OPIC
Office de la propriété intellectuelle du Canada

CIPO
Canadian Intellectual Property Office

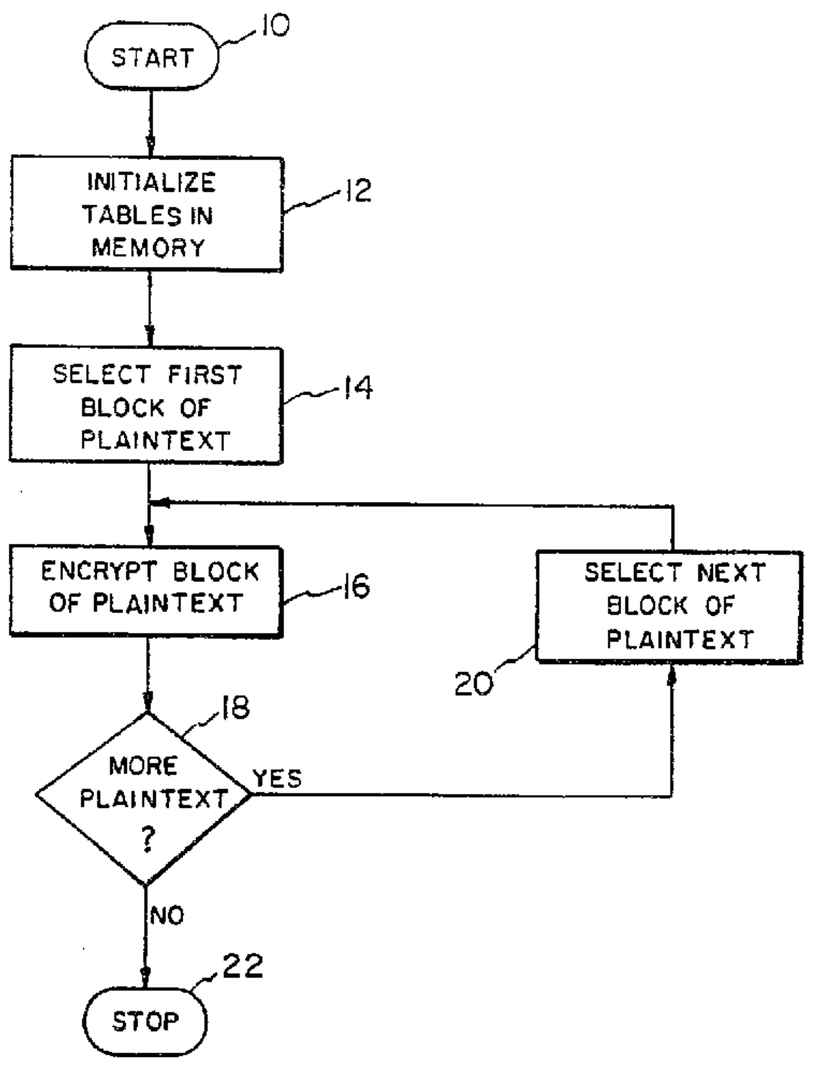
(12) (19) (CA) **Brevet-Patent**

(11) (21) (C) **2,064,769**
(86) 1990/03/14
(87) 1991/02/18
(45) 2000/02/08

(72) Wood, Michael C., US
(73) CRYPTECH, INC., US

(51) Int.Cl.[5] H04L 9/00
(30) 1989/08/17 (395,448) US

(54) **SYSTEME DE CRYPTAGE**
(54) **ENCRYPTION SYSTEM**



(57) On met le chiffre rond (R) à zéro (100), puis on augmente ledit chiffre rond (R) de 1 (102). Les données de texte en clair (104) sont soumises à une permutation variable (106). On sélectionne une entrée dans la mémoire (108) de la table de permutation, puis on sélectionne une valeur dans la mémoire (110) de la table de masques afin de procéder à la permutation variable (106). Ensuite, on affecte à une composante choisie (C) la valeur du chiffre rond (R). Puis on procède à une première opération d'addition (114) de code variable sur les données employant un code tiré de la mémoire (116) de la table de codes et employant une valeur tirée de la mémoire (110) de la table des masques. Dans l'étape suivante (118), on affecte à la composante choisie (C) une valeur supérieure de 1 au chiffre rond (R). L'étape suivante (120) détermine si la composante choisie (C) est égale à 11. Si la composante choisie (C) est égale à 11, alors on affecte à ladite composante choisie (C) la valeur 1 et l'on procède (122) à une autre addition de code variable, autrement, on procède immédiatement (122) à une addition de code variable.

(57) The round number (R) is set to zero (100), then the round number (R) is incremented by one (102). The plaintext data (104) is subjected to a variable permutation (106). An entry is selected from the permutation table memory (108) and a value is selected from the Mask table memory (110) to conduct the variable permutation (10b). Then, a choice component (C) is equated with round number (R). Next, a first variable key addition operation (114) is carried out on the data employing a key from the key table memory (116) and a value from the Mask table memory (110). In the next step (118), the choice component (C) is see to a value one greater than the round number (R). The following step (120) determines if choice component (C) is equal to 11. If the choice component (C) is equal to 11, then the choice component (C) is set equal to 1 and another variable key addition is performed (122). Otherwise, a variable key addition is performed immediately (122).

2064769

PCT WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 5 : H04L 9/06

A1

(11) International Publication Number: WO 91/03113

(43) International Publication Date: 7 March 1991 (07.03.91)

(21) International Application Number: PCT/US90/01391

(22) International Filing Date: 14 March 1990 (14.03.90)

(30) Priority data:
395,448 17 August 1989 (17.08.89) US

(71) Applicant: CRYPTECH, INC. [US/US]; 508 Lafayette Street, Jamestown, NY 14701 (US).

(72) Inventor: WOOD, Michael, C. ; 147 Prather Avenue, Jamestown, NY 14701 (US).

(74) Agent: BYRNE, Richard, L.; 515 Oliver Building, Pittsburgh, PA 15222-2363 (US).

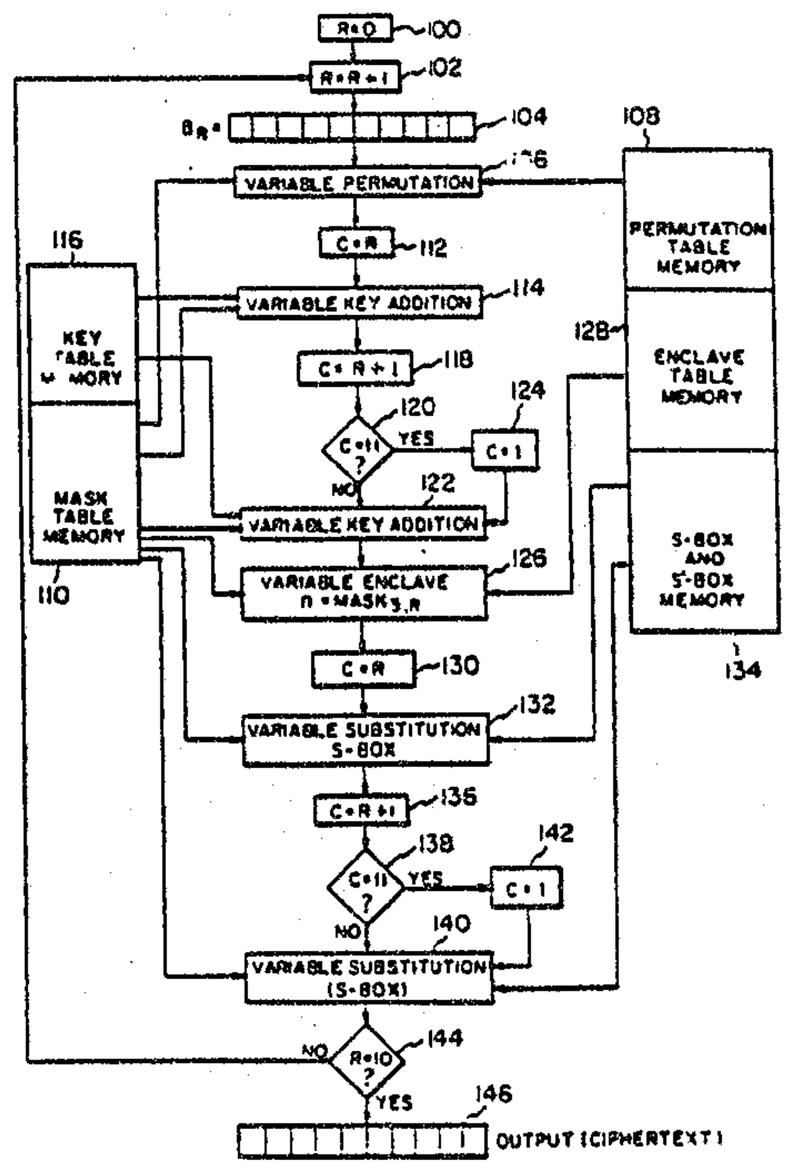
(81) Designated States: AT (European patent), AU, BE (European patent), BF (OAPI patent), BJ (OAPI patent), CA, CF (OAPI patent), CG (OAPI patent), CH (European patent), CM (OAPI patent), DE (European patent)*, DK (European patent), ES (European patent), FI, FR (European patent), GA (OAPI patent), GB (European patent), IT (European patent), JP, KR, LU (European patent), ML (OAPI patent), MR (OAPI patent), NL (European patent), NO, SE (European patent), SN (OAPI patent), TD (OAPI patent), TG (OAPI patent).

Published
With international search report.

(54) Title: ENCRYPTION SYSTEM

(57) Abstract

The round number (R) is set to zero (100), then the round number (R) is incremented by one (102). The plaintext data (104) is subjected to a variable permutation (106). An entry is selected from the permutation table memory (108) and a value is selected from the Mask table memory (110) to conduct the variable permutation (106). Then, a choice component (C) is equated with round number (R). Next, a first variable key addition operation (114) is carried out on the data employing a key from the key table memory (116) and a value from the Mask table memory (110). In the next step (118), the choice component (C) is set to a value one greater than the round number (R). The following step (120) determines if choice component (C) is equal to 11. If the choice component (C) is equal to 11, then the choice component (C) is set equal to 1 and another variable key addition is performed (122). Otherwise, a variable key addition is performed immediately (122).



* See back of page

ENCRYPTION SYSTEM

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to cryptography and, more particularly, to a system for protecting stored and transmitted data from cryptanalytic attack.

2. Description of the Prior Art

The use of various cryptographic systems for converting secret or sensitive information from an intelligible form to an unintelligible form is well established. The intelligible form of the information or data is called "plaintext" and the unintelligible form is called "ciphertext". The process of converting from plaintext to ciphertext is called "encryption" or "encipherment" and the reverse process is called "decryption" or "decipherment". Most cryptographic systems make use of a secret value called the key. Encryption and decryption are easy when the algorithm and the key are known, but decryption should be virtually impossible without the use of the correct key. The process of attempting to find a shortcut method, not envisioned by the designer of the algorithm, for decrypting the ciphertext when the key is unknown is called "cryptanalysis".

Cryptography has a long history, tracing its roots back to at least the time of Julius Caesar who employed a substitution cipher in which each letter in the plaintext was replaced by the third later letter in the alphabet. Thus, Julius Caesar employed a linear substitution cipher which used the number three as the secret key. Non-linear substitutions, in which the alphabet is scrambled or mixed, are also well-known. However, simple substitutions, whether linear or non-linear, are relatively easy to attack when only a few sentences of the ciphertext are known. Indeed, William Legrand in Edgar Allan Poe's short story "The Gold-Bug" was able to locate a fortune in buried gold and jewels by a cryptanalytic attack on Captain Kidd's message.

Todays businesses require a much more sophisticated and secure encryption system to protect private message transmissions from computers, facsimile machines, banking machines, and the like. The most secure key based system in the history of cryptography is the one time tape or one time pad. In this system, the key is as long as the message to be encrypted and is simply added (modular arithmetic) to the message. The key is used only once and is randomly derived. Although this method is secure, it is inefficient to create new keys for every block of information transmitted and then secretly distribute these keys. Therefore, the one time tape is seldom if ever used in most applications.

The goal of modern cryptography is to create an encryption system which may not be compromised through current cryptanalytic techniques, or the benefit of breaking the system is not worth the effort required to penetrate the system. In other words, the goal is to design a system which is very difficult to break with current cryptanalytic methods. This is in contrast to the one time pad technique which is impenetrable in both theory and in practice. The one time tape should remain cryptographically unbreakable despite advances in the art of cryptanalysis. However, other prior art systems can and will be broken in time.

Modern encryption systems generally use a short key, such as a key which is eight characters in length. A good example of a modern system is the Data Encryption Standard ("DES") which was developed by IBM in the early 1970's and which was adopted by the United States Bureau of Standards as the standard encryption system for business and non-military government use. Patents directed to the DES include U.S. Patents Nos. 3,958,081 and 3,962,539. The Data Encryption Standard is a block type of cipher in which a portion or block of the data to be encrypted is permutated with a prearranged permutation

table, modified with a key, and then substituted with a predetermined substitution table. This process is repeated numerous times in what are referred to as rounds. Permutation is also referred to as "transposition" and is a common cryptographic function in which the positions of letters in a message are scrambled in accordance with a predetermined set of directions.

Other modern encryption systems have attempted to simulate the key generation process of a one time pad by using pseudo-random generators which creates a long series of keys having the statistical property of randomness. Such patents includes U.S. Patents Nos. 3,700,806 and 4,369,332. The receiver on the other end of the transmission would have a pseudo-random generator generating keys and using them to decrypt the transmitted ciphertext. Thus the system can change keys as often as desired, even changing the key for every block to be encrypted. The use of pseudo-random generators has greatly enhanced the strength of many systems, but it does not perfectly create a one time pad.

In the cryptanalysis of non-military encryption systems, the following assumptions are generally made: (1) The cryptanalyst knows the encryption system and tables used. If a pseudo-random generator is used, it is also assumed to be known. (2) The cryptanalyst does not know the key. Items 1 and 2 together are generally referred to as Kerckhoff's assumption. (3) The cryptanalyst has a large quantity of previously transmitted plaintext. (4) The cryptanalyst has a large quantity of previously recovered ciphertext corresponding to the plaintext.

A cryptographic system must demonstrate adequate strength under the above conditions. A pseudo-random generator system does not meet all of the criteria for a one time tape. If a pseudo-random generator is used, the relationship between the keys generated would then be given. Although the cryptanalyst may not know the string

of keys output (if the generator were key based), he or she would still know the relationship of the key series as it is stated in the pseudo-random generator algorithm. In addition, pseudo-random generators must also be provided with a "seed" value. This, in essence, is another key which has to be generated and distributed for the system. The Data Encryption Standard, with its predetermined permutation and substitution tables and predetermined ordering of the use of these tables, is also subject to cryptanalytic attack. Although the Data Encryption Standard algorithm is a strong encryption system because it is quite complex, it is not impervious to attack by mathematical analysis.

Another technique employing some of the features of a one time pad uses a key table. In this technique, a table including numerous, predetermined keys is included in the encryption system. The keys are then each changed by the secret key. One example of this method can be seen in U.S. Patent No. 4,776,011. This technique does not perfectly simulate the one time pad for the same reasons the pseudo-random generators do not. The original key table gives the relationship of the keys. Also, in such systems, the order in which the keys are chosen is stated by the system's algorithm, the key combinations selected may be repeated, and without an initializing vector, the same key table will always be used until a new secret key is provided. The invention disclosed herein uses a key table in a unique methodology to overcome these obstacles.

Another method for creating a strong theoretical and practical encryption system is to use a one time function. In this method, every data block encrypted is enciphered by a different cryptographic function combination. In other words, the tables used in the encryption process are variable and a different combination will be chosen by each data block.

Variable functions have also been done in prior art. Once example is in U.S. Patent No. 4,751,733 which includes the use of variable substitution. This patent has many limitations: the patent provides encryption specifically for binary words; the substitution tables must be set up and operate in close relationship to the binary arrangement of the secret key; control codes, which form a key complement or auxiliary key, are needed to direct the substitution process; the method is specifically a substitution-permutation enciphering device; the method does not provide for a variable permutation or other functions; and the method does not provide for an initializing vector which is necessary for one time tape simulation.

It is, therefore, an object of an aspect of this invention to overcome the weaknesses found in other systems and produce a system which simulates the one time pad process yet requires only a single key. It is an object of an aspect of the present invention to provide an encryption system which cannot be compromised in theory or in practice, and which allows for a perfect simulation of a one time pad system. It is an object of an aspect of the invention to create a cryptographic system which provides a one time method approach in that every unique block of data is functionally transformed uniquely. Such has not been accomplished by the prior art and, as a result, the system would offer stronger cryptographic measures against attack. It is an object of an aspect of the present invention to provide a secure encryption system which is flexible enough for a variety of applications, such as file storage, data transmission, telecommunication coding and the like. It is an object of an aspect of the invention to provide an encryption system which permits the use of the block cipher format and provides complete inter-symbol dependency therein.

SUMMARY OF THE INVENTION

Accordingly, I have developed a cryptographic system which includes the creation of a key table from a single key such that the relationship between the keys in the key table cannot be determined even if the system implementation is known. This is accomplished through the use of variable functions in which the determinants are changed by the variable function chosen by the determinant. Thus, the functions used in creating the key table do not have to be one-to-one functions. The determinants are based on the key. From the key table, four blocks of bytes of additional key based determinants are formed which are called masks. These masks are formed from the keys. The original key does not exist in either the key table or the mask table.

The system in accordance with the preferred embodiment of the present invention uses the key table in a multiple round encryption process. Thus, every possible plaintext combination would be encrypted with a different key combination. The keys chosen from the table for a key addition operation are a function of the plaintext, the current state of the ciphertext, and the mask values. Therefore, the order in which the keys are chosen is not predetermined or patterned. The system also selects the other encryption functions, including permutations and substitutions, by the plaintext, current state of the ciphertext and the mask values. In this way, every block will be encrypted with a different combination of permutations and substitutions.

The cryptographic system introduces a function hereinafter referred to as the enclave function. This function also operates on lookup tables and creates complete inter-symbol dependency on the block of bytes. The particular table used with the enclave function is determined only by the mask values. In this way, every block will undergo the same enclave combinations.

However, the combination will still be unknown to an attack since the combination chosen is determined from the mask values which were derived from the unknown key.

After the information passes through the predetermined number of rounds of permutations, key additions, enclaves and substitutions, it can be transmitted or stored. Decryption is essentially accomplished by reversing the order of operations with the inverse functions of the substitutions, enclaves, key additions and permutations. The key additions are the same as their inverses.

Other aspects of this invention are as follows:

A method of cryptographically transforming electronic digital data from one form to another comprising the steps of:

a. establishing in memory at least one transformation table associated with a predetermined cryptographic function, said table including a plurality of addressable entries which each direct a predetermined transformation of data in accordance with said function;

b. establishing in memory one or more key based determinants;

c. selecting one of said entries in said transformation table based upon certain information in one of said data key based determinants; and

d. cryptographically transforming said data by said function in accordance with the directions of said selected entry in said transformation table.

A method of generating a table of keys for use in cryptographically transforming electronic digital data from one form to another comprising the steps of:

a. establishing an initial key;

b. establishing in memory at least one transformation table associated with a predetermined cryptographic function, said table including a plurality of addressable entries which each direct a predetermined transformation of data in accordance with said function;

c. selecting at least one of said entries in said transformation table based upon certain information in said initial key;

d. transforming said initial key by said function in accordance with the directions of said selected entry in said transformation table;

e. storing said transformed initial key as an entry in the key table memory;

f. selecting at least one of said entries in said transformation table based upon certain information in the initial key or in a key stored in the key table memory;

g. transforming the key used in step (f) above by said function in accordance with the directions of said selected entry in said transformation table;

h. storing said transformed key as another entry in the key table memory; and

i. performing steps (f)-(h) above repetitively until said key table memory has a desired plurality of keys stored therein.

A method of generating a table of keys for use in cryptographically transforming electronic digital data from one form to another comprising the steps of:

a. establishing an initial key having a plurality of bytes;

b. establishing in memory a plurality of transformation tables, each associated with a predetermined cryptographic function, each of

said tables including a plurality of addressable entries which direct a predetermined transformation of data in accordance with said function;

c. selecting, in turn, at least one of said entries in each of said transformation tables based upon certain information in said initial key;

d. transforming said initial key by said functions in accordance with the directions of said selected entries in said transformation tables;

e. storing said transformed initial key as an entry in the key table memory;

f. selecting, in turn, at least one of said entries in each of said transformation tables based upon certain information in at least one of the keys stored in the key table memory;

g. transforming the key used in step (f) above by said functions in accordance with the directions of said selected entries in said transformation tables;

h. storing said transformed key as another entry in the key table memory; and

i. performing steps (f)-(h) above repetitively until said key table memory has a desired plurality of keys stored therein.

A method cryptographically transforming electronic data from one form to another comprising the steps of:

a. establishing in memory a key table with a plurality of multi-byte key entries;

b. selecting a multi-byte block of data for transformation;

c. selecting an entry from the key table based on information in at least one of the bytes of the data block;

d. arithmetically combining each byte in the selected key with a corresponding byte in the data block, except that the bytes in the data block used to select the entry from the key table remain unchanged; and

e. repeating steps (c) and (d) above for a plurality of rounds and using a different byte of the data block in each round for selecting the entry from the key table.

A method of cryptographically transforming electronic data from one form to another comprising the steps of:

a. establishing in memory a key table with a plurality of multi-byte key entries;

b. selecting a multi-byte block of data for transformation;

c. selecting an entry from the key table based on information in at least one of the bytes of the data block;

d. arithmetically combining each byte in the selected key with a corresponding byte in the data block, except that the bytes in the data block used to select the entry from the key table remain unchanged; and

e. repeating steps (c) and (d) above for a plurality of rounds.

A method of cryptographically transforming electronic data from one form to another comprising the steps of:

a. establishing in memory a key table with a plurality of multi-byte key entries;

b. establishing in memory one or more multi-byte key based determinants;

c. selecting a multi-byte block of data for transformation;

d. selecting an entry from the key table based on information in at least one of the bytes of one of said key based determinants;

e. arithmetically combining each byte in the selected key with a corresponding byte in the data block; and

f. repeating steps (d) and (e) above for a plurality of rounds.

A method cryptographically transforming electronic data from one form to another comprising the steps of:

a. establishing in memory at least one transformation table associated with a predetermined cryptographic function, said table including a plurality of addressable entries which direct a predetermined transformation of data in accordance with said function;

b. selecting at least one of the entries in said transformation table based upon certain information in the data undergoing transformation;

c. cryptographically transforming the data by said function in accordance with the directions of the entry in the transformation table selected in step (b);

d. arithmetically combining the data transformed in step (c) above with a key;

e. selecting at least one other entry in said transformation table based upon certain information in the data transformed in step (d) above; and

f. cryptographically transforming the data transformed in step (d) above by said function in accordance with the directions of the entry in the transformation table selected in step (e).

A method of cryptographically transforming electronic data from one form to another comprising the steps of:

a. establishing in memory a first transformation table associated with a first cryptographic function and a second transformation table associated with a second cryptographic function, said tables each including a plurality of addressable entries which direct a predetermined transformation of data in accordance with said functions;

b. selecting at least one of the entries in said first transformation table based upon certain information in said data undergoing transformation;

c. cryptographically transforming said data by said first function in accordance with the directions of the entry in the first transformation table selected in step (b);

d. arithmetically combining the data transformed in step (c) above with a key;

e. selecting at least one of the entries in the second transformation table based upon certain information in the data transformed in step (d) above; and

f. cryptographically transforming the data transformed in step (d) above by the second function in accordance with the directions of the entry in the second transformation table selected in step (e).

An enclave function for cryptographically transforming electronic digital data from one form to another comprising the steps of:

a. establishing in memory an enclave table with a plurality of entries for directing an autoclave function on a portion of the data undergoing transformation;

b. selecting a block of data having an even number of bytes;

c. dividing said data block into a first half-block including one-half of the bytes of the data block and into a second half-block including the remaining bytes of the data block;

d. transforming the first half-block by said autoclave function as directed by a first entry in said enclave table;

e. transforming the resultant first half-block after step (d) above by said autoclave function as directed by a second entry in said enclave table;

f. combining the second half-block with the resultant first half-block after step (e) above by an Exclusive OR operation to generate resultant second half-block;

g. transforming the resultant second half-block after step (f) above by said autoclave function as directed by a third entry in said enclave table;

h. transforming the resultant second half-block after step (g) above by said autoclave function as directed by a fourth entry in said enclave table;

i. combining the resultant second half-block after step (h) above with the resultant first half-block after step (e) above by an Exclusive OR operation to generate a resultant first half-block; and

j. joining said resultant first half-block after step (i) above to said resultant second half-block after step (h) above to form the transformed data block.

