5  
 [1, 3] = 0895B9DA7A83A8BE  
 [2, 3] = 8306BA6FE621C29E  
 [3, 3] = C0D8A8E7C84FB7E1  
 [4, 3] = 933C4D25A82AF421  
 [0, 4] = 5621946AFA87C4B2  
 [1, 4] = 2B8707376C836071  
 [2, 4] = FC55AFEADF8507B6  
 [3, 4] = 663F5BC78231C00C  
 [4, 4] = 8F2845DE47EEFED9

The hash value is

95 5B 4D D1 BE 03 26 1B D7 6F 80 7A 7E FD 43 24  
 35 C4 17 36 28 11 B8 A5 0C 56 4E 7E E9 58 5E 1A  
 C7 62 6D DE 2F DC 03 0F 87 61 96 EA 26 7F 08 C3

## B.17 Dedicated Hash-Function 16 (SHA3-512)

NOTE 1 Data is presented in three different ways: bit strings, byte strings and  $w$ -length words (for the lanes).

NOTE 2 Bit strings are the sequence of bits from left to right.

NOTE 3 Byte strings are the bytes from left to right and the bits within the byte are right to left.

NOTE 4 Words are the integer representation of the values in the lanes.

The message as bit string

(empty message)



After  $\theta$ 

```

06 00 00 00 00 00 00 00 06 00 00 00 00 00 00 00
01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0C 00 00 00 00 00 00 80 00 00 00 00 00 00 00 00
06 00 00 00 00 00 00 00 01 00 00 00 00 00 00 00
00 00 00 00 00 00 00 80 0C 00 00 00 00 00 00 80
00 00 00 00 00 00 00 00 06 00 00 00 00 00 00 00
01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0C 00 00 00 00 00 00 80 00 00 00 00 00 00 00 00
06 00 00 00 00 00 00 00 01 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 0C 00 00 00 00 00 00 80
00 00 00 00 00 00 00 00 06 00 00 00 00 00 00 00
01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
      0C 00 00 00 00 00 00 80

```

After  $\rho$ 

```

06 00 00 00 00 00 00 00 0C 00 00 00 00 00 00 00
00 00 00 00 00 00 00 40 00 00 00 00 00 00 00 00
00 00 00 64 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 60 00 00 40 00 00 00 00 00 00 00
00 00 00 00 00 00 40 00 00 00 C8 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 18 00 00 00 00 00
00 00 00 00 00 08 00 00 60 00 00 00 00 00 00 00
00 00 00 00 40 06 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 C0 00 00 80 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 80 0C 00 00 00 00 00 00
00 00 00 00 00 00 00 00 18 00 00 00 00 00 00 00
00 00 00 00 00 00 00 20 00 00 00 00 00 00 00 00
      00 20 03 00 00 00 00 00

```

After  $\pi$ 

```

06 00 00 00 00 00 00 00 00 00 00 00 00 60 00 00
00 00 00 00 00 08 00 00 00 00 00 00 00 00 00 00
00 20 03 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 C8 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 C0 00 00 00 00 00 00 00 00 00 20
0C 00 00 00 00 00 00 00 40 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 80 0C 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 64 00 00 00 00
00 00 00 00 00 00 00 00 00 00 18 00 00 00 00 00
00 80 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 40 00 00 00 00 00 00 40 00
00 00 00 00 40 06 00 00 00 00 00 00 00 00 00 00
      18 00 00 00 00 00 00 00

```

After  $\chi$

```

06 00 00 00 00 08 00 00 00 00 00 00 00 60 00 00
00 20 03 00 00 08 00 00 06 00 00 00 00 00 00 00
00 20 03 00 00 60 00 00 00 00 00 00 00 00 00 00
00 00 c8 00 00 c0 00 00 00 00 00 00 00 00 00 20
00 00 00 00 00 c0 00 00 00 00 c8 00 00 00 00 20
0c 00 00 00 00 00 00 00 c0 0c 00 00 00 00 00 00
00 00 00 00 00 00 00 00 8c 0c 00 00 00 00 00 00
40 00 00 00 00 00 00 00 00 00 18 00 64 00 00 00
00 80 00 00 00 00 00 00 00 00 18 00 00 00 00 00
00 80 00 64 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 40 06 00 40 00 00 00 00 00 00 40 00
18 00 00 00 40 06 00 00 00 00 00 00 00 00 00 40
18 00 00 00 00 00 00 40 00

```

After  $\iota$

```

07 00 00 00 00 08 00 00 00 00 00 00 00 60 00 00
00 20 03 00 00 08 00 00 06 00 00 00 00 00 00 00
00 20 03 00 00 60 00 00 00 00 00 00 00 00 00 00
00 00 c8 00 00 c0 00 00 00 00 00 00 00 00 00 20
00 00 00 00 00 c0 00 00 00 00 c8 00 00 00 00 20
0c 00 00 00 00 00 00 00 c0 0c 00 00 00 00 00 00
00 00 00 00 00 00 00 00 8c 0c 00 00 00 00 00 00
40 00 00 00 00 00 00 00 00 00 18 00 64 00 00 00
00 80 00 00 00 00 00 00 00 00 18 00 00 00 00 00
00 80 00 64 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 40 06 00 40 00 00 00 00 00 00 40 00
18 00 00 00 40 06 00 00 00 00 00 00 00 00 00 40
18 00 00 00 00 00 00 40 00

```

(Skip rounds 1 to 22)

Round #23

After  $\theta$ 

AC 55 F3 6C 45 3B 9A 54 F3 B6 DB 13 0F 0F 54 16  
 AA 2B 77 77 09 39 9A 23 C0 30 53 CE 15 21 F0 24  
 AC 5F 9D 80 59 A4 0D 7B 08 65 07 88 55 78 03 79  
 74 8F 0C 18 AA D5 85 E1 37 BF CF DB F9 A4 3E E5  
 44 DE 1C E0 10 D0 A7 6D 51 2A 45 11 3C 32 8D 10  
 38 FC F6 18 A4 21 AC 04 CD 6E 92 AC 91 33 D1 48  
 88 28 43 70 19 90 E7 7C FC E9 C2 B5 B0 C0 6C 97  
 DA A0 65 1D C0 BB 4C EF 48 C4 8C FB EF D1 B2 CD  
 9D 20 37 49 6A D4 3D 7F A3 38 B2 81 F5 1A 4F FC  
 29 1C B2 12 B4 45 A2 EC CC 35 72 2D 4D 4F CB 1B  
 88 D9 B0 40 35 51 83 1E 34 52 E6 C0 03 FD 31 33  
 09 AF BE 8D 62 DC 6C 1D 9E BC 42 EE 0B AC 4E AD  
 68 AC A4 C7 72 12 57 48

After  $p$ 

AC 55 F3 6C 45 3B 9A 54 E6 6D B7 27 1E 1E A8 2C  
 EA CA DD 5D 42 8E E6 88 11 02 4F 02 0C 33 E5 5C  
 22 6D D8 63 FD EA 04 CC 58 85 37 90 87 50 76 80  
 80 A1 5A 5D 18 4E F7 C8 F9 CD EF F3 76 3E A9 4F  
 6F 0E 70 08 E8 D3 36 22 D3 08 11 A5 52 14 C1 23  
 C0 E1 B7 C7 20 0D 61 25 23 35 BB 49 B2 46 CE 44  
 82 CB 80 3C E7 43 44 19 81 D9 2E F9 D3 85 6B 61  
 0E E0 5D A6 77 6D D0 B2 F7 DF A3 65 9B 91 88 19  
 26 49 8D BA E7 AF 13 E4 27 FE 51 1C D9 C0 7A 8D  
 48 94 3D 85 43 56 82 B6 1B CC 35 72 2D 4D 4F CB  
 0D 7A 20 66 C3 02 D5 44 D0 48 99 03 0F F4 C7 CC  
 E1 D5 B7 51 8C 9B AD 23 BC 42 EE 0B AC 4E AD 9E  
 15 12 1A 2B E9 B1 9C C4

After  $\pi$ 

AC 55 F3 6C 45 3B 9A 54 80 A1 5A 5D 18 4E F7 C8  
 82 CB 80 3C E7 43 44 19 48 94 3D 85 43 56 82 B6  
 15 12 1A 2B E9 B1 9C C4 11 02 4F 02 0C 33 E5 5C  
 D3 08 11 A5 52 14 C1 23 C0 E1 B7 C7 20 0D 61 25  
 26 49 8D BA E7 AF 13 E4 E1 D5 B7 51 8C 9B AD 23  
 E6 6D B7 27 1E 1E A8 2C F9 CD EF F3 76 3E A9 4F  
 81 D9 2E F9 D3 85 6B 61 1B CC 35 72 2D 4D 4F CB  
 0D 7A 20 66 C3 02 D5 44 22 6D D8 63 FD EA 04 CC  
 58 85 37 90 87 50 76 80 23 35 BB 49 B2 46 CE 44  
 27 FE 51 1C D9 C0 7A 8D BC 42 EE 0B AC 4E AD 9E  
 EA CA DD 5D 42 8E E6 88 6F 0E 70 08 E8 D3 36 22  
 0E E0 5D A6 77 6D D0 B2 F7 DF A3 65 9B 91 88 19  
 D0 48 99 03 0F F4 C7 CC

After  $\chi$

AE 1F 73 4C A2 3A 9A 45 C8 B5 67 DC 18 5A 75 6E  
 97 C9 82 16 4F E2 58 59 E0 D1 DC C1 47 5C 80 A6  
 15 B2 12 3A F1 F5 F9 4C 11 E3 E9 40 2C 3A C5 58  
 F5 00 19 9D 95 B6 D3 E3 01 75 85 86 28 1D CD 26  
 36 4B C5 B8 E7 8F 53 B8 23 DD A7 F4 DE 9F AD 00  
 E6 7D B7 2F 9F 9F EA 0C E3 C9 FE F1 5A 76 AD C5  
 85 EB 2E FD 11 87 FB 65 F9 C9 A2 73 31 51 67 E3  
 14 FA 68 B6 A3 22 D4 07 01 5D 50 2A CD EC 8C 88  
 5C 4F 77 84 CE D0 46 09 BB 35 15 4A 96 48 4B 56  
 25 D3 41 7C 88 60 7A CD E4 C2 C9 9B AE 5E DF 9E  
 EA 2A D0 FB 55 A2 26 18 9E 11 D2 49 60 43 3E 2B  
 0E E0 45 A4 73 09 97 76 DD 5D E7 39 DB 9B A8 19  
 D5 4C B9 03 A7 A5 D7 EE

After  $\iota$

A6 9F 73 CC A2 3A 9A C5 C8 B5 67 DC 18 5A 75 6E  
 97 C9 82 16 4F E2 58 59 E0 D1 DC C1 47 5C 80 A6  
 15 B2 12 3A F1 F5 F9 4C 11 E3 E9 40 2C 3A C5 58  
 F5 00 19 9D 95 B6 D3 E3 01 75 85 86 28 1D CD 26  
 36 4B C5 B8 E7 8F 53 B8 23 DD A7 F4 DE 9F AD 00  
 E6 7D B7 2F 9F 9F EA 0C E3 C9 FE F1 5A 76 AD C5  
 85 EB 2E FD 11 87 FB 65 F9 C9 A2 73 31 51 67 E3  
 14 FA 68 B6 A3 22 D4 07 01 5D 50 2A CD EC 8C 88  
 5C 4F 77 84 CE D0 46 09 BB 35 15 4A 96 48 4B 56  
 25 D3 41 7C 88 60 7A CD E4 C2 C9 9B AE 5E DF 9E  
 EA 2A D0 FB 55 A2 26 18 9E 11 D2 49 60 43 3E 2B  
 0E E0 45 A4 73 09 97 76 DD 5D E7 39 DB 9B A8 19  
 D5 4C B9 03 A7 A5 D7 EE

After permutation

A6 9F 73 CC A2 3A 9A C5 C8 B5 67 DC 18 5A 75 6E  
 97 C9 82 16 4F E2 58 59 E0 D1 DC C1 47 5C 80 A6  
 15 B2 12 3A F1 F5 F9 4C 11 E3 E9 40 2C 3A C5 58  
 F5 00 19 9D 95 B6 D3 E3 01 75 85 86 28 1D CD 26  
 36 4B C5 B8 E7 8F 53 B8 23 DD A7 F4 DE 9F AD 00  
 E6 7D B7 2F 9F 9F EA 0C E3 C9 FE F1 5A 76 AD C5  
 85 EB 2E FD 11 87 FB 65 F9 C9 A2 73 31 51 67 E3  
 14 FA 68 B6 A3 22 D4 07 01 5D 50 2A CD EC 8C 88  
 5C 4F 77 84 CE D0 46 09 BB 35 15 4A 96 48 4B 56  
 25 D3 41 7C 88 60 7A CD E4 C2 C9 9B AE 5E DF 9E  
 EA 2A D0 FB 55 A2 26 18 9E 11 D2 49 60 43 3E 2B  
 0E E0 45 A4 73 09 97 76 DD 5D E7 39 DB 9B A8 19  
 D5 4C B9 03 A7 A5 D7 EE

State (as lanes of integers)

[0, 0] = C59A3AA2CC739FA6  
 [1, 0] = 6E755A18DC67B5C8  
 [2, 0] = 5958E24F1682C997  
 [3, 0] = A6805C47C1DCD1E0  
 [4, 0] = 4CF9F5F13A12B215  
 [0, 1] = 58C53A2C40E9E311  
 [1, 1] = E3D3B6959D1900F5  
 [2, 1] = 26CD1D2886857501  
 [3, 1] = B8538FE7B8C54B36  
 [4, 1] = 00AD9FDEF4A7DD23  
 [0, 2] = 0CEA9F9F2FB77DE6  
 [1, 2] = C5AD765AF1FEC9E3  
 [2, 2] = 65FB8711FD2EEB85  
 [3, 2] = E367513173A2C9F9  
 [4, 2] = 07D422A3B668FA14  
 [0, 3] = 888CECCD2A505D01  
 [1, 3] = 0946D0CE84774F5C  
 [2, 3] = 564B48964A1535BB  
 [3, 3] = CD7A60887C41D325  
 [4, 3] = 9EDF5EAE9BC9C2E4  
 [0, 4] = 1826A255FBD02AEA  
 [1, 4] = 2B3E436049D2119E  
 [2, 4] = 76970973A445E00E  
 [3, 4] = 19A89BDB39E75DDD  
 [4, 4] = EED7A5A703B94CD5

The hash value is

A6 9F 73 CC A2 3A 9A C5 C8 B5 67 DC 18 5A 75 6E  
 97 C9 82 16 4F E2 58 59 E0 D1 DC C1 47 5C 80 A6  
 15 B2 12 3A F1 F5 F9 4C 11 E3 E9 40 2C 3A C5 58  
 F5 00 19 9D 95 B6 D3 E3 01 75 85 86 28 1D CD 26

The message as bit string

1 1 0 0 1





After  $\theta$ 

```

D3 00 00 00 00 00 00 00 00 D3 00 00 00 00 00 00 00
01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
A6 01 00 00 00 00 00 80 00 00 00 00 00 00 00 00
D3 00 00 00 00 00 00 00 01 00 00 00 00 00 00 00
00 00 00 00 00 00 00 80 A6 01 00 00 00 00 00 80
00 00 00 00 00 00 00 00 D3 00 00 00 00 00 00 00
01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
A6 01 00 00 00 00 00 80 00 00 00 00 00 00 00 00
D3 00 00 00 00 00 00 00 01 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 A6 01 00 00 00 00 00 80
00 00 00 00 00 00 00 00 D3 00 00 00 00 00 00 00
01 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
A6 01 00 00 00 00 00 80

```

After  $\rho$ 

```

D3 00 00 00 00 00 00 00 A6 01 00 00 00 00 00 00
00 00 00 00 00 00 00 40 00 00 00 00 00 00 00 00
00 00 00 34 0D 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 30 0D 00 40 00 00 00 00 00 00 00
00 00 00 00 00 00 40 00 00 00 68 1A 00 00 00 00
00 00 00 00 00 00 00 00 00 4C 03 00 00 00 00 00
00 00 00 00 00 08 00 00 00 00 00 00 00 00 00 00
00 00 00 00 40 D3 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 60 1A 00 00 80 00 00 00 00 00 00
00 00 00 00 00 00 00 00 80 A6 01 00 00 00 00 00
00 00 00 00 00 00 00 00 4C 03 00 00 00 00 00 00
00 00 00 00 00 00 00 20 00 00 00 00 00 00 00 00
00 A0 69 00 00 00 00 00 00

```

After  $\pi$ 

```

D3 00 00 00 00 00 00 00 00 00 00 00 00 30 0D 00
00 00 00 00 00 08 00 00 00 00 00 00 00 00 00 00
00 A0 69 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 68 1A 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 60 1A 00 00 00 00 00 00 00 00 20
A6 01 00 00 00 00 00 00 40 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 80 A6 01 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 34 0D 00 00 00
00 00 00 00 00 00 00 00 00 00 4C 03 00 00 00 00
00 80 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 40 00 00 00 00 00 00 40 00
00 00 00 00 40 D3 00 00 00 00 00 00 00 00 00 00
4C 03 00 00 00 00 00 00

```

After  $\chi$

```

D3 00 00 00 00 08 00 00 00 00 00 00 00 30 0D 00
00 A0 69 00 00 08 00 00 D3 00 00 00 00 00 00 00
00 A0 69 00 00 30 0D 00 00 00 00 00 00 00 00 00
00 00 68 1A 00 60 1A 00 00 00 00 00 00 00 00 20
00 00 00 00 00 60 1A 00 00 00 68 1A 00 00 00 20
A6 01 00 00 00 00 00 00 C0 A6 01 00 00 00 00 00
00 00 00 00 00 00 00 00 26 A7 01 00 00 00 00 00
40 00 00 00 00 00 00 00 00 00 4C 03 34 0D 00 00
00 80 00 00 00 00 00 00 00 00 4C 03 00 00 00 00
00 80 00 34 0D 00 00 00 00 00 00 00 00 00 00
00 00 00 00 40 D3 00 40 00 00 00 00 00 00 40 00
4C 03 00 00 40 D3 00 00 00 00 00 00 00 00 40
4C 03 00 00 00 00 00 40 00

```

After  $\iota$

```

D2 00 00 00 00 08 00 00 00 00 00 00 00 30 0D 00
00 A0 69 00 00 08 00 00 D3 00 00 00 00 00 00 00
00 A0 69 00 00 30 0D 00 00 00 00 00 00 00 00 00
00 00 68 1A 00 60 1A 00 00 00 00 00 00 00 00 20
00 00 00 00 00 60 1A 00 00 00 68 1A 00 00 00 20
A6 01 00 00 00 00 00 00 C0 A6 01 00 00 00 00 00
00 00 00 00 00 00 00 00 26 A7 01 00 00 00 00 00
40 00 00 00 00 00 00 00 00 00 4C 03 34 0D 00 00
00 80 00 00 00 00 00 00 00 00 4C 03 00 00 00 00
00 80 00 34 0D 00 00 00 00 00 00 00 00 00 00
00 00 00 00 40 D3 00 40 00 00 00 00 00 00 40 00
4C 03 00 00 40 D3 00 00 00 00 00 00 00 00 40
4C 03 00 00 00 00 00 40 00

```

(Skip rounds 1 to 22)

Round #23

After  $\theta$ 

8C 3E 41 CB D0 65 FC 4C 7D 72 90 CA 3E 31 E5 16  
 BF 34 08 00 48 62 98 BF F7 11 2F 6C BD 36 ED 59  
 C3 26 A5 74 61 0B DF 40 80 43 3E 4A 07 80 B7 FD  
 08 30 A2 25 D7 C2 8D C6 E9 93 68 6B 6B 56 35 C5  
 7E DE A8 17 F1 8B 42 73 18 0C B8 DD 01 9B 77 E4  
 D2 90 45 92 85 F5 E6 0F D5 F4 0F 1B A4 3B DA AF  
 8F A7 AE 44 18 49 22 B3 09 A8 FD C7 C3 40 C0 D1  
 E3 B2 55 35 3F E5 88 2E 20 8F 13 0A DE F6 23 51  
 BE B7 81 D8 C4 87 AA C8 33 CA 45 F6 30 F5 40 38  
 72 4D 2E F8 3B D1 92 3E 95 1E D9 29 82 D7 3B A1  
 B9 3E B0 E5 2B 29 51 55 90 CA 7E 75 0C 69 34 81  
 C2 3E 37 EE C2 E0 DB D6 91 C8 5D 11 B2 D4 9F 3B  
 E0 54 36 27 2C FD 1B 30

After  $p$ 

8C 3E 41 CB D0 65 FC 4C FA E4 20 95 7D 62 CA 2D  
 2F 0D 02 00 92 18 E6 EF 6B D3 9E 75 1F F1 C2 D6  
 5B F8 06 1A 36 29 A5 0B 74 00 78 DB 0F 38 E4 A3  
 5A 72 2D DC 68 8C 00 23 71 FA 24 DA DA 9A 55 4D  
 6F D4 8B F8 45 A1 39 3F 79 47 8E C1 80 DB 1D B0  
 90 86 2C 92 2C AC 37 7F BE 56 D3 3F 6C 90 EE 68  
 25 C2 48 12 99 7D 3C 75 81 80 A3 13 50 FB 8F 87  
 9A 9F 72 44 97 71 D9 AA 14 BC ED 47 A2 40 1E 27  
 10 9B F8 50 15 D9 F7 36 20 9C 19 E5 22 7B 98 7A  
 5A D2 47 AE C9 05 7F 27 A1 95 1E D9 29 82 D7 3B  
 44 55 E5 FA C0 96 AF A4 42 2A FB D5 31 A4 D1 04  
 D8 E7 C6 5D 18 7C DB 5A C8 5D 11 B2 D4 9F 3B 91  
 06 0C 38 95 CD 09 4B FF

After  $\pi$ 

8C 3E 41 CB D0 65 FC 4C 5A 72 2D DC 68 8C 00 23  
 25 C2 48 12 99 7D 3C 75 5A D2 47 AE C9 05 7F 27  
 06 0C 38 95 CD 09 4B FF 6B D3 9E 75 1F F1 C2 D6  
 79 47 8E C1 80 DB 1D B0 90 86 2C 92 2C AC 37 7F  
 10 9B F8 50 15 D9 F7 36 D8 E7 C6 5D 18 7C DB 5A  
 FA E4 20 95 7D 62 CA 2D 71 FA 24 DA DA 9A 55 4D  
 81 80 A3 13 50 FB 8F 87 A1 95 1E D9 29 82 D7 3B  
 44 55 E5 FA C0 96 AF A4 5B F8 06 1A 36 29 A5 0B  
 74 00 78 DB 0F 38 E4 A3 BF 56 D3 3F 6C 90 EE 68  
 20 9C 19 E5 22 7B 98 7A C8 5D 11 B2 D4 9F 3B 91  
 2F 0D 02 00 92 18 E6 EF 6F D4 8B F8 45 A1 39 3F  
 9A 9F 72 44 97 71 D9 AA 14 BC ED 47 A2 40 1E 27  
 42 2A FB D5 31 A4 D1 04

After  $\chi$

A9 BE 01 C9 41 14 C0 18 00 62 2A 70 28 8C 43 21  
 21 CE 70 03 9D 75 3C AD D2 E0 06 E4 D9 61 CB 27  
 54 4C 14 81 E5 81 4B DC EB 53 BE 67 33 D5 E0 99  
 79 5E 5E 81 91 8A DD B0 58 E2 2A 9F 24 88 3F 37  
 33 8B E0 70 12 58 F7 B2 C8 E3 C6 DD 98 76 C6 7A  
 7A E4 A3 94 7D 03 40 AF 51 EF 38 12 F3 9A 05 75  
 C5 C0 42 31 90 EF A7 03 1B 35 1E DC 14 E2 97 32  
 45 4F E1 B0 42 0E BA E4 D0 AE 85 3E 56 A9 AF 43  
 74 88 70 1B 0D 53 F4 B1 77 17 D3 2D B8 14 CD E9  
 33 3C 1F ED 00 5B 1C 70 EC 5D 69 73 DD 8F 7B 31  
 BF 06 72 04 00 48 26 6F 6B F4 06 FB 65 A1 3F 3A  
 D8 9D 60 D4 86 D5 18 AA 39 B9 ED 47 20 58 38 CC  
 02 FA 72 2D 74 05 C8 14

After  $\iota$

A1 3E 01 49 41 14 C0 98 00 62 2A 70 28 8C 43 21  
 21 CE 70 03 9D 75 3C AD D2 E0 06 E4 D9 61 CB 27  
 54 4C 14 81 E5 81 4B DC EB 53 BE 67 33 D5 E0 99  
 79 5E 5E 81 91 8A DD B0 58 E2 2A 9F 24 88 3F 37  
 33 8B E0 70 12 58 F7 B2 C8 E3 C6 DD 98 76 C6 7A  
 7A E4 A3 94 7D 03 40 AF 51 EF 38 12 F3 9A 05 75  
 C5 C0 42 31 90 EF A7 03 1B 35 1E DC 14 E2 97 32  
 45 4F E1 B0 42 0E BA E4 D0 AE 85 3E 56 A9 AF 43  
 74 88 70 1B 0D 53 F4 B1 77 17 D3 2D B8 14 CD E9  
 33 3C 1F ED 00 5B 1C 70 EC 5D 69 73 DD 8F 7B 31  
 BF 06 72 04 00 48 26 6F 6B F4 06 FB 65 A1 3F 3A  
 D8 9D 60 D4 86 D5 18 AA 39 B9 ED 47 20 58 38 CC  
 02 FA 72 2D 74 05 C8 14

After permutation

A1 3E 01 49 41 14 C0 98 00 62 2A 70 28 8C 43 21  
 21 CE 70 03 9D 75 3C AD D2 E0 06 E4 D9 61 CB 27  
 54 4C 14 81 E5 81 4B DC EB 53 BE 67 33 D5 E0 99  
 79 5E 5E 81 91 8A DD B0 58 E2 2A 9F 24 88 3F 37  
 33 8B E0 70 12 58 F7 B2 C8 E3 C6 DD 98 76 C6 7A  
 7A E4 A3 94 7D 03 40 AF 51 EF 38 12 F3 9A 05 75  
 C5 C0 42 31 90 EF A7 03 1B 35 1E DC 14 E2 97 32  
 45 4F E1 B0 42 0E BA E4 D0 AE 85 3E 56 A9 AF 43  
 74 88 70 1B 0D 53 F4 B1 77 17 D3 2D B8 14 CD E9  
 33 3C 1F ED 00 5B 1C 70 EC 5D 69 73 DD 8F 7B 31  
 BF 06 72 04 00 48 26 6F 6B F4 06 FB 65 A1 3F 3A  
 D8 9D 60 D4 86 D5 18 AA 39 B9 ED 47 20 58 38 CC  
 02 FA 72 2D 74 05 C8 14

State (as lanes of integers)

[0, 0] = 98C0144149013EA1  
 [1, 0] = 21438C28702A6200  
 [2, 0] = AD3C759D0370CE21  
 [3, 0] = 27CB61D9E406E0D2  
 [4, 0] = DC4B81E581144C54  
 [0, 1] = 99E0D53367BE53EB  
 [1, 1] = B0DD8A91815E5E79  
 [2, 1] = 373F88249F2AE258  
 [3, 1] = B2F7581270E08B33  
 [4, 1] = 7AC67698DDC6E3C8  
 [0, 2] = AF40037D94A3E47A  
 [1, 2] = 75059AF31238EF51  
 [2, 2] = 03A7EF903142C0C5  
 [3, 2] = 3297E214DC1E351B  
 [4, 2] = E4BA0E42B0E14F45  
 [0, 3] = 43AFA9563E85AED0  
 [1, 3] = B1F4530D1B708874  
 [2, 3] = E9CD14B82DD31777  
 [3, 3] = 701C5B00ED1F3C33  
 [4, 3] = 317B8FDD73695DEC  
 [0, 4] = 6F264800047206BF  
 [1, 4] = 3A3FA165FB06F46B  
 [2, 4] = AA18D586D4609DD8  
 [3, 4] = CC38582047EDB939  
 [4, 4] = 14C805742D72FA02

The hash value is

A1 3E 01 49 41 14 C0 98 00 62 2A 70 28 8C 43 21  
 21 CE 70 03 9D 75 3C AD D2 E0 06 E4 D9 61 CB 27  
 54 4C 14 81 E5 81 4B DC EB 53 BE 67 33 D5 E0 99  
 79 5E 5E 81 91 8A DD B0 58 E2 2A 9F 24 88 3F 37

The message as bit string

110010100001101011011110100110



After  $\theta$ 

```

53 58 7B 99 01 00 00 00 53 58 7B 99 01 00 00 00
01 00 00 00 00 00 00 00 00 00 00 00 00 00 00
A6 B0 F6 32 03 00 00 80 00 00 00 00 00 00 00
53 58 7B 99 01 00 00 00 01 00 00 00 00 00 00
00 00 00 00 00 00 00 80 A6 B0 F6 32 03 00 00 80
00 00 00 00 00 00 00 00 53 58 7B 99 01 00 00
01 00 00 00 00 00 00 00 00 00 00 00 00 00 00
A6 B0 F6 32 03 00 00 80 00 00 00 00 00 00 00
53 58 7B 99 01 00 00 00 01 00 00 00 00 00 00
00 00 00 00 00 00 00 00 A6 B0 F6 32 03 00 00 80
00 00 00 00 00 00 00 00 53 58 7B 99 01 00 00
01 00 00 00 00 00 00 00 00 00 00 00 00 00 00
A6 B0 F6 32 03 00 00 80

```

After  $\rho$ 

```

53 58 7B 99 01 00 00 00 A6 B0 F6 32 03 00 00 00
00 00 00 00 00 00 00 40 00 00 00 00 00 00 00
00 00 00 34 85 B5 97 19 00 00 00 00 00 00 00
97 19 00 00 00 30 85 B5 40 00 00 00 00 00 00
00 00 00 00 00 00 40 00 00 00 68 0A 6B 2F 33 00
00 00 00 00 00 00 00 00 00 4C 61 ED 65 06 00 00
00 00 00 00 00 08 00 00 00 00 00 00 00 00 00
99 01 00 00 40 53 58 7B 00 00 00 00 00 00 00
2F 33 00 00 00 60 0A 6B 00 80 00 00 00 00 00
00 00 00 00 00 00 00 80 A6 B0 F6 32 03 00 00
00 00 00 00 00 00 00 00 4C 61 ED 65 06 00 00
00 00 00 00 00 00 00 20 00 00 00 00 00 00 00
00 A0 29 AC BD CC 00 00

```

After  $\pi$ 

```

53 58 7B 99 01 00 00 00 97 19 00 00 00 30 85 B5
00 00 00 00 00 08 00 00 00 00 00 00 00 00 00
00 A0 29 AC BD CC 00 00 00 00 00 00 00 00 00
00 00 68 0A 6B 2F 33 00 00 00 00 00 00 00 00
2F 33 00 00 00 60 0A 6B 00 00 00 00 00 00 20
A6 B0 F6 32 03 00 00 00 40 00 00 00 00 00 00
00 00 00 00 00 00 00 80 A6 B0 F6 32 03 00 00
00 00 00 00 00 00 00 00 00 00 34 85 B5 97 19
00 00 00 00 00 00 00 00 00 4C 61 ED 65 06 00 00
00 80 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 40 00 00 00 00 00 00 40 00
99 01 00 00 40 53 58 7B 00 00 00 00 00 00 00
4C 61 ED 65 06 00 00 00

```



After  $\chi$

```

53 58 7B 99 01 08 00 00 97 19 00 00 00 30 85 B5
00 A0 29 AC BD C4 00 00 53 58 52 11 00 00 00 00
84 A1 29 AC BD FC 85 B5 00 00 00 00 00 00 00 00
2F 33 68 0A 6B 4F 39 6B 00 00 00 00 00 00 00 00
2F 33 00 00 00 60 0A 6B 00 00 68 0A 6B 2F 33 20
A6 B0 F6 32 03 00 00 00 C0 A6 B0 F6 32 03 00 00
00 00 00 00 00 00 00 00 26 16 46 C4 31 03 00 00
40 00 00 00 00 00 00 00 00 00 4C 61 D9 E0 B3 97 19
00 80 00 00 00 00 00 00 00 00 4C 61 ED 65 06 00 00
00 80 00 34 85 B5 97 19 00 00 00 00 00 00 00 00
99 01 00 00 40 53 18 3B 00 00 00 00 00 00 40 00
D5 60 ED 65 46 53 58 7B 00 00 00 00 00 00 00 40
4C 61 ED 65 06 00 40 00

```

After  $\iota$

```

52 58 7B 99 01 08 00 00 97 19 00 00 00 30 85 B5
00 A0 29 AC BD C4 00 00 53 58 52 11 00 00 00 00
84 A1 29 AC BD FC 85 B5 00 00 00 00 00 00 00 00
2F 33 68 0A 6B 4F 39 6B 00 00 00 00 00 00 00 00
2F 33 00 00 00 60 0A 6B 00 00 68 0A 6B 2F 33 20
A6 B0 F6 32 03 00 00 00 C0 A6 B0 F6 32 03 00 00
00 00 00 00 00 00 00 00 26 16 46 C4 31 03 00 00
40 00 00 00 00 00 00 00 00 00 4C 61 D9 E0 B3 97 19
00 80 00 00 00 00 00 00 00 00 4C 61 ED 65 06 00 00
00 80 00 34 85 B5 97 19 00 00 00 00 00 00 00 00
99 01 00 00 40 53 18 3B 00 00 00 00 00 00 40 00
D5 60 ED 65 46 53 58 7B 00 00 00 00 00 00 00 40
4C 61 ED 65 06 00 40 00

```

(Skip rounds 1 to 22)

Round #23

After  $\theta$

90 F6 4A 2B 92 8C C7 53 FB 93 74 1B F2 C9 3F DA  
 5C CE AB BF CC 44 7B 46 A9 10 30 E8 9B 33 44 8A  
 B0 63 1E 7F 5F 54 47 76 4D B7 91 25 DA 72 72 10  
 D8 F6 AD 87 48 26 80 01 AB FE EA A9 2F 72 74 E0  
 20 1E DE FE 0D 29 89 54 44 C7 D9 E3 9F C2 B7 55  
 40 BB FA 09 2A E5 48 75 FA 43 A9 56 2A 7A E9 99  
 4D CD 11 4B D9 31 7E B3 00 A1 4A 74 91 04 9D BB  
 9D B6 4F FF F0 43 55 FE B2 69 27 A1 FB D7 83 E0  
 12 54 52 B5 86 B0 BE 82 10 A5 27 6C CD 62 3A 4D  
 E0 2A C0 16 4B C6 B7 D0 D6 B1 82 4F 04 ED 4D D1  
 D9 CA D2 EC 3B 67 4F 5D 2B B1 7F 96 90 64 78 A3  
 F2 F0 A1 C1 7B FB E3 09 89 72 89 B1 0D D4 0C 7B  
 0B AA 42 6A 00 B4 C7 41

After  $p$

90 F6 4A 2B 92 8C C7 53 F7 27 E9 36 E4 93 7F B4  
 97 F3 EA 2F 33 D1 9E 11 39 43 A4 98 0A 01 83 BE  
 A2 3A B2 83 1D F3 F8 FB A2 2D 27 07 D1 74 1B 59  
 7A 88 64 02 18 80 6D DF F8 AA BF 7A EA 8B 1C 1D  
 0F 6F FF 86 94 44 2A 10 7C 5B 45 74 9C 3D FE 29  
 03 DA D5 4F 50 29 47 AA 67 EA 0F A5 5A A9 E8 A5  
 58 CA 8E F1 9B 6D 6A 8E 09 3A 77 01 42 95 E8 22  
 7F F8 A1 2A FF 4E DB A7 42 F7 AF 07 C1 65 D3 4E  
 AA D6 10 D6 57 50 82 4A 9D 26 88 D2 13 B6 66 31  
 F8 16 1A 5C 05 D8 62 C9 D1 D6 B1 82 4F 04 ED 4D  
 3D 75 65 2B 4B B3 EF 9C AE C4 FE 59 42 92 E1 8D  
 1E 3E 34 78 6F 7F 3C 41 72 89 B1 0D D4 0C 7B 89  
 71 D0 82 AA 90 1A 00 ED