A method of cryptographically transforming electronic data from one form to another comprising the steps of:

a. establishing in memory a permutation table with a plurality of addressable entries for directing a particular permutation of said data undergoing transformation;

b. establishing in memory a substitution table with a plurality of addressable entries for directing a particular substitution on said data undergoing transformation;

c. selecting at least one of the entries in one of said permutation and substitution tables based upon certain information in said data undergoing transformation;

d. cryptographically transforming said data in accordance with the table entry selected in step (c) above and the function associated therewith;

e. arithmetically combining the data transformed in step (d) with a key;

f. selecting at least one of the entries in the other of said permutation and substitution tables; and

g. cryptographically transforming the data transformed in step (e) in accordance with the table entry selected in step (f) and the function associated therewith.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a flow chart of the encryption of a length of plaintext in accordance with the present invention;

FIG. 2 is a flow chart of the table initialization step shown in FIG. 1;

FIG. 3 is a block diagram showing the creation of each entry in the key table;

FIG. 4 is a diagram representing an example of one entity in a permutation table;

FIG. 5 is a schematic representation of an example of one entry in a substitution table;

FIG. 6 is a block diagram of the enclave function used in the present invention;

FIG. 7 is a block diagram of the autoclave function used in the enclave function of FIG. 6;

FIG. 8 is a flow chart of the overall encryption process of a block of plaintext in accordance with a preferred embodiment of the present invention;

FIG. 9 is a block diagram of the variable permutation used in the encryption process of FIG. 8;

FIG. 10 is a block diagram of the variable key addition used in the encryption process of FIG. 8;

FIG. 11 is a block diagram of the variable substitution used in the encryption process of FIG. 8;

FIG. 12 is a flow chart of the overall decryption process of a single block of ciphertext which was encrypted by the process shown in FIG. 8;

FIG. 13 is a block diagram of the inverse variable substitution used in the decryption process of FIG. 12;

FIG. 14 is a block diagram of the inverse enclave function used in the decryption process of FIG. 12;

FIG. 15 is a block diagram of a portion of the autoclave function used in the inverse enclave function of FIG. 14;

FIG. 16 is a block diagram of the inverse variable key addition used in the decryption process of FIG. 12; and

FIG. 17 is a block diagram of the inverse variable permutation used in the decryption process of FIG. 12.

DESCRIPTION OF THE PREFERRED EMBODIMENT

In a preferred embodiment, the cryptographic system of the present invention is operated in a block cipher format in which small chunks of the plaintext data, referred to commonly as blocks, are encrypted and decrypted at one time. Preferably, the encryption and decryption takes place in a multiple round block type of format. However, it is to be understood that the invention of the present application can also be used in other cryptographic systems, such as stream ciphers and the like, and that multiple rounds may not be employed. However, multiple rounds will strengthen the system considerably.

The encryption system of the present invention uses, in a preferred embodiment, modular arithmetic which is a cyclic mathematical function based on a particular whole number referred to as the modulus. Counting is done by successive incrementing until the number one is less

than the modulus reached, and then starting over again with zero. An example of modular 3, compared with whole numbers, can be shown as follows:

Whole:	0	1	2	3	4	5	6	7	8	9	10
Mod 3:	0	1	2	0	1	2	0	1	2	0	1

Thus, 10 modular 3, which is commonly abbreviated as 10 mod 3, is equal to 1. Modular arithmetic can more easily be done by successively subtracting the modular from the number in question until the result is between zero and the modulus minus 1. For example: 10 - 3 = 7; 7 - 3 = 4; and 4 - 3 = 1. Thus, 10 mod 3 = 1, since the last subtraction resulted in an answer between 0 and 2, with 2 = modulus - 1. The general format for a modular arithmetic function is (whole number) mod (modulus) = whole number smaller than the modulus.

As shown in FIG. 1, the system commences at the start, reference 10, and then control passes to reference 12 for the initialization of various tables in memory. As will be explained hereinafter in more detail, a number of tables are supplied to the system and a number of tables created within the system. This takes place initially before any plaintext or ciphertext is encrypted or decrypted. Control then passes to reference 14 where the first block of plaintext is selected. Although FIG. 1 is shown in connection with the encipherment of blocks of plaintext, the same steps would also be followed for decrypting selected blocks of ciphertext. Control then passes to reference 16 where the selected block of plaintext is encrypted in accordance with the cryptographic system of the present invention. If there is more plaintext left to be encrypted, as determined by query 18, the next block of plaintext is selected at reference 20 and the next block is encrypted. If there is no more plaintext, then the system stops operation at reference 22.

The step of initializing the tables in memory is shown in more detail in FIG. 2. A permutation table, an S-box table and an enclave table are initially loaded into the system's memory at reference 30. The permutation table includes a plurality of addressable entries which dictate in a particular fashion how the position of the bytes in the block of data undergoing encryption will be scrambled, or will be descrambled for decryption. This is a commonly used cryptographic technique. The S-box table is an arrangement for a plurality of substitution entries which dictate, as directed by a particular entry, how the actual values of each byte of the block undergoing transformation will be changed to another value. While this could be included in the form of a standard substitution table, the S-box table arrangement is more efficient computationally and is well-known in the field of cryptography. The enclave table, loaded into the memory at reference 30, will be explained hereinafter in more detail.

The initial key is then loaded into the system at reference 32. For purposes of this application, a key is any secret value or data block which is not expressly stated or set forth in the system implementation, algorithm or tables, but is installed or loaded into the system to direct the cryptographic process. Basically, a key is a secret value or values upon which the cryptographic process acts, but is not a part of the algorithmic implementation. The system then decides at query 34 whether an initializing vector is included. The use of an initializing vector is common in the field and is typically used when transmitting data across telephone lines and the like. The initializing vector is sent across the lines before the enciphered data and is used in further decryption of the data. As shown at reference 36, the key is combined with the initializing vector in an Exclusive OR operation, in a bit by bit manner, to modify

the initial key which is then used at reference 38 to generate the key table. Rather than use an Exclusive OR function, the values of each byte in the key could be added to the value of each byte in the initializing vector to modify the initial key. These are both standard techniques in cryptography for using an initializing vector in connection with a key. If no initializing vector is used, then control passes directly to reference 38 where the key table is generated from the unchanged initial key. Once the key table is created, then control passes to reference 40 where the mask table is generated from the entries generated in the key table. The particular processes used to generate the key table and mask table entries from the initial key are explained hereinafter in detail.

In accordance with a preferred embodiment of the present invention, the block size of the data undergoing cryptographic transformation is selected to be ten bytes long, with each byte including eight digital bits therein. Seven of the bits in each byte are used for the data values and the eighth bit is a parity bit as is well-known in the field. In the preferred embodiment here, the key has been selected to be the same length as the block of data undergoing encryption and decryption. However, the key could be other lengths, if desired. It is necessary that the key be long enough to make guessing the key by an exhaustive attack very difficult. When using seven value bits in each byte, it is preferred that each key include between eight and twenty bytes. While key lengths longer than twenty bytes can be used, it would make the computation in the cryptographic system much more difficult and time consuming and would increase the length of the various tables used in the system, correspondingly increasing the memory space required. The same considerations are applicable in selecting the block of plaintext undergoing encryption, particularly when small

blocks of information will be sent through the system. The block size should include an even number of bytes if the enclave function of the present invention is used. However, the block size could be an odd number of bytes if the enclave function was not used.

A major element of the cryptographic system of the present invention is that the particular permutation, substitution or enclave table used in performing a particular cryptographic function on the data is a function of certain values or elements in the data undergoing transformation. This aspect of the present invention is being referred to as a variable function, which is any function where two or more possible choices exist.

This aspect of the present invention is also used initially in generating, from an initial key, a key table which is later used in the encryption/decryption process. Generally, one or more elements from the key are selected and the result of a predetermined mathematical function is used to choose a variable function table. The function is performed on the present state of the key in accordance with the selected table to generate a new key. The result of the mathematical function could also be used to pick, from many available possibilities, the particular function used in conjunction with a particular table. In the preferred embodiment of this invention, the particular type of function is preset and only the table used in conjunction with that function is selected by means of the data undergoing encryption/decryption.

A particular arrangement for producing the elements of the key table, which uses substitution, permutation and enclave functions, is set forth in FIG. 3. The ten bytes of the key undergoing transformation are shown in element 50 as K_n1-K_n10. In selecting the substitution table used, the values of the last five bytes of the key are added together using modular arithmetic at

element 51 to generate a digital number stored in memory register Y at element 52. The modulus of the modular arithmetic used at element 51 would be determined by the size of the substitution table used in the system. In a preferred embodiment, the substitution table would include 32 tables for 128 byte values and, therefore, the arithmetic used at element 51 would have a modulus of 32. In an example included hereinafter in this application, the substitution table has, for ease of understanding, only 16 tables and element 51 would be modular 16. While FIG. 3 shows the addition of the values in the last five bytes of the key undergoing transformation to generate the number used in selecting the substitution table, it is to be understood that any combination of the ten bytes in the key, including all ten, could be used to generate the Y value at element 52.

In selecting the permutation table used in FIG. 3, the first five values of the key are added together using modular arithmetic at element 53 to generate a digital number stored in memory register X at element 54. Similar to the substitution table calculation, the modular arithmetic used at element 53 for generating the permutation table X would be dependent upon the size of the permutation table used in the system. In a preferred embodiment, there are 128 entries in the permutation table and, therefore, the modular arithmetic at element 53 would be modular 128.

The value Y generated at element 52 is used to select the substitution table which is used to modify the current state of the key. The key is then substituted in accordance with this table. Thereafter, the value X generated at element 54 is used to select the particular permutation table. The key, which previously underwent a substitution operation, is now permutated in accordance with the selected table. This operation, which transforms key_n to an intermediate state referred to as PSK_n, is set

forth in element 55 in FIG. 3. The transformed key, after undergoing first the substitution and then the permutation, is represented in FIG. 3 as element 56, including bytes PSK_n1 - PSK_n10.

A sample permutation table entry is shown in FIG. 4. The position of the eight bit bytes at the top of FIG. 4 will be scrambled as directed by the various arrows to the new position shown at the bottom of FIG. 4. Working from the top to the bottom gives an encryption of the data. To decrypt the data, the positioning is rearranged from the bottom to the top to recapture the initial arrangement of the data. This is a standard technique used in many cryptographic systems and need not be explained in further detail in this application. Likewise, a typical entry in the substitution table is shown in FIG. 5. If a particular plaintext value appears in any of the bytes of the data undergoing transformation, then the substitution table used will direct that the plaintext value be substituted by a new value. For instance, if the plaintext value is P_0, then, in accordance with the table shown in FIG. 5, it will be substituted by the new value of S_1. Working backwards through the substitution table, the encrypted data can then be decrypted to recapture the original plaintext values. Once again, this is a standard cryptographic technique and need not be explained in further detail. It must be understood that the particular arrangements shown in FIGS. 4 and 5 are only representative of the many possibilities of permutation and substitution table entries and that many other entries would be included in the tables used in the cryptographic system of the present invention.

In FIG. 3, the intermediate state of the key at element 56 is further modified in accordance with a newly developed function, referred to as an enclave function by the applicant. The enclave process is also a variable

function in which certain values of the data undergoing transformation are used to generate a number which in turn is used to select which of a plurality of enclave tables will be used to perform the further transformation of the data. In the embodiment shown in FIG. 3, certain values of the intermediate state of the key in element 56, bytes 3, 4, 5, 6 and 7 as shown, are added together using modular arithmetic at element 57 to create a digital number identified as Z and stored in memory register Z in element 58. In a preferred embodiment, the enclave table includes 32 entries and, accordingly, the arithmetic performed at element 57 would be modular 32. Thereafter, the intermediate state of the key is further transformed according to the particular enclave table selected and this transformed key is entered into the key table at element 59. The enclave function will be described in detail hereinafter in connection with FIGS. 6 and 7.

In accordance with the notation used in the present application, "Key" is used to represent the initial key. The initial key is used to generate the first key in the key table, which is identified as Key_0. Key_0 is stored in the key table and is then used to generate the next entry in the key table, namely, Key_1. Key_1 is created from Key_0 by following the same steps set forth in FIG. 3 for generating Key_0 from the original key. The remaining keys in the key table are generated in turn from the immediately preceeding key until the key table is filled. The generation of a key from its predecessor in the key table is represented as element 59 in FIG. 3 where Key_n is used to generate Key_{n+1}.

The number of entries in the key table should be a factor, or divide evenly into the alphabet space. In the preferred embodiment described herein, the alphabet space is 2^7 or 128. If the number of entries is not a factor of the alphabet space, then the statistical chance of certain keys being used is greater than other keys.

This discrepancy could aid a cryptanalyst and should be avoided. The maximum number of entries in the key table is the size of the alphabet space and the maximum has been used in the preferred embodiment.

In general, each key in the key table is generated as a result of a variable function performed on the previous key, with the particular variable function determined by information extracted from the prior installed or generated key. The initial key would be the installed key and the generated keys have been referred to as Key_0, Key_1, etc. In this manner, the key table does not include the initial secret key and, therefore, it is impossible to solve for the initial key from knowledge of information in the key table. As will be explained hereinafter in more detail, a different set of keys will be selected in each round of the encryption and this makes it impossible to search for or solve mathematically for one key used repetitively. This simulates a one time tape when an initializing vector is used with every transmission in connection with the initial key. Also, knowing one key in the key table cannot give the attacker the previous key since a cryptanalyst cannot work backward through the key table. Therefore, this arrangement is much better than a pseudo-random key generator.

It must be noted that the arrangement set forth in FIG. 3 is just one possible implementation of the present invention. There are almost an infinite number of variations possible without changing the spirit or scope of the invention. Any process using the initial key or an installed data block to choose a variable function to create a key table such that the variable function table chosen cannot be determined from the new key created would fall within the scope of this invention.

FIG. 6 represents a block diagram of the enclave function used in the present invention. The enclave function is used both in generating the key table in FIG.

3 and is also used in the encryption process shown hereinafter in FIG. 8. The block undergoing transformation is referred to as element 60 in FIG. 6. The block is divided into two portions, namely, a first or left half- block 61 including the first five bytes and a second or right half-block 62 including the last five bytes. Other arrangements for dividing the block into half-blocks can be used, including using the even bytes for the first half-block and the odd bytes for the second half-block, and other arrangements. The block undergoing transformation must include an even number of bytes for the enclave function.

An autoclave function is a known technique in cryptographic systems for changing a block by a function performed on itself. The enclave process of the present invention uses an autoclave type of function in conjunction with other manipulations on the data block to provide complete inter-symbol dependency throughout the entire ten byte block. Complete inter-symbol dependency is achieved when every byte of the block is a function of every other byte of the block and itself.

In the arrangement shown in FIG. 6, the right half-block 62 is transformed by an autoclave function referred to as E_{na} to a new data block referred to as element 63. The particular autoclave function used at E_{na} will be described hereinafter in more detail in connection with FIG. 7. The right half-block at element 63 then undergoes a second autoclave transformation, referred to as E_{nb}, to generate the half-block at element 64. This half-block is then combined by a bit by bit Exclusive OR function with the unchanged left half-block 61 at element 65 to generate a new left half-block at element 66. The left half-block at element 66 then undergoes an autoclave function E_{nc} to generate a transformed left half-block at element 67. Thereafter, the left half-block in element 67 undergoes a subsequent autoclave transformation E_{nd} to

generate a modified left half-block at element 68. Then the left half-block in element 68 is combined by an Exclusive OR function with the previously transformed right half-block at element 64. This Exclusive OR function generates a new right half-block at element 70. Then the left half-block at element 68 is joined to the right half-block at 70 to create an entire block at element 71 which has undergone the enclave function of the present invention.

After the right half-block 62 has undergone the two autoclave functions in accordance with E_{na} and E_{nb}, the right half-block has achieved complete inter-symbol dependency within itself. When the left half-block 61 and the current right half-block 64 are combined by an Exclusive OR function at element 65, the left half-block is completely inter-symbol dependent with the right half-block. When the left half-block at element 66 is then transformed by the two autoclave functions E_{nc} and E_{nd}, the left half-block at element 68 will be completely inter-symbol dependent with itself and with the right half-block. Therefore, the left half-block has achieved complete inter-symbol dependency with the entire ten byte block. After the right half-block at element 64 is combined by an Exclusive OR function with the current left half-block at element 69, the right half-block is entirely inter-symbol dependent on the entire ten byte block. When the left half-block at element 68 and the right half-block at element 70 are merged together to form the complete block at element 71, every byte of the block is a function of every other byte of the block and of itself.

The particular autoclave function used in the enclave function shown in FIG. 6 is a process where the element or byte in the half-block undergoing transformation is added to two other elements in the half-block. This process is repeated until each element in the half-block has been so modified. To create the

complete inter-symbol dependency within each half-block, it is necessary that at least two elements be added to the element being changed. In addition, this autoclave process is carried out twice on the entire half-block to insure that all of the bytes in the half-block are functions of themselves and of every other byte. E_{na}, E_{nb}, E_{nc}, and E_{nd} are represented by a plurality of enclave tables, each of which includes an entry a, an entry b, an entry c and an entry d. A sample table E_n is set forth below:

E_{na}	E_{nb}	E_{nc}	E_{nd}
3 1 5	5 4 3	4 1 3	3 4 5
5 3 4	2 3 1	3 2 5	5 2 1
4 2 1	4 2 5	1 5 2	4 1 3
1 4 2	3 1 2	2 3 4	2 5 4
2 5 3	1 5 4	5 4 1	1 3 2

Each sub-table has five columns and the autoclave function is performed in five steps from top to bottom. The height of the column of each of the sub tables must be equal in length to the half-block undergoing transformation. In the preferred embodiment, the height of the columns are five since the blocks are ten bytes long and the half-blocks are five bytes long. Every column must include a number signifying every byte in the half-block. In the preferred embodiment, the numbers 1-5 designate the bytes since there will be five bytes in each half-block. Every byte must be accounted for in every column. The row length must be greater than one-half the half-block length and every row must contain a distinct numerical value between one and five. In other words, none of the numbers one through five should be repeated in any row of a sub- table. The total number of tables E_n should be a factor of the encryption space. In summary, the vertical rows of each sub table of E_n must have a different number from one through five and each horizontal row must all have different numbers from one

through five. In addition, each of the second and third elements of the sub-table in a particular row must be different from the first entry. The first entry (i.e., in the first row) gives the identity of the byte of the block undergoing transformation and the second and third entries (in the second and third rows) represent the bytes which are arithmetically joined to the byte undergoing transformation to come up with the new value.

This autoclave function can be represented better in connection with FIG. 7 which shows the transformation of the right half-block in accordance with the specific sample table E_{na} set forth above. The first entry in E_{na} is "3 1 5" which means that the third byte of the half-block (i.e., byte 8 or B8) is added to the value of the first byte (B6) and the fifth byte (B10) to generate the new value of the third byte (B8). Modular arithmetic for each addition is used in accordance with the size of alphabet space. Here, modular 128 would be used in the arithmetic step since the alphabet space is 2^7 or 128 as determined by the seven data bits in each byte in the preferred embodiment. The next entry in E_{na} is "5 3 4" which means that the fifth byte (B10) is added to the third byte (B8 which had previously been transformed) and also to the fourth byte (B9). The third entry is "4 2 1", which means that the fourth byte (B9) is added to the second byte (B7) and the first byte (B6). The fourth entry, "1 4 2", instructs that the first byte (B6) is added to the fourth byte (B9) and the second byte (B7). The fifth entry in table E_{na} is "2 5 3" which means that the second byte (B7) is added to the fifth byte (B10) and the third byte (B8) to generate the new second byte (B7). As discussed above, the autoclave function is repeated with another table, E_{nb}, to create complete inter-symbol dependency within the particular half-block undergoing transformation. E_{na}, E_{nb}, E_{nc} and E_{nd} could all be

identical to each other, but it is better if each of the sub-tables within a particular enclave table E_n are different from each other.

The particular enclave table E_n selected is determined in accordance with a number generated previously through an arithmetic function on the data undergoing transformation. In connection with the creation of the key table, the enclave table selected is determined by the number Z which is generated at element 58 in FIG. 3. The notation "n" in connection with the enclave process in FIG. 6 is to be distinguished from the notation "n" used in connection with generating the entries of the key table in FIG. 3.

The last step shown in the initializing routine set forth in FIG. 2 is the creation of the Mask table at step 40. The Mask values are determinants which are used in the encryption and decryption process to aid in selecting particular entries within tables to perform a transformation on the data. The function of the Masks, which will be apparent later, is to add another distinguishing factor so that a cryptanalyst cannot work backward through the cryptographic algorithm and calculate the original key used in the system.

Generally, the Mask values are the arithmetic result of two or more values from the key table or the original key. The preferred embodiment contains four Mask values with a notation of $Mask_n$ where n can be from one to four. The maximum range for n is equivalent to the number of variable functions included in the cryptographic system. In the preferred embodiment, the system includes permutation, key addition, enclave, and substitution variable functions and, accordingly, the maximum n for the Masks will be four. Each Mask table entry is a block of ten bytes. Therefore, each of these bytes can be addressed as $Mask_{n,b}$ with b ranging from one to ten. In the preferred embodiment, the Masks are created as

follows: The first byte in $Mask_1$, referred to as $Mask_{1,1}$, is generated by summing the values of the first byte in the first 32 keys of the key table. These values are summed up using modular arithmetic, herein modular 128, as determined by the alphabet space. The subsequent bytes of the first Mask are each in turn generated by summing up the corresponding byte in each of the first 32 keys in the key table. The second Mask, referred to as $Mask_2$, is generated by a similar summation of the bytes in the next 32 keys in the table, i.e., $Key_{32} \cdot \cdot \cdot Key_{63}$. Similarly, the third Mask is created by operations on the next 32 keys in the key table, namely, Key_{64} through Key_{95}. Lastly, the fourth Mask is created by using Key_{96} through Key_{127}. The Mask creation can be represented mathematically by the following equations (with 1 less than or equal to b which is less than or equal to 10):

$$MASK_{1,b} = Key_{0,b} + Key_{1,b} + \cdot \cdot \cdot + Key_{31,b}$$
$$MASK_{2,b} = Key_{32,b} + Key_{33,b} + \cdot \cdot \cdot + Key_{63,b}$$
$$MASK_{3,b} = Key_{64,b} + Key_{65,b} + \cdot \cdot \cdot + Key_{95,b}$$
$$MASK_{4,b} = Key_{96,b} + Key_{97,b} + \cdot \cdot \cdot + Key_{127,b}$$

Other options are available for creating the key table and Masks. The Masks could be generated by just generating four more keys in the key table creation and using these four additional keys as the four Masks. Also, the keys in the key table could be created by the same method used in generating the Masks. Also, the key table could be generated by making the third key a function of the first two keys with or without the use of variable functions after the first two entries in the key table had been generated. Thus, succeeding keys can be created by any of the previously generated keys.

A flow chart showing the encryption process in accordance with the preferred embodiment of the present invention is shown in FIG. 8. Since the preferred embodiment includes a number of rounds of encryption on each block of data, the letter "R" will be used to

designate the round number hereinafter. Initially, the round number is set to zero at step 100. Then the round number R is incremented by one at step 102. The data undergoing encryption is represented by a ten byte block at step 104. During the first round of encryption, the data in element 104 will be the plaintext undergoing encryption. In subsequent rounds, this data will be an intermediate product different from the initial plaintext data but not yet the final ciphertext output.

The data is initially subjected to a variable permutation operation at step 106. As explained hereinafter in more detail in connection with FIG. 9, an entry is selected from the permutation table memory 108 and a value is selected from the Mask table memory 110 to conduct the variable permutation. Control then passes to step 112 where a choice component, referred to as "C", is equated with the round number R. Control then passes to step 114 where a first variable key addition operation is carried out on the data. As explained hereinafter in more detail in connection with FIG. 10, a key is selected from the key table memory 116 and a value is selected from the Mask table memory 110 to carry out the variable key addition. Control then passes to step 118 where the choice component C is set to a value one greater than the round number. Following the operation at step 118, control passes to query 120 where it is determined whether the choice component C is equal to 11. If it is not, then control passes directly to step 122 where a second variable key addition operation is carried out on the data, using a key from the key table memory 116 and using a value from the Mask table memory 110. If following the addition at step 118, the choice component C is equal to 11, then control is passed to step 124 where the choice component is set to a value of one. Then control is passed to the second variable key addition operation at step 122.

Following the second variable key addition function at step 122, control is passed to step 126 where a variable enclave is performed on the data. This variable enclave function was described above in connection with FIGS. 6 and 7, where it was shown that an entry is selected from the enclave table memory 128. The particular enclave table selected is determined by $Mask_{3,R}$ which is obtained from the Mask table memory 110. This can be represented by the equation $n = Mask_{3,R}$ where n is the enclave table memory selected for the operations in FIGS. 6 and 7. As will be explained hereinafter in more detail, $Mask_1$ was used in connection with the variable permutation operation at step 106, $Mask_2$ was used in connection with the variable key additions at steps 114 and 122, and $Mask_4$ will be used in the subsequent variable substitution operations.

Control then passes to step 130 where the choice component C is once again equated to the round number R. Thereafter, the data undergoes transformation in accordance with a first variable substitution at step 132. As will be explained hereinafter in more detail, the variable substitution uses a value from the Mask table memory 110 and selects an appropriate S-Box table from the S-Box and S'-Box memory 134. Control then passes to step 136 where the value of the choice component C is incremented by one. A decision is made at query 138 as to whether the choice component is equal to 11. If it is not, then control is passed directly to a second variable substitution at step 140. If the choice component after step 136 is equal to 11, then control is passed by query 138 to step 142 where the choice component is set to a value of one. Thereafter, control is passed to the second variable substitution at step 140. Like the first variable substitution at step 140, the second variable substitution is described in more detail in FIG. 11 and

uses a value from the Mask table memory 110 and uses a table from the S-Box and S'-Box memory 134 to transform the data.

Control thereafter passes to query 144 where it is determined whether the round number has reached a value of 10. If the round number has reached ten, then the encryption process is completed and the ciphertext is represented as an output at step 146. If the round number has not yet reached ten, control is passed back to step 102 where the round number is incremented by one. Then all of the above identified steps, including the variable permutation 106, the first variable key addition 114, the second variable key addition 112, the variable enclave 126, the first variable substitution 132 and the second variable substitution 140, are carried out.

The variable permutation of FIG. 8 is explained in more detail in the block diagram in FIG. 9. The data undergoing transformation is represented as bytes B1 through B10 at element 150. In order to select which table in the permutation table memory 108 is used to carry out the permutation, the values in the ten bytes of the data are added together at element 152 to generate a value stored in memory register Z at element 154. A value is generated by combining in a bit by bit Exclusive OR function the value in register Z generated at element 154 with $Mask_{1,R}$ from the Mask table memory 110. This value is stored in memory register W at element 156. For example, during the first round of encryption, $Mask_{1,1}$ would be used at element 156 to generate W by the Exclusive OR operation with Z. Since there are ten rounds of encryption in the preferred embodiment, each of the ten values in $Mask_1$ will be used in turn during the encryption rounds.

Control then passes to element 158 where a standard permutation is carried out on the block of data using the directions from permutation table W, represented

by P_W. The block of data after it has been permutated is shown in FIG. 9 at element 160 as bytes b1 through b10. It is important to use all ten bytes of the data undergoing encryption to select the permutation table used for the transformation since this renders it possible to decrypt the same data by the same steps. If only some of the bytes in the block were used to determine the permutation table used, then it would be impossible to determine during the decryption process which permutation table was selected. Rather than combining Z with $Mask_{1,R}$ by an Exclusive OR operation to generate W, it is also possible to sum the values of Z and $Mask_{1,R}$ modular arithmetic, to determine the permutation table used. This is also true throughout the remainder of the application where two digital values are combined together using an Exclusive OR operation. While an Exclusive OR operation is computationally easier to implement on a digital computer, the same result could be obtained in the present invention by merely arithmetically summing the values rather than carrying out the Exclusive OR operation.

The variable key addition function of the present invention, as shown in steps 114 and 122 of FIG. 8, is shown diagramatically in FIG. 10. Each variable key addition, whether the first at step 114 or the second at step 122, are identical except that the value of the choice component C is one higher in the second variable key addition than in the first key addition, except during the tenth round of encryption when the value of the choice component C is set at one. Otherwise, the steps followed in the variable key addition at step 114 and step 122 in FIG. 8 are identical as set forth in FIG. 10.

The particular key selected from the key table memory 116 for the variable key addition is determined by byte C (referred to as BC) and $Mask_{2,R}$. This is shown by element 172 in FIG. 10 where the value Z is equated to BC and by element 174 where W is equated to Z XOR $Mask_{2,R}$.

The value W is used to select the key from the key table memory 116 for use during that particular round of the variable key addition. The ten bytes of Key_W are shown as element 176 in FIG. 10. Thereafter, every byte in the block of bytes in element 170 is combined by an Exclusive OR function with the corresponding byte in Key_W through the series of Exclusive ORs at element 178. For example, B1 XOR Key_{W1} generates b1. Likewise, B2 XOR Key_{W2} generates b2. The only exception is that byte C (BC) in the block undergoing transformation is not combined with its corresponding byte in Key_W but remains unchanged and becomes directly bC. This is represented by the series of querys at element 180 associated with each byte of the data undergoing transformation at element 170 If C is equal to the byte number, then that byte is not combined with the corresponding key byte. The block of data after it has undergone a round of the variable key addition is shown as element 182 in FIG. 10.

The variable substitution for the encryption process shown in FIG. 8 is shown in more detail in FIG. 11. Similar to the variable key addition, the first variable substitution at step 132 is identical to the second variable substitution at step 140 except that the choice component C is changed for the second variable substitution. Otherwise, the steps followed in each are the same. In the substitution process, the S-Box chosen Z is determined by byte C in the data undergoing transformation and $Mask_{4,R}$. This is shown in FIG. 11 where Z is equated to BC at element 192 and W is equated to Z XOR $Mask_{4,R}$ at element 194. The value of W generated in element 194 is used to select the particular S-Box used for the substitution at element 196. After the selection of the S-Box, every byte of the block undergoing transformation at element 190 is substituted with the

chosen value according to S-Box$_W$, except for byte C (BC) which remains unchanged during this round of transformation.

It is important both in the variable key addition and in the variable substitution that byte C (BC) remains unchanged. In this way, it is possible to use the same transformation to work backwards in the decryption operation. A series of querys at element 198 connected to each byte of the block undergoing transformation in element 190 show how byte C remains unchanged and is passed directly and unchanged to the corresponding output byte in element 200. For example, when the choice component C is equal to 1, then B1 in element 190 would equal b1 in element 200. Otherwise, the remaining bytes in element 200 will have values different from the initial values in element 190 in accordance with the substitution protocol set forth S-Box$_W$. The same technique could be used for selecting the permutation table, i.e., use one of the bytes and leave that byte unchanged.

The steps followed in decrypting a block of ciphertext is shown in FIG. 12. Since the decryption is essentially a backwards iteration through the encryption steps followed in FIG. 8, the round number is initially set at ten in step 210. The block of data undergoing decryption is selected and is represented in element 212 as a block of ten data bytes. During the first round of decryption, the data at step 212 will be the initial ciphertext. Control is then passed to step 214 where the choice component C is set to a value one greater than the round number. A decision is made at query 216 whether the choice component is equal to 11. If it is not, then control is passed directly to step 218 where a first inverse variable substitution is carried out on the data. The inverse variable substitution is described in more detail in FIG. 13. The first inverse variable substitution 218 uses data from the Mask table memory 110

and from the S'-Box memory 134. If query 216 determines that the choice component C is equal to 11, then the choice component set to one at step 220 and control then passes to the first inverse variable substitution at element 218. Control then passes to step 222 where the choice component is equated to the round number, following which a second inverse variable substitution is carried out at step 224.

Subsequent to the second inverse variable substitution at step 224, the data is subjected to an inverse variable enclave function at element 226. This function is described in more detail hereinafter in connection with FIGS. 14 and 15. However, it must be noted here that $Mask_{3,R}$ is selected from the Mask table memory 110 and that value is used to select the particular enclave table memory used from the enclave table memory 128.

Control is then passed to step 228 where the choice component is incremented by one and then a decision is made at query 230 whether the choice component has reached the value of eleven. If the choice component has not yet reached a value of eleven, then control passes to the first inverse variable key addition at step 232. If the choice component has reached the value of eleven, it is reset at step 234 to a value of one and control is passed directly to the first inverse variable key addition at step 232. The first inverse variable key addition uses data from the Mask table memory 110 and the key table memory 116 to transform the data. This operation is shown in more detail in connection with FIG. 16. Control is then passed to step 236 where the choice component is equated with the round number. Then the data is subjected to a second inverse variable key addition at step 238. Other than the difference of the values of the choice

component, the first inverse variable key addition at step 232 is identical to the second inverse variable key addition at step 238.

Control is then passed to the inverse variable permutation at step 240. The data is then subjected to a particular inverse permutation using an entry from the Mask table memory 110 and an entry from the permutation table memory 108. The inverse variable permutation is described in more detail in connection with FIG. 17.

Control is then passed to query 242. If the round number for the decryption has reached a value of one, then no further decryption takes place and the current state of the data is output at step 244 as the plaintext output. If the round number has not yet reached a value of one, then the round number is decreased by 1 at step 246. Control is passed to step 212 for a further round of decryption in accordance with the first inverse variable substitution 218, the second inverse variable substitution 224, the inverse variable enclave 226, the first inverse variable key addition 232, the second inverse variable key addition 238, and the inverse variable permutation 240.

The inverse variable substitution is shown in more detail in FIG. 13. The data undergoing decryption is represented by bytes b1 through b10 in element 250. The inverse substitution box (S'-Box) chosen is determined by bC XOR $Mask_{4,R}$. This is represented in FIG. 13 where Z is equated to bC at element 252 and W is equated to Z XOR $Mask_{4,R}$ at element 254. W is then used to select the particular inverse substitution box ($S'\text{-}Box_W$) at element 256. Every byte in the block in element 250 is then substituted in accordance with the protocol of the chosen S'-Box except for byte bC. The result of the inverse variable substitution is a ten byte data block B1 through B10 at element 260. The arrangement by which byte bC is not substituted is shown by a series of querys 258

associated with each byte of the data undergoing decryption in element 250. For example, in the first round of decryption, where R is ten, b10 is both used to select the S'-Box used for the inverse substitution and is also unchanged during the inverse substitution. Since the tenth byte remained unchanged during the final variable substitution carried out on the data during the encryption process shown in FIG. 8, it is possible to recreate and work backwards through the encryption process through the ciphertext data. The same is true for the inverse variable key addition of FIG. 16.

The inverse variable enclave function is shown in detail in FIG. 14 and in conjunction with the particular autoclave function used in the inverse variable enclave in FIG. 15. The steps carried out in FIG. 14 are essentially the inverse of the steps taken in the variable enclave for encryption shown in FIG. 6. The block of data undergoing decryption at element 270 is split into a left half-block 272 and a right half-block 274. These two half-blocks are combined by a bit by bit Exclusvie OR function at element 276 to produce a subsequent right half-block 278. The left half-block at element 272 is first transformed by an inverse autoclave function E'_{nd} to left half-block element 280 and then is transformed by an inverse autoclave function E'_{nc} to left half-block 282. Right half-block element 278 is then combined through an Exclusive OR function at element 284 with left half-block 282 to form the final left half-block element 286. The right half-block at element 278 is first transformed by an inverse autoclave function E'_{nb} to right half-block element 288 and then is transformed by an inverse autoclave function E'_{na} to the final right half-block at element 290. The left half-block element 286 and right half-block element 290 are joined together to form the final ten byte block at 292 which is the result of the inverse enclave function.

A particular autoclave function used in the inverse enclave of FIG. 14 is shown, for one example, in FIG. 15. In general, the enclave tables, as described above, are used during the inverse autoclave function. However, the entries are read from the bottom of each column to the top and the byte undergoing transformation, identified by the entry in the first row, has its value reduced by the values of the other two bytes, identified by the second and third rows in the enclave table entry. An example of an inverse autoclave function used in the inverse enclave is set forth in FIG. 15 for the same autoclave function used in connection with FIG. 7. The last entry in the enclave table used is used first for the transformation in FIG. 15. Since this entry is "2 5 3", this means that the fifth byte (B10) and the third byte (B8) are subtracted from the second byte (B7) to generate the new value of the second byte. As in the enclave function used for encryption, the arithmetic is carried out by modular arithmetic. The next entry up from the bottom in the enclave table used in FIG. 15 is "1 4 2", which means that the fourth byte (B9) and the second byte (B7) are subtracted from the first byte (B6) to give the new value of the first byte (B6). Similarly, the third entry is "4 2 1", which means that the second byte (B7) and the first byte (B6) are subtracted from the fourth byte (B9) to give the new value of the fourth byte (B9). The next entry in the enclave table used is "5 3 4", which means that the third byte (B8) and the fourth byte (B9) are subtracted from the fifth byte (B10) to give the new value of the fifth byte (B10). Finally, the first entry in the enclave table is "3 1 5", which is used last in the inverse autoclave function. This entry means that the first byte (B6) and the fifth (B10) are subtracted from the third byte (B8) to give a new value for the third byte. The result of all of these modular arithmetic calculations is shown in FIG. 15 as the last block,

including bytes B6 through B10. The inverse variable key addition is shown diagramtically in FIG. 16. The particular key selected from the key table memory 116 for the inverse variable key addition is determined by byte C (referred to as bC) and $Mask_{2,R}$. This is shown by element 302 in FIG. 16, where the value Z is equated to bC, and by element 304 where W is equated to Z XOR $Mask_{2,R}$. The value W is used to select a key from the key table memory 116 for use during that particular round of the inverse variable key addition. The ten bytes of key_W are shown as element 306 in FIG. 16. Thereafter, every byte in the block of bytes in element 300 is combined by an Exclusive OR function with the corresponding byte in Key_W through the series of Exclusive ORs at element 310. For example, b1 XOR Key_{W1} generates B1. Likewise, b2 XOR Key_{W2} generates B2. The only exception is that byte C in the block undergoing transformation is not combined with its corresponding byte in Key_W, but remains unchanged and directly becomes BC. This is represented by the series of querys at elements 310 associated with each byte of the data undergoing transformation at element 300. If C is equal to the byte number, then that byte is not combined with the corresponding key byte. The block of data after it has undergone a round of the inverse variable key addition is shown as element 312 in FIG. 16.

The inverse variable permutation of FIG. 12 is explained in more detail in the block diagram in FIG. 17. The data undergoing transformation is represented as bytes b1 through b10 at element 320. In order to select which table in the permutation table memory 108 is used to carry out the inverse permutation, the values in the ten bytes of the data are added together using modular arithmetic at element 322 to generate a value Z at element 324. At element 326, a value W is generated by combining in a bit by bit Exclusive OR function the value Z generated at element 324 with $Mask_{1,R}$ from the Mask table memory 110.

For example, during the first round of decryption, $Mask_{1,1}$ would be used at element 326 to generate W by the Exclusive OR operation with Z.

Control then passes to element 328 where a standard inverse permutation, which is merely a working backward through the permutation table entry as shown earlier in connection with FIG. 4, is carried out on the block of data, using the directions from the permutation table W, represented by P'_W. The block of data after it has undergone the inverse permutation operation is shown in FIG. 17 at element 330 as bytes B1 through B10. Since during the encryption process all ten bytes of the data undergoing encryption were used to select a permutation table for the transformation, this rendered it possible to decrypt the same data by once again adding together all ten bytes of the ciphertext data to determine which permutation table should be used. This is possible since the permutation operation merely rearranged the order of the values. The information used in the encryption stage can be extracted by once again summing together the values in the data.

EXAMPLE

An example of the encryption of a ten byte block of plaintext data using the embodiment of the encryption system of the present invention discussed above will now be shown in detail. The system must be initialized with a permutation table, a substitution table and an enclave table. Tables used in this example, and created in accordance with the guidelines set forth above, are shown below in Tables I, IIA and B, and III, respectively. Then a ten byte initial key is selected for creating the key table and Mask table. For this example, the initial key is selected to be:

key = 27 115 21 1 12 41 2 92 17 81

Sum the first five values of the initial key (mod 128):

(27 + 115 + 21 + 1 + 12) mod 128 = 176 mod 128 = 48

Therefore, permutation table 48 will be used.

Sum the last five values of the initial key (mod 16):

(41 + 2 + 92 + 17 + 81) mod 16 = 233 mod 16 = 9

Therefore, substitution table 9 will be used.

Take key: 27 115 21 1 12 41 2 92 17 81

Substitute(tbl 9):

50 56 15 124 102 99 109 74 26 73

Permutate(tbl 48):

56 74 50 73 109 15 102 26 124 99

Sum values 3 - 7 of the current key block (mod 32):

(50 + 73 + 109 + 15 + 102) mod 32 = 349 Mod 32 = 29

Therefore, enclave table 29 will be used for the next step.

Current key block:

56 74 50 73 109 15 102 26 124 99

Enclave (tbl 29) :

30 34 55 63 9 73 74 107 109 33

Therefore key_0 =

30 34 55 63 9 73 74 107 109 33

It can be seen that the nitial key was used to create the first key, identified as key_0, in the key table. The above steps are reproduced using key_0 to generate key_1, key_1 to generate key_2, etc., until key_{126} is used to generate key_{127}. The completed key table, using the initial key identified above, is shown in Table IV below.

Next, the Mask table is generated using the previously generated key table. To generate the first byte or first value in $Mask_1$, the first mask, the values of the first bytes in key_0 to key_{31} are summed (mod 128):

0 + 10 + 26 + 0 + 102 + 105 + 111 + 91 + 95 + 68 + 6 + 70 + 95 + 67 + 55 + 39 + 109 + 23 + 39 + 31 + 120 + 50 + 46 + 71 + 34 + 48 + 105 + 51 + 45 + 123 + 4 + 1 = 1840 mod 128 = 48

Therefore, the first value or the first byte in $Mask_1$ is 48.

Value 2 in $Mask_1$ is the sum of the values of byte 2 in Key_0 to Key_{31} (mod 128). Value 3 in $Mask_1$ is the sum of the values of byte 3 in Key_0 to Key_{31} (mod 128). Value 4 in $Mask_1$ is the sum of the values of byte 4 in Key_0 to Key_{31} (mod 128). Value 5 in $Mask_1$ is the sum of the values of byte 5 in Key_0 to Key_{31} (mod 128). Value 6 in $Mask_1$ is the sum of the values of byte 6 in Key_0 to Key_{31} (mod 128). Value 7 in $Mask_1$ is the sum of the values of byte 7 in Key_0 to Key_{31} (mod 128). Value 8 in $Mask_1$ is the sum of the values of byte 8 in Key_0 to Key_{31} (mod 128). Value 9 in $Mask_1$ is the sum of the values of byte 9 in Key_0 to Key_{31} (mod 128). Value 10 in $Mask_1$ is the sum of the values of byte 10 in Key_0 to Key_{31} (mod 128).

Similarly, the ten bytes or values of $Mask_2$ are created from Key_{32} to Key_{63}, the values of $Mask_3$ are created from Key_{64} to Key_{95} and the values of $Mask_4$ are created from Key_{96} to Key_{127}.

The completed mask table, generated from the key table in Table IV, is set forth below:

$Mask_1$ =	48	2	121	18	60	105	33	50	11	60
$Mask_2$ =	26	78	24	72	69	13	77	43	9	99
$Mask_3$ =	64	113	72	61	37	13	49	71	24	60
$Mask_4$ =	104	62	69	87	18	31	102	101	32	125

Now that the key and mask tables have been generated from the initial key (which is not included in either table), data can be encrypted using additionally the permutation, enclave and substitution tables in Tables I, IIA and IIB, and III below. A particular block of plaintext data will be encrypted under the system of the present invention and for ten rounds of encryption.

ROUND 1

BLOCK =	104	101	108	108	111	32	116	104	101	114

(a) Variable Permutation.

Add all values in block (mod 128):

104 + 101 + 108 + 108 + 111 + 32 + 116 + 104 + 101 + 114 = 999 mod 128 = 103

$Mask_1$ value for round 1 ($Mask_{1,1}$) = 48

Permutation Table = Sum of the block XOR $Mask_{1,1}$:

103 XOR 48 = 87

Therefore, permutation table 87 shall be used for the permutation.

Block before permutation:

104 101 108 108 111 32 116 104 101 114

Block after permutation:

108 104 101 101 104 114 32 108 111 116

(b) First Key Addition.

$Mask_2$ value for round 1 ($Mask_{2,1}$) = 26

First key = Value 1 in the block XOR $Mask_{2,1}$:

108 XOR 26 = 118

Therefore, Key_{118} shall be used for the first key addition.

Block before key addition:

108 104 101 101 104 114 32 108 111 116

Block after key addition:

108 113 85 74 105 102 85 91 124 55

(c) Second Key Addition.

Second key = Value 2 in the block XOR $Mask_{2,1}$:

113 XOR 26 = 107

Therefore, Key_{107} shall be used for the second key addition.

Block before key addition:

108 113 85 74 105 102 85 91 124 55

Block after key addition:

72 113 120 64 94 93 56 118 30 47

(d) Variable Enclave.

Enclave table = value of $Mask_{3,1}$ (mod 32) = 64 2 mod 32 = 0

Therefore, enclave table 04 shall be used for the enclave.

Block before enclave:

72 113 120 64 94 93 56 118 30 47

Block after enclave:

2 108 96 114 88 16 101 106 118 56

(e) First Variable Substitution.

$Mask_4$ value for round 1 ($Mask_{4,1}$) = 104

First substitution table = Value 1 in block XOR $Mask_{4,1}$:

2 XOR 104 = 10

Therefore, substitution table 10 shall be used for the first substitution.

Block before substitution:

2 108 96 114 88 16 101 106 118 56

Block after substitution:

2 60 34 59 75 98 127 61 29 73

(f) Second Variable Substitution.

Second substitution table = Value 2 in block XOR $Mask_{4,1}$:

60 XOR 104 = 4

Therefore, substitution table 4 shall be used for the second substitution.

Block before substitution:

2 60 34 59 75 98 127 61 29 73

Block after substitution:

103 60 82 74 18 38 11 49 50 110

ROUND 2

BLOCK = 103 60 82 74 18 38 11 49 50 110

(a) Variable Permutation.

Add all values in block (mod 128):

103 + 60 + 82 + 74 + 18 + 38 + 11 + 49 + 50 + 110 = 595

mod 128 = 83

$Mask_1$ value for round 2 ($Mask_{1,2}$) = 2

Permutation table = Sum of the block XOR $Mask_{1,2}$:

83 XOR 2 = 81

Therefore, permutation table 81 shall be used for the permutation.

Block before permutation:

103 60 82 74 18 38 11 49 50 110

Block after permutation:

103 60 50 38 18 11 49 74 82 110

(b) First Key Addition.

$Mask_2$ value for round 2 ($Mask_{2,2}$) = 78

First key = Value 2 in the block XOR $Mask_{2,2}$:

60 XOR 78 = 114

Therefore, Key_{114} shall be used for the first key addition.

Block before key addition:

103 60 50 38 18 11 49 74 82 110

Block after key addition:

52 60 9 5 68 30 46 117 52 11

(c) Second Key Addition.

Second key = Value 3 in the block XOR $Mask_{2,2}$:

9 XOR 78 = 71

Therefore, Key_{71} shall be used for the second key addition.

Block before key addition:

52 60 9 5 68 30 46 117 52 11

Block after key addition:

35 108 9 12 107 21 112 115 84 112

(d) Variable Enclave.

Enclave table = value of $Mask_{3,2}$ (mod 32) = 113 mod 32 = 17

Therefore, enclave table 17 shall be used for the enclave.

Block before enclave:

35 108 9 12 107 21 112 115 84 112

Block after enclave:

43 37 14 65 92 20 110 59 17 111

(e) First Variable Substitution.

$Mask_4$ value for round 2 ($Mask_{4,2}$) = 62

First substitution table = Value 2 in block XOR $Mask_{4,2}$:

37 XOR 62 = 11

Therefore, substitution table 11 shall be used for the first substitution.

Block before substitution:

43 37 14 65 92 20 110 59 17 111

Block after substitution:

46 37 68 9 126 35 73 8 83 6

(f) Second Variable Substitution.

Second substitution table = Value 3 in block XOR $Mask_{4,2}$:

68 XOR 62 = 10

Therefore, substitution table 10 shall be used for the second substitution.

Block before substitution:

46 37 68 9 126 35 73 8 83 6

Block after substitution:

99 122 68 9 114 0 53 51 92 49

ROUND 3

BLOCK = 99 122 68 9 114 0 53 51 92 49

(a) Variable Permutation.

Add all values in block (mod 128):

99 + 122 + 68 + 9 + 114 + 0 + 53 + 51 + 92 + 49 = 657 mod 128 = 17

$Mask_1$ value for round 3 ($Mask_{1,3}$) = 121

Permutation table = Sum of the block XOR $Mask_{1,3}$:

17 XOR 121 =104

Therefore, permutation table 104 shall be used for the permutation.

Block before permutation:

99 122 68 9 114 0 53 51 92 49

Block after permutation:

68 53 51 114 122 0 9 99 49 92

(b) First Key Addition.

$Mask_2$ value for round 3 ($Mask_{2,3}$) = 24

First key = Value 3 in the block XOR $Mask_{2,3}$:

51 XOR 24 = 43

Therefore, Key_{43} shall be used for the first key addition.

Block before key addition:

68 53 51 114 122 0 9 99 49 92

Block after key addition:

84 59 51 126 4 30 98 119 73 113

(c) Second Key Addition.

Second key = Value 4 in the block XOR $Mask_{2,3}$:

126 XOR 24 = 102

Therefore, Key_{102} shall be used for the second key addition.

Block before key addition:

84 59 51 126 4 30 98 119 73 113

Block after key addition:

19 31 85 126 117 39 113 77 17 82

(d) Variable Enclave.

Enclave table = value of $Mask_{3,3}$ (mod 32) = 72 mod 32 = 8

Therefore, enclave table 8 shall be used for the enclave.

Block before enclave:

19 31 85 126 117 39 113 77 17 82

Block after enclave:

127 113 18 67 108 90 103 103 96 85

(e) First Variable Substitution.

$Mask_4$ value for round 3 ($Mask_{4,3}$) = 69

First substitution table = Value 3 in block XOR $Mask_{4,3}$:

18 XOR 69 = 7

Therefore, substitution table 7 shall be used for the first substitution.

Block before substitution:

127 113 18 67 108 90 103 103 96 85

Block after substitution:

76 38 18 30 46 28 71 71 60 112

(f) Second Variable Substitution.