After  $\pi$

90 F6 4A 2B 92 8C C7 53 7A 88 64 02 18 80 6D DF  
 58 CA 8E F1 9B 6D 6A 8E F8 16 1A 5C 05 D8 62 C9  
 71 D0 82 AA 90 1A 00 ED 39 43 A4 98 0A 01 83 BE  
 7C 5B 45 74 9C 3D FE 29 03 DA D5 4F 50 29 47 AA  
 AA D6 10 D6 57 50 82 4A 1E 3E 34 78 6F 7F 3C 41  
 F7 27 E9 36 E4 93 7F B4 F8 AA BF 7A EA 8B 1C 1D  
 09 3A 77 01 42 95 E8 22 D1 D6 B1 82 4F 04 ED 4D  
 3D 75 65 2B 4B B3 EF 9C A2 3A B2 83 1D F3 F8 FB  
 A2 2D 27 07 D1 74 1B 59 67 EA 0F A5 5A A9 E8 A5  
 9D 26 88 D2 13 B6 66 31 72 89 B1 0D D4 0C 7B 89  
 97 F3 EA 2F 33 D1 9E 11 0F 6F FF 86 94 44 2A 10  
 7F F8 A1 2A FF 4E DB A7 42 F7 AF 07 C1 65 D3 4E  
 AE C4 FE 59 42 92 E1 8D

After  $\chi$

```

90 B4 C0 DA 11 E1 C5 53 DA 9C 74 0E 1C 10 6D 9E
59 0A 0E 53 0B 6F 6A AA 78 30 52 5D 07 5C A5 DB
1B D8 A6 AA 98 1A 28 61 3A C3 34 93 4A 01 82 3C
D4 5F 45 E4 9B 6D 7E 69 17 F2 F1 67 78 06 7B AB
8B 97 90 56 57 50 01 F4 5A 26 75 1C FB 43 40 40
F6 37 A9 37 E4 87 9F 96 28 6E 3F F8 E7 8B 19 50
25 1B 33 28 42 26 EA B2 13 D4 39 96 EB 04 FD 6D
35 FD 73 63 41 BB EF 95 E7 F8 BA 23 17 7A 18 5F
3A 29 A7 55 D0 62 1D 49 05 63 3E A8 9E A1 F1 2D
1D 14 8A 50 1A 45 E6 43 72 8C B4 09 14 08 78 89
E7 63 EA 07 58 DB 4F B6 0F 68 F1 83 94 65 2A 58
D3 F8 F1 72 FD DC FB 26 53 C4 AF 21 F0 24 CD 5E
A6 C8 EB D9 C6 96 C1 8D

```

After  $\iota$

```

98 34 C0 5A 11 E1 C5 D3 DA 9C 74 0E 1C 10 6D 9E
59 0A 0E 53 0B 6F 6A AA 78 30 52 5D 07 5C A5 DB
1B D8 A6 AA 98 1A 28 61 3A C3 34 93 4A 01 82 3C
D4 5F 45 E4 9B 6D 7E 69 17 F2 F1 67 78 06 7B AB
8B 97 90 56 57 50 01 F4 5A 26 75 1C FB 43 40 40
F6 37 A9 37 E4 87 9F 96 28 6E 3F F8 E7 8B 19 50
25 1B 33 28 42 26 EA B2 13 D4 39 96 EB 04 FD 6D
35 FD 73 63 41 BB EF 95 E7 F8 BA 23 17 7A 18 5F
3A 29 A7 55 D0 62 1D 49 05 63 3E A8 9E A1 F1 2D
1D 14 8A 50 1A 45 E6 43 72 8C B4 09 14 08 78 89
E7 63 EA 07 58 DB 4F B6 0F 68 F1 83 94 65 2A 58
D3 F8 F1 72 FD DC FB 26 53 C4 AF 21 F0 24 CD 5E
A6 C8 EB D9 C6 96 C1 8D

```

After permutation

```

98 34 C0 5A 11 E1 C5 D3 DA 9C 74 0E 1C 10 6D 9E
59 0A 0E 53 0B 6F 6A AA 78 30 52 5D 07 5C A5 DB
1B D8 A6 AA 98 1A 28 61 3A C3 34 93 4A 01 82 3C
D4 5F 45 E4 9B 6D 7E 69 17 F2 F1 67 78 06 7B AB
8B 97 90 56 57 50 01 F4 5A 26 75 1C FB 43 40 40
F6 37 A9 37 E4 87 9F 96 28 6E 3F F8 E7 8B 19 50
25 1B 33 28 42 26 EA B2 13 D4 39 96 EB 04 FD 6D
35 FD 73 63 41 BB EF 95 E7 F8 BA 23 17 7A 18 5F
3A 29 A7 55 D0 62 1D 49 05 63 3E A8 9E A1 F1 2D
1D 14 8A 50 1A 45 E6 43 72 8C B4 09 14 08 78 89
E7 63 EA 07 58 DB 4F B6 0F 68 F1 83 94 65 2A 58
D3 F8 F1 72 FD DC FB 26 53 C4 AF 21 F0 24 CD 5E
A6 C8 EB D9 C6 96 C1 8D

```

State (as lanes of integers)

[0, 0] = D3C5E1115AC03498  
 [1, 0] = 9E6D101C0E749CDA  
 [2, 0] = AA6A6F0B530E0A59  
 [3, 0] = DBA55C075D523078  
 [4, 0] = 61281A98AAA6D81B  
 [0, 1] = 3C82014A9334C33A  
 [1, 1] = 697E6D9BE4455FD4  
 [2, 1] = AB7B067867F1F217  
 [3, 1] = F40150575690978B  
 [4, 1] = 404043FB1C75265A  
 [0, 2] = 969F87E437A937F6  
 [1, 2] = 50198BE7F83F6E28  
 [2, 2] = B2EA264228331B25  
 [3, 2] = 6DFD04EB9639D413  
 [4, 2] = 95EFBB416373FD35  
 [0, 3] = 5F187A1723BAF8E7  
 [1, 3] = 491D62D055A7293A  
 [2, 3] = 2DF1A19EA83E6305  
 [3, 3] = 43E6451A508A141D  
 [4, 3] = 8978081409B48C72  
 [0, 4] = B64FDB5807EA63E7  
 [1, 4] = 582A659483F1680F  
 [2, 4] = 26FEDCFD72F1F8D3  
 [3, 4] = 5ECD24F021AFC453  
 [4, 4] = 8DC196C6D9EBC8A6

The hash value is

98 34 C0 5A 11 E1 C5 D3 DA 9C 74 0E 1C 10 6D 9E  
 59 0A 0E 53 0B 6F 6A AA 78 30 52 5D 07 5C A5 DB  
 1B D8 A6 AA 98 1A 28 61 3A C3 34 93 4A 01 82 3C  
 D4 5F 45 E4 9B 6D 7E 69 17 F2 F1 67 78 06 7B AB

## B.18 Dedicated Hash-Function 17 (SM3)

### B.18.1 Example 1

In this example, the data string is the empty string, i.e. the string of length zero.

The hash-code is the following 256-bit string.

1AB21D83 55CFA17F 8E611948 31E81A8F 22BEC8C7 28FEFB74 7ED035EB 5082AA2B

### B.18.2 Example 2

In this example, the data string consists of a single byte, namely the ASCII-coded version of the letter “a”.

The hash-code is the following 256-bit string.

```
623476AC 18F65A29 09E43C7F EC61B49C 7E764A91 A18CCB82 F1917A29 C86C5E88
```

### B.18.3 Example 3

In this example, the data string is the 3-byte string consisting of the ASCII-coded version of “abc”. This is equivalent to the bitstring “01100001 01100010 01100011”.

After the padding process, the single 16-word block derived from the data string is as follows.

```
61626380 00000000 00000000 00000000 00000000 00000000 00000000 00000000
00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000018
```

The following are (hexadecimal representations of) the successive values of the variables  $X_0$ ,  $X_1$ ,  $X_2$ ,  $X_3$ ,  $X_4$ ,  $X_5$ ,  $X_6$  and  $X_7$ .

```
INIT: 7380166F 4914B2B9 172442D7 DA8A0600 A96F30BC 163138AA E38DEE4D B0FB0E4E
0 B9EDC12B 7380166F 29657292 172442D7 B2AD29F4 A96F30BC C550B189 E38DEE4D
1 EA52428C B9EDC12B 002CDEE7 29657292 AC353A23 B2AD29F4 85E54B79 C550B189
2 609F2850 EA52428C DB825773 002CDEE7 D33AD5FB AC353A23 4FA59569 85E54B79
3 35037E59 609F2850 A48519D4 DB825773 B8204B5F D33AD5FB D11D61A9 4FA59569
4 1F995766 35037E59 3E50A0C1 A48519D4 8AD212EA B8204B5F AFDE99D6 D11D61A9
5 374A0CA7 1F995766 06FCB26A 3E50A0C1 ACF0F639 8AD212EA 5AFDC102 AFDE99D6
6 33130100 374A0CA7 32AECC3F 06FCB26A 3391EC8A ACF0F639 97545690 5AFDC102
7 1022AC97 33130100 94194E6E 32AECC3F 367250A1 3391EC8A B1CD6787 97545690
8 D47CAF4C 1022AC97 26020066 94194E6E 6AD473A4 367250A1 64519C8F B1CD6787
9 59C2744B D47CAF4C 45592E20 26020066 C6A3CEAE 6AD473A4 8509B392 64519C8F
10 481BA2A0 59C2744B F95E99A8 45592E20 02AFB727 C6A3CEAE 9D2356A3 8509B392
11 694A3D09 481BA2A0 84E896B3 F95E99A8 9DD1B58C 02AFB727 7576351E 9D2356A3
12 89CB CD58 694A3D09 37454090 84E896B3 6370DB62 9DD1B58C B938157D 7576351E
13 24C95ABC 89CB CD58 947A12D2 37454090 1A4A2554 6370DB62 AC64EE8D B938157D
14 7C529778 24C95ABC 979AB113 947A12D2 3EE95933 1A4A2554 DB131B86 AC64EE8D
15 34D1691E 7C529778 92B57849 979AB113 61F99646 3EE95933 2AA0D251 DB131B86
16 796AFAB1 34D1691E A52EF0F8 92B57849 067550F5 61F99646 C999F74A 2AA0D251
17 7D27CC0E 796AFAB1 A2D23C69 A52EF0F8 B3C8669B 067550F5 B2330FCC C999F74A
18 D7820AD1 7D27CC0E D5F562F2 A2D23C69 575C37D8 B3C8669B 87A833AA B2330FCC
19 F84FD372 D7820AD1 4F981CFA D5F562F2 A5DCEAF1 575C37D8 34DD9E43 87A833AA
20 02C57896 F84FD372 0415A3AF 4F981CFA 74576681 A5DCEAF1 BEC2BAE1 34DD9E43
21 4D0C2FCD 02C57896 9FA6E5F0 0415A3AF 576F1D09 74576681 578D2EE7 BEC2BAE1
22 EEEEC41A 4D0C2FCD 8AF12C05 9FA6E5F0 B5523911 576F1D09 340BA2BB 578D2EE7
23 F368DA78 EEEEC41A 185F9A9A 8AF12C05 6A879032 B5523911 E84ABB78 340BA2BB
24 15CE1286 F368DA78 DD8835DD 185F9A9A 62063354 6A879032 C88DAA91 E84ABB78
25 C3FD31C2 15CE1286 D1B4F1E6 DD8835DD 4DB58F43 62063354 8193543C C88DAA91
26 6243BE5E C3FD31C2 9C250C2B D1B4F1E6 131152FE 4DB58F43 9AA31031 8193543C
27 A549BEAA 6243BE5E FA638587 9C250C2B CF65E309 131152FE 7A1A6DAC 9AA31031
28 E11EB847 A549BEAA 877CBCC4 FA638587 E5B64E96 CF65E309 97F0988A 7A1A6DAC
29 FF9BAC9D E11EB847 937D554A 877CBCC4 9811B46D E5B64E96 184E7B2F 97F0988A
30 A5A4A2B3 FF9BAC9D 3D708FC2 937D554A E92DF4EA 9811B46D 74B72DB2 184E7B2F
31 89A13E59 A5A4A2B3 37593BFF 3D708FC2 0A1FF572 E92DF4EA A36CC08D 74B72DB2
32 3720BD4E 89A13E59 4945674B 37593BFF CF7D1683 0A1FF572 A757496F A36CC08D
```

33 9CCD089C 3720BD4E 427CB313 4945674B DA8C835F CF7D1683 AB9050FF A757496F  
 34 C7A0744D 9CCD089C 417A9C6E 427CB313 0958FF1B DA8C835F B41E7BE8 AB9050FF  
 35 D955C3ED C7A0744D 9A113939 417A9C6E C533F0FF 0958FF1B 1AFED464 B41E7BE8  
 36 E142D72B D955C3ED 40E89B8F 9A113939 D4509586 C533F0FF F8D84AC7 1AFED464  
 37 E7250598 E142D72B AB87DBB2 40E89B8F C7F93FD3 D4509586 87FE299F F8D84AC7  
 38 2F13C4AD E7250598 85AE57C2 AB87DBB2 1A6CABC9 C7F93FD3 AC36A284 87FE299F  
 39 19F363F9 2F13C4AD 4A0B31CE 85AE57C2 C302BADB 1A6CABC9 FE9E3FC9 AC36A284  
 40 55E1DDE2 19F363F9 27895A5E 4A0B31CE 459DACCF C302BADB 5E48D365 FE9E3FC9  
 41 D4F4EFE3 55E1DDE2 E6C7F233 27895A5E 5CFBA85A 459DACCF D6DE1815 5E48D365  
 42 48DCBC62 D4F4EFE3 C3BBC4AB E6C7F233 6F49C7BB 5CFBA85A 667A2CED D6DE1815  
 43 8237B8A0 48DCBC62 E9DFC7A9 C3BBC4AB D89D2711 6F49C7BB 42D2E7DD 667A2CED  
 44 D8685939 8237B8A0 B978C491 E9DFC7A9 8EE87DF5 D89D2711 3DDB7A4E 42D2E7DD  
 45 D2090A86 D8685939 6F714104 B978C491 2E533625 8EE87DF5 388EC4E9 3DDB7A4E  
 46 E51076B3 D2090A86 D0B273B0 6F714104 D9F89E61 2E533625 EFAC7743 388EC4E9  
 47 47C5BE50 E51076B3 12150DA4 D0B273B0 3567734E D9F89E61 B1297299 EFAC7743  
 48 ABDDDBC8 47C5BE50 20ED67CA 12150DA4 3DFCDD11 3567734E F30ECFC4 B1297299  
 49 BD708003 ABDDDBC8 8B7CA08F 20ED67CA 93494BC0 3DFCDD11 9A71AB3B F30ECFC4  
 50 15E2F5D3 BD708003 BB7B9157 8B7CA08F C3956C3F 93494BC0 E889EFE6 9A71AB3B  
 51 13826486 15E2F5D3 E100077A BB7B9157 CD09A51C C3956C3F 5E049A4A E889EFE6  
 52 4A00ED2F 13826486 C5EBA62B E100077A 0741F675 CD09A51C 61FE1CAB 5E049A4A  
 53 F4412E82 4A00ED2F 04C90C27 C5EBA62B 7429807C 0741F675 28E6684D 61FE1CAB  
 54 549DB4B7 F4412E82 01DA5E94 04C90C27 F6BC15ED 7429807C B3A83A0F 28E6684D  
 55 22A79585 549DB4B7 825D05E8 01DA5E94 9D4DB19A F6BC15ED 03E3A14C B3A83A0F  
 56 30245B78 22A79585 3B696EA9 825D05E8 F6804C82 9D4DB19A AF6FB5E0 03E3A14C  
 57 6598314F 30245B78 4F2B0A45 3B696EA9 F522ADB2 F6804C82 8CD4EA6D AF6FB5E0  
 58 C3D629A9 6598314F 48B6F060 4F2B0A45 14FB0764 F522ADB2 6417B402 8CD4EA6D  
 59 DDB0A26A C3D629A9 30629ECB 48B6F060 589F7D5C 14FB0764 6D97A915 6417B402  
 60 71034D71 DDB0A26A AC535387 30629ECB 14D5C7F6 589F7D5C 3B20A7D8 6D97A915  
 61 5E636B4B 71034D71 6144D5BB AC535387 09CCD95E 14D5C7F6 EAE2C4FB 3B20A7D8  
 62 2BFA5F60 5E636B4B 069AE2E2 6144D5BB 4AC3CF08 09CCD95E 3FB0A6AE EAE2C4FB  
 63 1547E69B 2BFA5F60 C6D696BC 069AE2E2 E808F43B 4AC3CF08 CAF04E66 3FB0A6AE

The following eight words,  $Y_0$ ,  $Y_1$ ,  $Y_2$ ,  $Y_3$ ,  $Y_4$ ,  $Y_5$ ,  $Y_6$  and  $Y_7$ , represent the output of the final iteration of the round-function.

$Y_0 = 1547E69B \oplus 7380166F = 66C7F0F4$   
 $Y_1 = 2BFA5F60 \oplus 4914B2B9 = 62EEEDD9$   
 $Y_2 = C6D696BC \oplus 172442D7 = D1F2D46B$   
 $Y_3 = 069AE2E2 \oplus DA8A0600 = DC10E4E2$   
 $Y_4 = E808F43B \oplus A96F30BC = 4167C487$   
 $Y_5 = 4AC3CF08 \oplus 163138AA = 5CF2F7A2$   
 $Y_6 = CAF04E66 \oplus E38DEE4D = 297DA02B$   
 $Y_7 = 3FB0A6AE \oplus B0FB0E4E = 8F4BA8E0$

The hash-code is the following 256-bit string.

66C7F0F4 62EEEDD9 D1F2D46B DC10E4E2 4167C487 5CF2F7A2 297DA02B 8F4BA8E0

#### B.18.4 Example 4

In this example, the data string is the 14-byte string consisting of the ASCII-coded version of  
 “message digest”

The hash-code is the following 256-bit string.

C522A942 E89BD80D 97DD666E 7A5531B3 6188C981 7149E9B2 58DFE51E CE98ED77

### B.18.5 Example 5

In this example, the data string is the 26-byte string consisting of the ASCII-coded version of

“abcdefghijklmnopqrstuvwxyz”

The hash-code is the following 256-bit string.

B80FE97A 4DA24AFC 277564F6 6A359EF4 40462AD2 8DCC6D63 ADB24D5C 20A61595

### B.18.6 Example 6

In this example, the data string is the 62-byte string consisting of the ASCII-coded version of

“ABCDEFGHJKLMNOPQRSTUVWXYZabcdefghijklmnopqrstuvwxyz0123456789”

The hash-code is the following 256-bit string.

2971D10C 8842B70C 979E5506 3480C50B ACFFD90E 98E2E60D 2512AB8A BFDCEC5

### B.18.7 Example 7

In this example, the data string is the 80-byte string consisting of the ASCII-coded version of eight repetitions of

“1234567890”

The hash-code is the following 256-bit string.

AD818053 21F3E69D 251235BF 886A5648 44873B56 DD7DDE40 0F055B7D DE39307A

### B.18.8 Example 8

In this example, the data string is the 56-byte string consisting of the ASCII-coded version of

“abcdcbcdcedefdefgefghfghighijhijkijklklmklmnlmnomnopnopq”

After the padding process, the following two 16-word blocks are derived from the data string.

61626364 62636465 63646566 64656667 65666768 66676869 6768696A 68696A6B  
696A6B6C 6A6B6C6D 6B6C6D6E 6C6D6E6F 6D6E6F70 6E6F7071 80000000 00000000  
00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000  
00000000 00000000 00000000 00000000 00000000 00000000 00000000 000001c0

The following are (hexadecimal representations of) the successive values of the variables  $X_0$ ,  $X_1$ ,  $X_2$ ,  $X_3$ ,  $X_4$ ,  $X_5$ ,  $X_6$  and  $X_7$  in the first block process.

INIT: 7380166F 4914B2B9 172442D7 DA8A0600 A96F30BC 163138AA E38DEE4D B0FB0E4E  
0 5C8F61B7 7380166F 29657292 172442D7 B2E561D0 A96F30BC C550B189 E38DEE4D  
1 DC3DE4B3 5C8F61B7 002CDEE7 29657292 BA8630FD B2E561D0 85E54B79 C550B189  
2 8D1A8984 DC3DE4B3 1EC36EB9 002CDEE7 C6F3AD94 BA8630FD 0E85972B 85E54B79  
3 BBB4BF50 8D1A8984 7BC967B8 1EC36EB9 68627C7C C6F3AD94 87EDD431 0E85972B  
4 3E50B8BC BBB4BF50 3513091A 7BC967B8 55AB956B 68627C7C 6CA6379D 87EDD431  
5 8D4276DA 3E50B8BC 697EA177 3513091A AC958648 55AB956B E3E34313 6CA6379D  
6 C8DA9226 8D4276DA A171787C 697EA177 68CEE8E5 AC958648 AB5AAD5C E3E34313

7 F33FBDEC C8DA9226 84EDB51A A171787C ABF9D51E 68CEE8E5 324564AC AB5AAD5C  
 8 597E4171 F33FBDEC B5244D91 84EDB51A 970ACF5F ABF9D51E 472B4677 324564AC  
 9 DA746360 597E4171 7F7BD9E6 B5244D91 87674D2F 970ACF5F A8F55FCE 472B4677  
 10 BBD90A4E DA746360 FC82E2B2 7F7BD9E6 04B43D0B 87674D2F 7AFCB856 A8F55FCE  
 11 D97774B7 BBD90A4E E8C6C1B4 FC82E2B2 121D28AC 04B43D0B 697C3B3A 7AFCB856  
 12 78078302 D97774B7 B2149D77 E8C6C1B4 77C1DE3D 121D28AC E85825A1 697C3B3A  
 13 C80F6D38 78078302 EEE96FB2 B2149D77 51D1B562 77C1DE3D 456090E9 E85825A1  
 14 EACE16F6 C80F6D38 0F0604F0 EEE96FB2 6B06C8B2 51D1B562 F1EBBE0E 456090E9  
 15 2128F407 EACE16F6 1EDA7190 0F0604F0 5107AFF4 6B06C8B2 AB128E8D F1EBBE0E  
 16 93390D8D 2128F407 9C2DEDD5 1EDA7190 5EE90335 5107AFF4 45935836 AB128E8D  
 17 B9DCAB4B 93390D8D 51E80E42 9C2DEDD5 E7081AB8 5EE90335 7FA2883D 45935836  
 18 95473AFD B9DCAB4B 721B1B26 51E80E42 C12A2AF1 E7081AB8 19AAF748 7FA2883D  
 19 E100DFDA 95473AFD B9569773 721B1B26 A2BB4ADD C12A2AF1 D5C73840 19AAF748  
 20 2F9800CC E100DFDA 8E75FB2A B9569773 0838381E A2BB4ADD 578E0951 D5C73840  
 21 1A113298 2F9800CC 01BFB5C2 8E75FB2A 41D4677B 0838381E 56ED15DA 578E0951  
 22 7FEE2BD4 1A113298 3001985F 01BFB5C2 B77B5FEE 41D4677B C0F041C1 56ED15DA  
 23 D615FE59 7FEE2BD4 22653034 3001985F C62C3A46 B77B5FEE 3BDA0EA3 C0F041C1  
 24 A855127B D615FE59 DC57A8FF 22653034 C47ABE3F C62C3A46 FF75BBDA 3BDA0EA3  
 25 A8E3132D A855127B 2BFCB3AC DC57A8FF 386D8373 C47ABE3F D2363161 FF75BBDA  
 26 1A319D21 A8E3132D AA24F750 2BFCB3AC B4E3CC85 386D8373 F1FE23D5 D2363161  
 27 B8C7870B 1A319D21 C6265B51 AA24F750 349AB542 B4E3CC85 1B99C36C F1FE23D5  
 28 ED5910CB B8C7870B 633A4234 C6265B51 826818F2 349AB542 642DA71E 1B99C36C  
 29 B7B7C514 ED5910CB 8F0E1771 633A4234 014D92BE 826818F2 AA11A4D5 642DA71E  
 30 332D48CF B7B7C514 B22197DA 8F0E1771 67CC5228 014D92BE C7941340 AA11A4D5  
 31 00B8692D 332D48CF 6F8A296F B22197DA BD8784C7 67CC5228 95F00A6C C7941340  
 32 ED95F4E5 00B8692D 5A919E66 6F8A296F A9041B7A BD8784C7 91433E62 95F00A6C  
 33 D7EC1070 ED95F4E5 70D25A01 5A919E66 FF634BF8 A9041B7A 263DEC3C 91433E62  
 34 6D6DF2A0 D7EC1070 2BE9CBDB 70D25A01 208C87AC FF634BF8 DBD54820 263DEC3C  
 35 342F3AD6 6D6DF2A0 D820E1AF 2BE9CBDB DA74F6BE 208C87AC 5FC7FB1A DBD54820  
 36 822697C1 342F3AD6 DBE540DA D820E1AF A3C91873 DA74F6BE 3D610464 5FC7FB1A  
 37 B75F5102 822697C1 5E75AC68 DBE540DA 058DD4EB A3C91873 B5F6D3A7 3D610464  
 38 AB4D8A3D B75F5102 4D2F8304 5E75AC68 935C9926 058DD4EB C39D1E48 B5F6D3A7  
 39 586F130A AB4D8A3D BEA2056E 4D2F8304 9D26A8A7 935C9926 A7582C6E C39D1E48  
 40 2DBEEC34 586F130A 9B147B56 BEA2056E A104C193 9D26A8A7 C9349AE4 A7582C6E  
 41 2CB7CD53 2DBEEC34 DE2614B0 9B147B56 BC21D865 A104C193 453CE935 C9349AE4  
 42 A9DED8FE 2CB7CD53 7DD8685B DE2614B0 EFCD8176 BC21D865 0C9D0826 453CE935  
 43 8F6EA284 A9DED8FE 6F9AA659 7DD8685B B0EF6305 EFCD8176 C32DE10E 0C9D0826  
 44 4198155F 8F6EA284 BDB1FD53 6F9AA659 D1BF96EF B0EF6305 0BB77E6C C32DE10E  
 45 FE0F20D1 4198155F DD45091E BDB1FD53 6D2B4951 D1BF96EF 182D877B 0BB77E6C  
 46 939EAFE3 FE0F20D1 302ABE83 DD45091E F8DD3803 6D2B4951 B77E8DFC 182D877B  
 47 12A2E11E 939EAFE3 1E41A3FC 302ABE83 B65B77A8 F8DD3803 4A8B695A B77E8DFC  
 48 45F88856 12A2E11E 3D5FC727 1E41A3FC 1EAD7D75 B65B77A8 C01FC6E9 4A8B695A  
 49 91D7D82C 45F88856 45C23C25 3D5FC727 C0016D52 1EAD7D75 BD45B2DB C01FC6E9  
 50 287EF00E 91D7D82C F110AC8B 45C23C25 B8DF8FF0 C0016D52 EBA8F56B BD45B2DB  
 51 3D6C1633 287EF00E AFB05923 F110AC8B 286928FC B8DF8FF0 6A96000B EBA8F56B  
 52 D06316EC 3D6C1633 FDE01C50 AFB05923 77E4A5F5 286928FC 7F85C6FC 6A96000B  
 53 5AF5093D D06316EC D82C667A FDE01C50 E56749BB 77E4A5F5 47E14349 7F85C6FC  
 54 1658FDF5 5AF5093D C62DD9A0 D82C667A 9557584C E56749BB 2FABBF25 47E14349



```

55 52C7F5AC 1658FDF5 EA127AB5 C62DD9A0 109B96D2 9557584C 4DDF2B3A 2FABBF25
56 BE546CF1 52C7F5AC B1FBEA2C EA127AB5 E5AF8405 109B96D2 C264AABA 4DDF2B3A
57 731577CD BE546CF1 8FEB58A5 B1FBEA2C 2AFEB8A8C E5AF8405 B69084DC C264AABA
58 813558CC 731577CD A8D9E37C 8FEB58A5 8C01B50C 2AFEB8A8C 202F2D7C B69084DC
59 1986A1C9 813558CC 2AEF9AE6 A8D9E37C F217DF1C 8C01B50C D46157F5 202F2D7C
60 2D3B8ABC 1986A1C9 6AB19902 2AEF9AE6 EDDF3D93 F217DF1C A864600D D46157F5
61 C65C49EB 2D3B8ABC 0D439233 6AB19902 E50C2A6D EDDF3D93 F8E790BE A864600D
62 C3C11EE8 C65C49EB 7715785A 0D439233 AE18F3A1 E50C2A6D EC9F6EF9 F8E790BE
63 6ABB79FD C3C11EE8 B893D78C 7715785A B9DD7BBB AE18F3A1 536F2861 EC9F6EF9

```

The following eight words,  $Y_0$ ,  $Y_1$ ,  $Y_2$ ,  $Y_3$ ,  $Y_4$ ,  $Y_5$ ,  $Y_6$  and  $Y_7$ , represent the output of the round-function in the first block process.

```

 $Y_0 = 6ABB79FD \oplus 7380166F = 193B6F92$ 
 $Y_1 = C3C11EE8 \oplus 4914B2B9 = 8AD5AC51$ 
 $Y_2 = B893D78C \oplus 172442D7 = AFB7955B$ 
 $Y_3 = 7715785A \oplus DA8A0600 = AD9F7E5A$ 
 $Y_4 = B9DD7BBB \oplus A96F30BC = 10B24B07$ 
 $Y_5 = AE18F3A1 \oplus 163138AA = B829CB0B$ 
 $Y_6 = 536F2861 \oplus E38DEE4D = B0E2C62C$ 
 $Y_7 = EC9F6EF9 \oplus B0FB0E4E = 5C6460B7$ 

```

The following are (hexadecimal representations of) the successive values of the variables  $X_0$ ,  $X_1$ ,  $X_2$ ,  $X_3$ ,  $X_4$ ,  $X_5$ ,  $X_6$  and  $X_7$  in the second block process.

```

INIT: 193B6F92 8AD5AC51 AFB7955B AD9F7E5A 10B24B07 B829CB0B B0E2C62C 5C6460B7
0 F71ACD25 193B6F92 AB58A315 AFB7955B 5D580F7B 10B24B07 585DC14E B0E2C62C
1 42DF670C F71ACD25 76DF2432 AB58A315 301A33A1 5D580F7B 58388592 585DC14E
2 96EA0EDB 42DF670C 359A4BEE 76DF2432 FECE7B76 301A33A1 7BDAEAC0 58388592
3 0851B544 96EA0EDB BECE1885 359A4BEE 094B07B3 FECE7B76 9D0980D1 7BDAEAC0
4 00A8966D 0851B544 D41DB72D BECE1885 6CC097ED 094B07B3 DBB7F673 9D0980D1
5 ED15EFA6 00A8966D A36A8810 D41DB72D 519536E5 6CC097ED 3D984A58 DBB7F673
6 B1820DC8 ED15EFA6 512CDA01 A36A8810 8C851B7A 519536E5 BF6B6604 3D984A58
7 93EAECD0 B1820DC8 2BDF4DDA 512CDA01 422F81A2 8C851B7A B72A8CA9 BF6B6604
8 6903ACA3 93EAECD0 041B9163 2BDF4DDA F048BD9B 422F81A2 DBD46428 B72A8CA9
9 1F2BD8DB 6903ACA3 D5D9A127 041B9163 E5AE9D27 F048BD9B 0D12117C DBD46428
10 3DE4985A 1F2BD8DB 075946D2 D5D9A127 77AB882E E5AE9D27 ECDF8245 0D12117C
11 E0EDF809 3DE4985A 57B1B63E 075946D2 C2715679 77AB882E E93F2D74 ECDF8245
12 9058ACFC E0EDF809 C930B47B 57B1B63E 72B366DB C2715679 4173BD5C E93F2D74
13 AB17DC92 9058ACFC DBF013C1 C930B47B 3EDBFFA9 72B366DB B3CE138A 4173BD5C
14 32DDD4F1 AB17DC92 B159F920 DBF013C1 D5F4B6EA 3EDBFFA9 36DB959B B3CE138A
15 3990748B 32DDD4F1 2FB92556 B159F920 94FC9DF4 D5F4B6EA FD49F6DF 36DB959B
16 CDA22778 3990748B BBA9E265 2FB92556 5EDEEBF4 94FC9DF4 B756AFA5 FD49F6DF
17 0136EF6F CDA22778 20E91673 BBA9E265 B55FC7D9 5EDEEBF4 EFA4A7E4 B756AFA5
18 ECD46FAE 0136EF6F 444EF19B 20E91673 4B390AF7 B55FC7D9 5FA2F6F7 EFA4A7E4
19 6A5DF514 ECD46FAE 6DDEDE02 444EF19B 3BF2E429 4B390AF7 3ECDAAFE 5FA2F6F7
20 C3B5F0D2 6A5DF514 A8DF5DD9 6DDEDE02 BC4CA2BD 3BF2E429 57BA59C8 3ECDAAFE
21 645BAF5B C3B5F0D2 BBEA28D4 A8DF5DD9 E1A9773E BC4CA2BD 2149DF97 57BA59C8
22 B0ED09E5 645BAF5B 6BE1A587 BBEA28D4 37979EFC E1A9773E 15EDE265 2149DF97
23 85F08FB3 B0ED09E5 B75EB6C8 6BE1A587 DC23CE67 37979EFC B9F70D4B 15EDE265
24 CDEC3A25 85F08FB3 DA13CB61 B75EB6C8 C79B04E6 DC23CE67 F7E1BCBC B9F70D4B
25 5FE964F7 CDEC3A25 E11F670B DA13CB61 7233F530 C79B04E6 733EE11E F7E1BCBC

```

26 7F515284 5FE964F7 D8744B9B E11F670B DCE5766B 7233F530 27363CD8 733EE11E  
 27 07628BE9 7F515284 D2C9EEBF D8744B9B C4C6EB17 DCE5766B A983919F 27363CD8  
 28 EDFB1904 07628BE9 A2A508FE D2C9EEBF C1284E94 C4C6EB17 B35EE72B A983919F  
 29 F07795D3 EDFB1904 C517D20E A2A508FE F8C23138 C1284E94 58BE2637 B35EE72B  
 30 DAD7D8A8 F07795D3 F63209DB C517D20E 70D89EDF F8C23138 74A60942 58BE2637  
 31 476692E1 DAD7D8A8 EF2BA7E0 F63209DB 428BACA3 70D89EDF 89C7C611 74A60942  
 32 B1745ED9 476692E1 AFB151B5 EF2BA7E0 49A04792 428BACA3 F6FB86C4 89C7C611  
 33 985F0EAE B1745ED9 CD25C28E AFB151B5 1C70F25B 49A04792 651A145D F6FB86C4  
 34 A4EAC3C1 985F0EAE E8BDB362 CD25C28E BAEAFB1D 1C70F25B 3C924D02 651A145D  
 35 94D3CC2E A4EAC3C1 BE1D5D30 E8BDB362 F772A4E5 BAEAFB1D 92D8E387 3C924D02  
 36 AB64985E 94D3CC2E D5878349 BE1D5D30 CFD9ABF7 F772A4E5 D8EDD757 92D8E387  
 37 EA650863 AB64985E A7985D29 D5878349 37D676A0 CFD9ABF7 272FBB95 D8EDD757  
 38 7E9D76D0 EA650863 C930BD56 A7985D29 0E5B32C2 37D676A0 5FBE7ECD 272FBB95  
 39 9C804F2F 7E9D76D0 CA10C7D4 C930BD56 B9883A18 0E5B32C2 B501BEB3 5FBE7ECD  
 40 CC8BC84D 9C804F2F 3AEDA0FD CA10C7D4 89AF8633 B9883A18 961072D9 B501BEB3  
 41 1E44D2CD CC8BC84D 009E5F39 3AEDA0FD D3FF5A20 89AF8633 D0C5CC41 961072D9  
 42 9747774E 1E44D2CD 17909B99 009E5F39 94779237 D3FF5A20 319C4D7C D0C5CC41  
 43 21E48A42 9747774E 89A59A3C 17909B99 319302A0 94779237 D1069FFA 319C4D7C  
 44 4AA0D479 21E48A42 8EEE9D2E 89A59A3C 08A73B8F 319302A0 91BCA3BC D1069FFA  
 45 C9A40B98 4AA0D479 C9148443 8EEE9D2E 4D7508FF 08A73B8F 15018C98 91BCA3BC  
 46 050B4233 C9A40B98 41A8F295 C9148443 40C7B509 4D7508FF DC784539 15018C98  
 47 270A62CB 050B4233 48173193 41A8F295 D06C4A51 40C7B509 47FA6BA8 DC784539  
 48 7C3FCF98 270A62CB 1684660A 48173193 7ECBFA98 D06C4A51 A84A063D 47FA6BA8  
 49 0BA56393 7C3FCF98 14C5964E 1684660A 02154736 7ECBFA98 528E8362 A84A063D  
 50 27548370 0BA56393 7F9F30F8 14C5964E 6D3343B1 02154736 D4C3F65F 528E8362  
 51 79AAEB0E 27548370 4AC72617 7F9F30F8 F2556152 6D3343B1 39B010AA D4C3F65F  
 52 BD17409F 79AAEB0E A906E04E 4AC72617 1BDBA544 F2556152 1D8B699A 39B010AA  
 53 5CEA4FAA BD17409F 55D61CF3 A906E04E 0958FC62 1BDBA544 0A9792AB 1D8B699A  
 54 7FCE4D84 5CEA4FAA 2E813F7A 55D61CF3 B535CB5A 0958FC62 2A20DEDD 0A9792AB  
 55 44232436 7FCE4D84 D49F54B9 2E813F7A EA59CC69 B535CB5A E3104AC7 2A20DEDD  
 56 7FEDD3F5 44232436 9C9B08FF D49F54B9 CEE4B418 EA59CC69 5AD5A9AE E3104AC7  
 57 3648449E 7FEDD3F5 46486C88 9C9B08FF B1AA5387 CEE4B418 634F52CE 5AD5A9AE  
 58 4A8C2056 3648449E DBA7EAFB 46486C88 B1892488 B1AA5387 A0C67725 634F52CE  
 59 C7FF81C0 4A8C2056 90893C6C DBA7EAFB AE0ADA7D B1892488 9C3D8D52 A0C67725  
 60 D839686F C7FF81C0 1840AC95 90893C6C FD965E23 AE0ADA7D 24458C49 9C3D8D52  
 61 64861392 D839686F FF03818F 1840AC95 D109486D FD965E23 D3ED7056 24458C49  
 62 6C983266 64861392 72D0DFB0 FF03818F C7DF59B2 D109486D F11FECB2 D3ED7056  
 63 7AA00357 6C983266 0C2724C9 72D0DFB0 1792E073 C7DF59B2 436E884A F11FECB2

The following eight words,  $Y_0$ ,  $Y_1$ ,  $Y_2$ ,  $Y_3$ ,  $Y_4$ ,  $Y_5$ ,  $Y_6$  and  $Y_7$ , represent the output of the final iteration of the round-function.