Second substitution table = Value 4 in block XOR $Mask_{4,3}$:

30 XOR 69 = 11

Therefore, substitution table 11 shall be used for the second substitution.

Block before substitution:

76 38 18 30 46 28 71 71 60 112

Block after substitution:

3 100 107 30 13 54 58 58 36 14

ROUND 4

BLOCK = 3 100 107 30 13 54 58 58 36 14

(a) Variable Permutation.

Add all values in block (mod 128):

3 + 100 + 107 + 30 + 13 + 54 + 58 + 58 + 36 + 14 = 473

mod 128 = 89

$Mask_1$ value for round 4 ($Mask_{1,4}$) = 18

Permutation Table = Sum of the block XOR $Mask_{1,4}$:

89 XOR 18 = 75

Therefore, permutation table 75 shall be used for the permutation.

Block before permutation:

3 100 107 30 13 54 58 58 36 14

Block after permutation:

30 58 14 100 54 13 36 3 58 107

(b) First Key Addition.

$Mask_2$ value for round 4 ($Mask_{2,4}$) = 72

First key = Value 4 in the block XOR $Mask_{2,4}$:

100 XOR 72 = 44

Therefore, Key_{44} shall be used for the first key addition.

Block before key addition:

30 58 14 100 54 13 36 3 58 107

Block after key addition:

99 35 0 100 36 104 12 71 25 43

(c) Second Key Addition.

Second key = Value 5 in the block XOR $Mask_{2,4}$:

36 XOR 72 = 108

Therefore, Key_{108} shall be used for the second key addition.

Block before key addition:

99 35 0 100 36 104 12 71 25 43

Block after key addition:

77 95 115 53 36 35 19 119 56 69

(d) Variable Enclave.

Enclave Table = value of $Mask_{3,4}$ (mod 32) = 61 mod 32 = 29

Therefore, enclave table 29 shall be used for the enclave.

Block before enclave:

77 95 115 53 36 35 19 119 56 69

Block after enclave:

117 76 52 98 12 13 113 26 108 92

(e) First Variable Substitution.

$Mask_4$ value for round 4 ($Mask_{4,4}$) = 87

First substitution table = Value 4 in block XOR $Mask_{4,4}$:

98 XOR 87 = 5

Therefore, substitution table 5 shall be used for the first substitution.

Block before substitution:

117 76 52 98 12 13 113 26 108 92

Block after substitution:

64 80 83 98 58 48 50 31 49 43

(f) Second Variable Substitution.

Second substitution table = Value 5 in block XOR $Mask_{4,4}$:

58 XOR 87 = 13

Therefore, substitution table 13 shall be used for the second substitution.

Block before substitution:

64 80 83 98 58 48 50 31 49 43

Block after substitution:

122 28 81 29 58 127 22 16 26 49

ROUND 5

BLOCK = 122 28 81 29 58 127 22 16 26 49

(a) Variable Permutation.

Add all values in block (mod 128):

122 + 28 + 81 + 29 + 58 + 127 + 22 + 16 + 26 + 49 = 558

mod 128 = 46

$Mask_1$ value for round 5 ($Mask_{1,5}$) = 60

Permutation Table = Sum of the block XOR $Mask_{1,5}$:

46 XOR 60 = 18

Therefore, permutation table 18 shall be used for the permutation.

Block before permutation:

122 28 81 29 58 127 22 16 26 49

Block after permutation:

49 122 127 81 28 16 26 22 29 58

(b) First Key Addition.

$Mask_2$ value for round 5 ($Mask_{2,5}$) = 69

First key = Value 5 in the block XOR $Mask_{2,5}$:

28 XOR 69 = 89

Therefore, Key_{89} shall be used for the first key addition.

Block before key addition:

49 122 127 81 28 16 26 22 29 58

Block after key addition:

40 118 40 87 28 74 102 101 88 57

(c) Second Key Addition.

Second key = Value 6 in the block XOR $Mask_{2,5}$:

74 XOR 69 = 15

Therefore, Key_{15} shall be used for the second key addition.

Block before key addition:

40 118 40 87 28 74 102 101 88 57

Block after key addition:

15 50 22 72 90 74 7 76 15 92

(d) Variable Enclave.

Enclave Table = value of Mask 3,5 (mod 32) = 37 mod 32 = 5

Therefore, enclave table 5 shall be used for the enclave.

Block before enclave:

15 50 22 72 90 74 7 76 15 92

Block after enclave:

98 69 120 65 54 18 6 17 59 14

(e) First Variable Substitution.

$Mask_4$ value for round 5 ($Mask_{4,5}$) = 18

First substitution table = Value 5 in block XOR $Mask_{4,5}$:

54 XOR 18 = 4

Therefore, substitution table 4 shall be used for the first substitution.

Block before substitution:

98 69 120 65 54 18 6 17 59 14

Block after substitution:

38 0 92 68 54 89 122 4 74 106

(f) Second Variable Substitution.

Second substitution table = Value 6 in block XOR $Mask_{4,5}$:

89 XOR 18 = 11

Therefore, substitution table 11 shall be used for the second substitution.

Block before substitution:

38 0 92 68 54 89 122 4 74 106

Block after substitution:

100 24 126 122 108 89 39 45 93 28

ROUND 6

BLOCK = 100 24 126 122 108 89 39 45 93 28

(a) Variable Permutation.

Add all values in block (mod 128):

100 + 24 + 126 + 122 + 108 + 89 + 39 + 45 + 93 + 28 = 774

mod 128 = 6

$Mask_1$ value for round 6 ($Mask_{1,6}$) = 105

Permutation Table = Sum of the block XOR $Mask_{1,6}$:

6 XOR 105 = 111

Therefore, permutation table 111 shall be used for the permutation.

Block before permutation:

100 24 126 122 108 89 39 45 93 28

Block after permutation:

126 45 122 89 93 108 24 28 39 100

(b) First Key Addition.

$Mask_2$ value for round 6 ($Mask_{2,6}$) = 13

First key = Value 6 in the block XOR $Mask_{2,6}$:

2064769

108 XOR 13 = 97

Therefore, Key_{97} shall be used for the first key addition.

Block before key addition:

126 45 122 89 93 108 24 28 39 100

Block after key addition:

39 78 56 40 24 108 99 80 4 77

(c) Second key Addition.

Second key = $Value_7$ in the block XOR $Mask_{2,6}$:

99 XOR 13 = 110

Therefore, Key_{110} shall be used for the second key addition.

Block before key addition:

39 78 56 40 24 108 99 80 4 77

Block after key addition:

94 63 13 94 121 33 99 70 118 11

(d) Variable Enclave.

Enclave Table = value of $Mask_{3,6}$ (mod 32) = 13 = mod 32 =13

Therefore, enclave table 13 shall be used for the enclave.

Block before enclave:

94 63 13 94 121 33 99 70 118 11

Block after enclave:

89 102 105 113 44 117 86 106 57 50

(e) First Variable Substitution.

$Mask_4$ value for round 6 ($Mask_{4,6}$) = 31

First Substitution Table = Value 6 in block XOR $Mask_{4,6}$:

117 XOR 31 = 10

Therefore, substitution table 10 shall be used for the first substitution.

Block before substitution:

89 102 105 113 44 117 86 106 57 50

Block after substitution:

78 65 30 125 17 117 57 61 89 38

(f) Second Variable Substitution.

Second substitution table = Value 7 in block XOR $Mask_{4,6}$:
57 XOR 31 = 6
Therefore, substitution table 6 shall be used for the second substitution.

Block before substitution:

78 65 30 125 17 117 57 61 89 38

Block after substitution:

6 92 76 30 120 66 57 51 58 80

ROUND 7

BLOCK = 6 92 76 30 120 66 57 51 58 80

(a) Variable Permutation.

Add all values in block (mod 128):
6 + 92 + 76 + 30 + 120 + 66 + 57 + 51 + 58 + 80 = 636 mod 128 = 124

$Mask_1$ value for round 7 ($Mask_{1,7}$) = 33
Permutation Table = Sum of the block XOR $Mask_{1,7}$:
124 XOR 33 = 93
Therefore permutation table 93 shall be used for the permutation.

Block before permutation:

6 92 76 30 120 66 57 51 58 80

Block after permutation :

66 57 120 92 30 80 58 51 6 76

(b) First Key Addition.

$Mask_2$ value for round 7 ($Mask_{2,7}$) = 77
First key = Value 7 in the block XOR $Mask_{2,7}$:
58 XOR 77 = 119
Therefore, Key_{119} shall be used for the first key addition.

Block before key addition:

66 57 120 92 30 80 58 51 6 76

Block after key addition:

55 9 30 92 21 117 5? 32 16 97

(c) Second Key Addition.

Second key = Value 8 in the block XOR $Mask_{2,7}$:
32 XOR 77 = 109

Therefore, Key_{109} shall be used for the second key addition.

Block before key addition:

55 9 30 92 21 117 58 32 16 97

Block after key addition:

37 117 11 121 62 60 69 32 110 42

(d) Variable Enclave.

Enclave Table = value of $Mask_{3,7}$ (mod 32) = 49 mod 32 = 17

Therefore, enclave table 17 shall be used for the enclave.

Block before enclave:

37 117 11 121 62 60 69 32 110 42

Block after enclave:

80 95 116 23 78 60 94 113 112 2

(e) First Variable Substitution.

$Mask_4$ value for round 7 ($Mask_{4,7}$) = 102

First substitution table = Value 7 in block XOR $Mask_{4,7}$: 94 XOR 102 = 8

Therefore, substitution table 8 shall be used for the first substitution.

Block before substitution:

80 95 116 23 78 60 94 113 112 2

Block after substitution:

1 9 24 39 52 98 94 99 108 35

(f) Second Variable Substitution.

Second substitution table = Value 8 in block XOR $Mask_{4,7}$: 99 XOR 102 = 5

Therefore, substitution table 5 shall be used for the second substitution.

Block before substitution:

1 9 24 39 52 98 94 99 108 35

Block after substitution:

85 98 36 57 83 51 90 99 49 9

ROUND 8

BLOCK = 85 98 36 57 83 51 90 99 49 9

(a) Variable Permutation.

Add all values in block (mod 128):

85 + 98 + 36 + 57 + 83 + 51 + 90 + 99 + 49 + 9 = 657 mod 128 = 17

$Mask_1$ value for round 8 ($Mask_{1,8}$) = 50

Permutation Table = Sum of the block XOR $Mask_{1,8}$:

17 XOR 50 = 35

Therefore, permutation table 35 shall be used for the permutation.

Block before permutation:

85 98 36 57 83 51 90 99 49 9

Block after permutation:

98 49 90 83 99 36 57 51 85 9

(b) First Key Addition.

$Mask_2$ value for round 8 ($Mask_{2,8}$) = 43

First key = Value 8 in the block XOR $Mask_{2,8}$:

51 XOR 43 = 24

Therefore, Key_{24} shall be used for the first key addition.

Block before key addition:

98 49 90 83 99 36 57 51 85 9

Block after key addition:

64 86 38 82 89 88 18 51 79 87

(c) Second Key Addition.

Second key = Value 9 in the block XOR $Mask_{2,8}$:

79 XOR 43 = 100

Therefore, Key_{100} shall be used for the second key addition.

Block before key addition:

64 86 38 82 89 88 18 51 79 87

Block after key addition:

68 55 56 89 35 4 56 79 79 83

(d) Variable Enclave.

Enclave Table = value of $Mask_{3,8}$ (mod 32) = 71 mod 32 = 7

Therefore, enclave table 7 shall be used for the enclave.

Block before enclave:

68 55 56 89 35 4 56 79 79 83

Block after enclave:

7 63 70 6 113 40 96 62 19 61

(e) First Variable Substitution.

$Mask_4$ value for round 8 ($Mask_{4,8}$) = 101

First Substitution Table = Value 8 block XOR $Mask_{4,8}$:

62 XOR 101 = 11

Therefore, substitution table 11 shall be used for the first substitution.

Block before substitution:

7 63 70 6 113 40 96 62 19 61

Block after substitution:

87 48 91 121 80 94 52 62 110 70

(f) Second Variable Substitution.

Second substitution table = Value 9 in block XOR $Mask_{4,8}$

110 XOR 101 = 11

Therefore, substitution table 11 shall be used for the second substitution.

Block before substitution:

87 48 91 121 80 94 52 62 110 70

Block after substitution:

25 124 95 23 67 88 102 79 110 91

ROUND 9

BLOCK = 25 124 95 23 67 88 102 79 110 91

(a) Variable Permutation.

Add all values in block (mod 128):

25 + 124 + 95 + 23 + 67 + 88 + 102 + 79 + 110 + 91 = 804

mod 128 = 36

$Mask_1$ value for round 9 ($Mask_{1,9}$) = 11

Permutation Table = Sum of the block XOR $Mask_{1,9}$:

36 XOR 11 = 47

Therefore, permutation table 47 shall be used for the permutation.

Block before permutation:

25 124 95 23 67 88 102 79 110 91

Block after permutation:

91 95 124 79 88 23 25 102 110 67

(b) First Key Addition.

$Mask_2$ value for round 9 ($Mask_{2,9}$) = 9

First key = Value 9 in the block XOR $Mask_{2,9}$:

110 XOR 9 = 103

Therefore, Key_{103} shall be used for the first key addition.

Block before key addition:

91 95 124 79 88 23 25 102 110 67

Block after key addition :

80 72 99 87 98 39 46 44 110 44

(c) Second Key Addition

Second key = Value 10 in the block XOR $Mask_{2,9}$:

44 XOR 9 = 37

Therefore, Key_{37} shall be used for the second key addition.

Block before key addition:

80 72 99 87 98 39 46 44 110 44

Block after key addition:

71 120 20 6 114 89 109 32 69 44

(d) Variable Enclave.

Enclave Table = value of Mask 3,9 (mod 32) = 24 mod 32 = 24

Therefore, enclave table 24 shall be used for the enclave.

Block before enclave:

71 120 20 114 89 109 32 69 44

Block after enclave:

41 71 57 98 55 2 41 99 106 92

(e) First Variable Substitution.

$Mask_4$ value for round 9 ($Mask_{4,9}$) = 32

First Substitution Table = Value 9 in block XOR $Mask_{4,9}$:

106 XOR 32 = 10

Therefore, substitution table 10 shall be used for the first substitution.

Block before substitution:

41 71 57 98 55 2 41 99 106 92

Block after substitution:

104 42 89 39 72 31 104 10 106 67

(f) Second Variable Substitution.

Second Substitution Table = Value 10 in block XOR $Mask_{4,9}$:

67 XOR 32 = 3

Therefore, substitution table 3 shall be used for the second substitution.

Block before substitution:

104 42 89 39 72 31 104 10 106 67

Block after substitution:

24 49 88 105 94 71 24 124 125 67

ROUND 10

BLOCK = 24 49 88 105 94 71 24 124 125 67

(a) Variable Permutation.

Add all values in block (mod 128):

24 + 49 + 88 + 105 + 94 + 71 + 24 + 124 + 125 + 67 = 771

mod 128 = 3

$Mask_1$ value for round 10 ($Mask_{1,10}$) = 60

Permutation Table = Sum of the block XOR $Mask_{1,10}$:

3 XOR 60 = 63

Therefore, permutation table 63 shall be used for the permutation.

Block before permutation:

24 49 88 105 94 71 24 124 125 67

Block after permutation:

67 124 105 88 125 24 24 94 49 71

(b) First Key Addition.

$Mask_2$ value for round 10 ($Mask_{2,10}$) = 99

First Key = Value 10 in the block XOR $Mask_{2,10}$:

71 XOR 99 = 36

Therefore, Key_{36} shall be used for the first key addition.

Block before key addition:

67 124 105 88 125 24 24 94 49 71

Block after key addition:

110 9 114 70 70 96 91 117 12 71

(c) Second Key Addition.

Second key = Value 10 in the block XOR $Mask_{2,10}$:

71 XOR 99 = 36

Therefore, Key_{36} shall be used for the second key addition.

Block before key addition:

110 9 114 70 70 96 91 117 12 71

Block after key addition:

67 124 105 88 125 24 24 94 49 71

(d) Variable Enclave.

Enclave Table = value of $Mask_{3,10}$ (mod 32) = 60 mod 32 = 28

Therefore, enclave table 28 shall be used for the enclave.

Block before enclave:

67 124 105 88 125 24 24 94 49 71

Block after enclave:

36 31 0 91 41 84 71 38 87 122

(e) First Variable Substitution.

$Mask_4$ value for round 10 ($Mask_{4,10}$) = 125

First Substitution Table = Value 10 in block XOR $Mask_{4,10}$:

122 XOR 125 = 7

Therefore, substitution table 7 shall be used for the first substitution.

Block before substitution:

36 31 0 91 41 84 71 38 87 122

Block after substitution:

90 27 11 41 114 117 56 33 72 122

(f) Second Variable Substitution.

Second Substitution Table = Value 10 in block XOR $Mask_{4,10}$:

122 XOR 125 = 7

Therefore, substitution table 7 shall be used for the second substitution.

Block before substitution:

90 27 11 41 114 117 56 33 72 122

Block after substitution:

28 4 87 114 88 23 122 105 44 122

TRANSMITTED BLOCK:

28 4 87 114 88 23 122 105 44 122

After ten rounds of encryption in accordance with the present invention, the plaintext block has been converted into a ciphertext block as follows:

Plaintext:

110 111 32 116 101 115 116 115 32 112

Ciphertext:

28 4 87 114 88 23 122 105 144 122

Having described above the presently preferred embodiments of this invention, it is to be understood that it may be otherwise embodied within the scope of the appended claims.

TABLE I - PERMUTATION TABLE

Perm 0	=	1	6	7	9	10	2	5	8	3	4
Perm 1	=	10	4	8	3	1	7	2	9	5	6
Perm 2	=	1	6	4	9	8	5	10	2	3	7
Perm 3	=	9	8	3	4	5	10	6	1	7	2
Perm 4	=	9	4	6	3	8	1	10	2	5	7
Perm 5	=	5	2	4	9	1	6	10	7	8	3
Perm 6	=	2	8	6	1	5	9	3	4	10	7
Perm 7	=	7	8	10	2	5	4	3	1	9	6
Perm 8	=	1	2	10	3	8	7	4	6	9	5
Perm 9	=	10	8	2	3	5	9	7	1	6	4
Perm 10	=	7	3	8	5	4	1	2	9	10	6
Perm 11	=	6	5	7	2	10	4	3	9	1	8
Perm 12	=	8	5	2	7	6	3	9	1	4	10
Perm 13	=	4	1	6	7	5	10	2	3	8	9
Perm 14	=	10	2	7	1	5	4	8	9	6	3
Perm 15	=	3	5	7	9	8	1	2	10	4	6
Perm 16	=	6	8	9	5	3	7	10	4	1	2
Perm 17	=	2	6	1	4	7	5	3	9	10	8
Perm 18	=	2	5	4	9	10	3	8	6	7	1
Perm 19	=	3	10	5	8	6	7	4	2	1	9
Perm 20	=	9	10	5	6	3	7	2	1	4	8
Perm 21	=	3	5	4	7	6	1	2	8	10	9
Perm 22	=	6	5	2	7	1	9	10	8	3	4
Perm 23	=	4	1	3	6	7	8	9	10	5	2
Perm 24	=	7	3	5	1	6	4	9	10	8	2
Perm 25	=	7	5	4	9	1	3	6	8	10	2
Perm 26	=	7	1	5	10	9	2	4	6	8	3
Perm 27	=	5	1	3	10	9	7	8	2	4	6
Perm 28	=	6	3	4	9	1	8	2	7	5	10
Perm 29	=	1	2	4	9	7	3	10	8	5	6
Perm 30	=	8	2	9	4	3	7	1	6	10	5
Perm 31	=	3	4	9	10	8	5	1	6	2	7
Perm 32	=	9	10	2	1	6	8	4	5	7	3
Perm 33	=	5	1	7	6	4	8	9	10	2	3
Perm 34	=	10	3	6	9	4	2	5	7	8	1
Perm 35	=	9	1	6	7	4	8	3	5	2	10
Perm 36	=	8	9	4	7	10	2	6	1	5	3
Perm 37	=	4	6	7	5	2	1	3	9	10	8
Perm 38	=	3	9	7	4	10	2	1	6	8	5
Perm 39	=	2	4	5	6	7	10	1	8	9	3
Perm 40	=	5	1	2	4	8	10	6	9	7	3
Perm 41	=	10	1	5	8	2	7	4	6	3	9
Perm 42	=	5	3	4	9	2	10	7	6	1	8
Perm 43	=	6	5	10	4	1	2	9	8	3	7
Perm 44	=	9	1	7	6	4	5	10	3	8	2
Perm 45	=	9	7	2	10	5	8	4	6	3	1
Perm 46	=	4	10	5	1	2	8	7	9	6	3
Perm 47	=	7	3	2	6	10	5	8	4	9	1
Perm 48	=	3	1	6	9	7	10	5	2	8	4
Perm 49	=	6	4	2	1	7	3	9	10	5	8
Perm 50	=	2	8	3	9	7	1	6	4	5	10
Perm 51	=	3	10	4	7	1	5	6	2	8	9
Perm 52	=	5	1	3	6	10	4	7	9	2	8

Perm 53	=	10	5	2	4	9	1	6	7	8	3
Perm 54	=	5	9	2	8	6	3	4	10	1	7
Perm 55	=	6	1	5	10	8	4	2	3	9	7
Perm 56	=	2	9	3	1	6	10	8	4	5	7
Perm 57	=	2	5	3	6	10	9	1	8	7	4
Perm 58	=	9	7	1	6	10	2	3	5	4	8
Perm 59	=	2	10	4	5	1	9	6	7	8	3
Perm 60	=	7	2	6	4	1	9	10	3	8	5
Perm 61	=	3	2	4	5	8	10	7	6	9	1
Perm 62	=	1	7	8	3	9	10	6	5	4	2
Perm 63	=	6	9	4	3	8	10	7	2	5	1
Perm 64	=	7	1	6	2	4	5	8	10	3	9
Perm 65	=	7	2	5	9	1	6	10	3	4	8
Perm 66	=	10	5	4	3	8	9	1	6	7	2
Perm 67	=	9	2	3	6	8	7	5	4	1	10
Perm 68	=	9	4	6	10	8	7	5	1	3	2
Perm 69	=	1	2	7	3	4	5	10	8	6	9
Perm 70	=	2	6	8	5	10	1	3	4	9	7
Perm 71	=	9	4	3	1	5	6	10	8	2	7
Perm 72	=	1	8	7	10	3	9	6	4	5	2
Perm 73	=	3	10	7	9	4	6	5	1	8	2
Perm 74	=	8	5	9	6	7	10	3	4	2	1
Perm 75	=	8	4	10	1	6	5	9	2	7	3
Perm 76	=	8	6	9	10	5	7	1	4	2	3
Perm 77	=	10	4	5	7	8	6	9	3	2	1
Perm 78	=	1	5	8	10	3	9	6	7	4	2
Perm 79	=	4	9	7	5	8	2	3	1	10	6
Perm 80	=	1	8	9	7	3	2	5	6	10	4
Perm 81	=	1	2	9	8	5	4	6	7	3	10
Perm 82	=	7	9	6	2	1	8	4	10	5	3
Perm 83	=	10	4	8	3	5	2	6	9	1	7
Perm 84	=	8	5	7	3	2	9	1	4	6	10
Perm 85	=	9	10	3	1	4	7	6	5	8	2
Perm 86	=	9	7	2	6	5	8	3	10	1	4
Perm 87	=	5	3	8	1	9	7	10	2	4	6
Perm 88	=	6	9	1	8	2	3	7	10	5	4
Perm 89	=	4	7	9	5	2	8	10	3	6	1
Perm 90	=	8	5	1	4	6	9	2	10	3	7
Perm 91	=	10	2	4	8	3	7	9	5	6	1
Perm 92	=	4	2	3	9	5	7	8	10	1	6
Perm 93	=	9	4	10	5	3	1	2	8	7	6
Perm 94	=	3	2	6	5	4	9	8	10	7	1
Perm 95	=	6	4	10	3	7	9	5	1	2	8
Perm 96	=	6	8	2	9	3	10	7	5	4	1
Perm 97	=	10	4	8	7	9	5	3	2	1	6
Perm 98	=	2	1	5	7	10	9	3	8	6	4
Perm 99	=	3	6	10	5	8	2	9	7	4	1
Perm 100	=	3	8	2	6	7	5	4	9	1	10
Perm 101	=	8	1	9	3	6	7	4	10	2	5
Perm 102	=	4	10	2	8	6	3	9	5	7	1
Perm 103	=	4	8	2	3	7	1	10	5	6	9
Perm 104	=	8	5	1	7	4	6	2	3	10	9
Perm 105	=	7	10	5	1	6	8	4	3	9	2
Perm 106	=	2	5	3	8	10	9	6	4	1	7
Perm 107	=	2	9	6	1	7	8	5	4	3	10

Perm 108 =	4	2	3	10	9	5	7	8	6	1
Perm 109 =	5	2	10	8	4	1	3	7	6	9
Perm 110 =	6	5	8	3	7	4	9	10	2	1
Perm 111 =	10	7	1	3	6	4	9	2	5	8
Perm 112 =	9	7	8	4	6	1	2	5	3	10
Perm 113 =	3	4	8	7	2	5	10	9	1	6
Perm 114 =	5	8	7	1	9	2	6	10	4	3
Perm 115 =	5	4	3	1	2	8	10	7	9	6
Perm 116 =	9	7	1	3	5	6	8	2	4	10
Perm 117 =	9	4	10	6	1	2	7	5	3	8
Perm 118 =	1	6	5	10	9	8	2	7	4	3
Perm 119 =	10	3	8	2	5	6	7	1	9	4
Perm 120 =	6	10	2	5	8	3	4	9	7	1
Perm 121 =	6	1	8	10	5	4	2	7	9	3
Perm 122 =	9	10	8	2	5	1	3	7	4	6
Perm 123 =	1	3	7	6	2	9	5	4	10	8
Perm 124 =	7	6	1	5	3	9	8	2	10	4
Perm 125 =	4	7	10	6	1	8	2	5	3	9
Perm 126 =	9	8	3	7	1	10	5	6	2	4
Perm 127 =	7	8	5	10	9	3	4	2	1	6

TABLE IIA - SUBSTITUTION TABLE - PART A

ORIGINAL	TBL 0	TBL 1	TBL 2	TBL 3	TBL 4	TBL 5	TBL 6	TBL 7
0	90	47	19	90	25	123	55	11
1	46	89	44	26	51	85	122	54
2	66	87	95	75	103	71	123	82
3	21	20	25	106	116	13	7	62
4	50	15	87	4	37	117	68	101
5	57	84	38	54	88	92	94	70
6	84	0	36	46	122	47	88	108
7	67	65	125	41	7	107	79	119
8	80	83	111	115	15	29	110	17
9	91	4	71	107	44	98	117	121
10	44	49	97	124	13	104	47	124
11	124	70	43	36	111	108	67	87
12	94	66	35	113	30	58	83	25
13	126	110	84	126	120	48	69	74
14	25	37	94	123	106	60	9	7
15	125	73	107	35	114	89	93	126
16	8	127	58	67	27	21	13	29
17	37	68	24	58	4	14	120	111
18	82	38	98	109	89	112	62	79
19	28	64	4	52	78	121	37	58
20	33	103	89	101	23	118	90	18
21	14	124	53	10	34	67	10	77
22	30	96	63	72	107	79	115	116
23	115	126	52	114	126	22	98	102
24	0	85	96	14	123	36	52	14
25	71	112	33	42	12	24	85	107
26	83	111	100	7	112	31	77	8
27	68	86	116	98	117	41	50	4
28	18	74	108	84	96	97	109	12
29	123	53	28	43	50	10	104	92

30	92	52	10	62	80	65	76	66
31	34	82	93	71	102	52	95	27
32	74	123	102	39	119	32	64	84
33	97	93	65	31	81	81	44	105
34	4	79	51	2	82	37	111	113
35	53	9	83	5	101	9	2	45
36	76	80	91	80	8	122	59	90
37	27	33	55	91	72	6	33	96
38	5	10	99	37	67	73	80	33
39	35	27	110	105	108	57	78	52
40	70	35	117	20	47	116	40	65
41	43	88	56	34	21	35	45	114
42	127	48	127	49	6	111	17	83
43	79	19	86	61	66	18	31	98
44	81	61	42	70	109	0	87	34
45	16	45	120	44	35	1	22	115
46	42	60	77	116	48	94	73	50
47	32	40	18	87	94	26	15	75
48	51	125	16	112	26	66	82	61
49	106	36	67	111	97	115	61	20
50	104	92	39	15	65	91	75	109
51	120	57	14	29	85	55	118	118
52	87	95	122	120	77	83	89	97
53	48	99	72	11	99	82	25	43
54	22	3	15	85	52	2	42	49
55	45	67	73	97	57	11	74	36
56	118	105	62	78	113	27	43	122
57	54	75	13	73	39	87	48	15
58	75	5	113	3	83	77	36	81
59	10	71	69	74	74	88	4	89
60	121	116	31	1	16	16	0	123
61	85	77	79	65	49	86	51	10
62	119	100	57	122	121	5	53	9
63	100	98	92	102	93	56	97	63
64	61	101	78	25	61	113	126	100
65	116	115	76	79	68	40	92	93
66	110	44	103	77	62	7	16	16
67	86	30	121	9	84	72	119	30
68	89	56	109	32	29	38	32	32
69	9	81	106	63	0	46	8	31
70	12	51	26	28	118	100	108	22
71	13	32	37	103	17	84	24	56
72	108	117	54	94	98	74	106	44
73	69	26	40	68	110	68	49	110
74	93	76	9	81	54	114	124	91
75	55	120	32	47	18	19	21	120
76	1	54	80	59	115	80	107	69
77	52	1	8	92	60	54	121	13
78	95	104	48	56	46	17	6	1
79	20	121	41	121	73	93	101	103
80	107	69	115	99	28	99	63	6
81	64	72	23	8	86	95	60	40
82	29	24	1	23	53	44	27	21
83	23	41	27	51	127	78	71	86
84	47	8	74	64	100	119	38	117

85	40	63	60	57	91	15	39	112
86	26	12	46	89	63	125	127	78
87	58	31	112	40	71	4	102	72
88	114	102	64	27	45	110	99	24
89	65	113	50	88	31	12	58	42
90	17	109	49	127	14	45	100	28
91	36	25	17	6	43	28	11	41
92	59	13	114	50	36	43	86	39
93	2	91	0	12	33	3	34	53
94	72	2	81	38	90	90	56	104
95	39	21	90	86	87	124	113	37
96	111	17	105	69	32	101	5	60
97	15	55	47	18	64	127	103	57
98	38	22	126	119	38	51	41	68
99	60	122	66	48	5	69	19	35
100	103	16	119	21	55	120	84	67
101	19	18	61	16	56	23	14	0
102	102	106	2	22	124	126	70	19
103	77	39	5	33	3	61	112	71
104	99	94	59	24	70	96	28	73
105	109	6	101	66	58	75	81	95
106	98	97	6	125	19	102	72	80
107	56	7	70	0	79	25	26	106
108	88	29	12	104	59	49	96	46
109	96	46	123	82	40	109	65	64
110	11	23	85	110	42	30	18	99
111	6	108	29	76	104	33	46	85
112	73	78	20	45	10	103	54	5
113	101	58	7	13	75	50	23	38
114	117	114	45	118	125	63	57	88
115	62	90	68	117	2	76	35	26
116	112	107	82	19	95	53	29	55
117	41	59	30	83	1	64	66	23
118	105	28	3	17	69	70	114	48
119	63	34	34	100	22	8	105	51
120	113	50	124	96	92	105	12	59
121	7	11	21	95	24	62	1	94
122	78	43	88	60	20	20	91	3
123	49	119	104	30	9	34	125	127
124	3	42	11	53	41	42	20	47
125	31	118	118	93	76	59	30	2
126	24	14	75	55	105	106	3	125
127	122	62	22	108	11	39	116	76

TABLE IIB - SUBSTITUTION TABLE - PART B

ORIGINAL	TBL 8	TBL 9	TBL 10	TBL 11	TBL 12	TBL 13	TBL 14	TBL 15
0	42	18	66	24	119	121	73	0
1	32	124	13	0	58	56	36	52
2	35	109	31	69	27	78	107	44
3	20	17	7	53	70	58	43	83
4	13	37	97	45	120	8	2	40
5	38	119	91	26	0	85	28	54
6	14	100	49	121	57	79	54	28

7	2	89	56	87	17	51	31	7
8	78	83	51	82	6	77	50	51
9	81	96	9	22	35	123	93	110
10	118	28	15	97	7	42	29	20
11	59	52	93	127	94	87	0	106
12	46	102	87	78	102	15	34	35
13	107	126	45	59	108	112	48	92
14	31	91	33	68	77	38	104	67
15	8	104	46	116	117	111	22	30
16	115	35	98	106	99	23	25	60
17	61	26	70	83	82	125	92	123
18	82	105	95	107	30	12	94	38
19	49	62	115	110	67	66	96	101
20	102	85	20	35	15	45	72	4
21	87	15	11	29	95	105	5	97
22	125	125	82	104	32	35	63	26
23	39	66	6	33	79	25	98	56
24	117	107	85	118	121	24	109	111
25	53	21	123	76	59	52	125	99
26	116	110	19	18	78	60	76	70
27	80	50	79	114	40	33	23	126
28	30	48	119	54	48	0	42	8
29	25	67	24	63	81	7	99	112
30	112	111	74	74	9	115	47	95
31	57	5	3	41	3	16	11	81
32	50	63	16	71	16	100	57	117
33	40	90	116	123	72	5	84	41
34	120	59	103	112	127	44	20	90
35	105	106	0	32	41	119	69	5
36	21	80	23	2	106	18	70	55
37	47	9	122	125	112	62	120	14
38	101	57	40	100	63	89	52	109
39	94	116	62	34	13	92	83	127
40	5	81	105	94	71	13	24	74
41	76	99	104	5	47	11	39	80
42	54	19	32	19	28	3	115	21
43	34	84	37	46	60	49	26	119
44	92	77	17	4	25	99	71	64
45	66	49	113	115	11	117	60	100
46	15	123	99	13	51	86	61	42
47	111	33	77	117	19	1	85	73
48	127	1	55	124	92	127	35	94
49	100	60	18	62	76	26	95	23
50	77	98	38	56	100	22	102	48
51	7	65	35	92	87	54	21	19
52	19	38	68	102	4	84	89	82
53	70	41	86	55	122	41	117	116
54	68	95	44	108	85	98	90	33
55	104	58	72	51	90	57	67	88
56	48	118	73	72	46	61	17	9
57	83	97	89	50	105	43	81	18
58	71	88	48	37	8	97	62	46
59	119	72	47	8	24	114	113	66
60	98	46	118	36	54	74	32	108
61	72	23	90	70	123	73	37	59

62	89	120	1	79	1	9	127	114
63	85	2	41	48	89	71	38	71
64	41	29	58	89	118	122	126	34
65	109	93	107	9	52	76	82	122
66	62	44	8	15	61	102	7	39
67	74	34	112	111	96	19	10	102
68	22	40	14	122	86	120	78	118
69	0	45	102	90	83	47	41	53
70	121	16	100	91	2	116	8	16
71	29	30	42	58	33	82	87	31
72	114	112	5	86	37	91	112	125
73	3	117	53	75	114	69	106	75
74	91	22	88	93	38	37	86	62
75	36	115	64	120	111	59	88	13
76	4	24	109	3	107	113	30	32
77	51	122	108	40	62	101	44	27
78	52	114	101	7	50	67	121	86
79	86	70	2	17	126	68	97	57
80	1	36	71	67	84	28	119	87
81	67	73	124	119	73	107	6	10
82	43	47	27	42	125	118	105	76
83	103	121	92	27	44	81	40	24
84	63	27	43	77	88	14	4	107
85	113	71	121	43	45	80	64	25
86	56	43	57	64	49	72	118	36
87	55	87	84	25	116	106	101	105
88	18	3	75	30	14	94	79	72
89	96	79	78	109	68	126	123	78
90	75	75	26	103	29	109	103	2
91	6	101	111	95	65	53	53	12
92	11	74	67	126	31	83	12	47
93	110	108	126	16	110	50	124	37
94	45	0	110	88	36	10	19	91
95	9	42	117	113	39	32	9	98
96	16	82	34	52	103	17	110	43
97	124	39	50	11	109	110	80	11
98	69	53	39	98	5	29	14	103
99	95	10	10	49	10	34	108	85
100	79	20	12	99	69	2	15	63
101	126	54	127	21	124	103	100	104
102	97	113	65	57	18	21	68	1
103	88	4	83	44	21	6	1	124
104	60	64	28	12	104	20	3	15
105	26	7	30	84	43	90	91	65
106	33	11	61	28	23	46	18	93
107	123	92	81	105	93	30	27	58
108	28	32	60	10	101	36	59	17
109	64	13	54	85	74	96	55	77
110	23	55	21	73	20	88	46	84
111	12	103	25	6	56	65	65	61
112	108	51	94	14	26	4	33	121
113	99	94	125	80	22	48	111	29
114	106	31	59	96	91	27	56	45
115	65	56	36	60	34	63	13	22
116	24	86	69	38	98	75	114	115

117	10	61	96	66	42	40	66	68
118	17	6	29	20	113	55	122	3
119	90	78	22	1	80	124	75	113
120	93	127	76	31	66	64	74	89
121	73	76	80	23	53	104	45	96
122	122	14	4	39	97	70	51	49
123	44	25	106	81	12	95	16	69
14	37	8	120	61	115	108	116	120
125	84	12	52	65	55	39	58	50
126	27	68	114	47	75	31	77	6
127	58	69	63	101	64	93	49	79

TABLE III - ENCLAVE TABLE

	a	b	c	d
TABLE 0:	5 2 3 4 3 1 2 5 4 1 4 5 3 1 2	3 5 2 1 3 5 2 4 1 5 1 4 4 2 3	5 4 2 4 3 1 1 5 3 3 2 5 2 1 4	5 4 2 2 5 1 1 3 5 3 2 4 4 1 3
TABLE 1:	3 1 2 4 3 1 2 5 4 5 2 3 1 4 5	3 2 5 5 1 4 2 4 3 4 3 1 1 5 2	4 2 1 3 4 5 5 1 4 1 3 2 2 5 3	4 2 3 5 3 1 2 1 5 3 5 4 1 4 2
TABLE 2:	4 1 3 1 2 5 3 5 1 2 3 4 5 4 2	1 4 2 4 5 3 2 1 4 3 2 5 5 3 1	2 5 3 3 2 5 4 3 1 1 4 2 5 1 4	2 5 3 4 3 5 3 2 1 5 1 4 1 4 2
TABLE 3:	1 2 4 4 5 1 2 3 5 3 4 2 5 1 3	5 3 4 4 5 2 2 1 3 3 4 1 1 2 5	2 4 5 4 2 1 1 5 3 5 3 4 3 1 2	4 2 3 2 5 4 5 3 1 3 1 2 1 4 5
TABLE 4:	2 5 3 4 1 2 5 2 4 1 3 5 3 4 1	2 3 1 4 2 5 5 1 4 1 4 3 3 5 2	4 2 1 1 4 2 2 3 5 3 5 4 5 1 3	2 5 3 1 4 5 4 3 2 3 2 1 5 1 4

TABLE 5:

1 4 3	2 4 1	2 3 4	5 3 1
5 1 2	4 5 3	3 1 2	3 5 2
2 3 4	1 2 5	1 5 3	1 4 3
3 2 5	5 3 4	5 4 1	4 2 5
4 5 1	3 1 2	4 2 5	2 1 4

TABLE 6:

1 5 4	1 5 2	3 5 2	5 1 4
3 1 2	2 1 3	4 2 1	3 4 2
5 4 3	4 3 5	1 3 4	4 3 1
4 2 5	3 4 1	2 4 5	1 2 5
2 3 1	5 2 4	5 1 3	2 5 3

TABLE 7:

2 5 1	2 1 5	5 4 2	3 5 4
5 1 2	1 5 2	2 1 3	4 3 2
3 4 5	5 4 3	3 2 5	5 2 1
4 2 3	4 3 1	4 3 1	2 1 5
1 3 4	3 2 4	1 5 4	1 4 3

TABLE 8:

2 5 4	1 2 4	4 2 5	2 3 1
1 2 3	5 3 1	2 3 4	5 2 4
3 4 1	2 4 5	1 5 3	1 5 2
4 3 5	3 5 2	5 1 2	3 4 5
5 1 2	4 1 3	3 4 1	4 1 3

TABLE 9:

1 3 2	4 1 2	4 5 1	4 3 2
5 1 3	1 3 5	1 2 3	3 1 5
2 5 4	3 2 1	5 3 2	5 4 1
4 2 5	5 4 3	3 4 5	2 5 3
3 4 1	2 5 4	2 1 4	1 2 4

TABLE 10:

1 4 3	5 4 3	5 2 3	2 5 1
2 5 1	2 3 5	1 4 5	3 4 2
3 1 5	1 5 4	3 1 2	5 1 4
5 2 4	3 1 2	2 5 4	1 2 3
4 3 2	4 2 1	4 3 1	4 3 5

TABLE 11:

5 1 2	1 4 2	2 4 5	3 1 4
4 5 3	2 3 1	3 5 4	2 4 3
1 2 4	5 1 4	1 2 3	5 2 1
3 4 5	4 5 3	5 1 2	4 3 5
2 3 1	3 2 5	4 3 1	1 5 2

TABLE 12:

4 1 2	2 5 3	5 3 2	5 1 4
5 4 3	4 2 5	2 1 4	4 5 2
2 3 1	5 1 4	4 5 1	3 2 1
1 2 5	3 4 1	1 4 3	1 4 3
3 5 4	1 3 2	3 2 5	2 3 5

TABLE 13:

2 3 1	4 2 5	3 2 4	5 2 4
1 4 2	5 3 1	2 4 5	3 1 5
5 2 4	2 5 4	4 3 1	4 5 1
3 1 5	3 1 2	5 1 2	2 4 3
4 5 3	1 4 3	1 5 3	1 3 2

TABLE 14:

5 3 2	2 3 4	4 3 1	4 2 5
3 2 5	5 1 2	2 4 5	1 5 2
2 1 4	4 2 5	1 5 2	3 4 1
1 4 3	1 4 3	3 2 4	2 1 3
4 5 1	3 5 1	5 1 3	5 3 4

TABLE 15:

1 2 5	3 5 1	5 3 2	2 3 5
5 4 2	5 3 4	1 4 5	5 1 3
3 5 4	2 4 3	4 2 3	1 2 4
2 3 1	4 1 2	2 5 1	3 4 2
4 1 3	1 2 5	3 1 4	4 5 1

TABLE 16:

2 4 1	2 3 1	2 1 5	5 1 3
4 5 2	3 4 5	1 4 3	3 2 1
1 2 3	4 5 2	5 3 2	4 5 2
3 1 5	1 2 4	3 2 4	2 3 4
5 3 4	5 1 3	4 5 1	1 4 5

TABLE 17:

4 3 5	2 3 5	5 2 1	5 3 4
3 2 4	4 5 1	1 3 2	3 5 1
5 1 2	5 1 3	3 5 4	1 4 2
2 4 1	3 2 4	2 4 5	2 1 5
1 5 3	1 4 2	4 1 3	4 2 3

TABLE 18:

2 4 1	3 1 4	5 1 4	5 3 1
4 3 5	1 5 3	2 5 1	4 1 3
1 2 4	4 3 2	4 3 2	1 4 2
5 1 3	2 4 5	3 4 5	3 2 5
3 5 2	5 2 1	1 2 3	2 5 4

TABLE 19:

2 5 3	4 1 3	2 5 3	4 5 2
4 3 5	3 4 2	1 3 2	3 2 5
3 4 1	1 3 5	4 1 5	5 1 3
5 1 2	2 5 1	5 4 1	2 4 1
1 2 4	5 2 4	3 2 4	1 3 4

TABLE 20:

3 1 4	4 2 1	4 2 1	3 4 2
2 4 5	3 1 4	2 1 4	5 1 4
1 5 2	2 3 5	1 3 5	2 3 1
5 2 3	1 5 3	3 5 2	1 5 3
4 3 1	5 4 2	5 4 3	4 2 5

TABLE 21:

2 4 5	5 2 3	4 5 3	1 3 2
3 5 1	3 4 2	5 4 2	2 1 4
5 1 2	4 5 1	2 3 1	3 2 5
1 3 4	1 3 5	1 2 5	4 5 1
4 2 3	2 1 4	3 1 4	5 4 3

TABLE 22:

3 1 4	4 5 1	1 3 4	2 5 1
5 4 2	5 2 3	2 5 1	5 3 4
1 5 3	2 3 5	5 1 2	3 4 2
4 2 5	1 4 2	4 2 3	1 2 5
2 3 1	3 1 4	3 4 5	4 1 3

TABLE 23:

2 3 5	4 1 5	5 2 3	1 3 2
1 4 3	3 2 1	2 3 1	4 1 5
4 5 2	5 4 2	4 1 5	2 4 1
5 2 1	1 3 4	1 4 2	3 5 4
3 1 4	2 5 3	3 5 4	5 2 3

TABLE 24:

2 1 5	3 5 2	3 2 5	3 2 1
5 4 3	2 3 1	1 4 2	4 1 5
3 2 4	1 4 3	2 5 3	1 5 4
4 5 1	5 1 4	5 1 4	2 4 3
1 3 2	4 2 5	4 3 1	5 3 2

TABLE 25:

4 5 2	4 2 1	2 5 3	4 3 1
3 1 4	5 3 4	3 2 4	1 4 5
1 3 5	2 1 3	1 4 5	2 5 3
5 2 3	3 5 2	5 1 2	3 1 2
2 4 1	1 4 5	4 3 1	5 2 4

TABLE 26:

4 2 5	5 4 3	3 2 1	1 4 5
1 4 2	2 1 4	5 3 4	5 2 3
2 3 4	1 3 5	2 1 5	3 1 2
5 1 3	4 2 1	4 5 3	4 5 1
3 5 1	3 5 2	1 4 2	2 3 4

TABLE 27:

2 1 5	2 5 1	3 2 5	4 5 2
4 2 3	4 1 3	1 3 2	2 4 5
1 4 2	1 3 5	2 4 1	1 3 4
5 3 4	3 4 2	5 1 4	5 1 3
3 5 1	5 2 4	4 5 3	3 2 1

TABLE 28:

3 1 5	5 4 3	4 1 3	3 4 5
5 3 4	2 3 1	3 2 5	5 2 1
4 2 1	4 2 5	1 5 2	4 1 3
1 4 2	3 1 2	2 3 4	2 5 4
2 5 3	1 5 4	5 4 1	1 3 2

TABLE 29:

4	5	3	4	3	2	2	3	1	3	4	2
5	1	4	2	5	1	4	5	2	2	1	4
1	3	2	5	4	3	5	2	4	4	3	5
3	2	5	1	2	4	1	4	3	5	2	1
2	4	1	3	1	5	3	1	5	1	5	3

TABLE 30:

2	4	1	2	4	3	1	5	3	4	1	5
3	5	4	4	1	2	2	4	1	3	5	2
5	1	3	3	5	4	4	3	2	1	4	3
1	2	5	5	2	1	5	2	4	2	3	4
4	3	2	1	3	5	3	1	5	5	2	1

TABLE 31:

5	3	1	4	1	5	4	2	3	1	5	2
1	2	4	2	3	1	3	5	4	3	1	4
3	1	5	1	5	3	1	4	2	4	2	1
4	5	2	3	4	2	5	3	1	2	3	5
2	4	3	5	2	4	2	1	5	5	4	3

TABLE IV - KEY TABLE

KEY 0 =	0	34	55	63	9	73	74	107	109	33
KEY 1 =	10	62	48	85	32	101	8	0	63	56
KEY 2 =	26	59	75	97	33	80	8	6	73	26
KEY 3 =	0	92	102	108	73	29	43	98	31	118
KEY 4 =	102	110	121	22	60	56	24	124	118	15
KEY 5 =	105	67	89	14	80	51	28	122	26	115
KEY 6 =	111	105	44	0	42	63	14	121	49	28
KEY 7 =	91	70	52	58	88	15	107	22	51	48
KEY 8 =	95	91	21	22	109	80	79	64	60	2
KEY 9 =	68	53	115	99	54	56	91	56	27	27
KEY 10 =	6	86	116	122	38	79	83	116	48	60
KEY 11 =	70	31	48	44	121	44	0	55	34	57
KEY 12 =	95	73	50	69	67	22	21	79	24	9
KEY 13 =	67	102	117	6	28	24	2	0	93	107
KEY 14 =	55	122	97	98	34	124	50	69	37	4
KEY 15 =	39	68	62	31	70	44	97	41	87	101
KEY 16 =	109	34	27	6	81	46	22	112	39	19
KEY 17 =	23	109	58	95	9	78	93	109	65	87
KEY 18 =	39	6	95	39	112	79	10	17	51	63
KEY 19 =	31	122	83	97	18	22	113	37	50	69
KEY 20 =	120	118	120	45	97	50	105	70	9	37
KEY 21 =	50	44	32	62	83	85	121	44	43	19
KEY 22 =	46	10	0	107	120	87	58	68	56	69
KEY 23 =	71	119	36	74	123	87	96	68	70	39
KEY 24 =	34	103	124	1	58	124	43	15	26	94
KEY 25 =	48	74	74	90	90	61	30	120	0	120
KEY 26 =	105	115	120	31	55	29	70	24	61	107
KEY 27 =	51	107	57	32	29	9	59	50	18	95
KEY 28 =	45	4	53	89	114	78	73	56	105	48
KEY 29 =	123	68	4	24	30	1	47	48	97	83
KEY 30 =	4	84	30	125	59	11	74	74	38	62
KEY 31 =	1	92	44	83	92	109	82	106	17	35
KEY 32 =	105	96	0	11	16	108	0	70	39	109