$Y_0 = 7AA00357 \oplus 193B6F92 = 639B6CC5$   
 $Y_1 = 6C983266 \oplus 4914B2B9 = E64D9E37$   
 $Y_2 = 0C2724C9 \oplus 172442D7 = A390B192$   
 $Y_3 = 72D0DFB0 \oplus DA8A0600 = DF4FA1EA$   
 $Y_4 = 1792E073 \oplus A96F30BC = 0720AB74$   
 $Y_5 = C7DF59B2 \oplus 163138AA = 7FF692B9$   
 $Y_6 = 436E884A \oplus E38DEE4D = F38C4E66$   
 $Y_7 = F11FECB2 \oplus B0FB0E4E = AD7B8C05$

The hash-code for this message is

639B6CC5 E64D9E37 A390B192 DF4FA1EA 0720AB74 7FF692B9 F38C4E66 AD7B8C05.

### B.18.9 Example 9

In this example, the data string is the 1 000 000-byte string consisting of the ASCII-coded version of “a” repeated  $10^6$  times.

The hash-code is the following 256-bit string.

C8AAF894 29554029 E231941A 2ACC0AD6 1FF2A5AC D8FADD25 847A3A73 2B3B02C3

### B.18.10 Example 10

In this example, the data string is the 112-byte string consisting of the ASCII-coded version of

“abcdefghijklm  
 nijklmnopq  
 rlmnopqrst  
 uvwxyz”

(with no line break after the first n).

The hash-code is the following 256-bit string.

78BCFB58 6ACD983D 7FAE8E69 30157F15 62019E2C AF68F1C9 8A855F1A 95BB89BB

### B.18.11 Example 11

In this example, the data string is the 32-byte string consisting of the ASCII-coded version of

“abcdefghijklmnopqrstuvwxyz”

The hash-code is the following 256-bit string.

F6556D8D B8BED431 81A678DA 7F6AFFE4 51DEBA50 115F3150 F19DEBB8 10B9958A

## Annex C (informative)

### SHA-3 Extendable-Output Functions

#### C.1 SHAKE-128

##### C.1.1 Parameters, functions and constants

###### C.1.1.1 Parameters

For SHAKE-128,  $L_1 = r = 1\,344$ ,  $L_2 = b = 1\,600$  and  $c = b - r = 256$ . For SHAKE-128,  $d$  is a variable to determine the output length.

###### C.1.1.2 Byte ordering convention

Each data input  $D$  to the round-function  $\phi$  is a block of 1 344 bits that is XORed into the part of the state. The permutation  $f$  is then applied to the state. Because the step mappings that comprise the permutation are defined on the array form of the state, it is convenient to regard  $D$  as a sequence of 64-bit words that are XORed directly into the state array. For this purpose, when  $D$  is represented as a sequence of 168 bytes,  $B_0, B_1, \dots, B_{167}$ , then  $D$  should be interpreted as a sequence of 21 lane words,  $Z_0, Z_1, \dots, Z_{20}$ , as follows:

$$Z_i = 2^{56}B_{8i+7} + 2^{48}B_{8i+6} + 2^{40}B_{8i+5} + 2^{32}B_{8i+4} + 2^{24}B_{8i+3} + 2^{16}B_{8i+2} + 2^8B_{8i+1} + B_{8i},$$

for  $0 \leq i \leq 20$ .

Hence, each group of eight consecutive bytes is a word and the bytes of the word are arranged in increasing order of significance, so that the first byte in the group becomes the least significant byte of the word.

For dedicated hash-function 14, the function is defined on a  $5 \times 5 \times w$  state array. For each array six sub-arrays are defined for step-mappings. Lane is one of the subarrays and defined in [19.2.3.3](#). Under this interpretation,  $D$  is XORed with the state array as follows.

If  $j$  and  $k$  are the elements of  $\{0, 1, 2, 3, 4\}$ , such that  $(j, k)$  is the unique pair for which  $i = 5k + j$ , then for  $0 \leq i \leq 20$ ,  $\text{Lane}'(j, k) = Z_i \oplus \text{Lane}(j, k)$ , where  $\text{Lane}'(j, k)$  is the updated value of the lane.

###### C.1.1.3 Functions

The functions, including the function  $Rnd$  and step mappings, for the dedicated SHAKE-128 are the same as Dedicated Hash-Function 13 and is specified in [Clause 19](#).

###### C.1.1.4 Constants

The constants used for the mapping are the offsets defined in [Clause 19](#).

###### C.1.1.5 Initializing value

The initializing value is a 1 600-bit all-zero string.

### C.1.2 Padding method

The data  $M$  will be padded with “1111” before applying the padding method  $\text{pad}_{10^*1}(x, m)$  specified in 19.2 with  $x = 1\ 344$ .

That is, the padded data is  $P = M \parallel 1111 \parallel 10^*1$ , such that the length of  $P$  is a multiple of 1 344.

### C.1.3 Description of round-function

The round-function for SHAKE-128 is the permutation KECCAK- $p$  specified in Clause 19. Notice that KECCAK- $p$  is considered as defined in ISO/IEC 10118-1. However, for each execution of KECCAK- $p$ , it iterates the  $Rnd$  function 24 times. That is, it executes

$$Rnd(\mathbf{A}, i_r) = \iota(\chi < \pi\{\rho[\theta(\mathbf{A})]\} >, i_r)$$

for  $i_r = 0, 1, \dots, 23$ .

### C.1.4 Output transformation

In step h) of SPONGE[ $f$ ,  $\text{pad}$ ,  $r$ ]( $N$ ,  $d$ ) specified in Clause 19,  $f = \text{KECCAK-}p$ , each execution of  $f$  in the squeezing stage for SHAKE-128 generates  $r = 1\ 344$  bits. The output is concatenated until enough bits are generated to obtain  $d$  bits. That is, for a given  $d$ , after the last data block is inputted, it generates the first  $r$  bits of output.

Then, it executes the function  $f[d/r] - 1$  times to generate a total of  $[d/r] \cdot r$  output bits and then truncates to  $d$  bits.

### C.1.5 Examples

NOTE 1 Data is presented in three different ways: bit strings, byte strings and  $w$ -length words (for the lanes).

NOTE 2 Bit strings are the sequence of bits from left to right.

NOTE 3 Byte strings are the bytes from left to right and the bits within the byte are right to left.

NOTE 4 Words are the integer representation of the values in the lanes.

SHAKE-128 sample to produce 4 096 bits of output

The message as bit string

(empty message)

about to call last of the absorb phase

## XORed state (in bytes)

```

1F 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 80 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00

```

## XORed state (as lanes of integers)

```

[0, 0] = 00000000000000001F
[1, 0] = 000000000000000000
[2, 0] = 000000000000000000
[3, 0] = 000000000000000000
[4, 0] = 000000000000000000
[0, 1] = 000000000000000000
[1, 1] = 000000000000000000
[2, 1] = 000000000000000000
[3, 1] = 000000000000000000
[4, 1] = 000000000000000000
[0, 2] = 000000000000000000
[1, 2] = 000000000000000000
[2, 2] = 000000000000000000
[3, 2] = 000000000000000000
[4, 2] = 000000000000000000
[0, 3] = 000000000000000000
[1, 3] = 000000000000000000
[2, 3] = 000000000000000000
[3, 3] = 000000000000000000
[4, 3] = 000000000000000000
[0, 4] = 800000000000000000
[1, 4] = 000000000000000000
[2, 4] = 000000000000000000
[3, 4] = 000000000000000000
[4, 4] = 000000000000000000

```

Round #0

After  $\theta$ 

```

1F 00 00 00 00 00 00 00 00 1F 00 00 00 00 00 00 80
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
3F 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
1F 00 00 00 00 00 00 00 80 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 3F 00 00 00 00 00 00
00 00 00 00 00 00 00 00 1F 00 00 00 00 00 00 80
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
3F 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
1F 00 00 00 00 00 00 00 80 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 3F 00 00 00 00 00 00
00 00 00 00 00 00 00 00 80 1F 00 00 00 00 00 80
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
3F 00 00 00 00 00 00 00 00

```

After  $\rho$ 

```

1F 00 00 00 00 00 00 00 3F 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 F8 01 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 F8 01 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 F0 03 00 00 00 00
00 00 00 00 00 00 00 00 00 00 7E 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 80 1F 00 00 00 00 00 00 00 00 00
00 00 00 00 90 F0 03 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 3F 00 00 00 00 00
00 00 02 00 00 00 00 00 00 00 7E 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 C0 0F 00 00 00 00 00 00

```

After  $\pi$ 

```

1F 00 00 00 00 00 00 00 00 00 00 00 00 F8 01 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 C0 0F 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 F0 03 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 F0 03 00 00 00 00 00 00 00 00
3F 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 3F 00 00 00 00 00
00 00 02 00 00 00 00 00 00 00 00 F8 01 00 00 00
00 00 00 00 00 00 00 00 00 00 7E 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 80 1F 00 00 00 00 00 00 00 00 00
7E 00 00 00 00 00 00 00

```

After  $\chi$ 

```

1F 00 00 00 00 00 00 00 00 00 00 00 00 00 F8 01 00
00 C0 0F 00 00 00 00 00 1F 00 00 00 00 00 00 00
00 C0 0F 00 00 F8 01 00 00 00 00 00 00 00 00 00
00 00 F0 03 00 F0 03 00 00 00 00 00 00 00 00 00
00 00 00 00 00 F0 03 00 00 00 F0 03 00 00 00 00
3F 00 00 00 00 00 00 00 00 00 3F 00 00 00 00 00
00 00 02 00 00 00 00 00 3F 3F 00 00 00 00 00 00
00 00 02 00 00 00 00 00 00 7E 00 F8 01 00 00 00
00 00 00 00 00 00 00 00 00 7E 00 00 00 00 00 00
00 00 00 F8 01 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 80 1F 00 00 00 00 00 00 00 00 00 00
7E 00 00 00 80 1F 00 00 00 00 00 00 00 00 00 00
      7E 00 00 00 00 00 00 00

```

After  $\iota$ 

```

1E 00 00 00 00 00 00 00 00 00 00 00 00 00 F8 01 00
00 C0 0F 00 00 00 00 00 1F 00 00 00 00 00 00 00
00 C0 0F 00 00 F8 01 00 00 00 00 00 00 00 00 00
00 00 F0 03 00 F0 03 00 00 00 00 00 00 00 00 00
00 00 00 00 00 F0 03 00 00 00 F0 03 00 00 00 00
3F 00 00 00 00 00 00 00 00 00 3F 00 00 00 00 00
00 00 02 00 00 00 00 00 3F 3F 00 00 00 00 00 00
00 00 02 00 00 00 00 00 00 7E 00 F8 01 00 00 00
00 00 00 00 00 00 00 00 00 7E 00 00 00 00 00 00
00 00 00 F8 01 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 80 1F 00 00 00 00 00 00 00 00 00 00
7E 00 00 00 80 1F 00 00 00 00 00 00 00 00 00 00
      7E 00 00 00 00 00 00 00

```

(Skip rounds 1 to 22)

Round #23



After  $\theta$ 

F5 86 2B A6 68 65 BA FC 10 4E F5 EE AA FB E0 C4  
 33 8C FB C6 D3 83 A0 23 DB BC EE C7 0F 60 AD BF  
 47 27 0B 74 8C A7 51 68 7D B6 65 F4 D1 54 62 D4  
 60 CC 97 44 A6 82 E7 57 C9 7F A9 4D B1 05 A8 C2  
 09 99 B6 5D 41 E7 9C 86 6A 84 85 BE B2 F6 54 C1  
 6B 3D 70 76 CF AE CE DE 5F 9F 5D 03 93 F2 B3 CD  
 9D 37 63 58 1F 40 58 FE 66 C7 E1 A8 11 DD 4F EB  
 B1 A9 CB 54 8D A8 4B 33 AC A8 76 D1 29 4A CF 06  
 61 54 AF E1 B5 72 C9 13 9F 5F E9 3A 08 3F 51 04  
 53 D5 1C F8 52 52 E1 78 BF 91 01 1A BE D4 39 CF  
 84 04 0B 06 B2 E7 23 7E FD 0F B0 4B CE 2A 1E 72  
 BB 9F 26 93 52 D4 77 B1 EB 15 3A 7D 4F D1 8C E6  
 BB C7 7B 02 3C 4C D2 44

After  $\rho$ 

F5 86 2B A6 68 65 BA FC 21 9C EA DD 55 F7 C1 89  
 0C E3 BE F1 F4 20 E8 C8 00 D6 FA BB CD EB 7E FC  
 3C 8D 42 3B 3A 59 A0 63 1F 4D 25 46 DD 67 5B 46  
 49 64 2A 78 7E 05 C6 7C 70 F2 5F 6A 53 6C 01 AA  
 4C DB AE A0 73 4E C3 84 4F 15 AC 46 58 E8 2B 6B  
 5E EB 81 B3 7B 76 75 F6 36 7F 7D 76 0D 4C CA CF  
 C3 FA 00 C2 F2 EF BC 19 BA 9F D6 CD 8E C3 51 23  
 AA 46 D4 A5 99 D8 D4 65 A2 53 94 9E 0D 58 51 ED  
 35 BC 56 2E 79 22 8C EA 28 82 CF AF 74 1D 84 9F  
 2A 1C 6F AA 9A 03 5F 4A CF BF 91 01 1A BE D4 39  
 8F F8 11 12 2C 18 C8 9E F5 3F C0 2E 39 AB 78 C8  
 F7 D3 64 52 8A FA 2E 76 15 3A 7D 4F D1 8C E6 EB  
 34 D1 EE F1 9E 00 0F 93

After  $\pi$ 

F5 86 2B A6 68 65 BA FC 49 64 2A 78 7E 05 C6 7C  
 C3 FA 00 C2 F2 EF BC 19 2A 1C 6F AA 9A 03 5F 4A  
 34 D1 EE F1 9E 00 0F 93 00 D6 FA BB CD EB 7E FC  
 4F 15 AC 46 58 E8 2B 6B 5E EB 81 B3 7B 76 75 F6  
 35 BC 56 2E 79 22 8C EA F7 D3 64 52 8A FA 2E 76  
 21 9C EA DD 55 F7 C1 89 70 F2 5F 6A 53 6C 01 AA  
 BA 9F D6 CD 8E C3 51 23 CF BF 91 01 1A BE D4 39  
 8F F8 11 12 2C 18 C8 9E 3C 8D 42 3B 3A 59 A0 63  
 1F 4D 25 46 DD 67 5B 46 36 7F 7D 76 0D 4C CA CF  
 28 82 CF AF 74 1D 84 9F 15 3A 7D 4F D1 8C E6 EB  
 0C E3 BE F1 F4 20 E8 C8 4C DB AE A0 73 4E C3 84  
 AA 46 D4 A5 99 D8 D4 65 A2 53 94 9E 0D 58 51 ED  
 F5 3F C0 2E 39 AB 78 C8

After  $\chi$ 

77 1C 2B 24 E8 8F 82 FD 61 60 45 50 76 05 85 3E  
 D7 3B 80 93 F6 EF BC 88 EB 1A 6E AC FA 66 EF 26  
 3C B1 EE A9 88 00 4B 93 10 3C FB 0A EE FD 2A 68  
 6E 01 FA 4A 58 E8 A3 63 9C A8 A1 E3 F9 AE 57 E2  
 35 B8 CC 87 3C 23 DC 62 B8 D2 60 16 9A FA 2F 75  
 AB 91 6A 58 D9 74 91 88 35 D2 5E 6A 43 50 85 B2  
 BA DF D6 DF AA C3 59 A5 EF BB 7B CC 4B 59 D5 38  
 DF 9A 04 30 2E 10 C8 BC 1C BF 1A 0B 3A 51 20 EA  
 17 CD A7 CF AD 76 5F 56 23 47 4D 36 8C CC A8 AF  
 00 07 CD 9F 5E 4C 84 9F 16 7A 58 0B 14 AA BD EF  
 AE E7 EE F4 7C B0 FC A9 4C CA AE BA 77 4E C2 0C  
 FF 6A 94 85 A9 7B FC 65 AA 93 AA 4F C9 58 D1 ED  
 B5 27 C0 2E 3A E5 7B CC

After  $\iota$ 

7F 9C 2B A4 E8 8F 82 7D 61 60 45 50 76 05 85 3E  
 D7 3B 80 93 F6 EF BC 88 EB 1A 6E AC FA 66 EF 26  
 3C B1 EE A9 88 00 4B 93 10 3C FB 0A EE FD 2A 68  
 6E 01 FA 4A 58 E8 A3 63 9C A8 A1 E3 F9 AE 57 E2  
 35 B8 CC 87 3C 23 DC 62 B8 D2 60 16 9A FA 2F 75  
 AB 91 6A 58 D9 74 91 88 35 D2 5E 6A 43 50 85 B2  
 BA DF D6 DF AA C3 59 A5 EF BB 7B CC 4B 59 D5 38  
 DF 9A 04 30 2E 10 C8 BC 1C BF 1A 0B 3A 51 20 EA  
 17 CD A7 CF AD 76 5F 56 23 47 4D 36 8C CC A8 AF  
 00 07 CD 9F 5E 4C 84 9F 16 7A 58 0B 14 AA BD EF  
 AE E7 EE F4 7C B0 FC A9 4C CA AE BA 77 4E C2 0C  
 FF 6A 94 85 A9 7B FC 65 AA 93 AA 4F C9 58 D1 ED  
 B5 27 C0 2E 3A E5 7B CC

After permutation

7F 9C 2B A4 E8 8F 82 7D 61 60 45 50 76 05 85 3E  
 D7 3B 80 93 F6 EF BC 88 EB 1A 6E AC FA 66 EF 26  
 3C B1 EE A9 88 00 4B 93 10 3C FB 0A EE FD 2A 68  
 6E 01 FA 4A 58 E8 A3 63 9C A8 A1 E3 F9 AE 57 E2  
 35 B8 CC 87 3C 23 DC 62 B8 D2 60 16 9A FA 2F 75  
 AB 91 6A 58 D9 74 91 88 35 D2 5E 6A 43 50 85 B2  
 BA DF D6 DF AA C3 59 A5 EF BB 7B CC 4B 59 D5 38  
 DF 9A 04 30 2E 10 C8 BC 1C BF 1A 0B 3A 51 20 EA  
 17 CD A7 CF AD 76 5F 56 23 47 4D 36 8C CC A8 AF  
 00 07 CD 9F 5E 4C 84 9F 16 7A 58 0B 14 AA BD EF  
 AE E7 EE F4 7C B0 FC A9 4C CA AE BA 77 4E C2 0C  
 FF 6A 94 85 A9 7B FC 65 AA 93 AA 4F C9 58 D1 ED  
 B5 27 C0 2E 3A E5 7B CC

State (as lanes of integers)

[0, 0] = 7D828FE8A42B9C7F  
 [1, 0] = 3E85057650456061  
 [2, 0] = 88BCEFF693803BD7  
 [3, 0] = 26EF66FAAC6E1AEB  
 [4, 0] = 934B0088A9EEB13C  
 [0, 1] = 682AFDEE0AFB3C10  
 [1, 1] = 63A3E8584AFA016E  
 [2, 1] = E257AEF9E3A1A89C  
 [3, 1] = 62DC233C87CCB835  
 [4, 1] = 752FFA9A1660D2B8  
 [0, 2] = 889174D9586A91AB  
 [1, 2] = B28550436A5ED235  
 [2, 2] = A559C3AADFD6DFBA  
 [3, 2] = 38D5594BCC7BBBEF  
 [4, 2] = BCC8102E30049ADF  
 [0, 3] = EA20513A0B1ABF1C  
 [1, 3] = 565F76ADCFA7CD17  
 [2, 3] = AFA8CC8C364D4723  
 [3, 3] = 9F844C5E9FCD0700  
 [4, 3] = EFBDA1140B587A16  
 [0, 4] = A9FCB07CF4EEE7AE  
 [1, 4] = 0CC24E77BAAECA4C  
 [2, 4] = 65FC7BA985946AFF  
 [3, 4] = EDD158C94FAA93AA  
 [4, 4] = CC7BE53A2EC027B5

About to call squeeze (again)

State before permutation

7F 9C 2B A4 E8 8F 82 7D 61 60 45 50 76 05 85 3E  
 D7 3B 80 93 F6 EF BC 88 EB 1A 6E AC FA 66 EF 26  
 3C B1 EE A9 88 00 4B 93 10 3C FB 0A EE FD 2A 68  
 6E 01 FA 4A 58 E8 A3 63 9C A8 A1 E3 F9 AE 57 E2  
 35 B8 CC 87 3C 23 DC 62 B8 D2 60 16 9A FA 2F 75  
 AB 91 6A 58 D9 74 91 88 35 D2 5E 6A 43 50 85 B2  
 BA DF D6 DF AA C3 59 A5 EF BB 7B CC 4B 59 D5 38  
 DF 9A 04 30 2E 10 C8 BC 1C BF 1A 0B 3A 51 20 EA  
 17 CD A7 CF AD 76 5F 56 23 47 4D 36 8C CC A8 AF  
 00 07 CD 9F 5E 4C 84 9F 16 7A 58 0B 14 AA BD EF  
 AE E7 EE F4 7C B0 FC A9 4C CA AE BA 77 4E C2 0C  
 FF 6A 94 85 A9 7B FC 65 AA 93 AA 4F C9 58 D1 ED  
 B5 27 C0 2E 3A E5 7B CC

State before permutation (as lanes of integers)

[0, 0] = 7D828FE8A42B9C7F  
 [1, 0] = 3E85057650456061  
 [2, 0] = 88BCEFF693803BD7  
 [3, 0] = 26EF66FAAC6E1AEB  
 [4, 0] = 934B0088A9EEB13C  
 [0, 1] = 682AFDEE0AFB3C10  
 [1, 1] = 63A3E8584AFA016E  
 [2, 1] = E257AEF9E3A1A89C  
 [3, 1] = 62DC233C87CCB835  
 [4, 1] = 752FFA9A1660D2B8  
 [0, 2] = 889174D9586A91AB  
 [1, 2] = B28550436A5ED235  
 [2, 2] = A559C3AADFD6DFBA  
 [3, 2] = 38D5594BCC7BBBEF  
 [4, 2] = BCC8102E30049ADF  
 [0, 3] = EA20513A0B1ABF1C  
 [1, 3] = 565F76ADCFA7CD17  
 [2, 3] = AFA8CC8C364D4723  
 [3, 3] = 9F844C5E9FCD0700  
 [4, 3] = EFBDA140B587A16  
 [0, 4] = A9FCB07CF4EEE7AE  
 [1, 4] = 0CC24E77BAAECA4C  
 [2, 4] = 65FC7BA985946AFF  
 [3, 4] = EDD158C94FAA93AA  
 [4, 4] = CC7BE53A2EC027B5

Round #0

After  $\theta$

44 50 E8 05 94 21 95 6E 4D CB 57 61 EF 89 AC EB  
 80 94 15 F9 75 7A E4 20 36 32 65 E4 5F 19 DC D1  
 4A EE CC 8C A0 C7 33 20 2B F0 38 AB 92 53 3D 7B  
 42 AA E8 7B C1 64 8A B6 CB 07 34 89 7A 3B 0F 4A  
 E8 90 C7 CF 99 5C EF 95 CE 8D 42 33 B2 3D 57 C6  
 90 5D A9 F9 A5 DA 86 9B 19 79 4C 5B DA DC AC 67  
 ED 70 43 B5 29 56 01 0D 32 93 70 84 EE 26 E6 CF  
 A9 C5 26 15 06 D7 B0 0F 27 73 D9 AA 46 FF 37 F9  
 3B 66 B5 FE 34 FA 76 83 74 E8 D8 5C 0F 59 F0 07  
 DD 2F C6 D7 FB 33 B7 68 60 25 7A 2E 3C 6D C5 5C  
 95 2B 2D 55 00 1E EB BA 60 61 BC 8B EE C2 EB D9  
 A8 C5 01 EF 2A EE A4 CD 77 BB A1 07 6C 27 E2 1A  
 C3 78 E2 0B 12 22 03 7F

After  $\rho$ 

44 50 E8 05 94 21 95 6E 9B 96 AF C2 DE 13 59 D7  
 20 65 45 7E 9D 1E 39 08 95 C1 1D 6D 23 53 46 FE  
 3D 9E 01 51 72 67 66 04 2A 39 D5 B3 B7 02 8F B3  
 BE 17 4C A6 68 2B A4 8A D2 F2 01 4D A2 DE CE 83  
 C8 E3 E7 4C AE F7 4A 74 73 65 EC DC 28 34 23 DB  
 84 EC 4A CD 2F D5 36 DC 9E 65 E4 31 6D 69 73 B3  
 AA 4D B1 0A 68 68 87 1B 4D CC 9F 65 26 E1 08 DD  
 0A 83 6B D8 87 D4 62 93 55 8D FE 6F F2 4F E6 B2  
 D6 9F 46 DF 6E 70 C7 AC F8 03 3A 74 6C AE 87 2C  
 E6 16 AD FB C5 F8 7A 7F 5C 60 25 7A 2E 3C 6D C5  
 AC EB 56 AE B4 54 01 78 83 85 F1 2E BA 0B AF 67  
 B5 38 E0 5D C5 9D B4 19 BB A1 07 6C 27 E2 1A 77  
 C0 DF 30 9E F8 82 84 C8

After  $\pi$ 

44 50 E8 05 94 21 95 6E BE 17 4C A6 68 2B A4 8A  
 AA 4D B1 0A 68 68 87 1B E6 16 AD FB C5 F8 7A 7F  
 C0 DF 30 9E F8 82 84 C8 95 C1 1D 6D 23 53 46 FE  
 73 65 EC DC 28 34 23 DB 84 EC 4A CD 2F D5 36 DC  
 D6 9F 46 DF 6E 70 C7 AC B5 38 E0 5D C5 9D B4 19  
 9B 96 AF C2 DE 13 59 D7 D2 F2 01 4D A2 DE CE 83  
 4D CC 9F 65 26 E1 08 DD 5C 60 25 7A 2E 3C 6D C5  
 AC EB 56 AE B4 54 01 78 3D 9E 01 51 72 67 66 04  
 2A 39 D5 B3 B7 02 8F B3 9E 65 E4 31 6D 69 73 B3  
 F8 03 3A 74 6C AE 87 2C BB A1 07 6C 27 E2 1A 77  
 20 65 45 7E 9D 1E 39 08 C8 E3 E7 4C AE F7 4A 74  
 0A 83 6B D8 87 D4 62 93 55 8D FE 6F F2 4F E6 B2  
 83 85 F1 2E BA 0B AF 67

After  $\chi$ 

44 18 59 0D 94 61 96 7F FA 05 40 57 ED BB DC EE  
 AA 84 A1 0E 50 6A 03 9B E2 16 65 FA C1 D9 6B 59  
 7A D8 34 3C 90 88 A4 48 11 49 1F 6C 24 92 52 FA  
 21 76 E8 CE 68 14 E2 FB A5 CC EA CD AE 58 06 CD  
 D6 5E 5B FF 4C 32 85 4A D7 1C 00 CD CD B9 95 18  
 96 9A 31 E2 DA 32 59 8B C2 D2 21 57 AA C2 AB 83  
 ED 47 CD E1 B6 A1 08 E5 4F 74 8C 3A 64 3F 35 42  
 EC 8B 56 A3 94 98 87 78 A9 DA 21 51 3A 0E 16 04  
 4A 3B CF F7 B7 84 0B BF 9D C5 E1 39 6E 29 6B E0  
 FC 1D 3A 65 3C AB E3 2C B9 80 D3 CE A2 E2 93 C4  
 22 65 4D EE 9C 1E 19 8B 9D EF 73 6B DE FC CE 54  
 88 83 6A D8 8F D4 6B D6 75 ED FA 3F F7 5B F6 BA  
 4B 07 53 2E 98 EA ED 13

After  $t$

45 18 59 0D 94 61 96 7F FA 05 40 57 ED BB DC EE  
AA 84 A1 0E 50 6A 03 9B E2 16 65 FA C1 D9 6B 59  
7A D8 34 3C 90 88 A4 48 11 49 1F 6C 24 92 52 FA  
21 76 E8 CE 68 14 E2 FB A5 CC EA CD AE 58 06 CD  
D6 5E 5B FF 4C 32 85 4A D7 1C 00 CD CD B9 95 18  
96 9A 31 E2 DA 32 59 8B C2 D2 21 57 AA C2 AB 83  
ED 47 CD E1 B6 A1 08 E5 4F 74 8C 3A 64 3F 35 42  
EC 8B 56 A3 94 98 87 78 A9 DA 21 51 3A 0E 16 04  
4A 3B CF F7 B7 84 0B BF 9D C5 E1 39 6E 29 6B E0  
FC 1D 3A 65 3C AB E3 2C B9 80 D3 CE A2 E2 93 C4  
22 65 4D EE 9C 1E 19 8B 9D EF 73 6B DE FC CE 54  
88 83 6A D8 8F D4 6B D6 75 ED FA 3F F7 5B F6 BA  
4B 07 53 2E 98 EA ED 13

(Skip rounds 1 to 22)

Round #23

After  $\theta$

38 EB E3 7D 36 5C 29 FB B3 4A 0D 6A BC 96 62 80  
A8 AE AB 8A 81 C2 F5 C6 6E A9 B2 90 4D 39 13 24  
1C 38 32 7D 93 63 CC EF 72 3E 0E EF 7F C5 39 7C  
B0 9C 84 F3 96 FB F9 70 7F 38 FD A8 E4 63 9A 41  
74 F7 FA 60 97 0E D4 66 D5 49 8A 48 94 CC F6 C9  
8E 33 8C 50 72 E6 8C 7A 75 51 1C 2D 3D 77 42 4C  
39 B6 D5 EE 66 D0 F3 92 8C 0D BC ED 0D E3 40 52  
A5 7D 92 41 35 0A 21 9D 5C 60 21 27 18 20 67 2C  
B2 A7 72 50 8E 9A 47 D5 64 AD 4B 1D 66 DF FE 31  
36 CE 9C 89 E7 3B CF 9A 15 E2 E0 AB F2 8C 59 69  
3A F0 98 FA 59 9F 6B AA 77 0F B2 DF 43 39 07 F6  
DC AA 81 F2 54 DB 92 E7 8F F1 7C 6C 29 40 9A 86  
EF C9 88 30 89 D1 CB B8

After  $\rho$ 

38 EB E3 7D 36 5C 29 FB 67 95 1A D4 78 2D C5 00  
 AA EB AA 62 A0 70 BD 31 94 33 41 E2 96 2A 0B D9  
 1C 63 7E E7 C0 91 E9 9B FE 57 9C C3 27 E7 E3 F0  
 38 6F B9 9F 0F 07 CB 49 D0 1F 4E 3F 2A F9 98 66  
 7B 7D B0 4B 07 6A 33 BA 6C 9F 5C 9D A4 88 44 C9  
 73 9C 61 84 92 33 67 D4 31 D5 45 71 B4 F4 DC 09  
 76 37 83 9E 97 CC B1 AD C6 81 A4 18 1B 78 DB 1B  
 A0 1A 85 90 CE D2 3E C9 4E 30 40 CE 58 B8 C0 42  
 0E CA 51 F3 A8 5A F6 54 FF 18 B2 D6 A5 0E B3 6F  
 E7 59 D3 C6 99 33 F1 7C 69 15 E2 E0 AB F2 8C 59  
 AE A9 EA C0 63 EA 67 7D DF 3D C8 7E 0F E5 1C D8  
 5B 35 50 9E 6A 5B F2 9C F1 7C 6C 29 40 9A 86 8F  
 32 EE 7B 32 22 4C 62 F4

After  $\pi$ 

38 EB E3 7D 36 5C 29 FB 38 6F B9 9F 0F 07 CB 49  
 76 37 83 9E 97 CC B1 AD E7 59 D3 C6 99 33 F1 7C  
 32 EE 7B 32 22 4C 62 F4 94 33 41 E2 96 2A 0B D9  
 6C 9F 5C 9D A4 88 44 C9 73 9C 61 84 92 33 67 D4  
 0E CA 51 F3 A8 5A F6 54 5B 35 50 9E 6A 5B F2 9C  
 67 95 1A D4 78 2D C5 00 D0 1F 4E 3F 2A F9 98 66  
 C6 81 A4 18 1B 78 DB 1B 69 15 E2 E0 AB F2 8C 59  
 AE A9 EA C0 63 EA 67 7D 1C 63 7E E7 C0 91 E9 9B  
 FE 57 9C C3 27 E7 E3 F0 31 D5 45 71 B4 F4 DC 09  
 FF 18 B2 D6 A5 0E B3 6F F1 7C 6C 29 40 9A 86 8F  
 AA EB AA 62 A0 70 BD 31 7B 7D B0 4B 07 6A 33 BA  
 A0 1A 85 90 CE D2 3E C9 4E 30 40 CE 58 B8 C0 42  
 DF 3D C8 7E 0F E5 1C D8