KEY 33 =	85	49	62	75	1	41	29	123	87	14
KEY 34 =	31	29	51	125	101	42	123	98	45	69
KEY 35 =	67	114	81	52	121	45	51	32	86	98
KEY 36 =	45	117	27	30	59	120	67	43	61	124
KEY 37 =	23	48	119	81	16	126	67	12	43	98
KEY 38 =	11	47	51	0	113	122	20	26	123	17
KEY 39 =	57	121	57	28	91	30	123	61	91	60
KEY 40 =	65	123	111	68	34	94	79	92	15	88
KEY 41 =	59	89	79	104	121	43	46	27	6	50
KEY 42 =	120	47	47	85	117	120	50	42	89	51
KEY 43 =	16	14	103	12	126	30	107	20	120	45
KEY 44 =	125	25	14	33	18	101	40	68	35	64
KEY 45 =	12	111	36	10	68	92	14	25	119	3
KEY 46 =	48	95	71	14	11	40	61	123	82	73
KEY 47 =	48	71	12	44	99	63	108	27	73	103
KEY 48 =	58	91	42	42	2	52	32	73	58	31
KEY 49 =	67	97	120	32	97	126	90	39	49	48
KEY 50 =	87	52	104	84	33	24	3	4	42	94
KEY 51 =	26	44	3	123	85	70	21	74	76	121
KEY 52 =	43	106	74	52	20	50	45	18	126	112
KEY 53 =	19	5	43	68	28	65	75	95	104	84
KEY 54 =	102	52	81	40	26	86	16	106	13	47
KEY 55 =	53	95	62	82	55	87	78	47	49	40
KEY 56 =	65	34	38	8	94	4	91	15	15	108
KEY 57 =	57	80	6	41	87	7	55	17	104	21
KEY 58 =	15	4	113	24	55	117	104	57	26	76
KEY 59 =	124	14	1	83	103	92	71	29	4	104
KEY 60 =	3	6	115	41	16	90	125	124	42	34
KEY 61 =	72	98	79	121	27	7	74	40	3	8
KEY 62 =	40	83	118	121	107	108	5	52	72	78
KEY 63 =	70	69	24	2	42	115	127	28	32	75
KEY 64 =	124	61	6	10	112	117	42	111	57	9
KEY 65 =	20	76	85	6	88	12	108	22	87	101
KEY 66 =	75	111	25	52	95	28	98	40	87	122
KEY 67 =	48	68	75	26	77	8	0	41	23	79
KEY 68 =	26	61	44	79	11	9	46	80	62	23
KEY 69 =	58	20	97	59	90	89	50	120	59	52
KEY 70 =	42	119	74	86	34	104	30	59	49	108
KEY 71 =	23	80	54	9	47	11	94	6	96	123
KEY 72 =	41	96	73	71	58	26	111	65	117	90
KEY 73 =	115	76	68	105	29	24	95	5	96	122
KEY 74 =	101	85	81	11	51	68	28	77	3	108
KEY 75 =	126	86	99	30	21	54	122	119	124	16
KEY 76 =	62	15	15	33	90	104	8	53	86	114
KEY 77 =	33	120	87	109	49	51	57	35	61	100
KEY 78 =	4	43	72	61	35	9	12	95	17	12
KEY 79 =	82	102	0	66	46	105	109	45	34	71
KEY 80 =	116	98	35	20	110	27	82	122	8	99
KEY 81 =	103	39	69	34	83	86	74	81	9	119
KEY 82 =	33	26	44	87	97	27	13	86	78	71
KEY 83 =	73	1	4	69	5	82	74	87	49	117
KEY 84 =	104	45	121	122	14	12	67	31	9	13
KEY 85 =	118	42	61	121	19	2	54	81	99	93
KEY 86 =	34	73	118	14	69	42	123	83	119	77
KEY 87 =	81	104	102	74	57	34	78	5	19	0

```
KEY  88 =  51  114   30  103  127   85  108  123  113   24
KEY  89 =  25   12   87    6   64   90  124  115   69    3
KEY  90 = 110  116   65  121   12    5   19  108   21   60
KEY  91 =  26  108   63   82   31   84   90   48   10  116
KEY  92 = 110  127  117   96   91   98   99   33   70  104
KEY  93 = 101   95   21.   6  112    9   77   74   10    6
KEY  94 = 103  125   43   52   33   76   97   58   80   82
KEY  95 =  72   73   57   33  100   99   36   11  123    2
KEY  96 =  63  107   84   51   18  102   59  101  102   36
KEY  97 =  89   99   66  113   69  115  123   76   35   41
KEY  98 =  29   63   39   94   76   82   26   61   22  115
KEY  99 =  97  104   51  103   52   50  110   68   28   12
KEY 100 =   4   97   30   11  122   92   42  124   91    4
KEY 101 =  88   11   36   32   24  105  119   40   91   55
KEY 102 =  71   36  102  125  113   57   19   58   88   35
KEY 103 =  11   23   31   24   58   48   55   74  125  111
KEY 104 =   4   95  102  126  125  100   92    3   92   55
KEY 105 =  12   83   82   75   36   71  126   77   79   61
KEY 106 =  39   95  101   69   77  110   29   97   47  102
KEY 107 =  36  123   45   10   55   59  109   45   98   24
KEY 108 =  46  124  115   81   65   75   31   48   33  110
KEY 109 =  18  124   21   37   43   73  127   37  126   75
KEY 110 = 121  113   53  118   97   77   41   22  114   70
KEY 111 =  33   81   68   67   74    3   67   24   60   96
KEY 112 = 104   31   67  124   84   99   68   95    9   20
KEY 113 =  74  121   92  101   12   57  114   65   45    3
KEY 114 =  83   17   59   35   86   21   31   63  102  101
KEY 115 =  31    7   87  110   11   35   94   35  110  118
KEY 116 =  35   51   66  112   33  113   66   43   58    4
KEY 117 =  36    6   59   82   58   77    2   36  103   93
KEY 118 =  95   25   48   47    1   20  117   55   19   67
KEY 119 = 117   48  102    0   11   37   94   19   22   45
KEY 120 =  14  125   59   92   35   94   58  104   84   71
KEY 121 =  37   34   56  124  124   29   67   33    4   14
KEY 122 =  97   54  123  125   69   95   37  118   19    4
KEY 123 =  72  104   81   10   40   85  125   25  121  109
KEY 124 =  95   27  107  111    5   53  110   29  116   37
KEY 125 =  44   46  118   68   34   69  125    3   94   65
KEY 126 =  62  110   70   27  124   31  119   97    9    2
KEY 127 =  11   54   25   87  107   73    4  118   62   34
```

I Claim:

1. A method of cryptographically transforming electronic digital data from one form to another comprising the steps of:

a. establishing in memory at least one transformation table associated with a predetermined cryptographic function, said table including a plurality of addressable entries which each direct a predetermined transformation of data in accordance with said function;

b. establishing in memory one or more key based determinants;

c. selecting one of said entries in said transformation table based upon certain information in one of said data key based determinants; and

d. cryptographically transforming said data by said function in accordance with the directions of said selected entry in said transformation table.

2. A method of generating a table of keys for use in cryptographically transforming electronic digital data from one form to another comprising the steps of:

a. establishing an initial key;

b. establishing in memory at least one transformation table associated with a predetermined cryptographic function, said table including a plurality of addressable entries which each direct a predetermined transformation of data in accordance with said function;

c. selecting at least one of said entries in said transformation table based upon certain information in said initial key;

d. transforming said initial key by said function in accordance with the directions of said selected entry in said transformation table;

e. storing said transformed initial key as an entry in the key table memory;

f. selecting at least one of said entries in said transformation table based upon certain information in the initial key or in a key stored in the key table memory;

g. transforming the key used in step (f) above by said function in accordance with the directions of said selected entry in said transformation table;

h. storing said transformed key as another entry in the key table memory; and

i. performing steps (f)—(h) above repetitively until said key table memory has a desired plurality of keys stored therein.

3. The method of claim 2 wherein said initial key is not stored as an entry in the key table memory.

4. The method of claim 2 wherein said transformation table entry selected in step (f) above is based upon certain information in the latest key stored in the key table memory.

5. A method of generating a table of keys for use in cryptographically transforming electronic digital data from one form to another comprising the steps of:

a. establishing an initial key having a plurality of bytes;

b. establishing in memory a plurality of transformation tables, each associated with a predetermined cryptographic function, each of said tables including a plurality of addressable entries which direct a predetermined transformation of data in accordance with said function;

c. selecting, in turn, at least one of said entries in each of said transformation tables based upon certain information in said initial key;

d. transforming said initial key by said functions in accordance with the directions of said selected entries in said transformation tables;

e. storing said transformed initial key as an entry in the key table memory;

f. selecting, in turn, at least one of said entries in each of said transformation tables based upon certain information in at least one of the keys stored in the key table memory;

g. transforming the key used in step (f) above by said functions in accordance with the directions of said selected entries in said transformation tables;

h. storing said transformed key as another entry in the key table memory; and

i. performing steps (f)–(h) above repetitively until said key table memory has a desired plurality of keys stored therein.

6. The method of claim 5 wherein said initial key is not stored as an entry in the key table memory.

7. The method of claim 5 wherein the entries in the transformation tables selected in step (f) above are based upon certain information in the latest key stored in the key table memory.

8. The method of claim 5 wherein said transformation tables include a substitution table with a plurality of entries for directing a particular substitution on said key undergoing transformation.

9. The method of claim 5 wherein said transformation tables include a permutation table with a plurality of entries for directing a particular permutation on said key undergoing transformation.

10. The method of claim 5 wherein said transformation tables include an enclave table with a plurality of entries for directing a particular transformation on said key undergoing transformation in which each byte in said key becomes a function of itself and of every other byte in the key.

11. The method of claim 5 wherein said transformation tables include a substitution table with a plurality of entries for directing a particular substitution on said key undergoing transformation and a permutation table with a plurality of entries for directing a particular permutation on said key undergoing transformation.

12. The method of claim 5 wherein said transformation tables include a substitution table with a plurality of entries for directing a particular substitution on said key undergoing transformation, a permutation table with a plurality of entries for directing a particular permutation on said key undergoing transformation, and an enclave table with a plurality of entries for directing a particular transformation on said key undergoing

transformation in which each byte in said key becomes a function of itself and of every other byte in the key.

13. The method of claim 12 wherein the substitution table entry, the permutation table entry and the enclave table entry selected is determined by an arithmetic combination of the values of a portion of the bytes in the key undergoing transformation.

14. The method of claim 12 wherein said key undergoing transformation is first substituted in accordance with the selected entry in the substitution table, is then permutated in accordance with the selected entry in the permutation table, and is then transformed in accordance with the selected entry in the enclave table.

15. The method of claim 14 wherein the substitution and permutation table entries selected are determined by an arithmetic combination of the values of a portion of the bytes in the key undergoing transformation, and the enclave table entry selected is determined by an arithmetic combination of the values of a portion of the bytes in the key after it has been substituted and permutated.

16. The method of claim 15 wherein the substitution table entry selected is determined by an arithmetic combination of the values of one-half of the bytes in the key undergoing transformation and the permutation table entry selected is determined by an arithmetic combination of the values of the other half of the bytes in the key undergoing transformation

17. A method cryptographically transforming electronic data from one form to another comprising the steps of:

a. establishing in memory a key table with a

plurality of multi-byte key entries;

b. selecting a multi-byte block of data for transformation;

c. selecting an entry from the key table based on information in at least one of the bytes of the data block;

d. arithmetically combining each byte in the selected key with a corresponding byte in the data block, except that the bytes in the data block used to select the entry from the key table remain unchanged; and

e. repeating steps (c) and (d) above for a plurality of rounds and using a different byte of the data block in each round for selecting the entry from the key table.

18. A method of cryptographically transforming electronic data from one form to another comprising the steps of:

a. establishing in memory a key table with a plurality of multi-byte key entries;

b. selecting a multi-byte block of data for transformation;

c. selecting an entry from the key table based on information in at least one of the bytes of the data block;

d. arithmetically combining each byte in the selected key with a corresponding byte in the data block, except that the bytes in the data block used to select the entry from the key table remain unchanged; and

e. repeating steps (c) and (d) above for a plurality of rounds.

19. The method of claims 17 or 18 further including the steps of generating from the key table a determinant table having a plurality of entries which are each the result of an arithmetic combination of two or more values in the key table, and then combining an entry from said determinant table with said one of the values in the data block undergoing transformation to select an entry from the key table.

20. The method of claim 19 wherein a different entry from said determinant table is used during each round.

21. The method of claim 19 wherein the entry from the determinant table and said one of the bytes in the data block are combined by an Exclusive OR operation.

22. The method of claim 19 wherein the value of the entry from the determinant table is added to the value of said one of the bytes in the data block.

23. A method of cryptographically transforming electronic data from one form to another comprising the steps of:

a. establishing in memory a key table with a plurality of multi-byte key entries;

b. establishing in memory one or more multi-byte key based determinants;

c. selecting a multi-byte block of data for transformation;

d. selecting an entry from the key table based on information in at least one of the bytes of one of said key based determinants;

e. arithmetically combining each byte in the selected key with a corresponding byte in the data block; and

f. repeating steps (d) and (e) above for a

plurality of rounds.

24. The method of claims 17, 18 or 23 wherein the bits in the selected key are arithmetically combined with the corresponding bits in the data block undergoing transformation by an Exclusive OR operation.

25. The method of claims 17, 18 or 23 wherein the values of the bytes in the selected key are added to the values of the corresponding bytes in the data block undergoing transformation.

26. The method of claims 17, 18 or 23 wherein said established by the steps of:

f. establishing an initial key;

g. establishing in memory at least one transformation table associated with a predetermined cryptographic function, said table including a plurality of addressable entries which each direct a predetermined transformation of data in accordance with said function;

h. selecting at least one of said entries in said transformation table based upon certain information in said initial key;

i. transforming said initial key by said function in accordance with the directions of said selected entry in said transformation table;

j. storing said transformed initial key as an entry in the key table memory;

k. selecting at least one of said entries in said transformation table based upon certain information in the initial key or in a key stored in the key table memory;

l. transforming the key used in step (k) above by

said function in accordance with the directions of said selected entry in said transformation table;

m. storing said transformed key as another entry in the key table memory; and

n. performing steps (k)—(m) above repetitively until said key table memory has a desired plurality of keys stored therein.

27. The method of claim 26 wherein said initial key as an entry in the key table memory.

28. The method of claim 26 wherein Said transformation table entry selected in step (k) above is based upon certain information in the latest key stored in the key table memory.

29. The method of claims 17, 18 or 23 wherein said key table is generated by the steps of:

f. establishing an initial key having a plurality of bytes;

g. establishing in memory a plurality of transformation tables, each associated with a predetermined cryptographic function, each of said tables including a plurality of addressable entries which direct a predetermined transformation of data in accordance with said function;

h. selecting, in turn, at least one of said entries in each of said transformation tables based upon certain information in said initial key;

i. transforming said initial key by said functions in accordance with the directions of said selected entries in said transformation tables;

j. storing said transformed initial key as an entry in the key table memory;

k. selecting, in turn, at least one of said

entries in each of said transformation tables based upon certain information in at least one of the keys stored in the key table memory;

1. transforming the key used in step (k) above by said functions in accordance with the directions of said selected entries in said transformation tables;

m. storing said transformed key as another entry in the key table memory; and

n. performing steps (k)-(m) above repetitively until said key table memory has a desired plurality of keys stored therein.

30. The method of claim 29 wherein said initial key is not stored as an entry in the key table memory.

31. The method of claim 29 wherein the entries in the transformation tables selected in step (k) above are based upon certain information in the latest key stored in the key table memory.

32. The method of claim 29 wherein said transformation tables include a substitution table with a plurality of entries for directing a particular substitution on said key undergoing transformation and a permutation table with a plurality of entries for directing a particular permutation on said key undergoing transformation.

33. The method of claim 29 wherein said transformation tables include a substitution table with a plurality of entries for directing a particular substitution on said key undergoing transformation, a permutation table with a plurality of entries for directing a particular permutation on said key undergoing transformation, and an enclave table with a plurality of entries for directing a particular transformation on said key undergoing transformation in which each byte in said key becomes a

function of itself and of every other byte in the key.

34. A method cryptographically transforming electronic data from one form to another comprising the steps of:

a. establishing in memory at least one transformation table associated with a predetermined cryptographic function, said table including a plurality of addressable entries which direct a predetermined transformation of data in accordance with said function;

b. selecting at least one of the entries in said transformation table based upon certain information in the data undergoing transformation;

c. cryptographically transforming the data by said function in accordance with the directions of the entry in the transformation table selected in step (b);

d. arithmetically combining the data transformed in step (c) above with a key;

e. selecting at least one other entry in said transformation table based upon certain information in the data transformed in step (d) above; and

f. cryptographically transforming the data transformed in step (d) above by said function in accordance with the directions of the entry in the transformation table selected in step (e).

35. The method of claim 34 wherein steps (b) through (f) are carried out repetitively in a predetermined number of rounds.

36. A method of cryptographically transforming electronic data from one form to another comprising the steps of:

a. establishing in memory a first transformation table associated with a first cryptographic function and a

second transformation table associated with a second cryptographic function, said tables each including a plurality of addressable entries which direct a predetermined transformation of data in accordance with said functions;

b. selecting at least one of the entries in said first transformation table based upon certain information in said data undergoing transformation;

c. cryptographically transforming said data by said first. function in accordance with the directions of the entry in the first transformation table selected in step (b);

d. arithmetically combining the data transformed in step (c} above with a key;

e. selecting at least one of the entries in the second transformation table based upon certain information in the data transformed in step (d) above; and

f. cryptographically transforming the data transformed in step (d) above by the second function in accordance with the directions of the entry in the second transformation table selected in step (e).

37. The method of claim 36 wherein steps (b) through (f) are carried out repetitively in a predetermined number of rounds.

38. An enclave function for cryptographically transforming electronic digital data from one form to another comprising the steps of:

a. establishing in memory an enclave table with a plurality of entries for directing an autoclave function on a portion of the data undergoing transformation;

b. selecting a block of data having an even number of bytes;

c. dividing said data block into a first half-block including one—half of the bytes of the data block and

into a second half-block including the remaining bytes of the data block;

d. transforming the first half-block by said autoclave function as directed by a first entry in said enclave table;

e. transforming the resultant first half-block after step (d) above by said autoclave function as directed by a second entry in said enclave table;

f. combining the second half-block with the resultant first half-block after step (e) above by an Exclusive OR operation to generate resultant second half-block;

g. transforming the resultant second half-block after step (f) above by said autoclave function as directed by a third entry in said enclave table;

h. transforming the resultant second half-block after step (g) above by said autoclave function as directed by a fourth entry in said enclave table;

i. combining the resultant second half-block after step (h) above with the resultant first half-block after step (e) above by an Exclusive OR operation to generate a resultant first half- block; and

j. joining said resultant first half-block after step (i) above to said resultant second half-block after step (h) above to form the transformed data block.

39. The method of claim 38 wherein the autoclave function used includes the steps of modifying a byte in the half-block undergoing transformation by adding said byte to at least two other bytes in the half-block, and sequentially repeating this addition process on each of the other bytes in the half-block, using. different bytes in each repetition to be added to the byte, undergoing transformation.

40. A method of cryptographically transforming electronic data from one form to another comprising the steps of:

a. establishing in memory a permutation table with a plurality of addressable entries for directing a particular permutation of said data undergoing transformation;

b. establishing in memory a substitution table with a plurality of addressable entries for directing a particular substitution on said data undergoing transformation;

c. selecting at least one of the entries in one of said permutation and substitution tables based upon certain information in said data undergoing transformation;

d. cryptographically transforming said data in accordance with the table entry selected in step (c) above and the function associated therewith;

e. arithmetically combining the data transformed in step (d) with a key;

f. selecting at least one of the entries in the other of said permutation and substitution tables; and

g. cryptographically transforming the data transformed in step (e) in accordance with the table entry selected in step (f) and the function associated therewith.

41. The method of claim 40 wherein the substitution table entry selected is determined by the value of one of the bytes in the data undergoing transformation and the substitution function is carried out on all bytes in the data except for the byte used to select the entry from the substitution table, which byte remains unchanged.

42. The method of claims 40 or 41 further including the steps of establishing an enclave table with a

plurality of entries for directing an enclave transformation in which each byte in the data undergoing transformation becomes a function of itself and of every other byte in the data, selecting at least one of said entries in said enclave table, and transforming the data in accordance with the directions of the selected entry in the enclave table.

43. The method of claim 40 further including the steps of generating from said key a determinant table having a plurality of entries which are the result of an arithmetic combination of two or more values in the key, and then using one entry in said determinant table to select the entry from the enclave table used in the enclave function transformation of the data.

44. The method of claim 40 wherein steps (b) through (g) are carried out repetitively in a predetermined number of rounds.

45. The method of claim 44 wherein the substitution table entry selected is determined by the value of one of the bytes in the data undergoing transformation, the substitution function is carried out on all bytes in the data except for the byte used to select the entry from the substitution table, which byte remains unchanged, and a different byte in the data undergoing transformation is used in each round to select the substitution table entry.

46. The method of claim 45 further including the steps of selecting a second entry in the substitution table based upon certain information in the data undergoing transformation after it has been subjected to said substitution function, and then cryptographically transforming said data by a second substitution function in accordance with the second entry selected.

47. The method of claim 46 wherein the

substitution table entry selected for the second substitution is determined by the value of one of the bytes in the data undergoing transformation, excluding the byte used in claim 62 for determining the substitution table entry for the initial substitution function.

48. The method of claim 44 wherein the step of combining the transformed data with a key includes the steps of:

h. establishing in memory a key table with a plurality of multi-byte key entries;

i. selecting an entry from the key table based on information in at least one of the bytes in the data undergoing transformation; and

j. arithmetically combining each byte in the selected key with a corresponding byte in the data undergoing transformation, except that the data bytes used to select the key from the table entry remain unchanged, with a different byte in the data undergoing transformation used in each round to select the entry from the key table.

49. The method of claim 44 wherein the step of combining the transformed data with a key includes the steps of:

h. establishing in memory a key table with a plurality of multi-byte key entries;

i. selecting an entry from the key table based on information in at least one of the bytes in the data undergoing transformation; and

j. arithmetically combining each byte in the selected key with a corresponding byte in the data undergoing transformation, except that the data bytes used to select the key from the table entry remain unchanged.

50. The method of claim 44 wherein the step of

combining the transformed data with a key includes the steps of:

h. establishing in memory a key table with a plurality of multi-byte key entries;

i. selecting an entry from the key table based on information in at least one of the bytes in the data undergoing transformation; and

j. arithmetically combining each byte in the selected key with a corresponding byte in the data undergoing transformation.

51. The method of claims 48, 49 or 50 wherein bits in the selected key are arithmetically combined with the corresponding bits in the data undergoing transformation by an Exclusive OR operation.

52. The method of claims 48, 49, or 50 further including the steps of generating from the key table a determinant table having a plurality of entries which are each the result of an arithmetic combination of two or more values in the key table, and then combining an entry from said determinant table with said one of the values in the data undergoing transformation to select an entry from the key table.

53. The method of claim 52 wherein a different entry from said determinant table is used during each round.

54. The method of claim 52 wherein the entry from the determinant table and said one of the bytes in the data undergoing transformation are combined by an Exclusive OR operation.

55. The method of claims 48, 49 or 50 wherein said established by the steps of:

k. establishing an initial key having a plurality of bytes;

l. selecting, in turn, at least one of said entries in each of said permutation and substitution tables based upon certain information in said initial key;

m. transforming said initial key by said substitution and permutation functions in accordance with the directions of said selected entries in said tables;

n. storing said transformed initial key as an entry in the key table memory;

o. electing, in turn, at least one of said entries in each of said substitution and permutation tables based upon certain information in at least one of the keys stored in the key table memory;

p. transforming the key used in step (o) above by said substitution and permutation functions in accordance with the directions of said selected entries in said tables;

q. storing said transformed key as another entry in the key table memory; and

r. performing steps (o)-(q) above repetitively until said key table memory has a desired plurality of keys stored therein.

56. The method of claim 55 wherein said initial key is not stored as an entry in the key table memory.

57. The method of claim 55 wherein the entries in the substitution and permutation tables selected in step (o) above are based upon certain information in the latest key stored in the key table memory.

58. The method of claims 48, 49 or 50 further including the steps of establishing an enclave table with a plurality of entries for directing an enclave transformation in which each byte in the data undergoing transformation becomes a function of itself and of every other byte in the data, selecting at least one of said entries in said enclave

table, and transforming the data in accordance with the directions of the selected entry in the enclave table.

59. The method of claim 58 further including the steps of generating from said key table a determinant table having a plurality of entries which are the result of an arithmetic combination of two or more values in the key table, and then using one entry in said determinant table to select the entry from the enclave table used in the enclave function transformation of the data.

60. The method of claim 59 wherein a different entry from said determinant table is used during each round.

61. The method of claims 48, 49 or 50 further including the steps of selecting a second key from the key table memory based on the value of one of the bytes in the data undergoing transformation, excluding the byte used in claims 48, 49 or 50 and arithmetically combining each byte in the selected second key with a corresponding byte in the data undergoing transformation, except that the byte used to select the second key remains unchanged, with a different byte in the data undergoing transformation used in each round to select the second key.

62. The method of claims 40 or 44 wherein the permutation table entry selected is determined by an arithmetic combination of the values of the bytes in the data undergoing transformation.