After  $\chi$ 

7E FB E1 7D A6 94 19 5F B9 27 E9 DF 07 34 8B 19  
 66 91 AB AE B5 80 B3 2D EF 58 53 8B 8D 23 F8 77  
 32 EA 63 B0 2B 4F A0 F4 87 33 60 E2 84 19 28 CD  
 60 DD 4C EE 8C C0 D4 C9 22 A9 61 88 D0 32 67 5C  
 8A C8 50 93 3C 7A FF 15 33 B9 4C 83 4A DB B6 9C  
 61 15 BA D4 69 2D 86 19 F9 0B 0C DF 8A 7B 9C 26  
 40 29 AC 18 5B 70 B8 3F 28 01 F2 F4 B3 F7 0C 59  
 3E A3 AE EB 61 3A 7F 1B 1D E3 3F D7 50 81 F5 92  
 30 5F 2E 45 26 ED C0 96 31 B1 09 58 F4 64 D8 89  
 F3 1B A0 10 25 0F DA 7F 13 68 EC 29 67 FC 84 EF  
 2A E9 AF F2 68 E0 B1 70 35 5D F0 05 17 42 F3 B8  
 31 17 0D A0 C9 97 22 51 6E F2 62 CE F8 A8 61 63  
 8E 29 D8 77 08 EF 1E 52

After t

```

76 7B E1 FD A6 94 19 DF B9 27 E9 DF 07 34 8B 19
66 91 AB AE B5 80 B3 2D EF 58 53 8B 8D 23 F8 77
32 EA 63 B0 2B 4F A0 F4 87 33 60 E2 84 19 28 CD
60 DD 4C EE 8C C0 D4 C9 22 A9 61 88 D0 32 67 5C
8A C8 50 93 3C 7A FF 15 33 B9 4C 83 4A DB B6 9C
61 15 BA D4 69 2D 86 19 F9 0B 0C DF 8A 7B 9C 26
40 29 AC 18 5B 70 B8 3F 28 01 F2 F4 B3 F7 0C 59
3E A3 AE EB 61 3A 7F 1B 1D E3 3F D7 50 81 F5 92
30 5F 2E 45 26 ED C0 96 31 B1 09 58 F4 64 D8 89
F3 1B A0 10 25 0F DA 7F 13 68 EC 29 67 FC 84 EF
2A E9 AF F2 68 E0 B1 70 35 5D F0 05 17 42 F3 B8
31 17 0D A0 C9 97 22 51 6E F2 62 CE F8 A8 61 63
      8E 29 D8 77 08 EF 1E 52

```

After permutation

```

76 7B E1 FD A6 94 19 DF B9 27 E9 DF 07 34 8B 19
66 91 AB AE B5 80 B3 2D EF 58 53 8B 8D 23 F8 77
32 EA 63 B0 2B 4F A0 F4 87 33 60 E2 84 19 28 CD
60 DD 4C EE 8C C0 D4 C9 22 A9 61 88 D0 32 67 5C
8A C8 50 93 3C 7A FF 15 33 B9 4C 83 4A DB B6 9C
61 15 BA D4 69 2D 86 19 F9 0B 0C DF 8A 7B 9C 26
40 29 AC 18 5B 70 B8 3F 28 01 F2 F4 B3 F7 0C 59
3E A3 AE EB 61 3A 7F 1B 1D E3 3F D7 50 81 F5 92
30 5F 2E 45 26 ED C0 96 31 B1 09 58 F4 64 D8 89
F3 1B A0 10 25 0F DA 7F 13 68 EC 29 67 FC 84 EF
2A E9 AF F2 68 E0 B1 70 35 5D F0 05 17 42 F3 B8
31 17 0D A0 C9 97 22 51 6E F2 62 CE F8 A8 61 63
      8E 29 D8 77 08 EF 1E 52

```



State (as lanes of integers)

[0,0] = DF1994A6FDE17B76  
 [1,0] = 198B3407DFE927B9  
 [2,0] = 2DB380B5AEAB9166  
 [3,0] = 77F8238D8B5358EF  
 [4,0] = F4A04F2BB063EA32  
 [0,1] = CD281984E2603387  
 [1,1] = C9D4C08CEE4CDD60  
 [2,1] = 5C6732D08861A922  
 [3,1] = 15FF7A3C9350C88A  
 [4,1] = 9CB6DB4A834CB933  
 [0,2] = 19862D69D4BA1561  
 [1,2] = 269C7B8ADF0C0BF9  
 [2,2] = 3FB8705B18AC2940  
 [3,2] = 590CF7B3F4F20128  
 [4,2] = 1B7F3A61EBAEA33E  
 [0,3] = 92F58150D73FE31D  
 [1,3] = 96C0ED26452E5F30  
 [2,3] = 89D864F45809B131  
 [3,3] = 7FDA0F2510A01BF3  
 [4,3] = EF84FC6729EC6813  
 [0,4] = 70B1E068F2AFE92A  
 [1,4] = B8F3421705F05D35  
 [2,4] = 512297C9A00D1731  
 [3,4] = 6361A8F8CE62F26E  
 [4,4] = 521EEF0877D8298E

About to call squeeze (again)

State before permutation (in bytes)

76 7B E1 FD A6 94 19 DF B9 27 E9 DF 07 34 8B 19  
 66 91 AB AE B5 80 B3 2D EF 58 53 8B 8D 23 F8 77  
 32 EA 63 B0 2B 4F A0 F4 87 33 60 E2 84 19 28 CD  
 60 DD 4C EE 8C C0 D4 C9 22 A9 61 88 D0 32 67 5C  
 8A C8 50 93 3C 7A FF 15 33 B9 4C 83 4A DB B6 9C  
 61 15 BA D4 69 2D 86 19 F9 0B 0C DF 8A 7B 9C 26  
 40 29 AC 18 5B 70 B8 3F 28 01 F2 F4 B3 F7 0C 59  
 3E A3 AE EB 61 3A 7F 1B 1D E3 3F D7 50 81 F5 92  
 30 5F 2E 45 26 ED C0 96 31 B1 09 58 F4 64 D8 89  
 F3 1B A0 10 25 0F DA 7F 13 68 EC 29 67 FC 84 EF  
 2A E9 AF F2 68 E0 B1 70 35 5D F0 05 17 42 F3 B8  
 31 17 0D A0 C9 97 22 51 6E F2 62 CE F8 A8 61 63  
 8E 29 D8 77 08 EF 1E 52

State before permutation (as lanes of integers)

[0, 0] = DF1994A6FDE17B76  
 [1, 0] = 198B3407DFE927B9  
 [2, 0] = 2DB380B5AEAB9166  
 [3, 0] = 77F8238D8B5358EF  
 [4, 0] = F4A04F2BB063EA32  
 [0, 1] = CD281984E2603387  
 [1, 1] = C9D4C08CEE4CDD60  
 [2, 1] = 5C6732D08861A922  
 [3, 1] = 15FF7A3C9350C88A  
 [4, 1] = 9CB6DB4A834CB933  
 [0, 2] = 19862D69D4BA1561  
 [1, 2] = 269C7B8ADF0C0BF9  
 [2, 2] = 3FB8705B18AC2940  
 [3, 2] = 590CF7B3F4F20128  
 [4, 2] = 1B7F3A61EBAEA33E  
 [0, 3] = 92F58150D73FE31D  
 [1, 3] = 96C0ED26452E5F30  
 [2, 3] = 89D864F45809B131  
 [3, 3] = 7FDA0F2510A01BF3  
 [4, 3] = EF84FC6729EC6813  
 [0, 4] = 70B1E068F2AFE92A  
 [1, 4] = B8F3421705F05D35  
 [2, 4] = 512297C9A00D1731  
 [3, 4] = 6361A8F8CE62F26E  
 [4, 4] = 521EEF0877D8298E

Round #0

After  $\theta$

9F 2C BB 27 A8 69 0A A0 17 1E 87 BD 73 97 54 DD  
 E3 93 BA 64 3B B3 23 BA AE 8C 5A 40 51 68 89 7C  
 AD 3D 06 5F 13 C4 F7 00 6E 64 3A 38 8A E4 3B B2  
 CE E4 22 8C F8 63 0B 0D A7 AB 70 42 5E 01 F7 CB  
 CB 1C 59 58 E0 31 8E 1E AC 6E 29 6C 72 50 E1 68  
 88 42 E0 0E 67 D0 95 66 57 32 62 BD FE D8 43 E2  
 C5 2B BD D2 D5 43 28 A8 69 D5 FB 3F 6F BC 7D 52  
 A1 74 CB 04 59 B1 28 EF F4 B4 65 0D 5E 7C E6 ED  
 9E 66 40 27 52 4E 1F 52 B4 B3 18 92 7A 57 48 1E  
 B2 CF A9 DB F9 44 AB 74 8C BF 89 C6 5F 77 D3 1B  
 C3 BE F5 28 66 1D A2 0F 9B 64 9E 67 63 E1 2C 7C  
 B4 15 1C 6A 47 A4 B2 C6 2F 26 6B 05 24 E3 10 68  
 11 FE BD 98 30 64 49 A6

After  $\rho$

9F 2C BB 27 A8 69 0A A0 2F 3C 0E 7B E7 2E A9 BA  
 F8 A4 2E D9 CE EC 88 EE 85 96 C8 E7 CA A8 05 14  
 20 BE 07 68 ED 31 F8 9A A3 48 BE 23 EB 46 A6 83  
 C2 88 3F B6 D0 E0 4C 2E F2 E9 2A 9C 90 57 C0 FD  
 8E 2C 2C F0 18 47 8F 65 15 8E C6 EA 96 C2 26 07  
 43 14 02 77 38 83 AE 34 89 5F C9 88 F5 FA 63 0F  
 95 AE 1E 42 41 2D 5E E9 78 FB A4 D2 AA F7 7F DE  
 82 AC 58 94 F7 50 BA 65 1A BC F8 CC DB E9 69 CB  
 E8 44 CA E9 43 CA D3 0C 24 0F DA 59 0C 49 BD 2B  
 68 95 4E F6 39 75 3B 9F 1B 8C BF 89 C6 5F 77 D3  
 88 3E 0C FB D6 A3 98 75 6D 92 79 9E 8D 85 B3 F0  
 B6 82 43 ED 88 54 D6 98 26 6B 05 24 E3 10 68 2F  
 92 69 84 7F 2F 26 0C 59

After  $\pi$

9F 2C BB 27 A8 69 0A A0 C2 88 3F B6 D0 E0 4C 2E  
 95 AE 1E 42 41 2D 5E E9 68 95 4E F6 39 75 3B 9F  
 92 69 84 7F 2F 26 0C 59 85 96 C8 E7 CA A8 05 14  
 15 8E C6 EA 96 C2 26 07 43 14 02 77 38 83 AE 34  
 E8 44 CA E9 43 CA D3 0C B6 82 43 ED 88 54 D6 98  
 2F 3C 0E 7B E7 2E A9 BA F2 E9 2A 9C 90 57 C0 FD  
 78 FB A4 D2 AA F7 7F DE 1B 8C BF 89 C6 5F 77 D3  
 88 3E 0C FB D6 A3 98 75 20 BE 07 68 ED 31 F8 9A  
 A3 48 BE 23 EB 46 A6 83 89 5F C9 88 F5 FA 63 0F  
 24 0F DA 59 0C 49 BD 2B 26 6B 05 24 E3 10 68 2F  
 F8 A4 2E D9 CE EC 88 EE 8E 2C 2C F0 18 47 8F 65  
 82 AC 58 94 F7 50 BA 65 1A BC F8 CC DB E9 69 CB  
 6D 92 79 9E 8D 85 B3 F0

After  $\chi$

8A 0A BB 67 A9 64 18 61 AA 99 7F 02 E8 B0 6D 38  
 07 C6 9E 4B 47 2F 5A A9 65 91 75 F6 B9 3C 39 3F  
 D2 E9 80 EF 7F A6 48 57 C7 86 C8 F2 E2 A9 8D 24  
 BD CE 0E 62 D5 8A 77 0F 55 96 03 73 B0 97 AA A4  
 E9 50 42 EB 01 62 D2 08 A6 8A 45 E5 9C 16 F4 9B  
 27 2E 8A 39 CD 8E 96 B8 F1 ED 31 95 D4 5F C0 FC  
 F8 C9 A4 A0 BA 57 F7 FA 3C 8C BD 89 E7 53 56 59  
 58 FF 2C 7F C6 F2 D8 30 28 A9 46 E0 F9 89 B9 96  
 87 48 AC 72 E3 47 3A A3 8B 3F CC AC 16 EA 23 0B  
 24 9B D8 11 00 68 2D BB A5 2B BD 27 E1 56 6E 2E  
 F8 24 7E DD 29 FC B8 EE 96 3C 8C B8 10 EE CE EF  
 E7 AE 59 86 F3 54 28 55 8A 98 FE 8D 99 81 61 C5  
 6B 9A 79 BE 9D 86 B4 F1

After  $t$

8B 0A BB 67 A9 64 18 61 AA 99 7F 02 E8 B0 6D 38  
 07 C6 9E 4B 47 2F 5A A9 65 91 75 F6 B9 3C 39 3F  
 D2 E9 80 EF 7F A6 48 57 C7 86 C8 F2 E2 A9 8D 24  
 BD CE 0E 62 D5 8A 77 0F 55 96 03 73 B0 97 AA A4  
 E9 50 42 EB 01 62 D2 08 A6 8A 45 E5 9C 16 F4 9B  
 27 2E 8A 39 CD 8E 96 B8 F1 ED 31 95 D4 5F C0 FC  
 F8 C9 A4 A0 BA 57 F7 FA 3C 8C BD 89 E7 53 56 59  
 58 FF 2C 7F C6 F2 D8 30 28 A9 46 E0 F9 89 B9 96  
 87 48 AC 72 E3 47 3A A3 8B 3F CC AC 16 EA 23 0B  
 24 9B D8 11 00 68 2D BB A5 2B BD 27 E1 56 6E 2E  
 F8 24 7E DD 29 FC B8 EE 96 3C 8C B8 10 EE CE EF  
 E7 AE 59 86 F3 54 28 55 8A 98 FE 8D 99 81 61 C5  
 6B 9A 79 BE 9D 86 B4 F1

(Skip rounds 1 to 22)

Round #23

After  $\theta$

24 F3 4C 0B 2B 53 2B E5 01 58 E8 86 76 54 27 BB  
 E5 CB C8 81 CC B9 AC E4 E7 35 DC 86 4F 5D B1 57  
 63 96 A9 1E E8 8B 43 5A AC 21 84 1F FE 01 8C A9  
 CF 3E 10 19 17 03 6B E5 88 F0 B1 AA B6 3C AD 4F  
 E7 B5 59 BA 83 7E 0B 57 C4 85 48 7C A2 1E E5 C7  
 02 D1 1B 7B 79 0A 7B 03 47 86 2E 94 35 80 AF E5  
 AA 5A CB A6 5B 31 93 6C 0B 8D A0 96 16 73 60 82  
 D0 05 D4 79 71 59 70 81 8A 03 71 AB D6 C1 89 72  
 A3 5F 4A 54 8E 95 3A EE 93 8B 08 B7 84 CA B1 E0  
 90 6A E4 9A 38 12 09 72 DD 04 C3 7E 0B 12 60 ED  
 44 1A CD AE A8 6A D3 2E E3 F4 95 B6 6B 53 43 4C  
 DE 97 C5 E5 AE E6 E3 05 AA 64 4A 2C 9A 95 46 47  
 B5 EA 07 D7 61 5F AD EA

After  $\rho$ 

24 F3 4C 0B 2B 53 2B E5 03 B0 D0 0D ED A8 4E 76  
 F9 32 72 20 73 2E 2B 79 D4 15 7B 75 5E C3 6D F8  
 5F 1C D2 1A B3 4C F5 40 E1 1F C0 98 CA 1A 42 F8  
 91 71 31 B0 56 FE EC 03 13 22 7C AC AA 2D 4F EB  
 DA 2C DD 41 BF 85 AB F3 51 7E 4C 5C 88 C4 27 EA  
 10 88 DE D8 CB 53 D8 1B 96 1F 19 BA 50 D6 00 BE  
 36 DD 8A 99 64 53 D5 5A E6 C0 04 17 1A 41 2D 2D  
 BC B8 2C B8 40 E8 02 EA 56 AD 83 13 E5 14 07 E2  
 89 CA B1 52 C7 7D F4 4B 58 F0 C9 45 84 5B 42 E5  
 22 41 0E 52 8D 5C 13 47 ED DD 04 C3 7E 0B 12 60  
 4D BB 10 69 34 BB A2 AA 8D D3 57 DA AE 4D 0D 31  
 FB B2 B8 DC D5 7C BC C0 64 4A 2C 9A 95 46 47 AA  
 AB 7A AD FA C1 75 D8 57

After  $\pi$ 

24 F3 4C 0B 2B 53 2B E5 91 71 31 B0 56 FE EC 03  
 36 DD 8A 99 64 53 D5 5A 22 41 0E 52 8D 5C 13 47  
 AB 7A AD FA C1 75 D8 57 D4 15 7B 75 5E C3 6D F8  
 51 7E 4C 5C 88 C4 27 EA 10 88 DE D8 CB 53 D8 1B  
 89 CA B1 52 C7 7D F4 4B 58 F0 C9 45 84 5B 42 E5  
 03 B0 D0 0D ED A8 4E 76 13 22 7C AC AA 2D 4F EB  
 E6 C0 04 17 1A 41 2D 2D ED DD 04 C3 7E 0B 12 60  
 4D BB 10 69 34 BB A2 AA 5F 1C D2 1A B3 4C F5 40  
 E1 1F C0 98 CA 1A 42 F8 96 1F 19 BA 50 D6 00 BE  
 58 F0 C9 45 84 5B 42 E5 64 4A 2C 9A 95 46 47 AA  
 F9 32 72 20 73 2E 2B 79 DA 2C DD 41 BF 85 AB F3  
 BC B8 2C B8 40 E8 02 EA 56 AD 83 13 E5 14 07 E2  
 8D D3 57 DA AE 4D 0D 31

After  $\chi$ 

02 7F C6 02 0B 52 3A BD 91 71 35 F2 DF F2 EE 06  
 BF E7 2B 31 24 72 1D 4A 26 C0 4E 53 A7 5E 30 E7  
 3A 7A 9C 4A 95 D9 1C 55 D4 95 E9 F5 1D D0 B5 E9  
 D8 3C 6D 5E 8C E8 03 AA 62 B8 D6 54 DB 53 D0 9B  
 8D CF F2 73 CD FE B5 73 FA D8 BC D4 55 78 BE C2  
 E7 70 D0 1E FD E8 6E 72 1A 3F 7C 6C CE 27 5D AB  
 E6 E2 14 3F 1A F1 8D A7 EF DD C4 C7 B7 0B 5E 34  
 5D B9 3C C9 36 BE A3 23 49 1C CB 38 A3 88 F5 46  
 A9 FF 00 DD 4E 13 00 B9 B2 15 3D 20 41 D2 05 B4  
 43 E4 1B 45 A6 53 F2 A5 C4 49 2C 1A DD 54 45 12  
 DD A2 52 98 33 46 2B 71 98 29 5E 42 1A 91 AE F3  
 35 EA 78 70 4A A1 0A FB 26 8D A3 33 B4 36 25 AA  
 8F DF DA 9B 22 CC 8D B3

After t

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0A FF C6 82 0B 52 3A 3D 91 71 35 F2 DF F2 EE 06
BF E7 2B 31 24 72 1D 4A 26 C0 4E 53 A7 5E 30 E7
3A 7A 9C 4A 95 D9 1C 55 D4 95 E9 F5 1D D0 B5 E9
D8 3C 6D 5E 8C E8 03 AA 62 B8 D6 54 DB 53 D0 9B
8D CF F2 73 CD FE B5 73 FA D8 BC D4 55 78 BE C2
E7 70 D0 1E FD E8 6E 72 1A 3F 7C 6C CE 27 5D AB
E6 E2 14 3F 1A F1 8D A7 EF DD C4 C7 B7 0B 5E 34
5D B9 3C C9 36 BE A3 23 49 1C CB 38 A3 88 F5 46
A9 FF 00 DD 4E 13 00 B9 B2 15 3D 20 41 D2 05 B4
43 E4 1B 45 A6 53 F2 A5 C4 49 2C 1A DD 54 45 12
DD A2 52 98 33 46 2B 71 98 29 5E 42 1A 91 AE F3
35 EA 78 70 4A A1 0A FB 26 8D A3 33 B4 36 25 AA
      8F DF DA 9B 22 CC 8D B3

```

After permutation

```

0A FF C6 82 0B 52 3A 3D 91 71 35 F2 DF F2 EE 06
BF E7 2B 31 24 72 1D 4A 26 C0 4E 53 A7 5E 30 E7
3A 7A 9C 4A 95 D9 1C 55 D4 95 E9 F5 1D D0 B5 E9
D8 3C 6D 5E 8C E8 03 AA 62 B8 D6 54 DB 53 D0 9B
8D CF F2 73 CD FE B5 73 FA D8 BC D4 55 78 BE C2
E7 70 D0 1E FD E8 6E 72 1A 3F 7C 6C CE 27 5D AB
E6 E2 14 3F 1A F1 8D A7 EF DD C4 C7 B7 0B 5E 34
5D B9 3C C9 36 BE A3 23 49 1C CB 38 A3 88 F5 46
A9 FF 00 DD 4E 13 00 B9 B2 15 3D 20 41 D2 05 B4
43 E4 1B 45 A6 53 F2 A5 C4 49 2C 1A DD 54 45 12
DD A2 52 98 33 46 2B 71 98 29 5E 42 1A 91 AE F3
35 EA 78 70 4A A1 0A FB 26 8D A3 33 B4 36 25 AA
      8F DF DA 9B 22 CC 8D B3

```

State (as lanes of integers)

[0,0] = 3D3A520B82C6FF0A  
 [1,0] = 06EEF2DFF2357191  
 [2,0] = 4A1D7224312BE7BF  
 [3,0] = E7305EA7534EC026  
 [4,0] = 551CD9954A9C7A3A  
 [0,1] = E9B5D01DF5E995D4  
 [1,1] = AA03E88C5E6D3CD8  
 [2,1] = 9BD053DB54D6B862  
 [3,1] = 73B5FECDD73F2CF8D  
 [4,1] = C2BE7855D4BCD8FA  
 [0,2] = 726EE8FD1ED070E7  
 [1,2] = AB5D27CE6C7C3F1A  
 [2,2] = A78DF11A3F14E2E6  
 [3,2] = 345E0BB7C7C4DDEF  
 [4,2] = 23A3BE36C93CB95D  
 [0,3] = 46F588A338CB1C49  
 [1,3] = B900134EDD00FFA9  
 [2,3] = B405D241203D15B2  
 [3,3] = A5F253A6451BE443  
 [4,3] = 124554DD1A2C49C4  
 [0,4] = 712B46339852A2DD  
 [1,4] = F3AE911A425E2998  
 [2,4] = FB0AA14A7078EA35  
 [3,4] = AA2536B433A38D26  
 [4,4] = B38DCC229BDADF8F

About to call squeeze (again)

State before permutation (in bytes)

0A FF C6 82 0B 52 3A 3D 91 71 35 F2 DF F2 EE 06  
 BF E7 2B 31 24 72 1D 4A 26 C0 4E 53 A7 5E 30 E7  
 3A 7A 9C 4A 95 D9 1C 55 D4 95 E9 F5 1D D0 B5 E9  
 D8 3C 6D 5E 8C E8 03 AA 62 B8 D6 54 DB 53 D0 9B  
 8D CF F2 73 CD FE B5 73 FA D8 BC D4 55 78 BE C2  
 E7 70 D0 1E FD E8 6E 72 1A 3F 7C 6C CE 27 5D AB  
 E6 E2 14 3F 1A F1 8D A7 EF DD C4 C7 B7 0B 5E 34  
 5D B9 3C C9 36 BE A3 23 49 1C CB 38 A3 88 F5 46  
 A9 FF 00 DD 4E 13 00 B9 B2 15 3D 20 41 D2 05 B4  
 43 E4 1B 45 A6 53 F2 A5 C4 49 2C 1A DD 54 45 12  
 DD A2 52 98 33 46 2B 71 98 29 5E 42 1A 91 AE F3  
 35 EA 78 70 4A A1 0A FB 26 8D A3 33 B4 36 25 AA  
 8F DF DA 9B 22 CC 8D B3

State before permutation (as lanes of integers)

[0, 0] = 3D3A520B82C6FF0A  
 [1, 0] = 06EEF2DFF2357191  
 [2, 0] = 4A1D7224312BE7BF  
 [3, 0] = E7305EA7534EC026  
 [4, 0] = 551CD9954A9C7A3A  
 [0, 1] = E9B5D01DF5E995D4  
 [1, 1] = AA03E88C5E6D3CD8  
 [2, 1] = 9BD053DB54D6B862  
 [3, 1] = 73B5FECD73F2CF8D  
 [4, 1] = C2BE7855D4BCD8FA  
 [0, 2] = 726EE8FD1ED070E7  
 [1, 2] = AB5D27CE6C7C3F1A  
 [2, 2] = A78DF11A3F14E2E6  
 [3, 2] = 345E0BB7C7C4DDEF  
 [4, 2] = 23A3BE36C93CB95D  
 [0, 3] = 46F588A338CB1C49  
 [1, 3] = B900134EDD00FFA9  
 [2, 3] = B405D241203D15B2  
 [3, 3] = A5F253A6451B5443  
 [4, 3] = 124554DD1A2C49C4  
 [0, 4] = 712B46339852A2DD  
 [1, 4] = F3AE911A425E2998  
 [2, 4] = FE0AA14A7078EA35  
 [3, 4] = AA2536B433A38D26  
 [4, 4] = B38DCC229BDADF8F

Round #0

After  $\theta$

18 3A D9 EA 90 AA CE B2 44 50 0B 2E 78 11 4E E5  
 9E 35 D0 4D 72 50 1A 59 36 99 37 F4 5A F3 EC F5  
 40 88 91 49 AD 5F 6F D8 C6 50 F6 9D 86 28 41 66  
 0D 1D 53 82 2B 0B A3 49 43 6A 2D 28 8D 71 D7 88  
 9D 96 8B D4 30 53 69 61 80 2A B1 D7 6D FE CD 4F  
 F5 B5 CF 76 66 10 9A FD CF 1E 42 B0 69 C4 FD 48  
 C7 30 EF 43 4C D3 8A B4 FF 84 BD 60 4A A6 82 26  
 27 4B 31 CA 0E 38 D0 AE 5B D9 D4 50 38 70 01 C9  
 7C DE 3E 01 E9 F0 A0 5A 93 C7 C6 5C 17 F0 02 A7  
 53 BD 62 E2 5B FE 2E B7 BE BB 21 19 E5 D2 36 9F  
 CF 67 4D F0 A8 BE DF FE 4D 08 60 9E BD 72 0E 10  
 14 38 83 0C 1C 83 0D E8 36 D4 DA 94 49 9B F9 B8  
 F5 2D D7 98 1A 4A FE 3E



After  $\rho$ 

18 3A D9 EA 90 AA CE B2 89 A0 16 5C F0 22 9C CA  
 67 0D 74 93 1C 94 46 96 35 CF 5E 6F 93 79 43 AF  
 FD 7A C3 06 42 8C 4C 6A 69 88 12 64 66 0C 65 DF  
 25 B8 B2 30 9A D4 D0 31 E2 90 5A 0B 4A 63 DC 35  
 CB 45 6A 98 A9 B4 B0 4E DF FC 04 A8 12 7B DD E6  
 AF AF 7D B6 33 83 D0 EC 23 3D 7B 08 C1 A6 11 F7  
 1F 62 9A 56 A4 3D 86 79 4C 05 4D FE 09 7B C1 94  
 65 07 1C 68 D7 93 A5 18 A1 70 E0 02 92 B7 B2 A9  
 27 20 1D 1E 54 8B CF DB 81 D3 C9 63 63 AE 0B 78  
 DF E5 76 AA 57 4C 7C CB 9F BE BB 21 19 E5 D2 36  
 7E FB 3F 9F 35 C1 A3 FA 34 21 80 79 F6 CA 39 40  
 02 67 90 81 63 B0 01 9D D4 DA 94 49 9B F9 B8 36  
 BF 4F 7D CB 35 A6 86 92

After  $\pi$ 

18 3A D9 EA 90 AA CE B2 25 B8 B2 30 9A D4 D0 31  
 1F 62 9A 56 A4 3D 86 79 DF E5 76 AA 57 4C 7C CB  
 BF 4F 7D CB 35 A6 86 92 35 CF 5E 6F 93 79 43 AF  
 DF FC 04 A8 12 7B DD E6 AF AF 7D B6 33 83 D0 EC  
 27 20 1D 1E 54 8B CF DB 02 67 90 81 63 B0 01 9D  
 89 A0 16 5C F0 22 9C CA E2 90 5A 0B 4A 63 DC 35  
 4C 05 4D FE 09 7B C1 94 9F BE BB 21 19 E5 D2 36  
 7E FB 3F 9F 35 C1 A3 FA FD 7A C3 06 42 8C 4C 6A  
 69 88 12 64 66 0C 65 DF 23 3D 7B 08 C1 A6 11 F7  
 81 D3 C9 63 63 AE 0B 78 D4 DA 94 49 9B F9 B8 36  
 67 0D 74 93 1C 94 46 96 CB 45 6A 98 A9 B4 B0 4E  
 65 07 1C 68 D7 93 A5 18 A1 70 E0 02 92 B7 B2 A9  
 34 21 80 79 F6 CA 39 40

After  $\chi$ 

02 78 D1 AC B4 83 C8 FA E5 3D D6 98 C9 94 A8 B3  
 3F 68 93 17 84 9F 04 69 DF D5 F6 8A D7 44 34 EB  
 9A CF 5F DB 3F F2 96 93 15 CC 27 79 B2 F9 43 A7  
 DF FC 04 A0 56 73 D2 F5 AF E8 FD 37 10 B3 D0 E8  
 12 A8 53 70 C4 C2 8D F9 C8 57 90 01 63 B2 9D DD  
 85 A5 13 A8 F1 3A 9D 4A 71 2A E8 0A 5A E7 CE 17  
 2C 44 49 60 2D 7B E0 5C 1E BE BB 61 D9 C7 CE 36  
 1C EB 77 9C 3F 80 E3 CF FF 4F AA 0E C3 2E 5C 4A  
 E9 4A 92 07 44 04 6F D7 77 35 6F 00 59 F7 A1 F1  
 A8 F3 8A 65 23 AA 4F 30 D4 5A 84 29 BF F9 99 A3  
 43 0F 60 F3 4A 97 43 86 4B 35 8A 9A A9 90 A2 EF  
 71 06 1C 11 B3 DB AC 58 E2 7C 94 80 9A A3 F4 3F  
 BC 61 8A 71 57 EA 89 08

After  $t$

```

03 78 D1 AC B4 83 C8 FA E5 3D D6 98 C9 94 A8 B3
3F 68 93 17 84 9F 04 69 DF D5 F6 8A D7 44 34 EB
9A CF 5F DB 3F F2 96 93 15 CC 27 79 B2 F9 43 A7
DF FC 04 A0 56 73 D2 F5 AF E8 FD 37 10 B3 D0 E8
12 A8 53 70 C4 C2 8D F9 C8 57 90 01 63 B2 9D DD
85 A5 13 A8 F1 3A 9D 4A 71 2A E8 0A 5A E7 CE 17
2C 44 49 60 2D 7B E0 5C 1E BE BB 61 D9 C7 CE 36
1C EB 77 9C 3F 80 E3 CF FF 4F AA 0E C3 2E 5C 4A
E9 4A 92 07 44 04 6F D7 77 35 6F 00 59 F7 A1 F1
A8 F3 8A 65 23 AA 4F 30 D4 5A 84 29 BF F9 99 A3
43 0F 60 F3 4A 97 43 86 4B 35 8A 9A A9 90 A2 EF
71 06 1C 11 B3 DB AC 58 E2 7C 94 80 9A A3 F4 3F
BC 61 8A 71 57 EA 89 08

```

(Skip rounds 1 to 22)

Round #23

After  $\theta$

```

9F 9A 64 FF 91 6E D1 4E E0 09 19 1C 08 53 23 C9
05 F4 79 31 88 3D 47 ED B5 81 93 66 7C C3 CF F6
45 26 41 E5 63 41 BD 53 1A 1A 50 2B 22 D9 A9 34
5B E2 45 6C EF E9 02 8E 1E 94 C0 52 DF 97 85 ED
EC 5B BD DA 1F 0D 85 A9 07 E5 AF C8 B4 A0 65 9E
6D 68 DA 16 B7 76 85 2F FC CA A1 CF 21 76 A4 0A
CA 7B 74 0E 76 37 DD FE 30 67 35 85 78 58 DE 68
EF D6 98 47 0F 55 CB 85 1F 7A 33 E4 23 D9 21 29
8C 6D 66 BE 7D 07 0C 53 7B 76 B5 AC 0B F3 38 C8
1F 59 C5 71 43 C7 4C 2C E9 38 BC C0 33 C9 D2 68
9B 2D 28 8A 7F A4 9E 29 48 33 F4 1B 54 72 A7 68
0C 74 FD 1D E0 08 07 7A E2 F1 31 E9 B6 66 D2 9E
2E 9B 2C D8 E5 5E 5F 53

```

After  $\rho$ 

9F 9A 64 FF 91 6E D1 4E C1 13 32 38 10 A6 46 92  
 01 7D 5E 0C 62 CF 51 7B 37 FC 6C 5F 1B 38 69 C6  
 0B EA 9D 2A 32 09 2A 1F 22 92 9D 4A A3 A1 01 B5  
 C4 F6 9E 2E F0 B8 25 5E BB 07 25 B0 D4 F7 65 61  
 AD 5E ED 8F 86 C2 54 F6 5A E6 79 50 FE 8A 4C 0B  
 69 43 D3 B6 B8 B5 2B 7C 2A F0 2B 87 3E 87 D8 91  
 73 B0 BB E9 F6 57 DE A3 B0 BC D1 60 CE 6A 0A F1  
 A3 87 AA E5 C2 77 6B CC C8 47 B2 43 52 3E F4 66  
 CC B7 EF 80 61 8A B1 CD 1C E4 3D BB 5A D6 85 79  
 98 89 E5 23 AB 38 6E E8 68 E9 38 BC C0 33 C9 D2  
 7A A6 6C B6 A0 28 FE 91 21 CD D0 6F 50 C9 9D A2  
 81 AE BF 03 1C E1 40 8F F1 31 E9 B6 66 D2 9E E2  
 D7 94 CB 26 0B 76 B9 D7

After  $\pi$ 

9F 9A 64 FF 91 6E D1 4E C4 F6 9E 2E F0 B8 25 5E  
 73 B0 BB E9 F6 57 DE A3 98 89 E5 23 AB 38 6E E8  
 D7 94 CB 26 0B 76 B9 D7 37 FC 6C 5F 1B 38 69 C6  
 5A E6 79 50 FE 8A 4C 0B 69 43 D3 B6 B8 B5 2B 7C  
 CC B7 EF 80 61 8A B1 CD 81 AE BF 03 1C E1 40 8F  
 C1 13 32 38 10 A6 46 92 BB 07 25 B0 D4 F7 65 61  
 B0 BC D1 60 CE 6A 0A F1 68 E9 38 BC C0 33 C9 D2  
 7A A6 6C B6 A0 28 FE 91 0B EA 9D 2A 32 09 2A 1F  
 22 92 9D 4A A3 A1 01 B5 2A F0 2B 87 3E 87 D8 91  
 1C E4 3D BB 5A D6 85 79 F1 31 E9 B6 66 D2 9E E2  
 01 7D 5E 0C 62 CF 51 7B AD 5E ED 8F 86 C2 54 F6  
 A3 87 AA E5 C2 77 6B CC C8 47 B2 43 52 3E F4 66  
 21 CD D0 6F 50 C9 9D A2

After  $\chi$ 

AC 9A 45 3E 97 29 0B EF 4C FF DA 2C F9 90 05 16  
 34 A4 B1 ED F6 11 4F B4 90 83 C1 FA 3B 30 2E E0  
 97 F0 51 26 6B E6 9D C7 16 FD EE F9 1B 0D 4A B2  
 DE 52 55 50 BF 80 DC 8A 68 4B C3 B5 A4 D4 6B 7E  
 FA E7 AF DC 62 92 98 8D C9 AC AE 03 F8 63 44 86  
 C1 AB E2 78 1A AE 4C 02 F3 46 0D 2C D4 E6 A4 63  
 A2 BA 95 62 EE 62 3C F0 E9 F8 2A B4 D0 B5 C9 D0  
 40 A2 69 36 64 79 DF F0 03 8A BF AF 2E 0F F2 1F  
 36 96 89 72 E3 F1 04 DD CB E1 EB 83 1A 87 C2 13  
 16 2E 29 B3 4A DF A5 64 D1 21 E9 F6 E7 72 9F 42  
 03 FC 5C 6C 22 FA 7A 73 E5 1E FD 8D 96 CA C0 D4  
 82 0F EA C9 C2 B6 62 4C C8 77 BC 43 70 38 B4 3F  
 8D CF 71 EC D4 C9 99 26

After t

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A4 1A 45 BE 97 29 0B 6F 4C FF DA 2C F9 90 05 16
34 A4 B1 ED F6 11 4F B4 90 83 C1 FA 3B 30 2E E0
97 F0 51 26 6B E6 9D C7 16 FD EE F9 1B 0D 4A B2
DE 52 55 50 BF 80 DC 8A 68 4B C3 B5 A4 D4 6B 7E
FA E7 AF DC 62 92 98 8D C9 AC AE 03 F8 63 44 86
C1 AB E2 78 1A AE 4C 02 F3 46 0D 2C D4 E6 A4 63
A2 BA 95 62 EE 62 3C F0 E9 F8 2A B4 D0 B5 C9 D0
40 A2 69 36 64 79 DF F0 03 8A BF AF 2E 0F F2 1F
36 96 89 72 E3 F1 04 DD CB E1 EB 83 1A 87 C2 13
16 2E 29 B3 4A DF A5 64 D1 21 E9 F6 E7 72 9F 42
03 FC 5C 6C 22 FA 7A 73 E5 1E FD 8D 96 CA C0 D4
82 0F EA C9 C2 B6 62 4C C8 77 BC 43 70 38 B4 3F
      8D CF 71 EC D4 C9 99 26

```

After permutation

```

A4 1A 45 BE 97 29 0B 6F 4C FF DA 2C F9 90 05 16
34 A4 B1 ED F6 11 4F B4 90 83 C1 FA 3B 30 2E E0
97 F0 51 26 6B E6 9D C7 16 FD EE F9 1B 0D 4A B2
DE 52 55 50 BF 80 DC 8A 68 4B C3 B5 A4 D4 6B 7E
FA E7 AF DC 62 92 98 8D C9 AC AE 03 F8 63 44 86
C1 AB E2 78 1A AE 4C 02 F3 46 0D 2C D4 E6 A4 63
A2 BA 95 62 EE 62 3C F0 E9 F8 2A B4 D0 B5 C9 D0
40 A2 69 36 64 79 DF F0 03 8A BF AF 2E 0F F2 1F
36 96 89 72 E3 F1 04 DD CB E1 EB 83 1A 87 C2 13
16 2E 29 B3 4A DF A5 64 D1 21 E9 F6 E7 72 9F 42
03 FC 5C 6C 22 FA 7A 73 E5 1E FD 8D 96 CA C0 D4
82 0F EA C9 C2 B6 62 4C C8 77 BC 43 70 38 B4 3F
      8D CF 71 EC D4 C9 99 26

```

State (as lanes of integers)

[0, 0] = 6F0B2997BE451AA4  
 [1, 0] = 160590F92CDAFF4C  
 [2, 0] = B44F11F6EDB1A434  
 [3, 0] = E02E303BFAC18390  
 [4, 0] = C79DE66B2651F097  
 [0, 1] = B24A0D1BF9EEFD16  
 [1, 1] = 8ADC80BF505552DE  
 [2, 1] = 7E6BD4A4B5C34B68  
 [3, 1] = 8D989262DCAFE7FA  
 [4, 1] = 864463F803AEACC9  
 [0, 2] = 024CAE1A78E2ABC1  
 [1, 2] = 63A4E6D42C0D46F3  
 [2, 2] = F03C62EE6295BAA2  
 [3, 2] = D0C9B5D0B42AF8E9  
 [4, 2] = F0DF79643669A240  
 [0, 3] = 1FF20F2EAFBF8A03  
 [1, 3] = DD04F1E372899636  
 [2, 3] = 13C2871A838BE1CB  
 [3, 3] = 64A5DF4AB3292E16  
 [4, 3] = 429F72E7F6E921D1  
 [0, 4] = 737AFA226C5CFC03  
 [1, 4] = D4C0CA968DFD1EE5  
 [2, 4] = 4C62B6C2C9EA0F82  
 [3, 4] = 3FB4387043BC77C8  
 [4, 4] = 2699C9D4EC71CF8D

The hash value is

7F 9C 2B A4 E8 8F 82 7D 61 60 45 50 76 05 85 3E  
D7 3B 80 93 F6 EF BC 88 EB 1A 6E AC FA 66 EF 26  
3C B1 EE A9 88 00 4B 93 10 3C FB 0A EE FD 2A 68  
6E 01 FA 4A 58 E8 A3 63 9C A8 A1 E3 F9 AE 57 E2  
35 B8 CC 87 3C 23 DC 62 B8 D2 60 16 9A FA 2F 75  
AB 91 6A 58 D9 74 91 88 35 D2 5E 6A 43 50 85 B2  
BA DF D6 DF AA C3 59 A5 EF BB 7B CC 4B 59 D5 38  
DF 9A 04 30 2E 10 C8 BC 1C BF 1A 0B 3A 51 20 EA  
17 CD A7 CF AD 76 5F 56 23 47 4D 36 8C CC A8 AF  
00 07 CD 9F 5E 4C 84 9F 16 7A 58 0B 14 AA BD EF  
AE E7 EE F4 7C B0 FC A9 76 7B E1 FD A6 94 19 DF  
B9 27 E9 DF 07 34 8B 19 66 91 AB AE B5 80 B3 2D  
EF 58 53 8B 8D 23 F8 77 32 EA 63 B0 2B 4F A0 F4  
87 33 60 E2 84 19 28 CD 60 DD 4C EE 8C C0 D4 C9  
22 A9 61 88 D0 32 67 5C 8A C8 50 93 3C 7A FF 15  
33 B9 4C 83 4A DB B6 9C 61 15 BA D4 69 2D 86 19  
F9 0B 0C DF 8A 7B 9C 26 40 29 AC 18 5B 70 B8 3F  
28 01 F2 F4 B3 F7 0C 59 3E A3 AE EB 61 3A 7F 1B  
1D E3 3F D7 50 81 F5 92 30 5F 2E 45 26 ED C0 96  
31 B1 09 58 F4 64 D8 89 F3 1B A0 10 25 0F DA 7F  
13 68 EC 29 67 FC 84 EF 2A E9 AF F2 68 E0 B1 70  
0A FF C6 82 0B 52 3A 3D 91 71 35 F2 DF F2 EE 06  
BF E7 2B 31 24 72 1D 4A 26 C0 4E 53 A7 5E 30 E7  
3A 7A 9C 4A 95 D9 1C 55 D4 95 E9 F5 1D D0 B5 E9  
D8 3C 6D 5E 8C F8 03 AA 62 B8 D6 54 DB 53 D0 9B  
8D CF F2 73 CD FE B5 73 FA D8 BC D4 55 78 BE C2  
E7 70 D0 1E FD E8 6E 72 1A 3F 7C 6C CE 27 5D AB  
E6 E2 14 3F 1A F1 8D A7 EF DD C4 C7 B7 0B 5E 34  
5D B9 3C C9 36 BE A3 23 49 1C CB 38 A3 88 F5 46  
A9 FF 00 DD 4E 13 00 B9 B2 15 3D 20 41 D2 05 B4  
43 E4 1B 45 A6 53 F2 A5 C4 49 2C 1A DD 54 45 12  
DD A2 52 98 33 46 2B 71 A4 1A 45 BE 97 29 0B 6F

SHAKE-128 sample to produce 4 096 bits of output

The message as a bit string

1 1 0 0 1

About to call last of the absorb phase

## XORed state (in bytes)

|    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| F3 | 03 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 80 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
|    |    |    |    | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |    |    |    |    |    |

## XORed state (as lanes of integers)

```
[0, 0] = 000000000000000003F3
[1, 0] = 00000000000000000000
[2, 0] = 00000000000000000000
[3, 0] = 00000000000000000000
[4, 0] = 00000000000000000000
[0, 1] = 00000000000000000000
[1, 1] = 00000000000000000000
[2, 1] = 00000000000000000000
[3, 1] = 00000000000000000000
[4, 1] = 00000000000000000000
[0, 2] = 00000000000000000000
[1, 2] = 00000000000000000000
[2, 2] = 00000000000000000000
[3, 2] = 00000000000000000000
[4, 2] = 00000000000000000000
[0, 3] = 00000000000000000000
[1, 3] = 00000000000000000000
[2, 3] = 00000000000000000000
[3, 3] = 00000000000000000000
[4, 3] = 00000000000000000000
[0, 4] = 80000000000000000000
[1, 4] = 00000000000000000000
[2, 4] = 00000000000000000000
[3, 4] = 00000000000000000000
[4, 4] = 00000000000000000000
```

## Round #0

After  $\theta$ 

```

F3 03 00 00 00 00 00 00 F3 03 00 00 00 00 00 80
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
E7 07 00 00 00 00 00 00 00 00 00 00 00 00 00
F3 03 00 00 00 00 00 80 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 E7 07 00 00 00 00 00
00 00 00 00 00 00 00 00 F3 03 00 00 00 00 80
00 00 00 00 00 00 00 00 00 00 00 00 00 00
E7 07 00 00 00 00 00 00 00 00 00 00 00 00 00
F3 03 00 00 00 00 00 80 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 E7 07 00 00 00 00 00
00 00 00 00 00 00 00 80 F3 03 00 00 00 00 80
00 00 00 00 00 00 00 00 00 00 00 00 00 00
E7 07 00 00 00 00 00 00

```

After  $\rho$ 

```

F3 03 00 00 00 00 00 00 E7 07 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 38 3F 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 38 3F 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 70 7E 00 00 00 00
00 00 00 00 00 00 00 00 00 CE 0F 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 80 F3 03 00 00 00 00 00 00 00 00
00 00 00 00 00 70 7E 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 E7 07 00 00 00 00
00 00 02 00 00 00 00 00 CE 0F 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 C0 F9 01 00 00 00 00

```

After  $\pi$ 

```

F3 03 00 00 00 00 00 00 00 00 00 00 00 38 3F 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 C0 F9 01 00 00 00 00 00 00 00 00 00 00 00
00 00 70 7E 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 70 7E 00 00 00 00 00 00 00 00
E7 07 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 E7 07 00 00 00 00
00 00 02 00 00 00 00 00 00 00 00 38 3F 00 00
00 00 00 00 00 00 00 00 00 CE 0F 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 80 F3 03 00 00 00 00 00 00 00 00
CE 0F 00 00 00 00 00 00

```



After  $\chi$

```

F3 03 00 00 00 00 00 00 00 00 00 00 00 00 38 3F 00
00 C0 F9 01 00 00 00 00 F3 03 00 00 00 00 00 00 00
00 C0 F9 01 00 38 3F 00 00 00 00 00 00 00 00 00 00
00 00 70 7E 00 70 7E 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 70 7E 00 00 00 70 7E 00 00 00 00 00
E7 07 00 00 00 00 00 00 00 00 E7 07 00 00 00 00 00
00 00 00 00 00 00 00 00 E7 E0 07 00 00 00 00 00 00
00 00 02 00 00 00 00 00 00 CE 0F 38 3F 00 00 00 00
00 00 00 00 00 00 00 00 00 CE 0F 00 00 00 00 00 00
00 00 00 38 3F 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 80 F3 03 00 00 00 00 00 00 00 00 00 00
CE 0F 00 00 80 F3 03 00 00 00 00 00 00 00 00 00 00
CE 0F 00 00 00 00 00 00 00

```

After  $\iota$

```

F2 03 00 00 00 00 00 00 00 00 00 00 00 00 38 3F 00
00 C0 F9 01 00 00 00 00 F3 03 00 00 00 00 00 00 00
00 C0 F9 01 00 38 3F 00 00 00 00 00 00 00 00 00 00
00 00 70 7E 00 70 7E 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 70 7E 00 00 00 70 7E 00 00 00 00 00
E7 07 00 00 00 00 00 00 00 00 E7 07 00 00 00 00 00
00 00 00 00 00 00 00 00 E7 E0 07 00 00 00 00 00 00
00 00 02 00 00 00 00 00 00 CE 0F 38 3F 00 00 00 00
00 00 00 00 00 00 00 00 00 CE 0F 00 00 00 00 00 00
00 00 00 38 3F 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 80 F3 03 00 00 00 00 00 00 00 00 00 00
CE 0F 00 00 80 F3 03 00 00 00 00 00 00 00 00 00 00
CE 0F 00 00 00 00 00 00 00

```

(Skip rounds 1 to 22)

Round #23

After  $\theta$

22 B2 35 3A 97 67 32 8B 25 D8 47 EF FF E1 E6 1F  
61 F2 2A F1 55 B6 A2 61 5B EF 58 FA 3C E5 7D 06  
04 B6 51 87 0C 89 F8 9A 51 47 E1 4F 69 AA F7 A9  
F6 DB BB 5C 44 76 AF 6E F8 D0 7A 6E 83 5C B3 AD  
7F 82 9C 4E D6 60 8F FD 3E B1 1B B7 C6 E1 78 5D  
FD 45 12 71 C0 DF EF 29 F8 7E F7 D2 F7 BA 4C BB  
1C BD F7 09 4F F5 CA 6F 9E 65 00 E6 EB FD 11 00  
23 C4 D2 83 D4 7C B0 C8 CA 4C 6C B0 A1 4A 79 B2  
AA ED 13 4D 1B 0D CA 7B 81 78 5E 33 F7 B0 9C 7B  
56 58 FF 75 56 B6 FB 5E 27 F1 CC F8 DD DC C2 EE  
32 76 AE 9C D8 F8 7C BB D9 69 77 20 8C AF 2A 66  
DB 44 C6 BF 3D 51 A1 79 9F 88 9C 53 5B 0C D7 A6  
64 74 A5 78 C0 BF DF AF

After  $p$

22 B2 35 3A 97 67 32 8B 4A B0 8F DE FF C3 CD 3F  
98 BC 4A 7C 95 AD 68 58 53 DE 67 B0 F5 8E A5 CF  
48 C4 D7 24 B0 8D 3A 64 94 A6 7A 9F 1A 75 14 FE  
CB 45 64 F7 EA 66 BF BD 2B 3E B4 9E DB 20 D7 6C  
41 4E 27 6B B0 C7 FE 3F 8E D7 E5 13 BB 71 6B 1C  
E9 2F 92 88 03 FE 7E 4F ED E2 FB DD 4B DF EB 32  
4F 78 AA 57 7E E3 E8 BD FB 23 00 3C CB 00 CC D7  
41 6A 3E 58 E4 11 62 E9 60 43 95 F2 64 95 99 D8  
A2 69 A3 41 79 4F B5 7D CE BD 40 3C AF 99 7B 58  
76 DF CB 0A EB BF CE CA EE 27 F1 CC F8 DD DC C2  
F3 ED CA D8 B9 72 62 E3 65 A7 DD 81 30 BE AA 98  
9B C8 F8 B7 27 2A 34 6F 88 9C 53 5B 0C D7 A6 9F  
F7 2B 19 5D 29 1E F0 EF

After  $\pi$

22 B2 35 3A 97 67 32 8B CB 45 64 F7 EA 66 BF BD  
4F 78 AA 57 7E E3 E8 BD 76 DF CB 0A EB BF CE CA  
F7 2B 19 5D 29 1E F0 EF 53 DE 67 B0 F5 8E A5 CF  
8E D7 E5 13 BB 71 6B 1C E9 2F 92 88 03 FE 7E 4F  
A2 69 A3 41 79 4F B5 7D 9B C8 F8 B7 27 2A 34 6F  
4A B0 8F DE FF C3 CD 3F 2B 3E B4 9E DB 20 D7 6C  
FB 23 00 3C CB 00 CC D7 EE 27 F1 CC F8 DD DC C2  
F3 ED CA D8 B9 72 62 E3 48 C4 D7 24 B0 8D 3A 64  
94 A6 7A 9F 1A 75 14 FE ED E2 FB DD 4B DF EB 32  
CE BD 40 3C AF 99 7B 58 88 9C 53 5B 0C D7 A6 9F  
98 BC 4A 7C 95 AD 68 58 41 4E 27 6B B0 C7 FE 3F  
41 6A 3E 58 E4 11 62 E9 60 43 95 F2 64 95 99 D8  
65 A7 DD 81 30 BE AA 98

After  $\chi$

```

26 8A BF 3A 83 E6 72 8B FB C2 25 FF 6B 7A B9 FF
CE 58 BA 02 7E E3 D8 98 76 4F EF 28 7D DE CC CA
3E 6E 59 98 41 1E 7D DB 32 F6 75 38 F5 00 B1 8C
8C 97 C4 52 C3 70 EA 2C F0 AF CA 3E 05 DE 7E 4D
E2 7F A4 41 A9 CB 34 FD 17 C9 78 B4 2D 5B 7E 7F
9A B1 8F FE FF C3 C5 AC 2F 3A 45 5E EB FD C7 6C
EA EB 0A 2C CA 22 EE F6 E6 37 F4 CA BE 5C 51 DE
D2 E3 FA D8 B9 52 70 A3 21 84 56 64 F1 07 D1 64
96 BB 7A BF BE 75 04 B6 ED E2 E8 9E 4B 99 6F B5
8E FD C4 18 1F 91 63 38 1C BE 7B C0 06 A7 A2 05
98 9C 52 6C D1 BD 68 98 61 4F A6 C9 B0 43 67 2F
44 CE 76 59 F4 3B 40 E9 F8 5B 97 8E E1 94 D9 98
24 E5 F8 82 10 FC 3C BF

```

After  $\iota$

```

2E 0A BF BA 83 E6 72 0B FB C2 25 FF 6B 7A B9 FF
CE 58 BA 02 7E E3 D8 98 76 4F EF 28 7D DE CC CA
3E 6E 59 98 41 1E 7D DB 32 F6 75 38 F5 00 B1 8C
8C 97 C4 52 C3 70 EA 2C F0 AF CA 3E 05 DE 7E 4D
E2 7F A4 41 A9 CB 34 FD 17 C9 78 B4 2D 5B 7E 7F
9A B1 8F FE FF C3 C5 AC 2F 3A 45 5E EB FD C7 6C
EA EB 0A 2C CA 22 EE F6 E6 37 F4 CA BE 5C 51 DE
D2 E3 FA D8 B9 52 70 A3 21 84 56 64 F1 07 D1 64
96 BB 7A BF BE 75 04 B6 ED E2 E8 9E 4B 99 6F B5
8E FD C4 18 1F 91 63 38 1C BE 7B C0 06 A7 A2 05
98 9C 52 6C D1 BD 68 98 61 4F A6 C9 B0 43 67 2F
44 CE 76 59 F4 3B 40 E9 F8 5B 97 8E E1 94 D9 98
24 E5 F8 82 10 FC 3C BF

```

After permutation

```

2E 0A BF BA 83 E6 72 0B FB C2 25 FF 6B 7A B9 FF
CE 58 BA 02 7E E3 D8 98 76 4F EF 28 7D DE CC CA
3E 6E 59 98 41 1E 7D DB 32 F6 75 38 F5 00 B1 8C
8C 97 C4 52 C3 70 EA 2C F0 AF CA 3E 05 DE 7E 4D
E2 7F A4 41 A9 CB 34 FD 17 C9 78 B4 2D 5B 7E 7F
9A B1 8F FE FF C3 C5 AC 2F 3A 45 5E EB FD C7 6C
EA EB 0A 2C CA 22 EE F6 E6 37 F4 CA BE 5C 51 DE
D2 E3 FA D8 B9 52 70 A3 21 84 56 64 F1 07 D1 64
96 BB 7A BF BE 75 04 B6 ED E2 E8 9E 4B 99 6F B5
8E FD C4 18 1F 91 63 38 1C BE 7B C0 06 A7 A2 05
98 9C 52 6C D1 BD 68 98 61 4F A6 C9 B0 43 67 2F
44 CE 76 59 F4 3B 40 E9 F8 5B 97 8E E1 94 D9 98
24 E5 F8 82 10 FC 3C BF

```

State (as lanes of integers)

[0, 0] = 0B72E683BABF0A2E  
 [1, 0] = FFB97A6BFF25C2FB  
 [2, 0] = 98D8E37E02BA58CE  
 [3, 0] = CACCDE7D28EF4F76  
 [4, 0] = DB7D1E4198596E3E  
 [0, 1] = 8CB100F53875F632  
 [1, 1] = 2CEA70C352C4978C  
 [2, 1] = 4D7EDE053ECAAFF0  
 [3, 1] = FD34CBA941A47FE2  
 [4, 1] = 7F7E5B2DB478C917  
 [0, 2] = ACC5C3FFFE8FB19A  
 [1, 2] = 6CC7FDEB5E453A2F  
 [2, 2] = F6EE22CA2C0AEBEA  
 [3, 2] = DE515CBEC4F437E6  
 [4, 2] = A37052B9D8FAE3D2  
 [0, 3] = 64D107F164568421  
 [1, 3] = B60475BEBF7ABB96  
 [2, 3] = B56F994B9EE8E2ED  
 [3, 3] = 3863911F18C4FD8E  
 [4, 3] = 05A2A706C07BBE1C  
 [0, 4] = 9868BDD16C529C98  
 [1, 4] = 2F6743E0C9A64F61  
 [2, 4] = E9403BF45976CE44  
 [3, 4] = 98D994E18E975BF8  
 [4, 4] = BF3CFC1082F8E524

About to call squeeze (again)

State before permutation (in bytes)

2E 0A BF BA 83 E6 72 0B FB C2 25 FF 6B 7A B9 FF  
 CE 58 BA 02 7E E3 D8 98 76 4F EF 28 7D DE CC CA  
 3E 6E 59 98 41 1E 7D DB 32 F6 75 38 F5 00 B1 8C  
 8C 97 C4 52 C3 70 EA 2C F0 AF CA 3E 05 DE 7E 4D  
 E2 7F A4 41 A9 CB 34 FD 17 C9 78 B4 2D 5B 7E 7F  
 9A B1 8F FE FF C3 C5 AC 2F 3A 45 5E EB FD C7 6C  
 EA EB 0A 2C CA 22 EE F6 E6 37 F4 CA BE 5C 51 DE  
 D2 E3 FA D8 B9 52 70 A3 21 84 56 64 F1 07 D1 64  
 96 BB 7A BF BE 75 04 B6 ED E2 E8 9E 4B 99 6F B5  
 8E FD C4 18 1F 91 63 38 1C BE 7B C0 06 A7 A2 05  
 98 9C 52 6C D1 BD 68 98 61 4F A6 C9 B0 43 67 2F  
 44 CE 76 59 F4 3B 40 E9 F8 5B 97 8E E1 94 D9 98  
 24 E5 F8 82 10 FC 3C BF

State before permutation (as lanes of integers)

[0,0] = 0B72E683BABF0A2E  
 [1,0] = FFB97A6BFF25C2FB  
 [2,0] = 98D8E37E02BA58CE  
 [3,0] = CACCDE7D28EF4F76  
 [4,0] = DB7D1E4198596E3E  
 [0,1] = 8CB100F53875F632  
 [1,1] = 2CEA70C352C4978C  
 [2,1] = 4D7EDE053ECAAFF0  
 [3,1] = FD34CBA941A47FE2  
 [4,1] = 7F7E5B2DB478C917  
 [0,2] = ACC5C3FFFE8FB19A  
 [1,2] = 6CC7FDEB5E453A2F  
 [2,2] = F6EE22CA2C0AEBEA  
 [3,2] = DE515CBEC4F437E6  
 [4,2] = A37052B9D8FAE3D2  
 [0,3] = 64D107F164568421  
 [1,3] = B60475BEBF7ABB96  
 [2,3] = B56F994B9EE8E2ED  
 [3,3] = 3863911F18C4FD8E  
 [4,3] = 05A2A706C07BBE1C  
 [0,4] = 9868BDD16C529C98  
 [1,4] = 2F6743B0C9A64F61  
 [2,4] = E9403BF45976CE44  
 [3,4] = 98D994E18E975BF8  
 [4,4] = BF3CFC1082F8E524

Round #0

After  $\theta$

B3 22 16 06 DB 28 70 FB 3E F7 AC 24 DF 9F C9 D6  
 69 81 1B EC 1B BB 09 2C 8C 40 BB 93 F4 FA 71 CE  
 45 65 37 45 87 6D 11 3D AF DE DC 84 AD CE B3 7C  
 49 A2 4D 89 77 95 9A 05 57 76 6B D0 60 86 AF F9  
 18 70 F0 FA 20 EF 89 F9 6C C2 16 69 EB 28 12 99  
 07 99 26 42 A7 0D C7 5C EA 0F CC 85 5F 18 B7 45  
 4D 32 AB C2 AF 7A 3F 42 1C 38 A0 71 37 78 EC DA  
 A9 E8 94 05 7F 21 1C 45 BC AC FF D8 A9 C9 D3 94  
 53 8E F3 64 0A 90 74 9F 4A 3B 49 70 2E C1 BE 01  
 74 F2 90 A3 96 B5 DE 3C 67 B5 15 1D C0 D4 CE E3  
 05 B4 FB D0 89 73 6A 68 A4 7A 2F 12 04 A6 17 06  
 E3 17 D7 B7 91 63 91 5D 02 54 C3 35 68 B0 64 9C  
 5F EE 96 5F D6 8F 50 59

After  $\rho$ 

B3 22 16 06 DB 28 70 FB 7D EE 59 49 BE 3F 93 AD  
 5A E0 06 FB C6 6E 02 4B AF 1F E7 CC 08 B4 3B 49  
 6C 8B E8 29 2A BB 29 3A D8 EA 3C CB F7 EA CD 4D  
 94 78 57 A9 59 90 24 DA FE 95 DD 1A 34 98 E1 6B  
 38 78 7D 90 F7 C4 7C 0C 22 91 C9 26 6C 91 B6 8E  
 3A C8 34 11 3A 6D 38 E6 16 A9 3F 30 17 7E 61 DC  
 15 7E D5 FB 11 6A 92 59 F0 D8 B5 39 70 40 E3 6E  
 82 BF 10 8E A2 54 74 CA B1 53 93 A7 29 79 59 FF  
 9E 4C 01 92 EE 73 CA 71 DF 00 A5 9D 24 38 97 60  
 D6 9B 87 4E 1E 72 D4 B2 E3 67 B5 15 1D C0 D4 CE  
 A9 A1 15 D0 EE 43 27 CE 90 EA BD 48 10 98 5E 18  
 FC E2 FA 36 72 2C B2 6B 54 C3 35 68 B0 64 9C 02  
 54 D6 97 BB E5 97 F5 23

After  $\pi$ 

B3 22 16 06 DB 28 70 FB 94 78 57 A9 59 90 24 DA  
 15 7E D5 FB 11 6A 92 59 D6 9B 87 4E 1E 72 D4 B2  
 54 D6 97 BB E5 97 F5 23 AF 1F E7 CC 08 B4 3B 49  
 22 91 C9 26 6C 91 B6 8E 3A C8 34 11 3A 6D 38 E6  
 9E 4C 01 92 EE 73 CA 71 FC E2 FA 36 72 2C B2 6B  
 7D EE 59 49 BE 3F 93 AD FE 95 DD 1A 34 98 E1 6B  
 F0 D8 B5 39 70 40 E3 6E E3 67 B5 15 1D C0 D4 CE  
 A9 A1 15 D0 EE 43 27 CE 6C 8B E8 29 2A BB 29 3A  
 D8 EA 3C CB F7 EA CD 4D 16 A9 3F 30 17 7E 61 DC  
 DF 00 A5 9D 24 38 97 60 54 C3 35 68 B0 64 9C 02  
 5A E0 06 FB C6 6E 02 4B 38 78 7D 90 F7 C4 7C 0C  
 82 BF 10 8E A2 54 74 CA B1 53 93 A7 29 79 59 FF  
 90 EA BD 48 10 98 5E 18

After  $\chi$ 

B2 24 96 54 DB 42 E2 FA 56 F9 55 AD 57 80 60 78  
 15 3A C5 4A F0 EF B3 58 75 BB 87 4A 04 5A D4 6A  
 50 8E D6 12 E5 07 F1 23 B7 57 D3 DD 1A D8 33 29  
 A6 95 C8 A4 A8 83 74 9F 5A 6A CE 35 2A 61 08 EC  
 9D 51 04 5A E6 E3 C3 71 FC 62 F2 14 16 2D 36 ED  
 7D A6 79 68 FE 7F 91 A9 FD B2 DD 1E 39 18 F5 EB  
 F8 58 B5 F9 92 43 C0 6E B7 29 FD 1C 0D FC 44 EF  
 2B B0 91 C2 EE C3 47 8C 6A 8A EB 19 2A AF 09 AA  
 11 EA BC 46 D7 EA 5B 6D 16 6A 2F 50 87 3A 69 DE  
 F7 08 6D 9C 2E A3 B6 58 C4 A3 21 AA 65 24 58 47  
 D8 67 06 F5 C6 7E 02 89 09 38 FE B1 FE ED 75 39  
 82 17 3C C6 B2 D4 72 CA FB 53 91 14 EF 1F 59 BC  
 B0 F2 C4 48 21 18 22 1C

After  $t$

B3 24 96 54 DB 42 E2 FA 56 F9 55 AD 57 80 60 78  
 15 3A C5 4A F0 EF B3 58 75 BB 87 4A 04 5A D4 6A  
 50 8E D6 12 E5 07 F1 23 B7 57 D3 DD 1A D8 33 29  
 A6 95 C8 A4 A8 83 74 9F 5A 6A CE 35 2A 61 08 EC  
 9D 51 04 5A E6 E3 C3 71 FC 62 F2 14 16 2D 36 ED  
 7D A6 79 68 FE 7F 91 A9 FD B2 DD 1E 39 18 F5 EB  
 F8 58 B5 F9 92 43 C0 6E B7 29 FD 1C 0D FC 44 EF  
 2B B0 91 C2 EE C3 47 8C 6A 8A EB 19 2A AF 09 AA  
 11 EA BC 46 D7 EA 5B 6D 16 6A 2F 50 87 3A 69 DE  
 F7 08 6D 9C 2E A3 B6 58 C4 A3 21 AA 65 24 58 47  
 D8 67 06 F5 C6 7E 02 89 09 38 FE B1 FE ED 75 39  
 82 17 3C C6 B2 D4 72 CA FB 53 91 14 EF 1F 59 BC  
 B0 F2 C4 48 21 18 22 1C

(Skip rounds 1 to 22)

Round #23

After  $\theta$

32 27 94 3E 45 37 CA 13 65 63 DD ED B3 8D FD BD  
 95 B5 6A DE 6F F2 64 5A 62 74 F1 03 67 37 B9 09  
 38 35 14 BD CB 14 70 24 AC 55 AB E9 DC CE 46 82  
 5F 20 1D 30 D8 49 FD B6 04 31 0D 87 63 9F D0 CF  
 FB 8C 9C 0A 10 AC 91 3E DD D8 C3 B6 1E F3 E0 02  
 23 26 E6 37 3A 22 35 F1 0C 4D 27 AD 49 12 B4 3A  
 76 3C AE A1 36 64 58 55 9A 7F 45 47 56 35 EA EB  
 E8 57 49 8B C0 A4 28 8A A5 79 4F ED AB 43 0C E6  
 95 DD 91 E4 86 6C 11 33 35 FE 10 3B 10 AA AA AD  
 02 31 FE A2 18 27 9A 93 97 CA E2 AE 00 92 46 78  
 FC A9 E2 65 1A 29 81 DD 02 98 AB A1 CB DB 32 AC  
 BA 3E 81 B4 91 1F 07 D1 9F EB E7 1D F5 9A 44 B3  
 47 FC 16 65 EC 11 97 45

After  $\rho$ 

32 27 94 3E 45 37 CA 13 CB C6 BA DB 67 1B FB 7B  
 65 AD 9A F7 9B 3C 99 56 76 93 9B 20 46 17 3F 70  
 A6 80 23 C1 A9 A1 E8 5D CE ED 6C 24 C8 5A B5 9A  
 01 83 9D D4 6F FB 05 D2 33 41 4C C3 E1 D8 27 F4  
 46 4E 05 08 D6 48 9F 7D 0F 2E D0 8D 3D 6C EB 31  
 1F 31 31 BF D1 11 A9 89 EA 30 34 9D B4 26 49 D0  
 0D B5 21 C3 AA B2 E3 71 6A D4 D7 35 FF 8A 8E AC  
 45 60 52 14 45 F4 AB A4 DA 57 87 18 CC 4B F3 9E  
 92 DC 90 2D 62 A6 B2 3B D5 D6 1A 7F 88 1D 08 55  
 44 73 52 20 C6 5F 14 E3 78 97 CA E2 AE 00 92 46  
 04 76 F3 A7 8A 97 69 A4 0A 60 AE 86 2E 6F CB B0  
 D7 27 90 36 F2 E3 20 5A EB E7 1D F5 9A 44 B3 9F  
 65 D1 11 BF 45 19 7B C4

After  $\pi$ 

32 27 94 3E 45 37 CA 13 01 83 9D D4 6F FB 05 D2  
 0D B5 21 C3 AA B2 E3 71 44 73 52 20 C6 5F 14 E3  
 65 D1 11 BF 45 19 7B C4 76 93 9B 20 46 17 3F 70  
 0F 2E D0 8D 3D 6C EB 31 1F 31 31 BF D1 11 A9 89  
 92 DC 90 2D 62 A6 B2 3B D7 27 90 36 F2 E3 20 5A  
 CB C6 BA DB 67 1B FB 7B 33 41 4C C3 E1 D8 27 F4  
 6A D4 D7 35 FF 8A 8E AC 78 97 CA E2 AE 00 92 46  
 04 76 F3 A7 8A 97 69 A4 A6 80 23 C1 A9 A1 E8 5D  
 CE ED 6C 24 C8 5A B5 9A EA 30 34 9D B4 26 49 D0  
 D5 D6 1A 7F 88 1D 08 55 EB E7 1D F5 9A 44 B3 9F  
 65 AD 9A F7 9B 3C 99 56 46 4E 05 08 D6 48 9F 7D  
 45 60 52 14 45 F4 AB A4 DA 57 87 18 CC 4B F3 9E  
 0A 60 AE 86 2E 6F CB B0

After  $\chi$ 

3E 13 B4 3D C5 37 28 32 41 C1 CF F4 2B B6 11 50  
 2C 35 20 5C AB B2 88 75 56 55 D6 20 C6 79 94 F0  
 64 51 18 7F 6F D1 7E 04 66 82 BA 12 86 06 3F F8  
 8F E2 50 8D 1F CA F9 03 5A 12 31 AD 41 50 A9 C9  
 B2 4C 9B 2D 66 B2 AD 1B DE 0B D0 BB CB 8B E0 5B  
 83 52 29 EF 79 19 73 73 23 42 44 01 E1 D8 37 B6  
 6E B4 E6 30 FF 1D E7 0C B3 17 C2 BA CB 08 00 1D  
 34 77 B7 A7 0A 57 6D 20 86 90 33 58 9D 85 A0 1D  
 DB 2B 66 46 C0 43 B5 9F C0 11 31 1D A6 66 FA 5A  
 D1 D6 38 7F A9 BC 40 15 A3 8A 51 D1 DA 1E A6 1D  
 64 8D C8 E3 9A 88 B9 D6 DC 59 80 00 5E 43 CF 67  
 45 40 7A 92 67 D0 A3 84 BF DA 97 69 5D 5B E3 D8  
 08 22 AB 8E 6A 2F CD 99