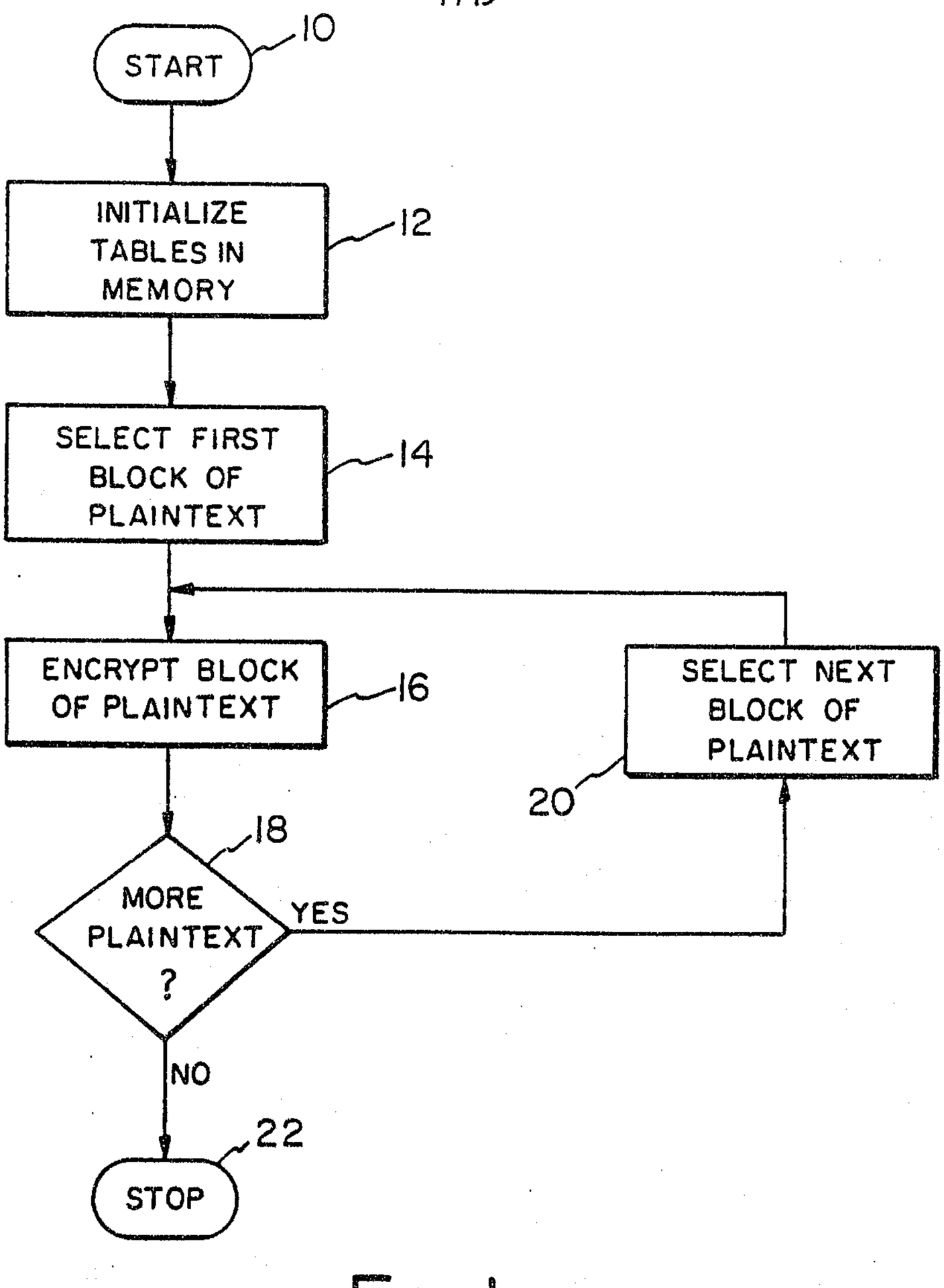

START
10
INITIALIZE TABLES IN MEMORY
12
SELECT FIRST BLOCK OF PLAINTEXT
14
ENCRYPT BLOCK OF PLAINTEXT
16
SELECT NEXT BLOCK OF PLAINTEXT
20
MORE PLAINTEXT ?
18
YES
NO
STOP
22

Fig. 1

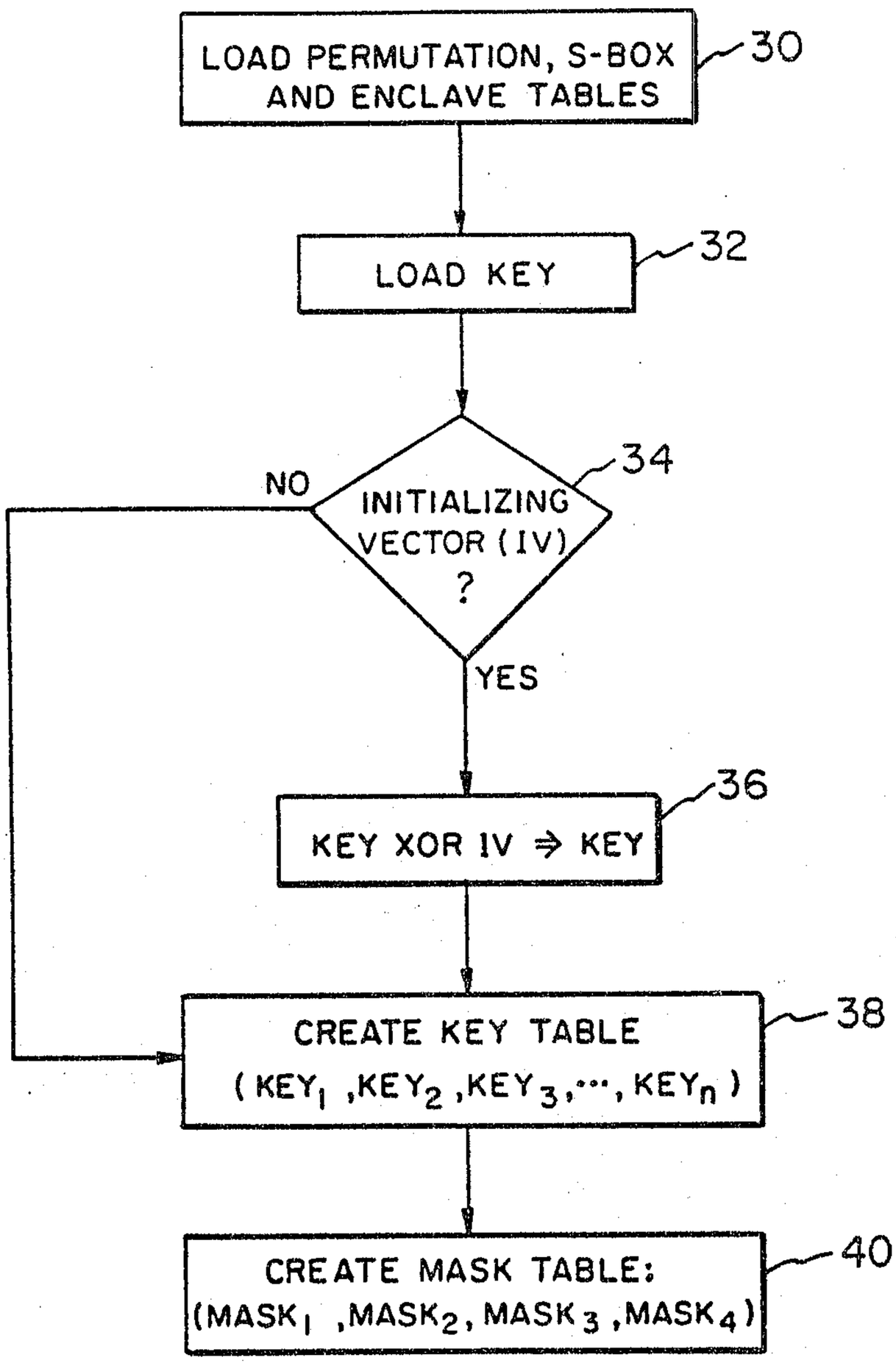

LOAD PERMUTATION, S-BOX AND ENCLAVE TABLES
30
LOAD KEY
32
INITIALIZING VECTOR (IV) ?
34
NO
YES
KEY XOR IV ⇒ KEY
36
CREATE KEY TABLE
(KEY1 ,KEY2 ,KEY3 ,···, KEYn)
38
CREATE MASK TABLE:
(MASK1 ,MASK2 , MASK3 ,MASK4)
40

Fig. 2

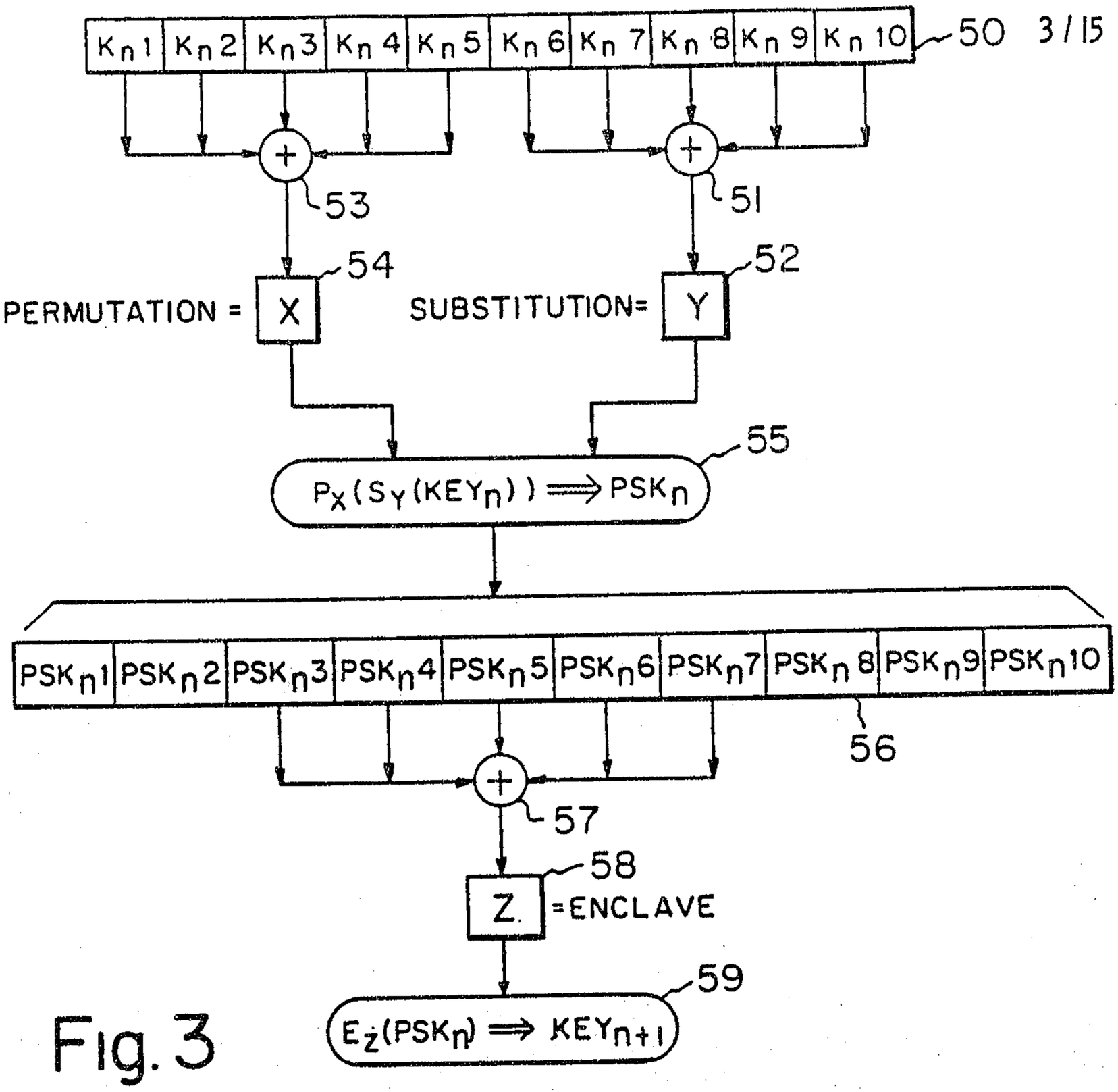

Kn1 Kn2 Kn3 Kn4 Kn5 Kn6 Kn7 Kn8 Kn9 Kn10
50
53
51
54
52
PERMUTATION = X
SUBSTITUTION= Y
55
Px(SY(KEYn)) ⟹ PSKn
PSKn1 PSKn2 PSKn3 PSKn4 PSKn5 PSKn6 PSKn7 PSKn8 PSKn9 PSKn10
56
57
58
Z. =ENCLAVE
59
Ez(PSKn) ⟹ KEYn+1

Fig. 3

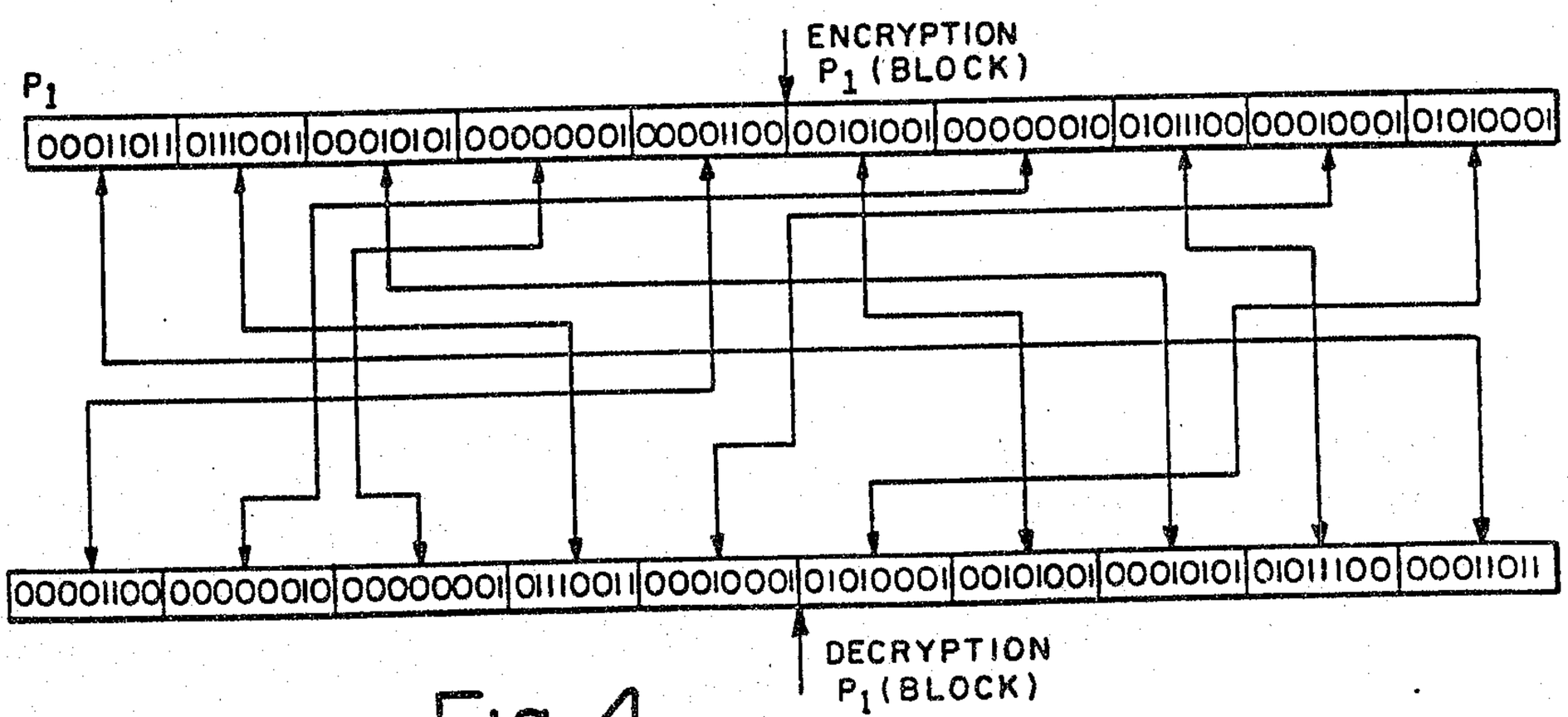

P1
ENCRYPTION
P1 (BLOCK)
00011011 01110011 00010101 00000001 00001100 00101001 00000010 01011100 00010001 01010001
00001100 00000010 00000001 01110011 00010001 01010001 00101001 00010101 01011100 00011011
DECRYPTION
P1 (BLOCK)

Fig. 4

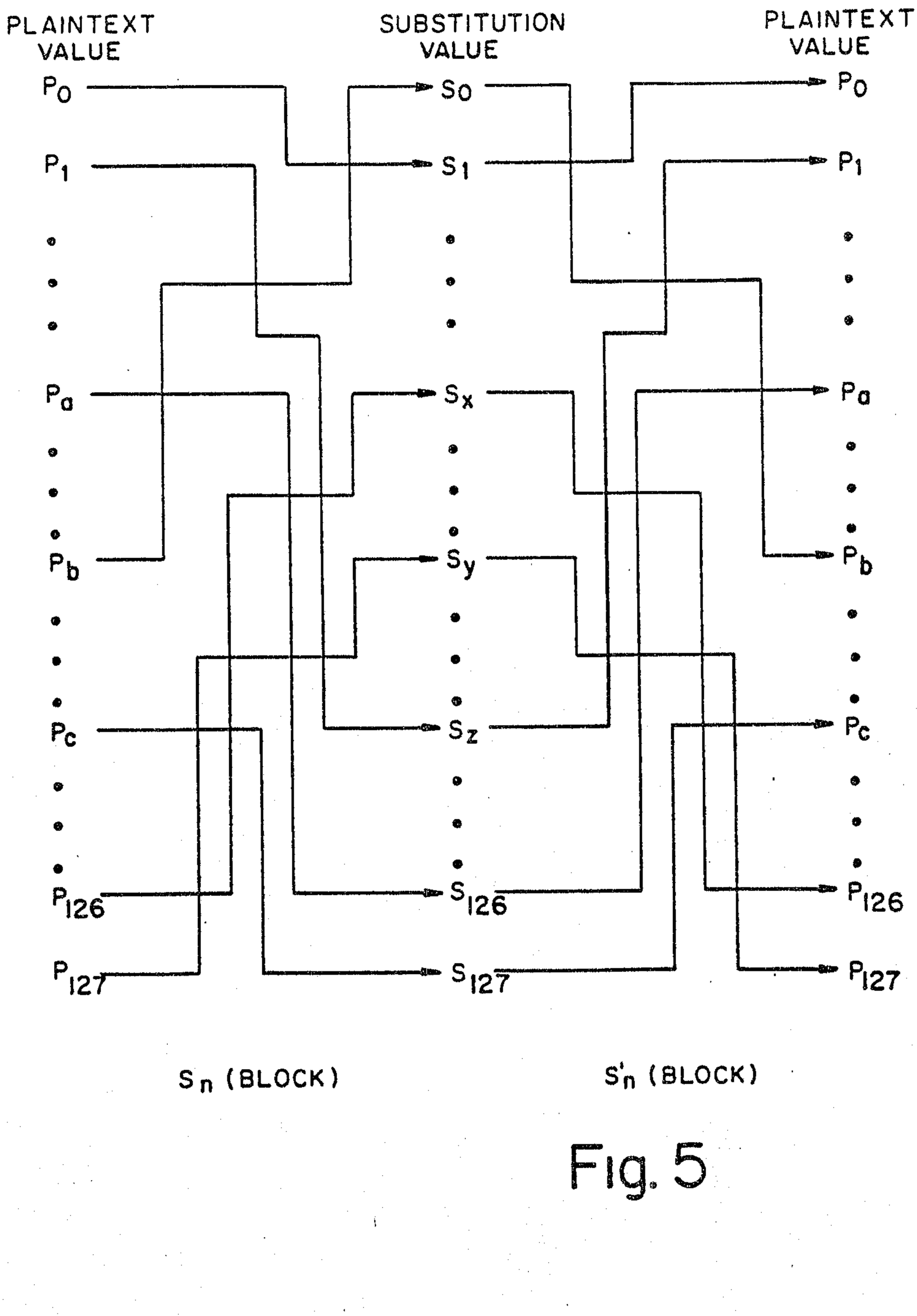

PLAINTEXT VALUE
SUBSTITUTION VALUE
PLAINTEXT VALUE
P0
P1
Pa
Pb
Pc
P126
P127
S0
S1
Sx
Sy
Sz
S126
S127
P0
P1
Pa
Pb
Pc
P126
P127
Sn (BLOCK)
S'n (BLOCK)

Fig. 5

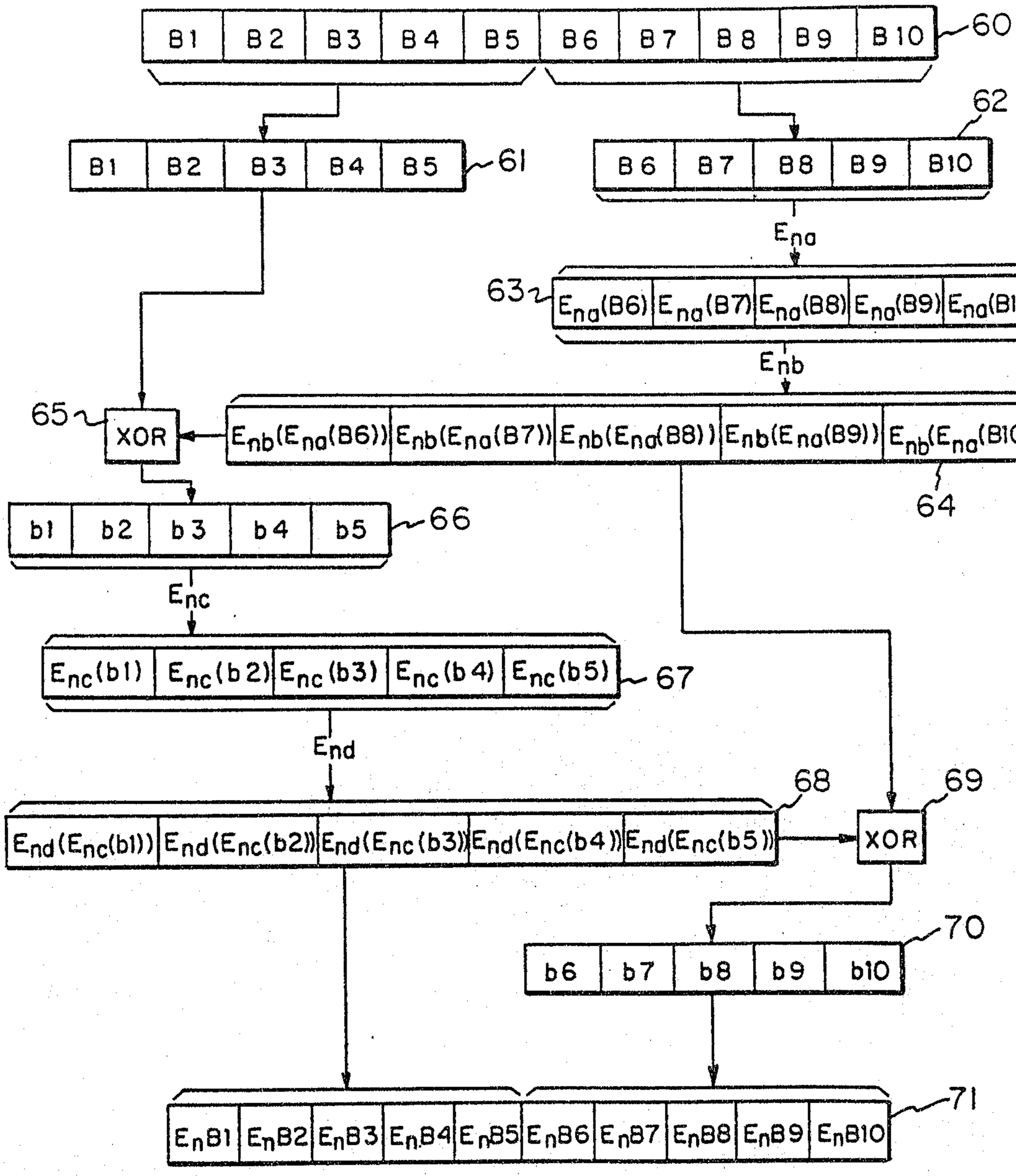

B1 B2 B3 B4 B5 B6 B7 B8 B9 B10
60
B1 B2 B3 B4 B5
61
B6 B7 B8 B9 B10
62
Ena
63
Ena(B6) Ena(B7) Ena(B8) Ena(B9) Ena(B10)
Enb
65
XOR
Enb(Ena(B6)) Enb(Ena(B7)) Enb(Ena(B8)) Enb(Ena(B9)) Enb(Ena(B10))
64
b1 b2 b3 b4 b5
66
Enc
Enc(b1) Enc(b2) Enc(b3) Enc(b4) Enc(b5)
67
End
68
End(Enc(b1)) End(Enc(b2)) End(Enc(b3)) End(Enc(b4)) End(Enc(b5))
69
XOR
70
b6 b7 b8 b9 b10
71
EnB1 EnB2 EnB3 EnB4 EnB5 EnB6 EnB7 EnB8 EnB9 EnB10