After t

```

36 93 B4 BD C5 37 28 B2 41 C1 CF F4 2B B6 11 50
2C 35 20 5C AB B2 88 75 56 55 D6 20 C6 79 94 F0
64 51 18 7F 6F D1 7E 04 66 82 BA 12 86 06 3F F8
8F E2 50 8D 1F CA F9 03 5A 12 31 AD 41 50 A9 C9
B2 4C 9B 2D 66 B2 AD 1B DE 0B D0 BB CB 8B E0 5B
83 52 29 EF 79 19 73 73 23 42 44 01 E1 D8 37 B6
6E B4 E6 30 FF 1D E7 0C B3 17 C2 BA CB 08 00 1D
34 77 B7 A7 0A 57 6D 20 86 90 33 58 9D 85 A0 1D
DB 2B 66 46 C0 43 B5 9F C0 11 31 1D A6 66 FA 5A
D1 D6 38 7F A9 BC 40 15 A3 8A 51 D1 DA 1E A6 1D
64 8D C8 E3 9A 88 B9 D6 DC 59 80 00 5E 43 CF 67
45 40 7A 92 67 D0 A3 84 BF DA 97 69 5D 5B E3 D8
08 22 AB 8E 6A 2F CD 99

```

After permutation

```

36 93 B4 BD C5 37 28 B2 41 C1 CF F4 2B B6 11 50
2C 35 20 5C AB B2 88 75 56 55 D6 20 C6 79 94 F0
64 51 18 7F 6F D1 7E 04 66 82 BA 12 86 06 3F F8
8F E2 50 8D 1F CA F9 03 5A 12 31 AD 41 50 A9 C9
B2 4C 9B 2D 66 B2 AD 1B DE 0B D0 BB CB 8B E0 5B
83 52 29 EF 79 19 73 73 23 42 44 01 E1 D8 37 B6
6E B4 E6 30 FF 1D E7 0C B3 17 C2 BA CB 08 00 1D
34 77 B7 A7 0A 57 6D 20 86 90 33 58 9D 85 A0 1D
DB 2B 66 46 C0 43 B5 9F C0 11 31 1D A6 66 FA 5A
D1 D6 38 7F A9 BC 40 15 A3 8A 51 D1 DA 1E A6 1D
64 8D C8 E3 9A 88 B9 D6 DC 59 80 00 5E 43 CF 67
45 40 7A 92 67 D0 A3 84 BF DA 97 69 5D 5B E3 D8
08 22 AB 8E 6A 2F CD 99

```

State (as lanes of integers)

[0, 0] = B22837C5BDB49336  
 [1, 0] = 5011B62BF4CFC141  
 [2, 0] = 7588B2AB5C20352C  
 [3, 0] = F09479C620D65556  
 [4, 0] = 047ED16F7F185164  
 [0, 1] = F83F068612BA8266  
 [1, 1] = 03F9CA1F8D50E28F  
 [2, 1] = C9A95041AD31125A  
 [3, 1] = 1BADB2662D9B4CB2  
 [4, 1] = 5BE08BCBBBD00BDE  
 [0, 2] = 73731979EF295283  
 [1, 2] = B637D8E101444223  
 [2, 2] = 0CE71DFF30E6B46E  
 [3, 2] = 1D0008CBBAC217B3  
 [4, 2] = 206D570AA7B77734  
 [0, 3] = 1DA0859D58339086  
 [1, 3] = 9FB543C046662BDB  
 [2, 3] = 5AFA66A61D3111C0  
 [3, 3] = 1540BCA97F38D6D1  
 [4, 3] = 1DA61EDAD1518AA3  
 [0, 4] = D6B9889AE3C88D64  
 [1, 4] = 67CF435E008059DC  
 [2, 4] = 8423D067927A4045  
 [3, 4] = D8E35B5D6997DABF  
 [4, 4] = 99CD2F6A8EAB2208

About to call squeeze (again)

State before permutation (in bytes)

36 93 B4 BD C5 37 28 B2 41 C1 CF F4 2B B6 11 50  
 2C 35 20 5C AB B2 88 75 56 55 D6 20 C6 79 94 F0  
 64 51 18 7F 6F D1 7E 04 66 82 BA 12 86 06 3F F8  
 8F E2 50 8D 1F CA F9 03 5A 12 31 AD 41 50 A9 C9  
 B2 4C 9B 2D 66 B2 AD 1B DE 0B D0 BB CB 8B E0 5B  
 83 52 29 EF 79 19 73 73 23 42 44 01 E1 D8 37 B6  
 6E B4 E6 30 FF 1D E7 0C B3 17 C2 BA CB 08 00 1D  
 34 77 B7 A7 0A 57 6D 20 86 90 33 58 9D 85 A0 1D  
 DB 2B 66 46 C0 43 B5 9F C0 11 31 1D A6 66 FA 5A  
 D1 D6 38 7F A9 BC 40 15 A3 8A 51 D1 DA 1E A6 1D  
 64 8D C8 E3 9A 88 B9 D6 DC 59 80 00 5E 43 CF 67  
 45 40 7A 92 67 D0 A3 84 BF DA 97 69 5D 5B E3 D8  
 08 22 AB 8E 6A 2F CD 99

XState before permutation (as lanes of integers)

[0,0] = B22837C5BDB49336  
 [1,0] = 5011B62BF4CFC141  
 [2,0] = 7588B2AB5C20352C  
 [3,0] = F09479C620D65556  
 [4,0] = 047ED16F7F185164  
 [0,1] = F83F068612BA8266  
 [1,1] = 03F9CA1F8D50E28F  
 [2,1] = C9A95041AD31125A  
 [3,1] = 1BADB2662D9B4CB2  
 [4,1] = 5BE08BCBBBD00BDE  
 [0,2] = 73731979EF295283  
 [1,2] = B637D8E101444223  
 [2,2] = 0CE71DFF30E6B46E  
 [3,2] = 1D0008CBBAC217B3  
 [4,2] = 206D570AA7B77734  
 [0,3] = 1DA0859D58339086  
 [1,3] = 9FB543C046662BDB  
 [2,3] = 5AFA66A61D3111C0  
 [3,3] = 1540BCA97F38D6D1  
 [4,3] = 1DA61EDAD1518AA3  
 [0,4] = D6B9889AE3C88D64  
 [1,4] = 67CF435E008059DC  
 [2,4] = 84A3D067927A4045  
 [3,4] = D8E35B5D6997DABF  
 [4,4] = 99CD2F6A8EAB2208

Round #0

After  $\theta$

C7 31 4B FD 4D 43 FB 72 4A 1A 6A 92 BE 00 52 7F  
 B4 22 5D 20 DF 5F 19 1F 80 9D 61 17 2E 48 3B 69  
 3E EF 80 29 8B BF 1E DB 97 20 45 52 0E 72 EC 38  
 84 39 F5 EB 8A 7C BA 2C C2 05 4C D1 35 BD 38 A3  
 64 84 2C 1A 8E 83 02 82 84 B5 48 ED 2F E5 80 84  
 72 F0 D6 AF F1 6D A0 B3 28 99 E1 67 74 6E 74 99  
 F6 A3 9B 4C 8B F0 76 66 65 DF 75 8D 23 39 AF 84  
 6E C9 2F F1 EE 39 0D FF 77 32 CC 18 15 F1 73 DD  
 D0 F0 C3 20 55 F5 F6 B0 58 06 4C 61 D2 8B 6B 30  
 07 1E 8F 48 41 8D EF 8C F9 34 C9 87 3E 70 C6 C2  
 95 2F 37 A3 12 FC 6A 16 D7 82 25 66 CB F5 8C 48  
 DD 57 07 EE 13 3D 32 EE 69 12 20 5E B5 6A 4C 41  
 52 9C 33 D8 8E 41 AD 46

After  $\rho$ 

C7 31 4B FD 4D 43 FB 72 94 34 D4 24 7D 01 A4 FE  
 AD 48 17 C8 F7 57 C6 07 82 B4 93 06 D8 19 76 E1  
 FC F5 D8 F6 79 07 4C 59 E5 20 C7 8E 73 09 52 24  
 BF AE C8 A7 CB 42 98 53 A8 70 01 53 74 4D 2F CE  
 42 16 0D C7 41 01 41 32 0E 48 48 58 8B D4 FE 52  
 95 83 B7 7E 8D 6F 03 9D 65 A2 64 86 9F D1 B9 D1  
 64 5A 84 B7 33 B3 1F DD 72 5E 09 CB BE EB 1A 47  
 78 F7 9C 86 7F B7 E4 97 31 2A E2 E7 BA EF 64 98  
 18 A4 AA DE 1E 16 1A 7E 35 18 2C 03 A6 30 E9 C5  
 F1 9D F1 C0 E3 11 29 A8 C2 F9 34 C9 87 3E 70 C6  
 AB 59 54 BE DC 8C 4A F0 5D 0B 96 98 2D D7 33 22  
 FB EA C0 7D A2 47 C6 BD 12 20 5E B5 6A 4C 41 69  
 AB 91 14 E7 0C B6 63 50

After  $\pi$ 

C7 31 4B FD 4D 43 FB 72 BF AE C8 A7 CB 42 98 53  
 64 5A 84 B7 33 B3 1F DD F1 9D F1 C0 E3 11 29 A8  
 AB 91 14 E7 0C B6 63 50 82 B4 93 06 D8 19 76 E1  
 0E 48 48 58 8B D4 FE 52 95 83 B7 7E 8D 6F 03 9D  
 18 A4 AA DE 1E 16 1A 7E FB EA C0 7D A2 47 C6 BD  
 94 34 D4 24 7D 01 A4 FE A8 70 01 53 74 4D 2F CE  
 72 5E 09 CB BE EB 1A 47 C2 F9 34 C9 87 3E 70 C6  
 AB 59 54 BE DC 8C 4A F0 FC F5 D8 F6 79 07 4C 59  
 E5 20 C7 8E 73 09 52 24 65 A2 64 86 9F D1 B9 D1  
 35 18 2C 03 A6 30 E9 C5 12 20 5E B5 6A 4C 41 69  
 AD 48 17 C8 F7 57 C6 07 42 16 0D C7 41 01 41 32  
 78 F7 9C 86 7F B7 E4 97 31 2A E2 E7 BA EF 64 98  
 5D 0B 96 98 2D D7 33 22

After  $\chi$ 

87 61 4F ED 7D F2 FC FE 2E 2B B9 E7 0B 42 B8 73  
 6E 5A 80 90 3F 15 5D 8D B5 BD BA D8 A2 50 B1 8A  
 93 1F 94 E5 8E B6 63 51 13 37 24 20 DC 32 77 6C  
 06 6C 40 D8 99 C4 E6 30 76 C9 F7 5F 2D 2E C7 1C  
 18 B0 B9 DC 46 0E 2A 3E F7 A2 88 25 A1 83 4E AF  
 C6 3A DC AC F7 A3 B4 FF 28 D1 35 53 75 59 4F 4E  
 5B 5E 49 FD E6 6B 10 77 D6 DD B4 C9 A6 3F D4 C8  
 83 19 55 ED DC C0 41 F0 FC 77 F8 F6 F5 D7 E5 88  
 F5 38 CF 8F 53 29 12 20 67 82 36 32 D7 9D B9 F9  
 D9 CD AC 41 B7 33 E5 D5 13 20 59 BD 68 44 53 4D  
 95 A9 87 C8 C9 E1 62 82 43 1E 6F A6 C1 49 41 3A  
 34 F6 88 9E 7A A7 F7 B5 91 6A E3 A7 68 EF A0 9D  
 1F 1D 9E 9F 2D D7 32 12

After t

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86 61 4F ED 7D F2 FC FE 2E 2B B9 E7 0B 42 B8 73
6E 5A 80 90 3F 15 5D 8D B5 BD BA D8 A2 50 B1 8A
93 1F 94 E5 8E B6 63 51 13 37 24 20 DC 32 77 6C
06 6C 40 D8 99 C4 E6 30 76 C9 F7 5F 2D 2E C7 1C
18 B0 B9 DC 46 0E 2A 3E F7 A2 88 25 A1 83 4E AF
C6 3A DC AC F7 A3 B4 FF 28 D1 35 53 75 59 4F 4E
5B 5E 49 FD E6 6B 10 77 D6 DD B4 C9 A6 3F D4 C8
83 19 55 ED DC C0 41 F0 FC 77 F8 F6 F5 D7 E5 88
F5 38 CF 8F 53 29 12 20 67 82 36 32 D7 9D B9 F9
D9 CD AC 41 B7 33 E5 D5 13 20 59 BD 68 44 53 4D
95 A9 87 C8 C9 E1 62 82 43 1E 6F A6 C1 49 41 3A
34 F6 88 9E 7A A7 F7 B5 91 6A E3 A7 68 EF A0 9D
1F 1D 9E 9F 2D D7 32 12

```

(Skip rounds 1 to 22)

Round #23

After 0

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7F B8 94 C4 39 9B 86 70 3B 89 48 FA 32 75 C3 E2
AE 9C 8E 91 39 CC 86 AF EF 55 83 9E CB BF 14 9F
A4 CA B3 FF ED BC BA 61 7A 8E 39 31 F8 6F DF C1
7C 13 22 A8 03 C0 9A A2 9B 4F 2C 70 28 7F E9 B1
D3 93 C4 9B C6 8D 29 FE 80 5A EB 0E 25 B2 C1 D5
BD F7 12 4D 48 A2 6A 36 FF 2E 6B CE 41 28 D8 4E
E6 6E E4 AA D6 EE A9 5C 07 01 C0 18 4E C2 EF 5A
23 BF 88 3F 02 E0 71 4C 66 D0 0C B6 55 FB B2 75
7A 4A 18 37 BE 9B 10 A0 EB E8 30 1D 07 93 4F B9
0E DD 19 67 64 9B 82 63 8C D9 19 58 5A F3 79 07
78 3C 6B 24 22 3C 24 90 F6 49 11 92 3F 53 A0 72
BC F4 74 C7 D5 E0 63 F5 40 25 4E 87 22 04 58 D7
37 17 4A B6 82 FC C4 DB

```

After  $\rho$

7F B8 94 C4 39 9B 86 70 77 12 91 F4 65 EA 86 C5  
 2B A7 63 64 0E B3 E1 AB FC 4B F1 F9 5B 35 E8 B9  
 E7 D5 0D 23 55 9E FD 6F 83 FF F6 1D AC E7 98 13  
 82 3A 00 AC 29 CA 37 21 EC E6 13 0B 1C CA 5F 7A  
 49 E2 4D E3 C6 14 FF E9 1B 5C 0D A8 B5 EE 50 22  
 E9 BD 97 68 42 12 55 B3 3B FD BB AC 39 07 A1 60  
 57 B5 76 4F E5 32 77 23 84 DF B5 0E 02 80 31 9C  
 1F 01 F0 38 A6 91 5F C4 6C AB F6 65 EB CC A0 19  
 E3 C6 77 13 02 54 4F 09 A7 DC 75 74 98 8E 83 C9  
 53 70 CC A1 3B E3 8C 6C 07 8C D9 19 58 5A F3 79  
 90 40 E2 F1 AC 91 88 F0 D9 27 45 48 FE 4C 81 CA  
 97 9E EE B8 1A 7C AC 9E 25 4E 87 22 04 58 D7 40  
 F1 F6 CD 85 92 AD 20 3F

After  $\pi$

7F B8 94 C4 39 9B 86 70 82 3A 00 AC 29 CA 37 21  
 57 B5 76 4F E5 32 77 23 53 70 CC A1 3B E3 8C 6C  
 F1 F6 CD 85 92 AD 20 3F FC 4B F1 F9 5B 35 E8 B9  
 1B 5C 0D A8 B5 EE 50 22 E9 BD 97 68 42 12 55 B3  
 E3 C6 77 13 02 54 4F 09 97 9E EE B8 1A 7C AC 9E  
 77 12 91 F4 65 EA 86 C5 EC E6 13 0B 1C CA 5F 7A  
 84 DF B5 0E 02 80 31 9C 07 8C D9 19 58 5A F3 79  
 90 40 E2 F1 AC 91 88 F0 E7 D5 0D 23 55 9E FD 6F  
 83 FF F6 1D AC E7 98 13 3B FD BB AC 39 07 A1 60  
 A7 DC 75 74 98 8E 83 C9 25 4E 87 22 04 58 D7 40  
 2B A7 63 64 0E B3 E1 AB 49 E2 4D E3 C6 14 FF E9  
 1F 01 F0 38 A6 91 5F C4 6C AB F6 65 EB CC A0 19  
 D9 27 45 48 FE 4C 81 CA

After  $\chi$

2A 3D E2 87 FD AB C6 72 82 7A 88 0C 33 0B BF 6D  
 F7 33 77 4B 65 3E 57 30 5D 78 DC E1 12 F1 0A 2C  
 71 F4 CD AD 92 ED 11 3E 1C EA 63 B9 19 25 ED 28  
 19 1E 6D BB B5 AA 5A 2A FD A5 1F C0 5A 3A F5 25  
 8B 87 66 52 43 55 0F 28 94 8A E2 B8 BE B6 BC 9C  
 77 0B 35 F0 67 EA A6 41 EF E6 5B 1A 44 90 9D 1B  
 14 9F 97 EE A6 01 39 1C 60 9E C8 1D 19 30 F5 7C  
 18 A4 E0 FA B4 91 D1 CA DF D5 04 83 44 9E DC 0F  
 07 FF B2 4D 2C 6F 9A 9A 3B FF 39 AE 3D 57 F5 60  
 65 4D 7D 75 C9 08 AB E6 25 64 75 3E AC 39 D7 50  
 3D A6 D3 7C 2E 32 E1 AF 29 48 4B A6 8F 58 5F F0  
 8E 05 F1 30 B2 91 5E 06 4E 2B D4 41 EB 7F C0 38  
 99 67 49 CB 3E 48 9F 8A

After t

```

22 BD E2 07 FD AB C6 F2 82 7A 88 0C 33 0B BF 6D
F7 33 77 4B 65 3E 57 30 5D 78 DC E1 12 F1 0A 2C
71 F4 CD AD 92 ED 11 3E 1C EA 63 B9 19 25 ED 28
19 1E 6D BB B5 AA 5A 2A FD A5 1F C0 5A 3A F5 25
8B 87 66 52 43 55 0F 28 94 8A E2 B8 BE B6 BC 9C
77 0B 35 F0 67 EA A6 41 EF E6 5B 1A 44 90 9D 1B
14 9F 97 EE A6 01 39 1C 60 9E C8 1D 19 30 F5 7C
18 A4 E0 FA B4 91 D1 CA DF D5 04 83 44 9E DC 0F
07 FF B2 4D 2C 6F 9A 9A 3B FF 39 AE 3D 57 F5 60
65 4D 7D 75 C9 08 AB E6 25 64 75 3E AC 39 D7 50
3D A6 D3 7C 2E 32 E1 AF 29 48 4B A6 8F 58 5F F0
8E 05 F1 30 B2 91 5E 06 4E 2B D4 41 EB 7F C0 38
99 67 49 CB 3E 48 9F 8A

```

After permutation

```

22 BD E2 07 FD AB C6 F2 82 7A 88 0C 33 0B BF 6D
F7 33 77 4B 65 3E 57 30 5D 78 DC E1 12 F1 0A 2C
71 F4 CD AD 92 ED 11 3E 1C EA 63 B9 19 25 ED 28
19 1E 6D BB B5 AA 5A 2A FD A5 1F C0 5A 3A F5 25
8B 87 66 52 43 55 0F 28 94 8A E2 B8 BE B6 BC 9C
77 0B 35 F0 67 EA A6 41 EF E6 5B 1A 44 90 9D 1B
14 9F 97 EE A6 01 39 1C 60 9E C8 1D 19 30 F5 7C
18 A4 E0 FA B4 91 D1 CA DF D5 04 83 44 9E DC 0F
07 FF B2 4D 2C 6F 9A 9A 3B FF 39 AE 3D 57 F5 60
65 4D 7D 75 C9 08 AB E6 25 64 75 3E AC 39 D7 50
3D A6 D3 7C 2E 32 E1 AF 29 48 4B A6 8F 58 5F F0
8E 05 F1 30 B2 91 5E 06 4E 2B D4 41 EB 7F C0 38
99 67 49 CB 3E 48 9F 8A

```

State (as lanes of integers)

[0, 0] = F2C6ABFD07E2BD22  
 [1, 0] = 6DBF0B330C887A82  
 [2, 0] = 30573E654B7733F7  
 [3, 0] = 2C0AF112E1DC785D  
 [4, 0] = 3E11ED92ADCDF471  
 [0, 1] = 28ED2519B963EA1C  
 [1, 1] = 2A5AAAB5BB6D1E19  
 [2, 1] = 25F53A5AC01FA5FD  
 [3, 1] = 280F55435266878B  
 [4, 1] = 9CBCB6BEB8E28A94  
 [0, 2] = 41A6EA67F0350B77  
 [1, 2] = 1B9D90441A5BE6EF  
 [2, 2] = 1C3901A6EE979F14  
 [3, 2] = 7CF530191DC89E60  
 [4, 2] = CAD191B4FAE0A418  
 [0, 3] = 0FDC9E448304D5DF  
 [1, 3] = 9A9A6F2C4DB2FF07  
 [2, 3] = 60F5573DAE39FF3B  
 [3, 3] = E6AB08C9757D4D65  
 [4, 3] = 50D739AC3E756425  
 [0, 4] = AFE1322E7CD3A63D  
 [1, 4] = F05F588FA64B4829  
 [2, 4] = 065E91B230F1058E  
 [3, 4] = 38C07FEB41D42B4E  
 [4, 4] = 8A9F483ECB496799

About to call squeeze (again)

State before permutation (in bytes)

22 BD E2 07 FD AB C6 F2 82 7A 88 0C 33 0B BF 6D  
 F7 33 77 4B 65 3E 57 30 5D 78 DC E1 12 F1 0A 2C  
 71 F4 CD AD 92 ED 11 3E 1C EA 63 B9 19 25 ED 28  
 19 1E 6D BB B5 AA 5A 2A FD A5 1F C0 5A 3A F5 25  
 8B 87 66 52 43 55 0F 28 94 8A E2 B8 BE B6 BC 9C  
 77 0B 35 F0 67 EA A6 41 EF E6 5B 1A 44 90 9D 1B  
 14 9F 97 EE A6 01 39 1C 60 9E C8 1D 19 30 F5 7C  
 18 A4 E0 FA B4 91 D1 CA DF D5 04 83 44 9E DC 0F  
 07 FF B2 4D 2C 6F 9A 9A 3B FF 39 AE 3D 57 F5 60  
 65 4D 7D 75 C9 08 AB E6 25 64 75 3E AC 39 D7 50  
 3D A6 D3 7C 2E 32 E1 AF 29 48 4B A6 8F 58 5F F0  
 8E 05 F1 30 B2 91 5E 06 4E 2B D4 41 EB 7F C0 38  
 99 67 49 CB 3E 48 9F 8A



State before permutation (as lanes of integers)

[0,0] = F2C6ABFD07E2BD22  
 [1,0] = 6DBF0B330C887A82  
 [2,0] = 30573E654B7733F7  
 [3,0] = 2C0AF112E1DC785D  
 [4,0] = 3E11ED92ADCDF471  
 [0,1] = 28ED2519B963EA1C  
 [1,1] = 2A5AAAB5BB6D1E19  
 [2,1] = 25F53A5AC01FA5FD  
 [3,1] = 280F55435266878B  
 [4,1] = 9CBCB6BEB8E28A94  
 [0,2] = 41A6EA67F0350B77  
 [1,2] = 1B9D90441A5BE6EF  
 [2,2] = 1C3901A6EE979F14  
 [3,2] = 7CF530191DC89E60  
 [4,2] = CAD191B4FAE0A418  
 [0,3] = 0FDC9E448304D5DE  
 [1,3] = 9A9A6F2C4DB2FF07  
 [2,3] = 60F5573DAE39FF3B  
 [3,3] = E6AB08C9757D4D65  
 [4,3] = 50E739AC3E756425  
 [0,4] = AFE1322E7CD3A63D  
 [1,4] = F05F588FA64B4829  
 [2,4] = 065E91B230F1058E  
 [3,4] = 38C07FEB41D42B4E  
 [4,4] = 8A9F483ECB496799

Round #0

After  $\theta$

D7 0E 9F 91 35 1C 88 2D 7F B2 84 4B F7 45 6E 88  
 96 09 86 38 D1 FE DD 4B 75 39 0C 2F 10 44 53 27  
 BA AC D0 55 2B 9F EB EF E9 59 1E 2F D1 92 A3 F7  
 E4 D6 61 FC 71 E4 8B CF 9C 9F EE B3 EE FA 7F 5E  
 A3 C6 B6 9C 41 E0 56 23 5F D2 FF 40 07 C4 46 4D  
 82 B8 48 66 AF 5D E8 9E 12 2E 57 5D 80 DE 4C FE  
 75 A5 66 9D 12 C1 B3 67 48 DF 18 D3 1B 85 AC 77  
 D3 FC FD 02 0D E3 2B 1B 2A 66 79 15 8C 29 92 D0  
 FA 37 BE 0A E8 21 4B 7F 5A C5 C8 DD 89 97 7F 1B  
 4D 0C AD BB CB BD F2 ED EE 3C 68 C6 15 4B 2D 81  
 C8 15 AE EA E6 85 AF 70 D4 80 47 E1 4B 16 8E 15  
 EF 3F 00 43 06 51 D4 7D 66 6A 04 8F E9 CA 99 33  
 52 3F 54 33 87 3A 65 5B

After  $\rho$ 

D7 0E 9F 91 35 1C 88 2D FF 64 09 97 EE 8B DC 10  
 65 82 21 4E B4 7F F7 92 41 34 75 52 97 C3 F0 02  
 F9 5C 7F D7 65 85 AE 5A 12 2D 39 7A 9F 9E E5 F1  
 C6 1F 47 BE F8 4C 6E 1D 17 E7 A7 FB AC BB FE 9F  
 63 5B CE 20 70 AB 91 51 6C D4 F4 25 FD 0F 74 40  
 14 C4 45 32 7B ED 42 F7 F9 4B B8 5C 75 01 7A 33  
 EB 94 08 9E 3D AB 2B 35 0A 59 EF 90 BE 31 A6 37  
 81 86 F1 95 8D 69 FE 7E 2A 18 53 24 A1 55 CC F2  
 57 01 3D 64 E9 4F FF C6 BF 0D AD 62 E4 EE C4 CB  
 57 BE BD 89 A1 75 77 B9 81 EE 3C 68 C6 15 4B 2D  
 BE C2 21 57 B8 AA 9B 17 50 03 1E 85 2F 59 38 56  
 FD 07 60 C8 20 8A BA EF 6A 04 8F E9 CA 99 33 66  
 D9 96 D4 0F D5 CC A1 4E

After  $\pi$ 

D7 0E 9F 91 35 1C 88 2D C6 1F 47 BE F8 4C 6E 1D  
 EB 94 08 9E 3D AB 2B 35 57 BE BD 89 A1 75 77 B9  
 D9 96 D4 0F D5 CC A1 4E 41 34 75 52 97 C3 F0 02  
 6C D4 F4 25 FD 0F 74 40 14 C4 45 32 7B ED 42 F7  
 57 01 3D 64 E9 4F FF C6 FD 07 60 C8 20 8A BA EF  
 FF 64 09 97 EE 8B DC 10 17 E7 A7 FB AC BB FE 9F  
 0A 59 EF 90 BE 31 A6 37 81 EE 3C 68 C6 15 4B 2D  
 BE C2 21 57 B8 AA 9B 17 F9 5C 7F D7 65 85 AE 5A  
 12 2D 39 7A 9F 9E E5 F1 F9 4B B8 5C 75 01 7A 33  
 BF 0D AD 62 E4 EE C4 CB 6A 04 8F E9 CA 99 33 66  
 65 82 21 4E B4 7F F7 92 63 5B CE 20 70 AB 91 51  
 81 86 F1 95 8D 69 FE 7E 2A 18 53 24 A1 55 CC F2  
 50 03 1E 85 2F 59 38 56

After  $\chi$ 

FE 8E 97 91 30 BF 89 0D D2 35 F2 BF 78 18 3A 95  
 63 94 48 98 69 23 AB 73 51 B6 B6 19 81 65 7F 98  
 D9 87 94 21 1D 8C C7 5E 51 34 74 40 95 23 F2 B5  
 2F D5 CC 61 7D 0D C9 40 BC C2 05 BA 7B 6D 42 DE  
 57 31 28 76 7E 0E BF C6 D1 C7 E0 ED 48 86 BE AF  
 F7 7C 41 97 FC 8B DC 30 96 41 B7 93 EC BF B7 97  
 34 59 EE 87 86 9B 36 25 C0 CA 34 E8 80 14 0F 2D  
 BE 41 87 3F B8 9A B9 98 10 1E FF D3 05 84 B4 58  
 14 29 3C 58 1F 70 61 39 B9 4B BA D5 7F 10 49 17  
 2E 55 DD 74 C1 EA 48 D3 68 25 8F C1 50 83 72 C7  
 E5 06 10 DB 39 3F 99 BC 49 43 CC 00 50 BF 91 D1  
 D1 85 FD 14 83 61 CE 7A 0F 98 72 6E 31 73 0B 72  
 52 5A D0 A5 6F D9 38 17

After 1

```

FF 8E 97 91 30 BF 89 0D D2 35 F2 BF 78 18 3A 95
63 94 48 98 69 23 AB 73 51 B6 B6 19 81 65 7F 98
D9 87 94 21 1D 8C C7 5E 51 34 74 40 95 23 F2 B5
2F D5 CC 61 7D 0D C9 40 BC C2 05 BA 7B 6D 42 DE
57 31 28 76 7E 0E BF C6 D1 C7 E0 ED 48 86 BE AF
F7 7C 41 97 FC 8B DC 30 96 41 B7 93 EC BF B7 97
34 59 EE 87 86 9B 36 25 C0 CA 34 E8 80 14 0F 2D
BE 41 87 3F B8 9A B9 98 10 1E FF D3 05 84 B4 58
14 29 3C 58 1F 70 61 39 B9 4B BA D5 7F 10 49 17
2E 55 DD 74 C1 EA 48 D3 68 25 8F C1 50 83 72 C7
E5 06 10 DB 39 3F 99 BC 49 43 CC 00 50 BF 91 D1
D1 85 FD 14 83 61 CE 7A 0F 98 72 6E 31 73 0B 72
52 5A D0 A5 6F D9 38 17

```

(Skip rounds 1 to 22)

Round #23

After 0

```

37 E8 EC 6A 7B 06 DA 58 CD F9 4D 54 60 33 DE 0F
0E 9D 66 56 32 64 53 73 0F A4 CA 2B 43 63 1C A7
E8 B3 06 EE F5 CA 0D 83 42 AD 23 B3 3A B8 5F E7
99 EB AB DF E1 6E 21 66 41 57 4A 94 20 47 29 06
36 0F 73 FE AF 49 5A 68 BE 60 D0 B4 B7 2C 98 0B
8C 86 9F C1 BF 2A C3 86 98 A9 EF FC 60 69 05 C4
F0 7B 93 6D 1C 8D 4E 5B 80 21 76 E4 EF CA 54 37
2A 09 9B 04 16 2E 65 6A D7 EE 90 D2 3C 62 6F C1
B4 E1 C8 B7 2B E9 E4 EF 03 35 0A 7C 6E 7F 0E 40
FE F9 A0 31 7A 7E BC 8B 46 68 9C 0E 43 96 BA 1E
A2 7A 2C 3B E9 E1 C7 A3 31 3B B1 00 C2 8C C8 4A
BE B9 41 20 3B 91 2D E0 40 15 75 78 DE BA 92 38
53 43 0B BF 4A 54 00 EB

```

After  $\rho$ 

37 E8 EC 6A 7B 06 DA 58 9A F3 9B A8 C0 66 BC 1F  
 43 A7 99 95 0C D9 D4 9C 34 C6 71 FA 40 AA BC 32  
 57 6E 18 44 9F 35 70 AF AB 83 FB 75 2E D4 3A 32  
 FA 1D EE 16 62 96 B9 BE 41 D0 95 12 25 C8 51 8A  
 87 39 FF D7 24 2D 34 9B 82 B9 E0 0B 06 4D 7B CB  
 64 34 FC 0C FE 55 19 36 10 63 A6 BE F3 83 A5 15  
 6C E3 68 74 DA 82 DF 9B 95 A9 6E 00 43 EC C8 DF  
 02 0B 97 32 35 95 84 4D A5 79 C4 DE 82 AF DD 21  
 F9 76 25 9D FC 9D 36 1C 07 A0 81 1A 05 3E B7 3F  
 8F 77 D1 3F 1F 34 46 CF 1E 46 68 9C 0E 43 96 BA  
 1F 8F 8A EA B1 EC A4 87 C5 EC C4 02 08 33 22 2B  
 37 37 08 64 27 B2 05 DC 15 75 78 DE BA 92 38 40  
 C0 FA D4 D0 C2 AF 12 15

After  $\pi$ 

37 E8 EC 6A 7B 06 DA 58 FA 1D EE 16 62 96 B9 BE  
 6C E3 68 74 DA 82 DF 9B 8F 77 D1 3F 1F 34 46 CF  
 C0 FA D4 D0 C2 AF 12 15 34 C6 71 FA 40 AA BC 32  
 82 B9 E0 0B 06 4D 7B CB 64 34 FC 0C FE 55 19 36  
 F9 76 25 9D FC 9D 36 1C 37 37 08 64 27 B2 05 DC  
 9A F3 9B A8 C0 66 BC 1F 41 D0 95 12 25 C8 51 8A  
 95 A9 6E 00 43 EC C8 DF 4E 46 68 9C 0E 43 96 BA  
 1F 8F 8A EA B1 EC A4 87 57 6E 18 44 9F 35 70 AF  
 AB 83 FB 75 2E D4 3A 32 10 63 A6 BE F3 83 A5 15  
 07 A0 81 1A 05 3E B7 3F 15 75 78 DE BA 92 38 40  
 43 A7 99 95 0C D9 D4 9C 87 39 FF D7 24 2D 34 9B  
 02 0B 97 32 35 95 84 4D A5 79 C4 DE 82 AF DD 21  
 C5 EC C4 02 08 33 22 2B

After  $\chi$ 

33 0A EC 0A E3 06 9C 59 79 09 7F 1D 67 A2 B9 FA  
 2C 6B 6C B4 1A 09 CF 8B B8 77 F9 15 26 34 8E 87  
 08 EF D6 C4 C2 3F 33 B3 50 C2 6D FE B8 BA BC 06  
 1B FB E1 9A 06 C5 5D C3 62 35 F4 6C FD 77 18 F6  
 F9 B6 54 07 BC 95 8E 3E B5 0E 88 65 21 F7 46 15  
 0E DA F1 A8 82 42 34 4A 4B 96 95 8E 29 CB 47 AA  
 94 20 EC 62 F2 40 E8 DA 9E 36 79 9C 4E 41 8E A2  
 5E 8F 8E F8 94 64 E5 07 47 0E 1C CE 4E 36 F5 AA  
 AC 03 FA 75 2A E8 28 18 00 36 DE 7A 49 03 AD 55  
 45 AA 81 1A 00 1B F7 90 BD F4 9B EF 9A 52 32 50  
 43 A5 99 B5 1D 49 54 D8 22 49 BF 1B A6 07 6D BB  
 42 8F 97 32 3D 85 A6 47 A7 7A DD 4B 86 67 09 B5  
 41 F4 A2 40 28 17 02 28

After t

```

3B 8A EC 8A E3 06 9C D9 79 09 7F 1D 67 A2 B9 FA
2C 6B 6C B4 1A 09 CF 8B B8 77 F9 15 26 34 8E 87
08 EF D6 C4 C2 3F 33 B3 50 C2 6D FE B8 BA BC 06
1B FB E1 9A 06 C5 5D C3 62 35 F4 6C FD 77 18 F6
F9 B6 54 07 BC 95 8E 3E B5 0E 88 65 21 F7 46 15
0E DA F1 A8 82 42 34 4A 4B 96 95 8E 29 CB 47 AA
94 20 EC 62 F2 40 E8 DA 9E 36 79 9C 4E 41 8E A2
5E 8F 8E F8 94 64 E5 07 47 0E 1C CE 4E 36 F5 AA
AC 03 FA 75 2A E8 28 18 00 36 DE 7A 49 03 AD 55
45 AA 81 1A 00 1B F7 90 BD F4 9B EF 9A 52 32 50
43 A5 99 B5 1D 49 54 D8 22 49 BF 1B A6 07 6D BB
42 8F 97 32 3D 85 A6 47 A7 7A DD 4B 86 67 09 B5
41 F4 A2 40 28 17 02 28

```

After permutation

```

3B 8A EC 8A E3 06 9C D9 79 09 7F 1D 67 A2 B9 FA
2C 6B 6C B4 1A 09 CF 8B B8 77 F9 15 26 34 8E 87
08 EF D6 C4 C2 3F 33 B3 50 C2 6D FE B8 BA BC 06
1B FB E1 9A 06 C5 5D C3 62 35 F4 6C FD 77 18 F6
F9 B6 54 07 BC 95 8E 3E B5 0E 88 65 21 F7 46 15
0E DA F1 A8 82 42 34 4A 4B 96 95 8E 29 CB 47 AA
94 20 EC 62 F2 40 E8 DA 9E 36 79 9C 4E 41 8E A2
5E 8F 8E F8 94 64 E5 07 47 0E 1C CE 4E 36 F5 AA
AC 03 FA 75 2A E8 28 18 00 36 DE 7A 49 03 AD 55
45 AA 81 1A 00 1B F7 90 BD F4 9B EF 9A 52 32 50
43 A5 99 B5 1D 49 54 D8 22 49 BF 1B A6 07 6D BB
42 8F 97 32 3D 85 A6 47 A7 7A DD 4B 86 67 09 B5
41 F4 A2 40 28 17 02 28

```

State (as lanes of integers)

[0, 0] = D99C06E38AEC8A3B  
 [1, 0] = FAB9A2671D7F0979  
 [2, 0] = 8BCF091AB46C6B2C  
 [3, 0] = 878E342615F977B8  
 [4, 0] = B3333FC2C4D6EF08  
 [0, 1] = 06BCBAB8FE6DC250  
 [1, 1] = C35DC5069AE1FB1B  
 [2, 1] = F61877FD6CF43562  
 [3, 1] = 3E8E95BC0754B6F9  
 [4, 1] = 1546F72165880EB5  
 [0, 2] = 4A344282A8F1DA0E  
 [1, 2] = AA47CB298E95964B  
 [2, 2] = DAE840F262EC2094  
 [3, 2] = A28E414E9C79369E  
 [4, 2] = 07E56494F88E8F5E  
 [0, 3] = AAF5364ECE1C0E47  
 [1, 3] = 1828E82A75FA03AC  
 [2, 3] = 55AD03497ADE3600  
 [3, 3] = 90F71B001A81AA45  
 [4, 3] = 5032529AEF9BF4BD  
 [0, 4] = D854491DB599A543  
 [1, 4] = BB6D07A61BBF4922  
 [2, 4] = 47A6853D32978F42  
 [3, 4] = B50967864BDD7AA7  
 [4, 4] = 2802172840A2F441

The hash value is

2E 0A BF BA 83 E6 72 0B FB C2 25 FF 6B 7A B9 FF  
 CE 58 BA 02 7E E3 D8 98 76 4F EF 28 7D DE CC CA  
 3E 6E 59 98 41 1E 7D DB 32 F6 75 38 F5 00 B1 8C  
 8C 97 C4 52 C3 70 EA 2C F0 AF CA 3E 05 DE 7E 4D  
 E2 7F A4 41 A9 CB 34 FD 17 C9 78 B4 2D 5B 7E 7F  
 9A B1 8F FE FF C3 C5 AC 2F 3A 45 5E EB FD C7 6C  
 EA EB 0A 2C CA 22 EE F6 E6 37 F4 CA BE 5C 51 DE  
 D2 E3 FA D8 B9 52 70 A3 21 84 56 64 F1 07 D1 64  
 96 BB 7A BF BE 75 04 B6 ED E2 E8 9E 4B 99 6F B5  
 8E FD C4 18 1F 91 63 38 1C BE 7B C0 06 A7 A2 05  
 98 9C 52 6C D1 BD 68 98 36 93 B4 BD C5 37 28 B2  
 41 C1 CF F4 2B B6 11 50 2C 35 20 5C AB B2 88 75  
 56 55 D6 20 C6 79 94 F0 64 51 18 7F 6F D1 7E 04  
 66 82 BA 12 86 06 3F F8 8F E2 50 8D 1F CA F9 03  
 5A 12 31 AD 41 50 A9 C9 B2 4C 9B 2D 66 B2 AD 1B  
 DE 0B D0 BB CB 8B E0 5B 83 52 29 EF 79 19 73 73  
 23 42 44 01 E1 D8 37 B6 6E B4 E6 30 FF 1D E7 0C  
 B3 17 C2 BA CB 08 00 1D 34 77 B7 A7 0A 57 6D 20  
 86 90 33 58 9D 85 A0 1D DE 2B 66 46 C0 43 B5 9F  
 C0 11 31 1D A6 66 FA 5A D1 D6 38 7F A9 BC 40 15  
 A3 8A 51 D1 DA 1E A6 1D 64 8D C8 E3 9A 88 B9 D6  
 22 BD E2 07 FD AB C6 F2 82 7A 88 0C 33 0B BF 6D  
 F7 33 77 4B 65 3E 57 30 5D 78 DC E1 12 F1 0A 2C  
 71 F4 CD AD 92 ED 11 3E 1C EA 63 B9 19 25 ED 28  
 19 1E 6D BB B5 AA 5A 2A FD A5 1F C0 5A 3A F5 25  
 8B 87 66 52 43 55 0F 28 94 8A E2 B8 BE B6 BC 9C  
 77 0B 35 F0 67 EA A6 41 EF E6 5B 1A 44 90 9D 1B  
 14 9F 97 EE A6 01 39 1C 60 9E C8 1D 19 30 F5 7C  
 18 A4 E0 FA B4 91 D1 CA DF D5 04 83 44 9E DC 0F  
 07 FF B2 4D 2C 6F 9A 9A 3B FF 39 AE 3D 57 F5 60  
 65 4D 7D 75 C9 08 AB E6 25 64 75 3E AC 39 D7 50  
 3D A6 D3 7C 2E 32 E1 AF 3B 8A EC 8A E3 06 9C D9

SHAKE-128 sample to produce 4 096 bits of output

The message as a bit string

110010100001101011011110100110

About to call last of the absorb phase

## XORed state (in bytes)

```

53 58 7B D9 07 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 80 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00

```

## XORed state (as lanes of integers)

```

[0, 0] = 00000007D97B5853
[1, 0] = 0000000000000000
[2, 0] = 0000000000000000
[3, 0] = 0000000000000000
[4, 0] = 0000000000000000
[0, 1] = 0000000000000000
[1, 1] = 0000000000000000
[2, 1] = 0000000000000000
[3, 1] = 0000000000000000
[4, 1] = 0000000000000000
[0, 2] = 0000000000000000
[1, 2] = 0000000000000000
[2, 2] = 0000000000000000
[3, 2] = 0000000000000000
[4, 2] = 0000000000000000
[0, 3] = 0000000000000000
[1, 3] = 0000000000000000
[2, 3] = 0000000000000000
[3, 3] = 0000000000000000
[4, 3] = 0000000000000000
[0, 4] = 8000000000000000
[1, 4] = 0000000000000000
[2, 4] = 0000000000000000
[3, 4] = 0000000000000000
[4, 4] = 0000000000000000

```

Round #0



After  $\theta$ 

```

53 58 7B D9 07 00 00 00 53 58 7B D9 07 00 00 80
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
A7 B0 F6 B2 0F 00 00 00 00 00 00 00 00 00 00
53 58 7B D9 07 00 00 80 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 A7 B0 F6 B2 0F 00 00
00 00 00 00 00 00 00 00 53 58 7B D9 07 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00
A7 B0 F6 B2 0F 00 00 00 00 00 00 00 00 00 00
53 58 7B D9 07 00 00 80 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 A7 B0 F6 B2 0F 00 00
00 00 00 00 00 00 00 80 53 58 7B D9 07 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00
A7 B0 F6 B2 0F 00 00 00

```

After  $\rho$ 

```

53 58 7B D9 07 00 00 00 A7 B0 F6 B2 0F 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 38 85 B5 97 7D 00 00 00 00 00 00 00
97 7D 00 00 00 38 85 B5 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 70 0A 6B 2F FB 00
00 00 00 00 00 00 00 00 00 4E 61 ED 65 1F 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00
D9 07 00 00 80 53 58 7B 00 00 00 00 00 00 00
2F FB 00 00 00 70 0A 6B 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 A7 B0 F6 B2 0F 00
00 00 02 00 00 00 00 00 4E 61 ED 65 1F 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 C0 29 AC BD EC 03 00

```

After  $\pi$ 

```

53 58 7B D9 07 00 00 00 97 7D 00 00 00 38 85 B5
00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 C0 29 AC BD EC 03 00 00 00 00 00 00 00 00
00 00 70 0A 6B 2F FB 00 00 00 00 00 00 00 00
2F FB 00 00 00 70 0A 6B 00 00 00 00 00 00 00
A7 B0 F6 B2 0F 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 A7 B0 F6 B2 0F 00
00 00 02 00 00 00 00 00 00 00 38 85 B5 97 7D
00 00 00 00 00 00 00 00 00 4E 61 ED 65 1F 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00
D9 07 00 00 80 53 58 7B 00 00 00 00 00 00 00
4E 61 ED 65 1F 00 00 00

```

After  $\chi$ 

```

53 58 7B D9 07 00 00 00 97 7D 00 00 00 38 85 B5
00 C0 29 AC BD EC 03 00 53 18 52 51 02 00 00 00
84 E5 29 AC BD D4 86 B5 00 00 00 00 00 00 00 00
2F FB 70 0A 6B 5F F1 6B 00 00 00 00 00 00 00
2F FB 00 00 00 70 0A 6B 00 00 70 0A 6B 2F FB 00
A7 B0 F6 B2 0F 00 00 00 00 A7 B0 F6 B2 0F 00 00
00 00 02 00 00 00 00 00 00 A7 17 44 44 BD 0F 00 00
00 00 02 00 00 00 00 00 00 00 4E 61 D5 E0 AA 97 7D
00 00 00 00 00 00 00 00 00 00 4E 61 ED 65 1F 00 00
00 00 00 38 85 B5 97 7D 00 00 00 00 00 00 00 00
D9 07 00 00 80 53 58 7B 00 00 00 00 00 00 00 00
97 66 ED 65 9F 53 58 7B 00 00 00 00 00 00 00 00
4E 61 ED 65 1F 00 00 00

```

After  $\iota$ 

```

52 58 7B D9 07 00 00 00 97 7D 00 00 00 38 85 B5
00 C0 29 AC BD EC 03 00 53 18 52 51 02 00 00 00
84 E5 29 AC BD D4 86 B5 00 00 00 00 00 00 00 00
2F FB 70 0A 6B 5F F1 6B 00 00 00 00 00 00 00
2F FB 00 00 00 70 0A 6B 00 00 70 0A 6B 2F FB 00
A7 B0 F6 B2 0F 00 00 00 00 A7 B0 F6 B2 0F 00 00
00 00 02 00 00 00 00 00 00 A7 17 44 44 BD 0F 00 00
00 00 02 00 00 00 00 00 00 00 4E 61 D5 E0 AA 97 7D
00 00 00 00 00 00 00 00 00 00 4E 61 ED 65 1F 00 00
00 00 00 38 85 B5 97 7D 00 00 00 00 00 00 00 00
D9 07 00 00 80 53 58 7B 00 00 00 00 00 00 00 00
97 66 ED 65 9F 53 58 7B 00 00 00 00 00 00 00 00
4E 61 ED 65 1F 00 00 00

```

(Skip rounds 1 to 22)

Round #23

After  $\theta$ 

E5 C9 38 91 7E 2D CB B6 4A 58 42 73 14 82 E1 30  
 C6 50 6D 1E 06 82 8D 5E 8B F9 05 58 45 03 D5 87  
 8E 5B 12 B3 03 98 A7 EF A3 87 68 10 6A CF 6C B1  
 4E 6B 71 A4 46 0A C2 25 DA DB 48 F1 BA 33 88 15  
 3C 04 56 F1 82 E8 B3 83 7E D0 A1 5C 3A 51 4D 4B  
 FB 44 D7 40 4E 41 AF AD 87 22 12 4D 83 EA 79 D4  
 2A C6 4E D0 A7 90 BE 27 E7 B4 40 C6 63 09 3B 93  
 36 ED 8D 06 58 2D 32 E0 26 54 B6 49 05 CD FC 47  
 4F 83 EA 78 1E F1 51 EB 2F B3 24 89 85 66 CF B6  
 B2 6B 35 F6 19 C3 E1 AC DF 6F 1B 5E E3 06 89 82  
 27 71 C4 F3 B6 99 32 7C 4C 8E F3 6D 8D 18 5A 13  
 60 56 56 76 79 A3 F4 B6 97 2F 9A CC 07 CF FB A1  
 08 96 F2 AF 4E B2 8B 8F

After  $\rho$ 

E5 C9 38 91 7E 2D CB B6 94 B0 84 E6 28 04 C3 61  
 31 54 9B 87 81 60 A3 97 34 50 7D B8 98 5F 80 55  
 C0 3C 7D 77 DC 92 98 1D A1 F6 CC 16 3B 7A 88 06  
 47 6A A4 20 5C E2 B4 16 85 F6 36 52 BC EE 0C 62  
 02 AB 78 41 F4 D9 41 1E D5 B4 E4 07 1D CA A5 13  
 DD 27 BA 06 72 0A 7A 6D 51 1F 8A 48 34 0D AA E7  
 82 3E 85 F4 3D 51 31 76 12 76 26 CF 69 81 8C C7  
 03 AC 16 19 70 9B F6 46 93 0A 9A F9 8F 4C A8 6C  
 1D CF 23 3E 6A FD 69 50 67 DB 97 59 92 C4 42 B3  
 38 9C 55 76 AD C6 3E 63 82 DF 6F 1B 5E E3 06 89  
 CA F0 9D C4 11 CF DB 66 30 39 CE B7 35 62 68 4D  
 CC CA CA 2E 6F 94 DE 16 2F 9A CC 07 CF FB A1 97  
 E2 23 82 A5 FC AB 93 EC

After  $\pi$ 

E5 C9 38 91 7E 2D CB B6 47 6A A4 20 5C E2 B4 16  
 82 3E 85 F4 3D 51 31 76 38 9C 55 76 AD C6 3E 63  
 E2 23 82 A5 FC AB 93 EC 34 50 7D B8 98 5F 80 55  
 D5 B4 E4 07 1D CA A5 13 DD 27 BA 06 72 0A 7A 6D  
 1D CF 23 3E 6A FD 69 50 CC CA CA 2E 6F 94 DE 16  
 94 B0 84 E6 28 04 C3 61 85 F6 36 52 BC EE 0C 62  
 12 76 26 CF 69 81 8C C7 82 DF 6F 1B 5E E3 06 89  
 CA F0 9D C4 11 CF DB 66 C0 3C 7D 77 DC 92 98 1D  
 A1 F6 CC 16 3B 7A 88 06 51 1F 8A 48 34 0D AA E7  
 67 DB 97 59 92 C4 42 B3 2F 9A CC 07 CF FB A1 97  
 31 54 9B 87 81 60 A3 97 02 AB 78 41 F4 D9 41 1E  
 03 AC 16 19 70 9B F6 46 93 0A 9A F9 8F 4C A8 6C  
 30 39 CE B7 35 62 68 4D

After  $\chi$ 

65 DD 39 45 5F 3C CA D6 7F EA F4 22 DC 64 BA 17  
 40 1D 07 75 6D 78 B0 FA 3D 54 6D 66 AF C2 76 71  
 E0 01 06 85 FC 69 A7 EC 3C 53 67 B8 FA 5F DA 39  
 D5 7C E5 3F 15 3F A4 03 1D 27 72 06 77 0A EC 6B  
 2D DF 16 AE FA B6 69 11 0D 6E 4A 29 6A 14 FB 14  
 86 B0 84 6B 69 05 43 E4 05 7F 7F 42 AA 8C 0E 6A  
 5A 56 B6 0B 68 8D 55 A1 96 DF 6F 39 76 E3 06 88  
 CB B6 AF D4 85 25 D7 64 90 35 7F 3F D8 97 BA FC  
 87 36 D9 07 B9 BA C8 16 59 1F C2 4E 79 36 0B E3  
 A7 FF A6 29 82 C4 5A BB 0E 58 4C 07 EC 93 A1 95  
 30 50 9D 9F 81 62 15 D7 92 A9 F0 A1 7B 9D 49 36  
 23 9D 52 1F 40 B9 B6 47 92 4E 8B F9 0F 4C 2B FE  
 32 92 AE F7 41 FB 28 45

After  $\iota$ 

6D 5D 39 C5 5F 3C CA 56 7F EA F4 22 DC 64 BA 17  
 40 1D 07 75 6D 78 B0 FA 3D 54 6D 66 AF C2 76 71  
 E0 01 06 85 FC 69 A7 EC 3C 53 67 B8 FA 5F DA 39  
 D5 7C E5 3F 15 3F A4 03 1D 27 72 06 77 0A EC 6B  
 2D DF 16 AE FA B6 69 11 0D 6E 4A 29 6A 14 FB 14  
 86 B0 84 6B 69 05 43 E4 05 7F 7F 42 AA 8C 0E 6A  
 5A 56 B6 0B 68 8D 55 A1 96 DF 6F 39 76 E3 06 88  
 CB B6 AF D4 85 25 D7 64 90 35 7F 3F D8 97 BA FC  
 87 36 D9 07 B9 BA C8 16 59 1F C2 4E 79 36 0B E3  
 A7 FF A6 29 82 C4 5A BB 0E 58 4C 07 EC 93 A1 95  
 30 50 9D 9F 81 62 15 D7 92 A9 F0 A1 7B 9D 49 36  
 23 9D 52 1F 40 B9 B6 47 92 4E 8B F9 0F 4C 2B FE  
 32 92 AE F7 41 FB 28 45

After permutation

6D 5D 39 C5 5F 3C CA 56 7F EA F4 22 DC 64 BA 17  
 40 1D 07 75 6D 78 B0 FA 3D 54 6D 66 AF C2 76 71  
 E0 01 06 85 FC 69 A7 EC 3C 53 67 B8 FA 5F DA 39  
 D5 7C E5 3F 15 3F A4 03 1D 27 72 06 77 0A EC 6B  
 2D DF 16 AE FA B6 69 11 0D 6E 4A 29 6A 14 FB 14  
 86 B0 84 6B 69 05 43 E4 05 7F 7F 42 AA 8C 0E 6A  
 5A 56 B6 0B 68 8D 55 A1 96 DF 6F 39 76 E3 06 88  
 CB B6 AF D4 85 25 D7 64 90 35 7F 3F D8 97 BA FC  
 87 36 D9 07 B9 BA C8 16 59 1F C2 4E 79 36 0B E3  
 A7 FF A6 29 82 C4 5A BB 0E 58 4C 07 EC 93 A1 95  
 30 50 9D 9F 81 62 15 D7 92 A9 F0 A1 7B 9D 49 36  
 23 9D 52 1F 40 B9 B6 47 92 4E 8B F9 0F 4C 2B FE  
 32 92 AE F7 41 FB 28 45

State (as lanes of integers)

[0,0] = 56CA3C5FC5395D6D  
 [1,0] = 17BA64DC22F4EA7F  
 [2,0] = FAB0786D75071D40  
 [3,0] = 7176C2AF666D543D  
 [4,0] = ECA769FC850601E0  
 [0,1] = 39DA5FFAB867533C  
 [1,1] = 03A43F153FE57CD5  
 [2,1] = 6BEC0A770672271D  
 [3,1] = 1169B6FAAE16DF2D  
 [4,1] = 14FB146A294A6E0D  
 [0,2] = E44305696B84B086  
 [1,2] = 6A0E8CAA427F7F05  
 [2,2] = A1558D680BB6565A  
 [3,2] = 8806E376396FDF96  
 [4,2] = 64D72585D4AFB6CB  
 [0,3] = FCBA97D83F7F3590  
 [1,3] = 16C8BAB907D93687  
 [2,3] = E30B36794EC21F59  
 [3,3] = BB5AC48229A6FFA7  
 [4,3] = 95A193EC074C580E  
 [0,4] = D71562819F9D5030  
 [1,4] = 36499D7BA1F0A992  
 [2,4] = 47B6B9401F529D23  
 [3,4] = FE2B4C0FF98B4E92  
 [4,4] = 4528FB41F7AE9232

About to call squeeze (again)

State before permutation (in bytes)

6D 5D 39 C5 5F 3C CA 56 7F EA F4 22 DC 64 BA 17  
 40 1D 07 75 6D 78 B0 FA 3D 54 6D 66 AF C2 76 71  
 E0 01 06 85 FC 69 A7 EC 3C 53 67 B8 FA 5F DA 39  
 D5 7C E5 3F 15 3F A4 03 1D 27 72 06 77 0A EC 6B  
 2D DF 16 AE FA B6 69 11 0D 6E 4A 29 6A 14 FB 14  
 86 B0 84 6B 69 05 43 E4 05 7F 7F 42 AA 8C 0E 6A  
 5A 56 B6 0B 68 8D 55 A1 96 DF 6F 39 76 E3 06 88  
 CB B6 AF D4 85 25 D7 64 90 35 7F 3F D8 97 BA FC  
 87 36 D9 07 B9 BA C8 16 59 1F C2 4E 79 36 0B E3  
 A7 FF A6 29 82 C4 5A BB 0E 58 4C 07 EC 93 A1 95  
 30 50 9D 9F 81 62 15 D7 92 A9 F0 A1 7B 9D 49 36  
 23 9D 52 1F 40 B9 B6 47 92 4E 8B F9 0F 4C 2B FE  
 32 92 AE F7 41 FB 28 45

State before permutation (as lanes of integers)

[0, 0] = 56CA3C5FC5395D6D  
 [1, 0] = 17BA64DC22F4EA7F  
 [2, 0] = FAB0786D75071D40  
 [3, 0] = 7176C2AF666D543D  
 [4, 0] = ECA769FC850601E0  
 [0, 1] = 39DA5FFAB867533C  
 [1, 1] = 03A43F153FE57CD5  
 [2, 1] = 6BEC0A770672271D  
 [3, 1] = 1169B6FAAE16DF2D  
 [4, 1] = 14FB146A294A6E0D  
 [0, 2] = E44305696B84B086  
 [1, 2] = 6A0E8CAA427F7F05  
 [2, 2] = A1558D680BB6565A  
 [3, 2] = 8806E376396FDF96  
 [4, 2] = 64D72585D4AFB6CB  
 [0, 3] = FCBA97D83F7F3590  
 [1, 3] = 16C8BAB907D93687  
 [2, 3] = E30B36794EC21F59  
 [3, 3] = BB5AC48229A6FFA7  
 [4, 3] = 95A193EC074C580E  
 [0, 4] = D71562819F9D5030  
 [1, 4] = 36499D7BA1F0A992  
 [2, 4] = 47B6B9401F529D23  
 [3, 4] = FE2B4C0FF98B4E92  
 [4, 4] = 4528FB41F7AE9232

Round #0

After  $\theta$

03 A3 B6 BF A2 ED EB A7 F3 ED 6B C6 DF 17 2E 9E  
 9D A0 33 CE 90 B7 F1 FE 74 9C 3C 5F 99 D3 C6 7D  
 BC 52 4E C8 79 51 36 00 52 AD E8 C2 07 8E FB C8  
 59 7B 7A DB 16 4C 30 8A C0 9A 46 BD 8A C5 AD 6F  
 64 17 47 97 CC A7 D9 1D 51 3D 02 64 EF 2C 6A F8  
 E8 4E 0B 11 94 D4 62 15 89 78 E0 A6 A9 FF 9A E3  
 87 EB 82 B0 95 42 14 A5 DF 17 3E 00 40 F2 B6 84  
 97 E5 E7 99 00 1D 46 88 FE CB F0 45 25 46 9B 0D  
 0B 31 46 E3 BA C9 5C 9F 84 A2 F6 F5 84 F9 4A E7  
 EE 37 F7 10 B4 D5 EA B7 52 0B 04 4A 69 AB 30 79  
 5E AE 12 E5 7C B3 34 26 1E AE 6F 45 78 EE DD BF  
 FE 20 66 A4 BD 76 F7 43 DB 86 DA C0 39 5D 9B F2  
 6E C1 E6 BA C4 C3 B9 A9

After  $\rho$ 

03 A3 B6 BF A2 ED EB A7 E7 DB D7 8C BF 2F 5C 3C  
 27 E8 8C 33 E4 6D BC 7F 39 6D DC 47 C7 C9 F3 95  
 8B B2 01 E0 95 72 42 CE 7C E0 B8 8F 2C D5 8A 2E  
 B7 6D C1 04 A3 98 B5 A7 1B B0 A6 51 AF 62 71 EB  
 8B A3 4B E6 D3 EC 0E B2 A2 86 1F D5 23 40 F6 CE  
 40 77 5A 88 A0 A4 16 AB 8E 27 E2 81 9B A6 FE 6B  
 84 AD 14 A2 28 3D 5C 17 E4 6D 09 BF 2F 7C 00 80  
 4C 80 0E 23 C4 CB F2 F3 8B 4A 8C 36 1B FC 97 E1  
 68 5C 37 99 EB 73 21 C6 A5 73 42 51 FB 7A C2 7C  
 5A FD D6 FD E6 1E 82 B6 79 52 0B 04 4A 69 AB 30  
 D2 98 78 B9 4A 94 F3 CD 7A B8 BE 15 E1 B9 77 FF  
 1F C4 8C B4 D7 EE 7E C8 86 DA C0 39 5D 9B F2 DB  
 6E AA 5B B0 B9 2E F1 70

After  $\pi$ 

03 A3 B6 BF A2 ED EB A7 B7 6D C1 04 A3 98 B5 A7  
 84 AD 14 A2 28 3D 5C 17 5A FD D6 FD E6 1E 82 B6  
 6E AA 5B B0 B9 2E F1 70 39 6D DC 47 C7 C9 F3 95  
 A2 86 1F D5 23 40 F6 CE 40 77 5A 88 A0 A4 16 AB  
 68 5C 37 99 EB 73 21 C6 1F C4 8C B4 D7 EE 7E C8  
 E7 DB D7 8C BF 2F 5C 3C 1B B0 A6 51 AF 62 71 EB  
 E4 6D 09 BF 2F 7C 00 80 79 52 0B 04 4A 69 AB 30  
 D2 98 78 B9 4A 94 F3 CD 8B B2 01 E0 95 72 42 CE  
 7C E0 B8 8F 2C D5 8A 2E 8E 27 E2 81 9B A6 FE 6B  
 A5 73 42 51 FB 7A C2 7C 86 DA C0 39 5D 9B F2 DB  
 27 E8 8C 33 E4 6D BC 7F 8B A3 4B E6 D3 EC 0E B2  
 4C 80 0E 23 C4 CB F2 F3 8B 4A 8C 36 1B FC 97 E1  
 7A B8 BE 15 E1 B9 77 FF

After  $\chi$ 

03 23 A2 1D AA C8 A3 B7 ED 3D 03 59 65 9A 37 07  
 A0 AF 1D A2 31 1D 2D 57 5B FC 72 F2 E4 DF 88 31  
 DA E6 1A B0 B8 3E E5 70 79 1C 9C 4F 47 6D F3 B4  
 8A 8E 3A C4 68 13 D7 8A 57 F7 D2 AC B4 28 48 A3  
 48 75 67 DA EB 72 A0 D3 9D 46 8F 24 F7 EE 7A 82  
 03 96 DE 22 BF 33 5C 3C 02 A2 A4 51 EF 63 DA DB  
 66 E5 79 06 2F E8 50 4D 5C 11 8C 00 FF 42 A7 00  
 CA B8 58 E8 4A D4 D2 0E 09 B5 43 E0 06 50 36 8F  
 5D B0 B8 DF 4C 8D 8A 3A 8C AF 62 A9 9F 27 CE E8  
 AC 53 43 91 7B 1A C2 78 F2 9A 78 36 75 1E 7A FB  
 63 E8 88 32 E0 6E 4C 3E 08 E9 CB F2 C8 D8 0B B2  
 3C 30 3C 22 24 CA 92 ED 8E 0A 8C 14 1F B8 1F E1  
 F2 BB FD D1 F2 39 75 7F

After  $t$

```

02 23 A2 1D AA C8 A3 B7 ED 3D 03 59 65 9A 37 07
A0 AF 1D A2 31 1D 2D 57 5B FC 72 F2 E4 DF 88 31
DA E6 1A B0 B8 3E E5 70 79 1C 9C 4F 47 6D F3 B4
8A 8E 3A C4 68 13 D7 8A 57 F7 D2 AC B4 28 48 A3
48 75 67 DA EB 72 A0 D3 9D 46 8F 24 F7 EE 7A 82
03 96 DE 22 BF 33 5C 3C 02 A2 A4 51 EF 63 DA DB
66 E5 79 06 2F E8 50 4D 5C 11 8C 00 FF 42 A7 00
CA B8 58 E8 4A D4 D2 0E 09 B5 43 E0 06 50 36 8F
5D B0 B8 DF 4C 8D 8A 3A 8C AF 62 A9 9F 27 CE E8
AC 53 43 91 7B 1A C2 78 F2 9A 78 36 75 1E 7A FB
63 E8 88 32 E0 6E 4C 3E 08 E9 CB F2 C8 D8 0B B2
3C 30 3C 22 24 CA 92 ED 8E 0A 8C 14 1F B8 1F E1
F2 BB FD D1 F2 39 75 7F

```

(Skip rounds 1 to 22)

Round #23

After  $\theta$

```

09 F3 BB 3C 65 7E 82 3C EF 00 38 23 F6 8E C9 98
72 91 67 37 64 1A 04 F9 FB DB 6B 5A 79 80 81 4A
4B 51 05 7A 71 CC B6 8F 7D 28 B4 85 38 12 31 98
CC 6D 01 50 57 2F 91 49 F9 84 11 A9 73 A4 54 0F
DF A1 88 22 46 AF 38 AA E2 1D 4D 19 09 96 A0 D9
C6 4D 09 A8 4D 58 7A 20 F0 C3 EB 57 78 1A 3B D3
88 50 D7 04 63 E2 E6 54 BD 1B 7D FA 78 8A 4B CD
43 39 45 52 3B 7E D7 A2 55 17 A5 4D 10 CC 2E 39
50 AC CF F1 0E 03 0F 0E 58 7D 18 B1 BA A1 89 E0
24 ED 4C 92 92 90 6B 04 23 5F D5 EC E2 47 AD 9F
98 94 82 64 17 1C 1D FE 85 51 42 86 54 FC BD F3
21 2F EE F3 75 C6 67 DD 9F DB AB 48 97 89 3A 18
B7 2E B6 63 34 C7 DE 63

```



After  $\rho$ 

09 F3 BB 3C 65 7E 82 3C DF 01 70 46 EC 1D 93 31  
 5C E4 D9 0D 99 06 41 BE 07 18 A8 B4 BF BD A6 95  
 63 B6 7D 5C 8A 2A D0 8B 88 23 11 83 D9 87 42 5B  
 00 75 F5 12 99 C4 DC 16 43 3E 61 44 EA 1C 29 D5  
 50 44 11 A3 57 1C D5 EF 09 9A 2D DE D1 94 91 60  
 31 6E 4A 40 6D C2 D2 03 4C C3 0F AF 5F E1 69 EC  
 26 18 13 37 A7 42 84 BA 14 97 9A 7B 37 FA F4 F1  
 A9 1D BF 6B D1 A1 9C 22 9B 20 98 5D 72 AA 2E 4A  
 39 DE 61 E0 C1 01 8A F5 44 70 AC 3E 8C 58 DD D0  
 72 8D 80 A4 9D 49 52 12 9F 23 5F D5 EC E2 47 AD  
 74 F8 63 52 0A 92 5D 70 17 46 09 19 52 F1 F7 CE  
 E4 C5 7D BE CE F8 AC 3B DB AB 48 97 89 3A 18 9F  
 F7 D8 AD 8B ED 18 CD B1

After  $\pi$ 

09 F3 BB 3C 65 7E 82 3C 00 75 F5 12 99 C4 DC 16  
 26 18 13 37 A7 42 84 BA 72 8D 80 A4 9D 49 52 12  
 F7 D8 AD 8B ED 18 CD B1 07 18 A8 B4 BF BD A6 95  
 09 9A 2D DE D1 94 91 60 31 6E 4A 40 6D C2 D2 03  
 39 DE 61 E0 C1 01 8A F5 44 70 AC 3E 8C 58 DD D0  
 DF 01 70 46 EC 1D 93 31 43 3E 61 44 EA 1C 29 D5  
 14 97 9A 7B 37 FA F4 F1 9F 23 5F D5 EC E2 47 AD  
 74 F8 63 52 0A 92 5D 70 63 B6 7D 5C 8A 2A D0 8B  
 88 23 11 83 D9 87 42 5B 4C C3 0F AF 5F E1 69 EC  
 44 70 AC 3E 8C 58 DD D0 DB AB 48 97 89 3A 18 9F  
 5C E4 D9 0D 99 06 41 BE 50 44 11 A3 57 1C D5 EF  
 A9 1D BF 6B D1 A1 9C 22 9B 20 98 5D 72 AA 2E 4A  
 17 46 09 19 52 F1 F7 CE

After  $\chi$ 

2F FB B9 19 43 7C 82 94 50 F0 75 92 81 CD 8E 16  
 A3 48 3E 3C C7 52 09 1B 7A AE 92 90 9D 2F 50 1E  
 F7 DC E9 89 75 98 91 B3 37 7C EA B4 93 FF E4 96  
 01 0A 0C 7E 51 95 99 94 F5 6F 56 5E 63 3A F6 09  
 3A C6 E1 E0 F0 04 88 71 EC 47 78 F4 8E F8 BD 5B  
 CB 80 EA 7D F9 FF 47 11 C8 1E 24 C0 22 1C 2A D9  
 74 4F BA 79 35 EA EC A1 14 22 4F D1 08 EF C5 AC  
 74 C6 62 52 08 92 75 B4 27 76 73 70 8C 4A F9 2F  
 88 13 B1 93 59 9F D6 4B D7 48 4F 2E 5E C3 69 E3  
 64 64 99 76 8E 58 1D D0 53 AA 48 14 D8 BF 1A CF  
 F5 FD 77 45 19 A7 49 BE 42 64 11 B7 75 16 F7 A7  
 AD 5B BE 6B D1 F0 4D A6 D3 80 48 59 FB AC 2E 7A  
 17 46 09 BB 14 E9 63 8F

After t

27 7B B9 99 43 7C 82 14 50 F0 75 92 81 CD 8E 16  
A3 48 3E 3C C7 52 09 1B 7A AE 92 90 9D 2F 50 1E  
F7 DC E9 89 75 98 91 B3 37 7C EA B4 93 FF E4 96  
01 0A 0C 7E 51 95 99 94 F5 6F 56 5E 63 3A F6 09  
3A C6 E1 E0 F0 04 88 71 EC 47 78 F4 8E F8 BD 5B  
CB 80 EA 7D F9 FF 47 11 C8 1E 24 C0 22 1C 2A D9  
74 4F BA 79 35 EA EC A1 14 22 4F D1 08 EF C5 AC  
74 C6 62 52 08 92 75 B4 27 76 73 70 8C 4A F9 2F  
88 13 B1 93 59 9F D6 4B D7 48 4F 2E 5E C3 69 E3  
64 64 99 76 8E 58 1D D0 53 AA 48 14 D8 BF 1A CF  
F5 FD 77 45 19 A7 49 BE 42 64 11 B7 75 16 F7 A7  
AD 5B BE 6B D1 F0 4D A6 D3 80 48 59 FB AC 2E 7A  
17 46 09 BB 14 E9 63 8F

After permutation

27 7B B9 99 43 7C 82 14 50 F0 75 92 81 CD 8E 16  
A3 48 3E 3C C7 52 09 1B 7A AE 92 90 9D 2F 50 1E  
F7 DC E9 89 75 98 91 B3 37 7C EA B4 93 FF E4 96  
01 0A 0C 7E 51 95 99 94 F5 6F 56 5E 63 3A F6 09  
3A C6 E1 E0 F0 04 88 71 EC 47 78 F4 8E F8 BD 5B  
CB 80 EA 7D F9 FF 47 11 C8 1E 24 C0 22 1C 2A D9  
74 4F BA 79 35 EA EC A1 14 22 4F D1 08 EF C5 AC  
74 C6 62 52 08 92 75 B4 27 76 73 70 8C 4A F9 2F  
88 13 B1 93 59 9F D6 4B D7 48 4F 2E 5E C3 69 E3  
64 64 99 76 8E 58 1D D0 53 AA 48 14 D8 BF 1A CF  
F5 FD 77 45 19 A7 49 BE 42 64 11 B7 75 16 F7 A7  
AD 5B BE 6B D1 F0 4D A6 D3 80 48 59 FB AC 2E 7A  
17 46 09 BB 14 E9 63 8F

State (as lanes of integers)

[0,0] = 14827C4399B97B27  
 [1,0] = 168ECD819275F050  
 [2,0] = 1B0952C73C3E48A3  
 [3,0] = 1E502F9D9092AE7A  
 [4,0] = B391987589E9DCF7  
 [0,1] = 96E4FF93B4EA7C37  
 [1,1] = 949995517E0C0A01  
 [2,1] = 09F63A635E566FF5  
 [3,1] = 718804F0E0E1C63A  
 [4,1] = 5BBDF88EF47847EC  
 [0,2] = 1147FFF97DEA80CB  
 [1,2] = D92A1C22C0241EC8  
 [2,2] = A1ECEA3579BA4F74  
 [3,2] = ACC5EF08D14F2214  
 [4,2] = B47592085262C674  
 [0,3] = 2FF94A8C70737627  
 [1,3] = 4BD69F5993B11388  
 [2,3] = E369C35E2E4F48D7  
 [3,3] = D01D588E76996464  
 [4,3] = CF1AEFD81448AA53  
 [0,4] = BE49A7194577FDF5  
 [1,4] = A7F71675B7116442  
 [2,4] = A64DF0D16BBE5BAD  
 [3,4] = 7A2EACFB594880D3  
 [4,4] = 8F63E914BB094617

About to call squeeze (again)

State before permutation (in bytes)

27 7B B9 99 43 7C 82 14 50 F0 75 92 81 CD 8E 16  
 A3 48 3E 3C C7 52 09 1B 7A AE 92 90 9D 2F 50 1E  
 F7 DC E9 89 75 98 91 B3 37 7C EA B4 93 FF E4 96  
 01 0A 0C 7E 51 95 99 94 F5 6F 56 5E 63 3A F6 09  
 3A C6 E1 E0 F0 04 88 71 EC 47 78 F4 8E F8 BD 5B  
 CB 80 EA 7D F9 FF 47 11 C8 1E 24 C0 22 1C 2A D9  
 74 4F BA 79 35 EA EC A1 14 22 4F D1 08 EF C5 AC  
 74 C6 62 52 08 92 75 B4 27 76 73 70 8C 4A F9 2F  
 88 13 B1 93 59 9F D6 4B D7 48 4F 2E 5E C3 69 E3  
 64 64 99 76 8E 58 1D D0 53 AA 48 14 D8 BF 1A CF  
 F5 FD 77 45 19 A7 49 BE 42 64 11 B7 75 16 F7 A7  
 AD 5B BE 6B D1 F0 4D A6 D3 80 48 59 FB AC 2E 7A  
 17 46 09 BB 14 E9 63 8F

State before permutation (as lanes of integers)

[0, 0] = 14827C4399B97B27  
 [1, 0] = 168ECD819275F050  
 [2, 0] = 1B0952C73C3E48A3  
 [3, 0] = 1E502F9D9092AE7A  
 [4, 0] = B391987589E9DCF7  
 [0, 1] = 96E4FF93B4EA7C37  
 [1, 1] = 949995517E0C0A01  
 [2, 1] = 09F63A635E566FF5  
 [3, 1] = 718804F0E0E1C63A  
 [4, 1] = 5BBDF88EF47847EC  
 [0, 2] = 1147FFF97DEA80CB  
 [1, 2] = D92A1C22C0241EC8  
 [2, 2] = A1ECEA3579BA4F74  
 [3, 2] = ACC5EF08D14F2214  
 [4, 2] = B47592085262C674  
 [0, 3] = 2FF94A8C70737627  
 [1, 3] = 4BD69F5993B11388  
 [2, 3] = E369C35E2E4F48D7  
 [3, 3] = D01D588E76996464  
 [4, 3] = CF1ABFD81448AA53  
 [0, 4] = BE49A7194577FDF5  
 [1, 4] = A7F71675B7116442  
 [2, 4] = A64DF0D16BBE5BAD  
 [3, 4] = 7A2EACFB594880D3  
 [4, 4] = 8F63E914BB094617

Round #0

After  $\theta$

AB EC F0 08 C0 43 9B 66 E8 0A 8E 4B 01 3E 70 F8  
 36 86 18 29 38 FF 49 7E 74 B7 D4 CF FC D6 26 D0  
 06 6A 7E CC 1D 8B 9C DF BB EB A3 25 10 C0 FD E4  
 B9 F0 F7 A7 D1 66 67 7A 60 A1 70 4B 9C 97 B6 6C  
 34 DF A7 BF 91 FD FE BF 1D F1 EF B1 E6 EB B0 37  
 47 17 A3 EC 7A C0 5E 63 70 E4 DF 19 A2 EF D4 37  
 E1 81 9C 6C CA 47 AC C4 1A 3B 09 8E 69 16 B3 62  
 85 70 F5 17 60 81 78 D8 AB E1 3A E1 0F 75 E0 5D  
 30 E9 4A 4A D9 6C 28 A5 42 86 69 3B A1 6E 29 86  
 6A 7D DF 29 EF A1 6B 1E A2 1C DF 51 B0 AC 17 A3  
 79 6A 3E D4 9A 98 50 CC FA 9E EA 6E F5 E5 09 49  
 38 95 98 7E 2E 5D 0D C3 DD 99 0E 06 9A 55 58 B4  
 E6 F0 9E FE 7C FA 6E E3

After  $\rho$ 

AB EC F0 08 C0 43 9B 66 D1 15 1C 97 02 7C E0 F0  
 8D 21 46 0A CE 7F 92 9F 6F 6D 02 4D 77 4B FD CC  
 58 E4 FC 36 50 F3 63 EE 02 01 DC 4F BE BB 3E 5A  
 7F 1A 6D 76 A6 97 0B 7F 1B 58 28 DC 12 E7 A5 2D  
 EF D3 DF C8 7E FF 5F 9A 0E 7B D3 11 FF 1E 6B BE  
 3B BA 18 65 D7 03 F6 1A DF C0 91 7F 67 88 BE 53  
 64 53 3E 62 25 0E 0F E4 2C 66 C5 34 76 12 1C D3  
 0B B0 40 3C EC 42 B8 FA C2 1F EA C0 BB 56 C3 75  
 49 29 9B 0D A5 14 26 5D 14 43 21 C3 B4 9D 50 B7  
 74 CD 43 AD EF 3B E5 3D A3 A2 1C DF 51 B0 AC 17  
 42 31 E7 A9 F9 50 6B 62 E9 7B AA BB D5 97 27 24  
 A7 12 D3 CF A5 AB 61 18 99 0E 06 9A 55 58 B4 DD  
 DB B8 39 BC A7 3F 9F BE

After  $\pi$ 

AB EC F0 08 C0 43 9B 66 7F 1A 6D 76 A6 97 0B 7F  
 64 53 3E 62 25 0E 0F E4 74 CD 43 AD EF 3B E5 3D  
 DB B8 39 BC A7 3F 9F BE 6F 6D 02 4D 77 4B FD CC  
 0E 7B D3 11 FF 1E 6B BE 3E BA 18 65 D7 03 F6 1A  
 49 29 9B 0D A5 14 26 5D A7 12 D3 CF A5 AB 61 18  
 D1 15 1C 97 02 7C E0 F0 1B 58 28 DC 12 E7 A5 2D  
 2C 66 C5 34 76 12 1C D3 A3 A2 1C DF 51 B0 AC 17  
 42 31 E7 A9 F9 50 6B 62 58 E4 FC 36 50 F3 63 EE  
 02 01 DC 4F BE BB 3E 5A DF C0 91 7F 67 88 BE 53  
 14 43 21 C3 B4 9D 50 B7 99 0E 06 9A 55 58 B4 DD  
 8D 21 46 0A CE 7F 92 9F EF D3 DF C8 7E FF 5F 9A  
 0B B0 40 3C EC 42 B8 FA C2 1F EA C0 BB 56 C3 75  
 E9 7B AA BB D5 97 27 24

After  $\chi$ 

AB AD E2 08 C1 4B 9F E6 6F 96 2C FB 6C A6 EB 66  
 EF 63 06 72 25 0A 15 66 54 89 83 AD AF 7B E5 7D  
 8F AA 34 CA 81 AB 9F A7 5E ED 0A 29 77 4A 69 CC  
 4E 7A 50 19 DF 0A 6B FB 9D A8 58 A7 D7 A8 B7 1A  
 01 44 9B 0D F7 54 BA 99 A7 00 02 DF 2D BF 63 2A  
 F5 33 D9 B7 66 6C F8 22 98 D8 30 17 13 47 05 29  
 6C 77 26 14 DE 52 5F B3 32 A6 04 C9 53 9C 2C 87  
 48 79 C7 E1 E9 D3 6E 6F 85 24 FD 06 11 F3 E3 EF  
 02 02 FC CF 2E AE 7E FE 56 CC 97 67 26 C8 1A 1B  
 54 A3 D9 E7 B4 3E 13 95 9B 0F 06 D3 FB 50 A8 CD  
 8D 01 46 3E 4E 7F 32 FF 2F DC 75 08 6D EB 1C 9F  
 22 D0 40 07 A8 C3 9C FA C6 1F AE C0 B1 3E 53 EE  
 8B A9 33 7B E5 17 6A 24

After  $t$

AA AD E2 08 C1 4B 9F E6 6F 96 2C FB 6C A6 EB 66  
 EF 63 06 72 25 0A 15 66 54 89 83 AD AF 7B E5 7D  
 8F AA 34 CA 81 AB 9F A7 5E ED 0A 29 77 4A 69 CC  
 4E 7A 50 19 DF 0A 6B FB 9D A8 58 A7 D7 A8 B7 1A  
 01 44 9B 0D F7 54 BA 99 A7 00 02 DF 2D BF 63 2A  
 F5 33 D9 B7 66 6C F8 22 98 D8 30 17 13 47 05 29  
 6C 77 26 14 DE 52 5F B3 32 A6 04 C9 53 9C 2C 87  
 48 79 C7 E1 E9 D3 6E 6F 85 24 FD 06 11 F3 E3 EF  
 02 02 FC CF 2E AE 7E FE 56 CC 97 67 26 C8 1A 1B  
 54 A3 D9 E7 B4 3E 13 95 9B 0F 06 D3 FB 50 A8 CD  
 8D 01 46 3E 4E 7F 32 FF 2F DC 75 08 6D EB 1C 9F  
 22 D0 40 07 A8 C3 9C FA C6 1F AE C0 B1 3E 53 EE  
 8B A9 33 7B E5 17 6A 24

(Skip rounds 1 to 22)

Round #23

After  $\theta$

6E E1 47 C1 F8 67 26 A8 EA D9 BA EA 82 E2 64 DC  
 15 5A 0C 64 0B 10 3F CA 05 64 49 91 73 CE 88 43  
 09 1F 7C A5 A1 B6 3E 1E FD 70 27 85 1B 63 8B 44  
 F5 0E F7 9F 6A 76 8F CE 9D CC F6 66 6A 4F 28 C2  
 04 99 7D 3D 06 C9 AD 4B E7 EF 86 0A 91 1A 76 9F  
 37 58 7F E7 98 74 3B 4B 27 53 05 7E AF EC 1C 78  
 16 56 09 A2 C6 0C 74 D3 66 72 25 BE 53 A9 82 5A  
 94 FB 83 EF D1 DC 63 8A E6 96 2A D7 E1 79 4A 75  
 E4 A9 E7 E1 25 27 7A 79 6E EB 1F 39 F0 67 39 8B  
 FD 13 06 B3 D0 6E A7 F1 DF 06 4A EA 4D 3C 0E 3F  
 16 80 59 7C 83 4B 43 BB FD 13 03 C0 F8 BA 92 F4  
 71 52 21 92 2F 61 23 F8 0B 4D C9 14 A4 0F CE E1  
 F6 AF A3 8E A4 15 A5 B4

After  $\rho$ 

6E E1 47 C1 F8 67 26 A8 D5 B3 75 D5 05 C5 C9 B8  
 85 16 03 D9 02 C4 8F 72 E7 8C 38 54 40 96 14 39  
 B5 F5 F1 48 F8 E0 2B 0D B8 31 B6 48 D4 0F 77 52  
 FF A9 66 F7 E8 5C EF 70 70 27 B3 BD 99 DA 13 8A  
 CC BE 1E 83 E4 D6 25 82 61 F7 79 FE 6E A8 10 A9  
 BA C1 FA 3B C7 A4 DB 59 E0 9D 4C 15 F8 BD B2 73  
 10 35 66 A0 9B B6 B0 4A 52 05 B5 CC E4 4A 7C A7  
 F7 68 EE 31 45 CA FD C1 AE C3 F3 94 EA CC 2D 55  
 3C BC E4 44 2F 8F 3C F5 9C 45 B7 F5 8F 1C F8 B3  
 ED 34 BE 7F C2 7A 16 DA 3F DF 06 4A EA 4D 3C 0E  
 0D ED 5A 00 66 F1 0D 2E F7 4F 0C 00 E3 EB 4A D2  
 4E 2A 44 F2 25 6C 04 3F 4D C9 14 A4 0F CE E1 0B  
 29 AD FD EB A8 23 69 45

After  $\pi$ 

6E E1 47 C1 F8 67 26 A8 FF A9 66 F7 E8 5C EF 70  
 10 35 66 A0 9B B6 B0 4A ED 34 BE 7F C2 7A 16 DA  
 29 AD FD EB A8 23 69 45 E7 8C 38 54 40 96 14 39  
 61 F7 79 FE 6E A8 10 A9 BA C1 FA 3B C7 A4 DB 59  
 3C BC E4 44 2F 8F 3C F5 4E 2A 44 F2 25 6C 04 3F  
 D5 B3 75 D5 05 C5 C9 B8 70 27 B3 BD 99 DA 13 8A  
 52 05 B5 CC E4 4A 7C A7 3F DF 06 4A EA 4D 3C 0E  
 0D ED 5A 00 66 F1 0D 2E B5 F5 F1 48 F8 E0 2B 0D  
 B8 31 B6 48 D4 0F 77 52 E0 9D 4C 15 F8 BD B2 73  
 9C 45 B7 F5 8F 1C F8 B3 4D C9 14 A4 0F CE E1 0B  
 85 16 03 D9 02 C4 8F 72 CC BE 1E 83 E4 D6 25 82  
 F7 68 EE 31 45 CA FD C1 AE C3 F3 94 EA CC 2D 55  
 F7 4F 0C 00 E3 EB 4A D2

After  $\chi$ 

6E F5 47 C1 EB C5 36 A2 12 A9 FE A8 A8 14 E9 E0  
 10 BC 27 20 B3 B7 D9 4F AB 74 BC 7F 92 3E 10 72  
 B8 A5 DD DD A8 3B A0 15 7D 8C BA 55 C1 92 DF 69  
 65 CB 7D BA 46 A3 34 0D F8 C3 FA 89 C7 C4 DB 53  
 9D 38 DC 40 6F 1D 2C F5 4E 59 05 58 0B 44 04 BF  
 D7 B3 71 95 61 C5 A5 9D 5D FD B1 BF 93 DF 13 82  
 52 25 ED CC E0 FA 7D 87 EF CD 23 9F EB 49 FC 9E  
 2D E9 D8 28 FE EB 1F 2C F5 79 B9 5D D0 50 AB 2C  
 A4 71 05 A8 D3 0F 3F D2 A1 15 4C 15 F8 7F B3 7B  
 2C 71 56 BD 7F 3C F2 B7 45 C9 12 A4 0B C1 B5 59  
 B6 56 E3 E9 03 CC 57 33 C4 3D 0F 07 4E D2 25 96  
 A6 64 E2 31 44 E9 BF 43 AE D3 F0 4D EA C8 A8 75  
 BF E7 10 02 07 F9 6A 52

After t

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66 75 47 41 EB C5 36 22 12 A9 FE A8 A8 14 E9 E0
10 BC 27 20 B3 B7 D9 4F AB 74 BC 7F 92 3E 10 72
B8 A5 DD DD A8 3B A0 15 7D 8C BA 55 C1 92 DF 69
65 CB 7D BA 46 A3 34 0D F8 C3 FA 89 C7 C4 DB 53
9D 38 DC 40 6F 1D 2C F5 4E 59 05 58 0B 44 04 BF
D7 B3 71 95 61 C5 A5 9D 5D FD B1 BF 93 DF 13 82
52 25 ED CC E0 FA 7D 87 EF CD 23 9F EB 49 FC 9E
2D E9 D8 28 FE EB 1F 2C F5 79 B9 5D D0 50 AB 2C
A4 71 05 A8 D3 0F 3F D2 A1 15 4C 15 F8 7F B3 7B
2C 71 56 BD 7F 3C F2 B7 45 C9 12 A4 0B C1 B5 59
B6 56 E3 E9 03 CC 57 33 C4 3D 0F 07 4E D2 25 96
A6 64 E2 31 44 E9 BF 43 AE D3 F0 4D EA C8 A8 75
      BF E7 10 02 07 F9 6A 52
    
```

After permutation

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66 75 47 41 EB C5 36 22 12 A9 FE A8 A8 14 E9 E0
10 BC 27 20 B3 B7 D9 4F AB 74 BC 7F 92 3E 10 72
B8 A5 DD DD A8 3B A0 15 7D 8C BA 55 C1 92 DF 69
65 CB 7D BA 46 A3 34 0D F8 C3 FA 89 C7 C4 DB 53
9D 38 DC 40 6F 1D 2C F5 4E 59 05 58 0B 44 04 BF
D7 B3 71 95 61 C5 A5 9D 5D FD B1 BF 93 DF 13 82
52 25 ED CC E0 FA 7D 87 EF CD 23 9F EB 49 FC 9E
2D E9 D8 28 FE EB 1F 2C F5 79 B9 5D D0 50 AB 2C
A4 71 05 A8 D3 0F 3F D2 A1 15 4C 15 F8 7F B3 7B
2C 71 56 BD 7F 3C F2 B7 45 C9 12 A4 0B C1 B5 59
B6 56 E3 E9 03 CC 57 33 C4 3D 0F 07 4E D2 25 96
A6 64 E2 31 44 E9 BF 43 AE D3 F0 4D EA C8 A8 75
      BF E7 10 02 07 F9 6A 52
    
```



State (as lanes of integers)

[0,0] = 2236C5EB41477566  
 [1,0] = E0E914A8A8FEA912  
 [2,0] = 4FD9B7B32027BC10  
 [3,0] = 72103E927FBC74AB  
 [4,0] = 15A03BA8DDDDA5B8  
 [0,1] = 69DF92C155BA8C7D  
 [1,1] = 0D34A346BA7DCB65  
 [2,1] = 53DBC4C789FAC3F8  
 [3,1] = F52C1D6F40DC389D  
 [4,1] = BF04440B5805594E  
 [0,2] = 9DA5C5619571B3D7  
 [1,2] = 8213DF93BFB1FD5D  
 [2,2] = 877DFAE0CCED2552  
 [3,2] = 9EFC49EB9F23CDEF  
 [4,2] = 2C1FEBFE28D8E92D  
 [0,3] = 2CAB50D05DB979F5  
 [1,3] = D23F0FD3A80571A4  
 [2,3] = 7BB37FF8154C15A1  
 [3,3] = B7F23C7FBD56712C  
 [4,3] = 59B5C10BA412C945  
 [0,4] = 3357CC03E9E356B6  
 [1,4] = 9625D24E070F3DC4  
 [2,4] = 43BFE94431E264A6  
 [3,4] = 75A8C8EA4DF0D3AE  
 [4,4] = 526AF9070210E7BF

About to call squeeze (again)

State before permutation (in bytes)

66 75 47 41 EB C5 36 22 12 A9 FE A8 A8 14 E9 E0  
 10 BC 27 20 B3 B7 D9 4F AB 74 BC 7F 92 3E 10 72  
 B8 A5 DD DD A8 3B A0 15 7D 8C BA 55 C1 92 DF 69  
 65 CB 7D BA 46 A3 34 0D F8 C3 FA 89 C7 C4 DB 53  
 9D 38 DC 40 6F 1D 2C F5 4E 59 05 58 0B 44 04 BF  
 D7 B3 71 95 61 C5 A5 9D 5D FD B1 BF 93 DF 13 82  
 52 25 ED CC E0 FA 7D 87 EF CD 23 9F EB 49 FC 9E  
 2D E9 D8 28 FE EB 1F 2C F5 79 B9 5D D0 50 AB 2C  
 A4 71 05 A8 D3 0F 3F D2 A1 15 4C 15 F8 7F B3 7B  
 2C 71 56 BD 7F 3C F2 B7 45 C9 12 A4 0B C1 B5 59  
 B6 56 E3 E9 03 CC 57 33 C4 3D 0F 07 4E D2 25 96  
 A6 64 E2 31 44 E9 BF 43 AE D3 F0 4D EA C8 A8 75  
 BF E7 10 02 07 F9 6A 52

State before permutation (as lanes of integers)

[0, 0] = 2236C5EB41477566  
 [1, 0] = E0E914A8A8FEA912  
 [2, 0] = 4FD9B7B32027BC10  
 [3, 0] = 72103E927FBC74AB  
 [4, 0] = 15A03BA8DDDDA5B8  
 [0, 1] = 69DF92C155BA8C7D  
 [1, 1] = 0D34A346BA7DCB65  
 [2, 1] = 53DBC4C789FAC3F8  
 [3, 1] = F52C1D6F40DC389D  
 [4, 1] = BF04440B5805594E  
 [0, 2] = 9DA5C5619571B3D7  
 [1, 2] = 8213DF93BFB1FD5D  
 [2, 2] = 877DFAE0CCED2552  
 [3, 2] = 9EFC49EB9F23CDEF  
 [4, 2] = 2C1FEBFE28D8E92D  
 [0, 3] = 2CAB50D05DB979F5  
 [1, 3] = D23F0FD3A80571A4  
 [2, 3] = 7BB37FF8154C15A1  
 [3, 3] = B7F23C7FBD56712C  
 [4, 3] = 59B5C10BA412C945  
 [0, 4] = 3357CC03E9E356B6  
 [1, 4] = 9625D24E070F3DC4  
 [2, 4] = 43BFE94431E264A6  
 [3, 4] = 75A8C8EA4DF0D3AE  
 [4, 4] = 526AF9070210E7BF

Round #0

After  $\theta$

D3 E8 34 4E 7A 02 FB F8 E6 9B 14 1E 60 24 BF 6F  
 ED 29 D5 83 55 3F 38 D3 55 29 26 28 18 79 AA CB  
 FC 4D 94 E6 1B B8 5A 5D C8 11 C9 5A 50 55 12 B3  
 91 F9 97 0C 8E 93 62 82 05 56 08 2A 21 4C 3A CF  
 63 65 46 17 E5 5A 96 4C 0A B1 4C 63 B8 C7 FE F7  
 62 2E 02 9A F0 02 68 47 A9 CF 5B 09 5B EF 45 0D  
 AF B0 1F 6F 06 72 9C 1B 11 90 B9 C8 61 0E 46 27  
 69 01 91 13 4D 68 E5 64 40 E4 CA 52 41 97 66 F6  
 50 43 EF 1E 1B 3F 69 5D 5C 80 BE B6 1E F7 52 E7  
 D2 2C CC EA F5 7B 48 0E 01 21 5B 9F B8 42 4F 11  
 03 CB 90 E6 92 0B 9A E9 30 0F E5 B1 86 E2 73 19  
 5B F1 10 92 A2 61 5E DF 50 8E 6A 1A 60 8F 12 CC  
 FB 0F 59 39 B4 7A 90 1A

After  $\rho$ 

D3 E8 34 4E 7A 02 FB F8 CC 37 29 3C C0 48 7E DF  
 7B 4A F5 60 D5 0F CE 74 91 A7 BA 5C 95 62 82 82  
 C0 D5 EA E2 6F A2 34 DF 05 55 25 31 8B 1C 91 AC  
 C9 E0 38 29 26 18 99 7F 73 81 15 82 4A 08 93 CE  
 32 A3 8B 72 2D 4B A6 B1 EC 7F AF 10 CB 34 86 7B  
 12 73 11 D0 84 17 40 3B 35 A4 3E 6F 25 6C BD 17  
 78 33 90 E3 DC 78 85 FD 1C 8C 4E 22 20 73 91 C3  
 89 26 B4 72 B2 B4 80 C8 A5 82 2E CD EC 81 C8 95  
 DD 63 E3 27 AD 0B 6A E8 A9 73 2E 40 5F 5B 8F 7B  
 0F C9 41 9A 85 59 BD 7E 11 01 21 5B 9F B8 42 4F  
 68 A6 0F 2C 43 9A 4B 2E C0 3C 94 C7 1A 8A CF 65  
 2B 1E 42 52 34 CC EB 7B 8E 6A 1A 60 8F 12 CC 50  
 A4 C6 FE 43 56 0E AD 1E

After  $\pi$ 

D3 E8 34 4E 7A 02 FB F8 C9 E0 38 29 26 18 99 7F  
 78 33 90 E3 DC 78 85 FD 0F C9 41 9A 85 59 BD 7E  
 A4 C6 FE 43 56 0E AD 1E 91 A7 BA 5C 95 62 82 82  
 EC 7F AF 10 CB 34 86 7B 12 73 11 D0 84 17 40 3B  
 DD 63 E3 27 AD 0B 6A E8 2B 1E 42 52 34 CC EB 7B  
 CC 37 29 3C C0 48 7E DF 73 81 15 82 4A 08 93 CE  
 1C 8C 4E 22 20 73 91 C3 11 01 21 5B 9F B8 42 4F  
 68 A6 0F 2C 43 9A 4B 2E C0 D5 EA E2 6F A2 34 DF  
 05 55 25 31 8B 1C 91 AC 35 A4 3E 6F 25 6C BD 17  
 A9 73 2E 40 5F 5B 8F 7B 8E 6A 1A 60 8F 12 CC 50  
 7B 4A F5 60 D5 0F CE 74 32 A3 8B 72 2D 4B A6 B1  
 89 26 B4 72 B2 B4 80 C8 A5 82 2E CD EC 81 C8 95  
 C0 3C 94 C7 1A 8A CF 65

After  $\chi$ 

E3 FB B4 8C A2 62 FF 78 CE 28 79 31 27 19 A1 7D  
 D8 35 2E A2 8E 7E 85 FD 5C E1 41 96 AD 59 EF 9E  
 AC C6 F6 62 52 16 AD 19 83 A7 AA 9C 91 61 C2 82  
 21 7F 4D 37 E2 3C AC BB 30 6F 11 80 94 D3 C1 28  
 4D C2 5B 2B 2C 29 6A 68 47 46 47 52 7E D8 EF 02  
 C0 3B 63 1C E0 3B 7E DE 72 80 34 DB D5 80 D1 C2  
 74 2A 40 06 60 71 98 E3 95 10 01 4B 1F F8 76 9E  
 5B 26 1B AE 49 9A CA 2E F0 75 F0 AC 4B C2 18 CC  
 8D 06 25 31 D1 0F 93 C4 33 AC 2E 4F A5 6C FD 17  
 E9 E6 CE C2 3F FB BF F4 8B 6A 1F 71 0F 0E 4D 70  
 F2 4E C1 60 47 BB CE 3C 16 23 81 FF 61 4A EE A4  
 C9 1A 24 70 A0 BE 87 A8 9E C0 4F ED 29 84 C8 85  
 C0 9D 9E D5 32 CA EF E4

After  $t$

E2 FB B4 8C A2 62 FF 78 CE 28 79 31 27 19 A1 7D  
D8 35 2E A2 8E 7E 85 FD 5C E1 41 96 AD 59 EF 9E  
AC C6 F6 62 52 16 AD 19 83 A7 AA 9C 91 61 C2 82  
21 7F 4D 37 E2 3C AC BB 30 6F 11 80 94 D3 C1 28  
4D C2 5B 2B 2C 29 6A 68 47 46 47 52 7E D8 EF 02  
C0 3B 63 1C E0 3B 7E DE 72 80 34 DB D5 80 D1 C2  
74 2A 40 06 60 71 98 E3 95 10 01 4B 1F F8 76 9E  
5B 26 1B AE 49 9A CA 2E F0 75 F0 AC 4B C2 18 CC  
8D 06 25 31 D1 0F 93 C4 33 AC 2E 4F A5 6C FD 17  
E9 E6 CE C2 3F FB BF F4 8B 6A 1F 71 0F 0E 4D 70  
F2 4E C1 60 47 BB CE 3C 16 23 81 FF 61 4A EE A4  
C9 1A 24 70 A0 BE 87 A8 9E C0 4F ED 29 84 C8 85  
C0 9D 9E D5 32 CA EF E4

(Skip rounds 1 to 22)

Round #23

After  $\theta$

F9 F3 31 CD DE 7F AA 7C C7 29 EA 3A 25 16 46 21  
D9 DC 2A 68 AB 06 96 C9 EA AE EB A0 89 44 A1 DF  
FE A3 F1 85 FB 75 44 07 74 0E F5 B6 28 5C C2 D8  
31 35 63 38 F6 C6 FE 3D 49 80 BE 20 6E EB 7A 7F  
8D 5B 31 30 16 E5 3F 80 99 83 69 F0 DF D0 C1 32  
C0 7C A7 42 18 2A 3E 57 DB 05 6F C2 91 67 0C 0A  
D1 9D 32 23 6F 9E AF 67 28 4B 65 DC 19 C2 90 EC  
08 4D 57 4A F3 90 A8 80 2E 3C 8C 93 E9 F6 8C 7D  
3E 4B 4D CB 2C 79 65 62 51 1E E0 AC 22 DC B3 71  
15 17 78 27 F0 30 55 4D 13 12 29 98 84 75 7D E5  
83 00 8C 30 62 77 FB D5 E0 5C EA 1E 67 2D 74 A2  
F0 51 87 FE C8 E8 5F BD 08 9D 84 2D 3A 0C BC 55  
CE 9E EC 8C BE 08 98 D0

After  $\rho$ 

F9 F3 31 CD DE 7F AA 7C 8E 53 D4 75 4A 2C 8C 42  
 36 B7 0A DA AA 81 65 72 48 14 FA AD EE BA 0E 9A  
 AF 23 3A F0 1F 8D 2F DC 8B C2 25 8C 4D B7 50 6F  
 86 63 6F EC DF 13 53 33 5F 12 A0 2F 88 DB BA DE  
 AD 18 18 8B F2 1F C0 C6 1D 2C 93 39 98 06 FF 0D  
 02 E6 3B 15 C2 50 F1 B9 28 6C 17 BC 09 47 9E 31  
 19 79 FB 7C 3D 8B EE 94 84 21 D9 51 96 CA B8 33  
 A5 79 48 54 40 84 A6 2B 27 D3 ED 19 FB 5C 78 18  
 69 99 25 AF 4C CC 67 A9 D9 B8 28 0F 70 56 11 EE  
 A6 AA A9 E2 02 EF 04 1E E5 13 12 29 98 84 75 7D  
 ED 57 0F 02 30 C2 88 DD 82 73 A9 7B 9C B5 D0 89  
 3E EA D0 1F 19 FD AB 17 9D 84 2D 3A 0C BC 55 08  
 26 B4 B3 27 3B A3 2F 02

After  $\pi$ 

F9 F3 31 CD DE 7F AA 7C 86 63 6F EC DF 13 53 33  
 19 79 FB 7C 3D 8B EE 94 A6 AA A9 E2 02 EF 04 1E  
 26 B4 B3 27 3B A3 2F 02 48 14 FA AD EE BA 0E 9A  
 1D 2C 93 39 98 06 FF 0D 02 E6 3B 15 C2 50 F1 B9  
 69 99 25 AF 4C CC 67 A9 3E EA D0 1F 19 FD AB 17  
 8E 53 D4 75 4A 2C 8C 42 5F 12 A0 2F 88 DB BA DE  
 84 21 D9 51 96 CA B8 33 E5 13 12 29 98 84 75 7D  
 ED 57 0F 02 30 C2 88 DD AF 23 3A F0 1F 8D 2F DC  
 8B C2 25 8C 4D B7 50 6F 28 6C 17 BC 09 47 9E 31  
 D9 B8 28 0F 70 56 11 EE 9D 84 2D 3A 0C BC 55 08  
 36 B7 0A DA AA 81 65 72 AD 18 18 8B F2 1F C0 C6  
 A5 79 48 54 40 84 A6 2B 27 D3 ED 19 FB 5C 78 18  
 82 73 A9 7B 9C B5 D0 89

After  $\chi$ 

E0 EB A1 DD FE F7 06 F8 20 E1 6F 6E DD 77 53 39  
 19 6D E9 79 04 8B C5 94 7F E9 A9 2A C6 B3 84 62  
 20 B4 FD 07 3A A3 7E 01 4A D6 D2 A9 AC EA 0E 2A  
 74 35 97 93 94 8A F9 0D 14 84 EB 05 D3 61 79 AF  
 29 8D 0F 0F AA CE 63 21 2B C2 D1 0F 09 F9 5A 12  
 0E 72 8D 25 5C 2C 8C 63 3E 00 A2 07 80 DF FF 92  
 8C 65 D4 53 B6 88 30 B3 E7 13 C2 5C D2 A8 71 7F  
 BC 57 2F 08 B0 11 BA 41 8F 0F 28 C0 1F CD A1 CC  
 5A 52 0D 8F 3D A7 51 A1 2C 68 12 8C 05 EF DA 31  
 FB 9B 3A CF 63 57 3B 3A 9D 44 28 36 4C 8E 05 2B  
 36 D6 4A 8E AA 01 43 5B AF 9A BD 82 49 47 98 D6  
 25 59 48 36 44 25 26 AA 13 57 EF 99 D9 5C 5D 6A  
 0B 7B B9 7A CC AB 50 0D

After t

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E8 6B A1 5D FE F7 06 78 20 E1 6F 6E DD 77 53 39
19 6D E9 79 04 8B C5 94 7F E9 A9 2A C6 B3 84 62
20 B4 FD 07 3A A3 7E 01 4A D6 D2 A9 AC EA 0E 2A
74 35 97 93 94 8A F9 0D 14 84 EB 05 D3 61 79 AF
29 8D 0F 0F AA CE 63 21 2B C2 D1 0F 09 F9 5A 12
0E 72 8D 25 5C 2C 8C 63 3E 00 A2 07 80 DF FF 92
8C 65 D4 53 B6 88 30 B3 E7 13 C2 5C D2 A8 71 7F
BC 57 2F 08 B0 11 BA 41 8F 0F 28 C0 1F CD A1 CC
5A 52 0D 8F 3D A7 51 A1 2C 68 12 8C 05 EF DA 31
FB 9B 3A CF 63 57 3B 3A 9D 44 28 36 4C 8E 05 2B
36 D6 4A 8E AA 01 43 5B AF 9A BD 82 49 47 98 D6
25 59 48 36 44 25 26 AA 13 57 EF 99 D9 5C 5D 6A
0B 7B B9 7A CC AB 50 0D

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After permutation

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E8 6B A1 5D FE F7 06 78 20 E1 6F 6E DD 77 53 39
19 6D E9 79 04 8B C5 94 7F E9 A9 2A C6 B3 84 62
20 B4 FD 07 3A A3 7E 01 4A D6 D2 A9 AC EA 0E 2A
74 35 97 93 94 8A F9 0D 14 84 EB 05 D3 61 79 AF
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8C 65 D4 53 B6 88 30 B3 E7 13 C2 5C D2 A8 71 7F
BC 57 2F 08 B0 11 BA 41 8F 0F 28 C0 1F CD A1 CC
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FB 9B 3A CF 63 57 3B 3A 9D 44 28 36 4C 8E 05 2B
36 D6 4A 8E AA 01 43 5B AF 9A BD 82 49 47 98 D6
25 59 48 36 44 25 26 AA 13 57 EF 99 D9 5C 5D 6A
0B 7B B9 7A CC AB 50 0D

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