Fig. 6

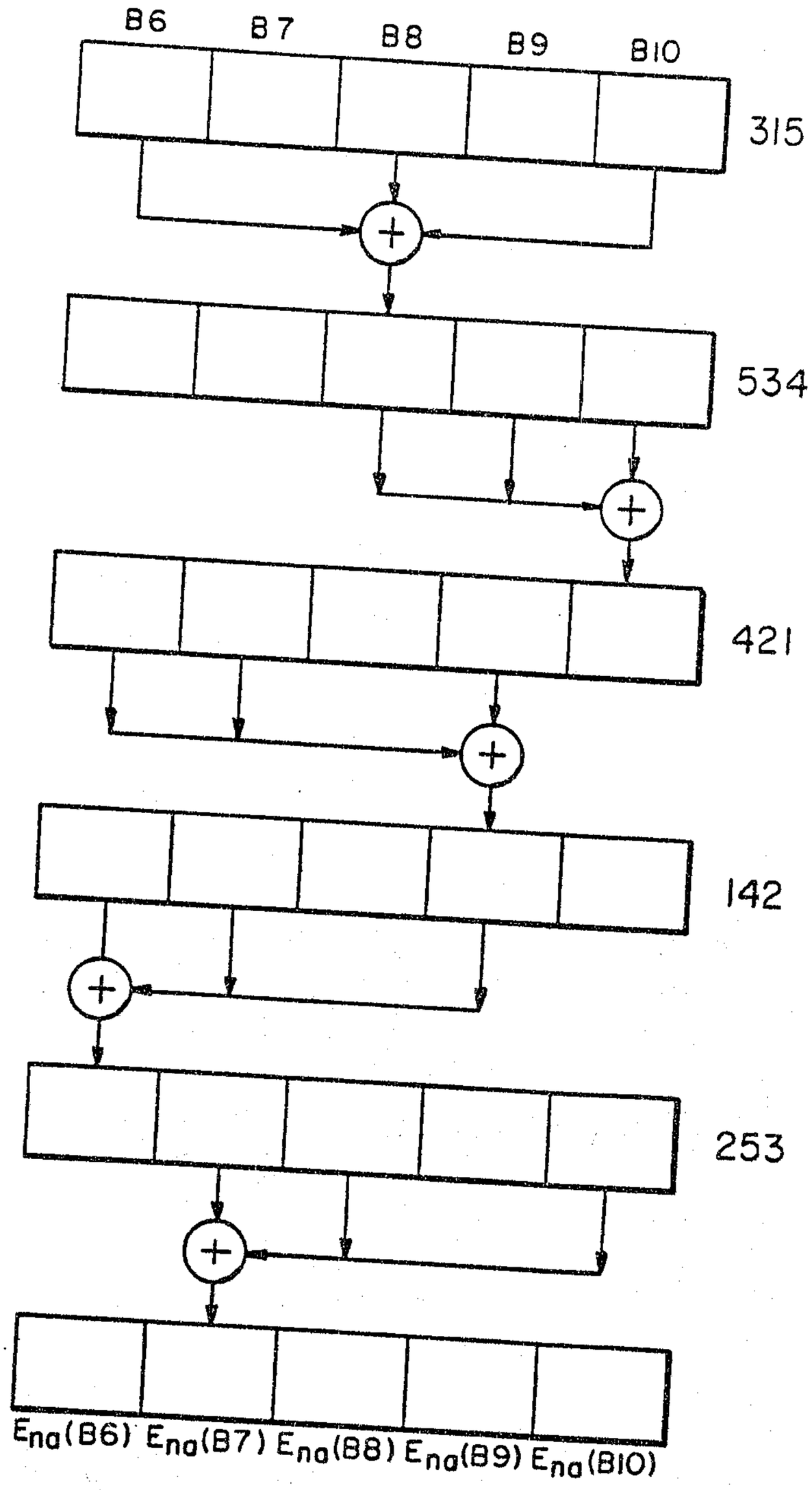

B6
B7
B8
B9
B10
315
534
421
142
253
Ena(B6) Ena(B7) Ena(B8) Ena(B9) Ena(B10)

Fig. 7

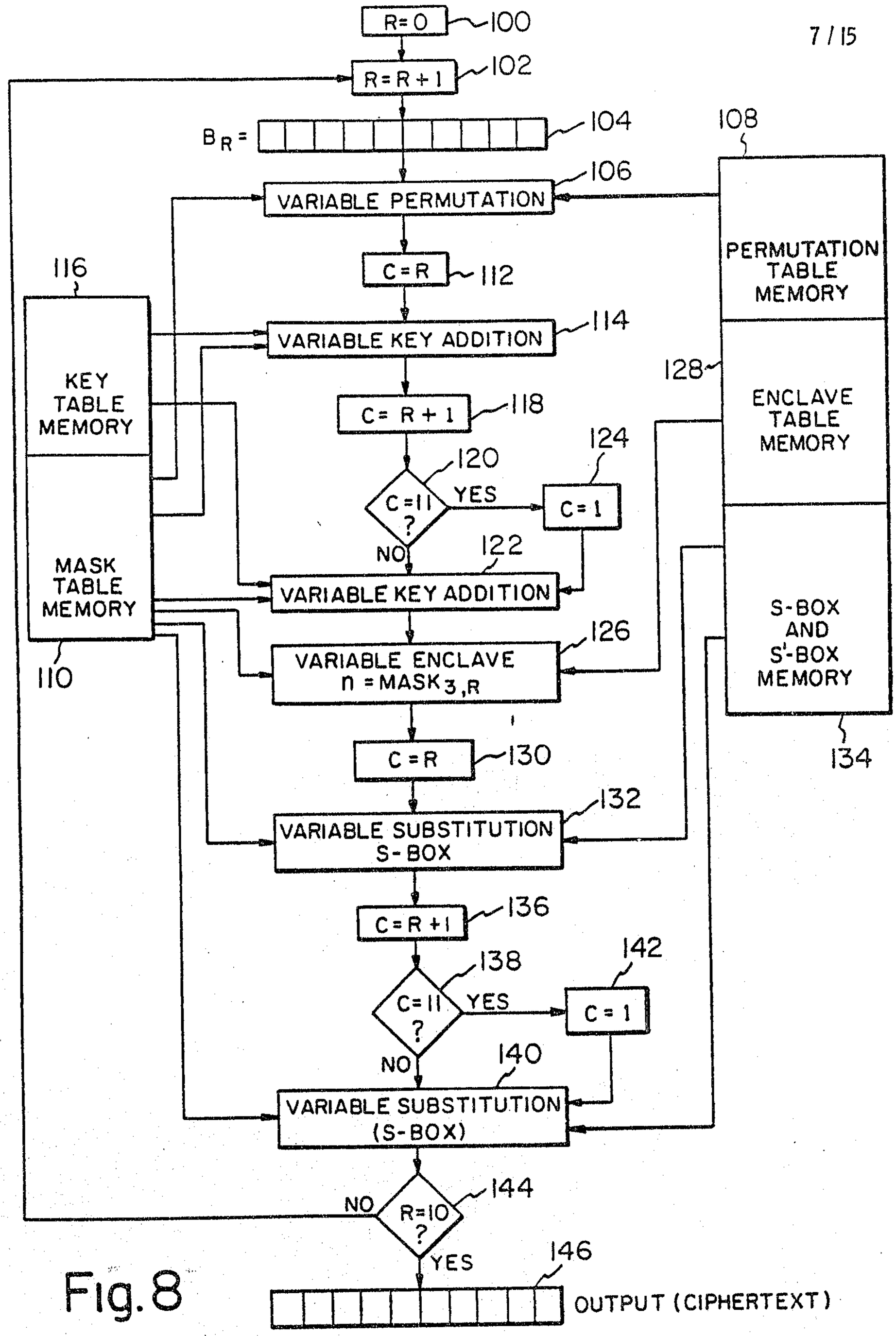

R=0
100
R=R+1
102
B_R =
104
108
VARIABLE PERMUTATION
106
PERMUTATION TABLE MEMORY
C=R
112
116
KEY TABLE MEMORY
VARIABLE KEY ADDITION
114
128
ENCLAVE TABLE MEMORY
C= R + 1
118
120
124
C=11 ?
YES
C=1
MASK TABLE MEMORY
NO
122
VARIABLE KEY ADDITION
S-BOX AND S'-BOX MEMORY
126
VARIABLE ENCLAVE
n = MASK 3,R
110
C=R
130
134
132
VARIABLE SUBSTITUTION S-BOX
C=R+1
136
142
138
C=11 ?
YES
C = 1
NO
140
VARIABLE SUBSTITUTION (S-BOX)
144
NO
R=10 ?
YES
146
OUTPUT (CIPHERTEXT)

Fig. 8

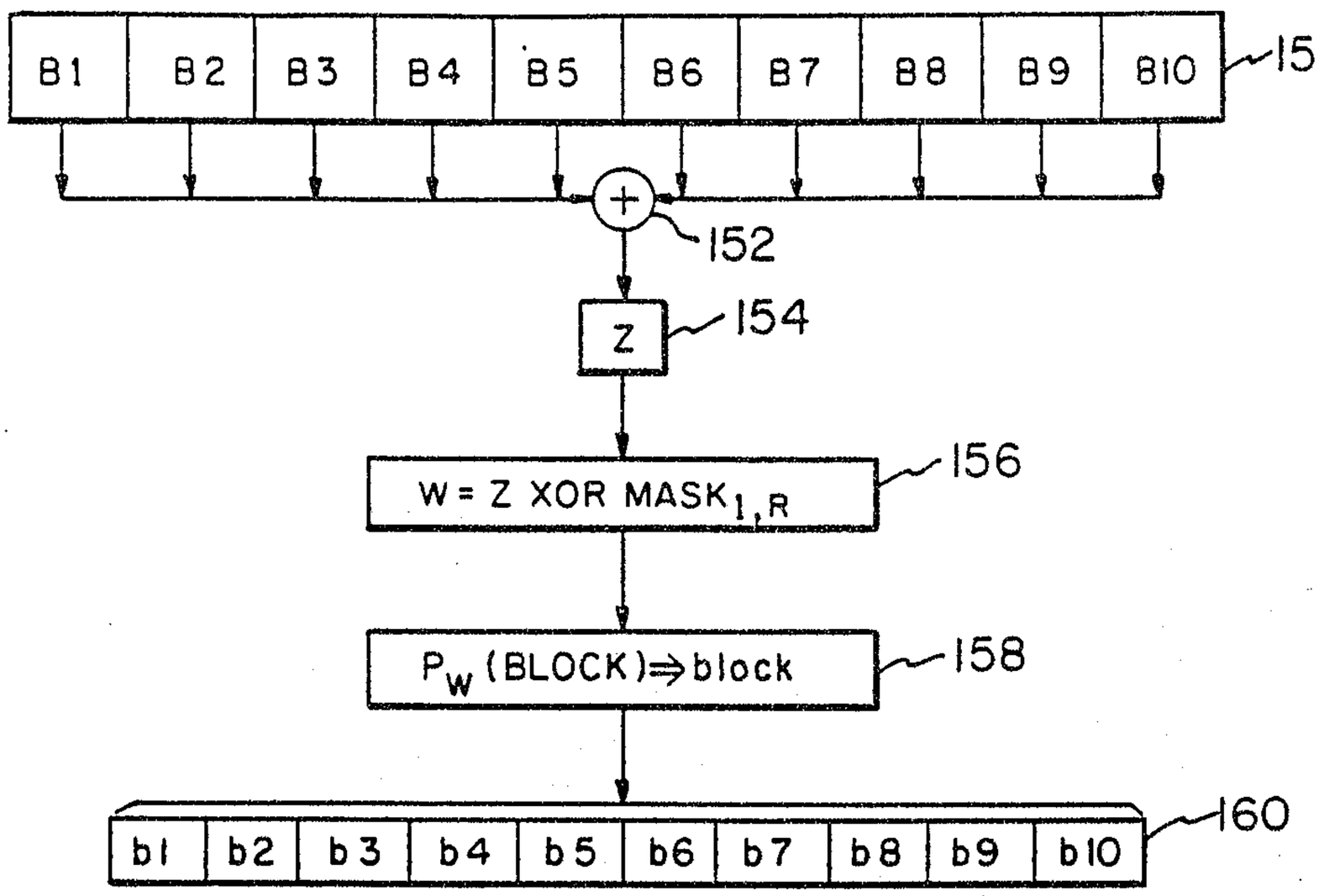

B1
B2
B3
B4
B5
B6
B7
B8
B9
B10
150
152
Z
154
W = Z XOR MASK1,R
156
Pw (BLOCK)⇒block
158
b1
b2
b3
b4
b5
b6
b7
b8
b9
b10
160

Fig. 9

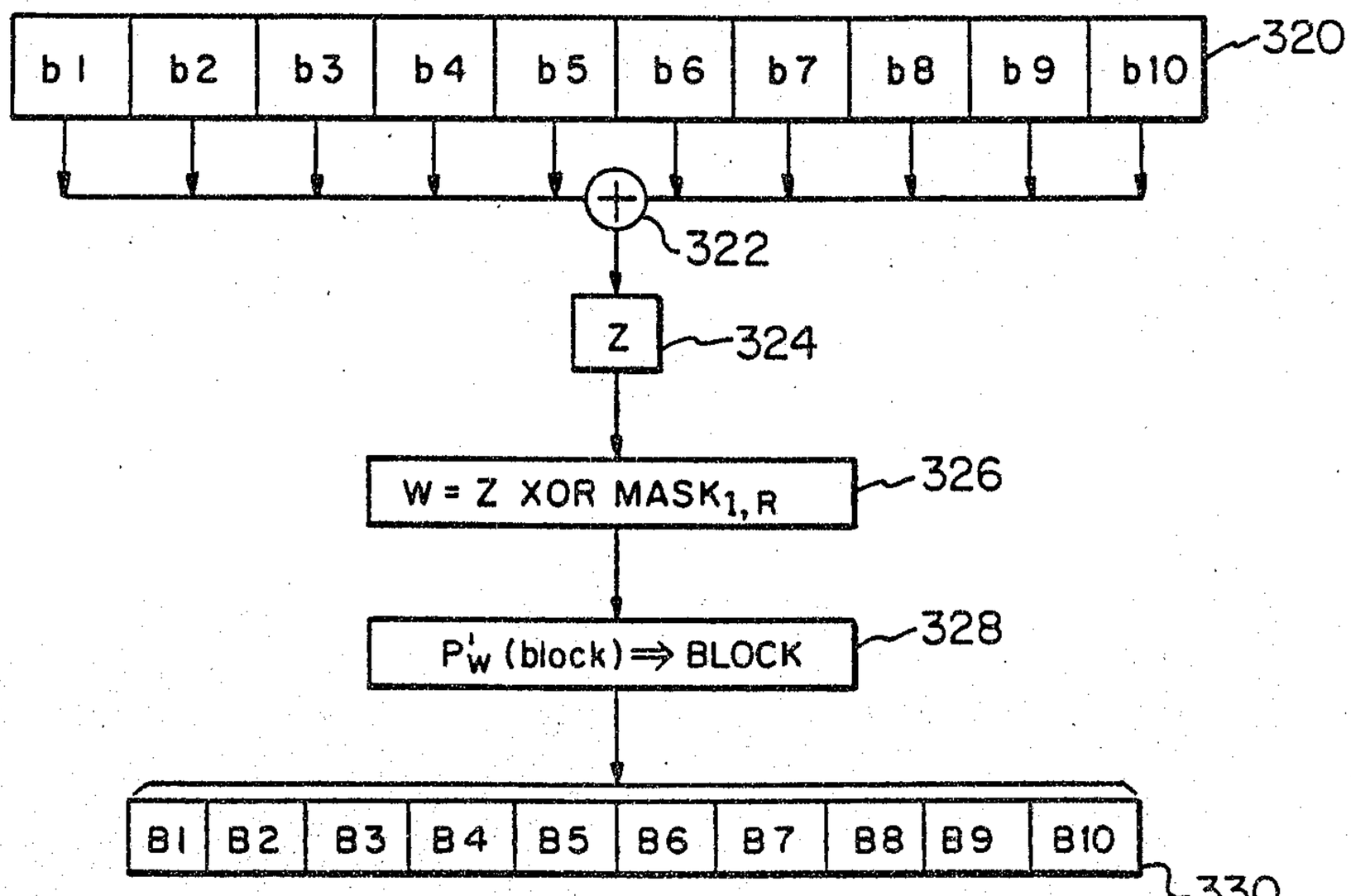

b1
b2
b3
b4
b5
b6
b7
b8
b9
b10
320
322
Z
324
W = Z XOR MASK1,R
326
P'w (block) ⇒ BLOCK
328
B1
B2
B3
B4
B5
B6
B7
B8
B9
B10
330

Fig. 17

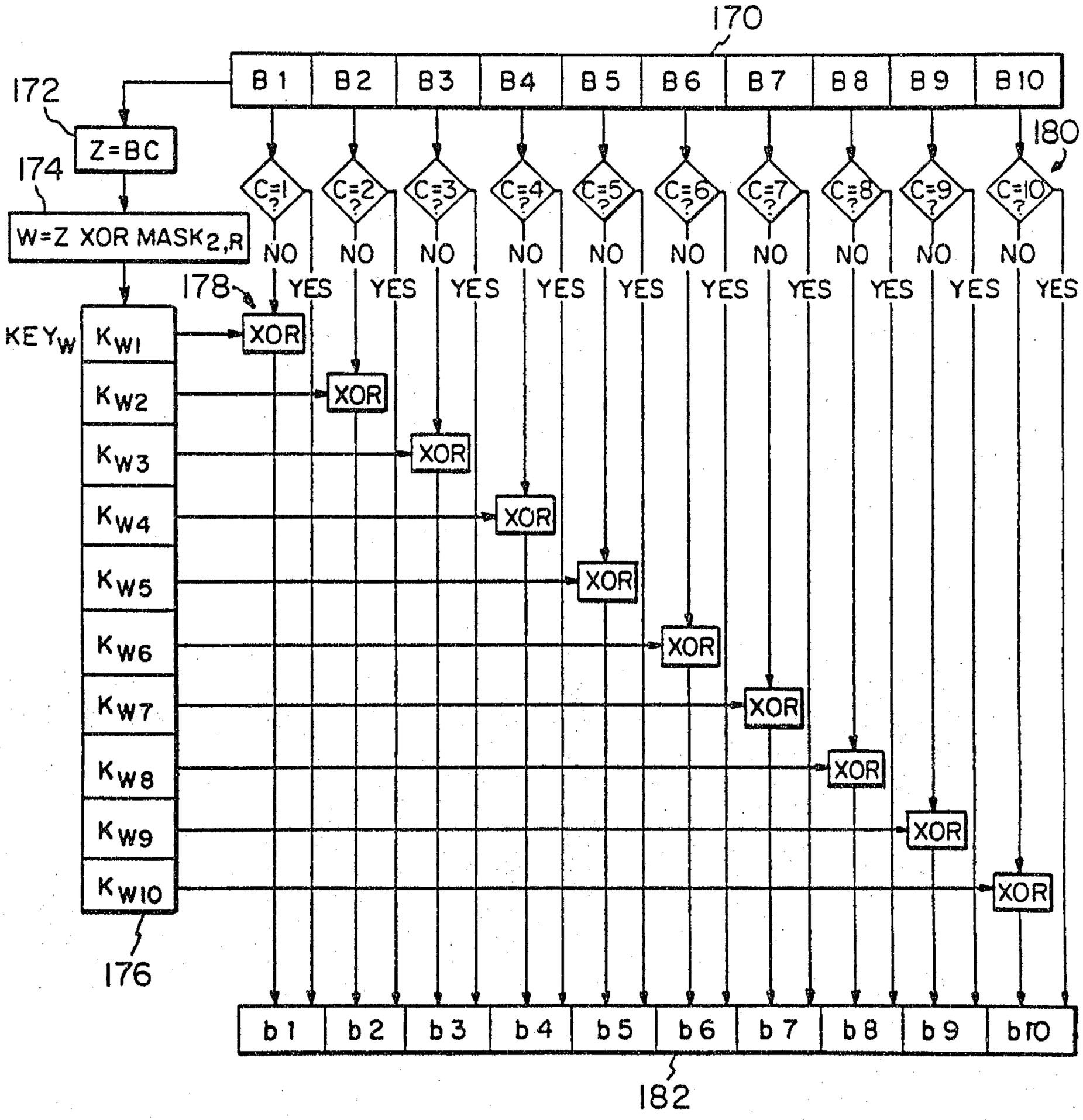

170
B1
B2
B3
B4
B5
B6
B7
B8
B9
B10
172
Z=BC
174
W=Z XOR MASK2,R
180
C=1?
C=2?
C=3?
C=4?
C=5?
C=6?
C=7?
C=8?
C=9?
C=10?
NO
YES
178
KEYW
KW1
KW2
KW3
KW4
KW5
KW6
KW7
KW8
KW9
KW10
XOR
176
b1
b2
b3
b4
b5
b6
b7
b8
b9
b10
182

Fig. 10

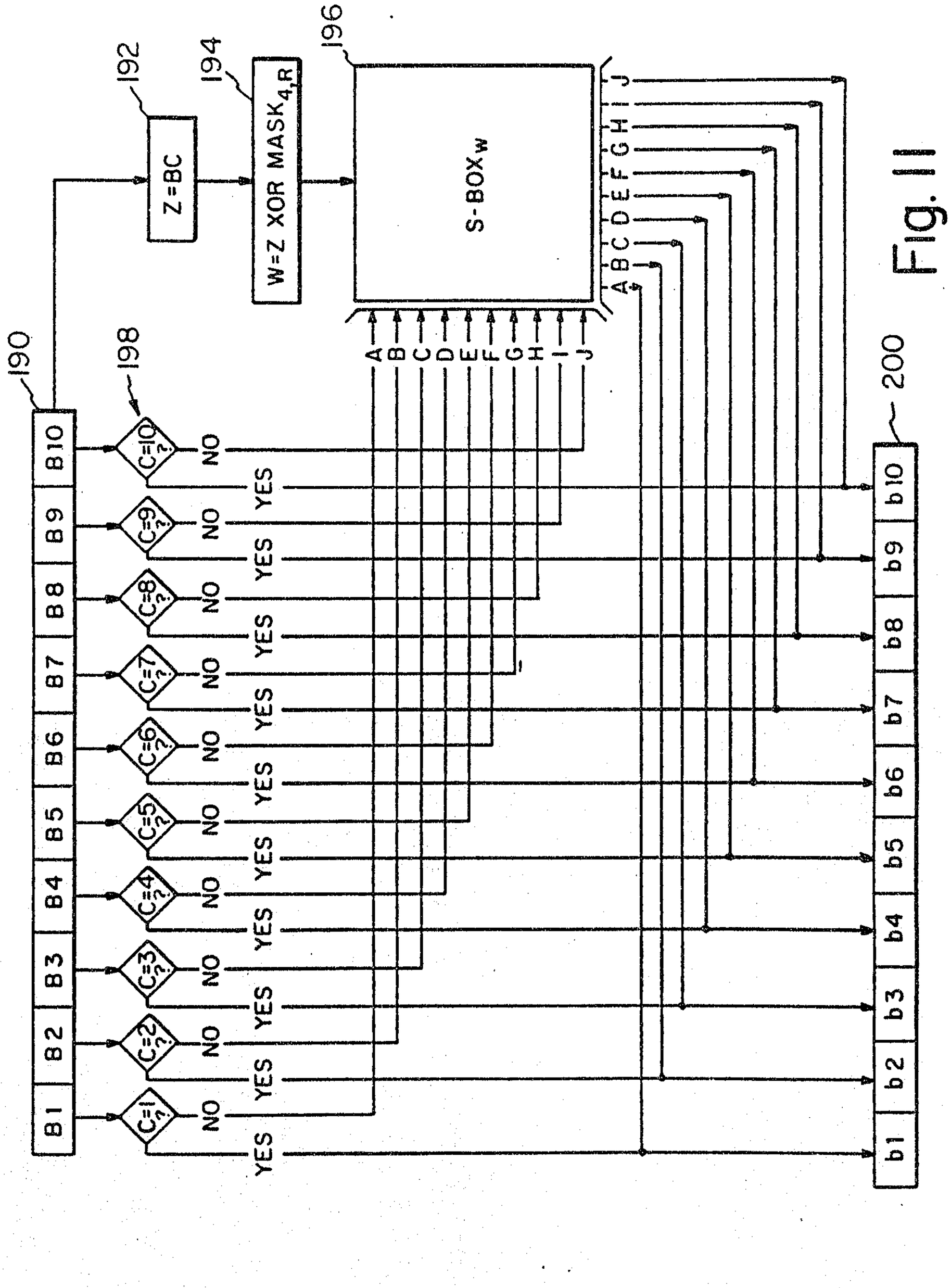

190
192
194
196
198
200
Z=BC
W=Z XOR MASK4,R
S-BOXW
A B C D E F G H I J
B10 B9 B8 B7 B6 B5 B4 B3 B2 B1
C=10? C=9? C=8? C=7? C=6? C=5? C=4? C=3? C=2? C=1?
NO
YES
b10 b9 b8 b7 b6 b5 b4 b3 b2 b1

Fig. 11

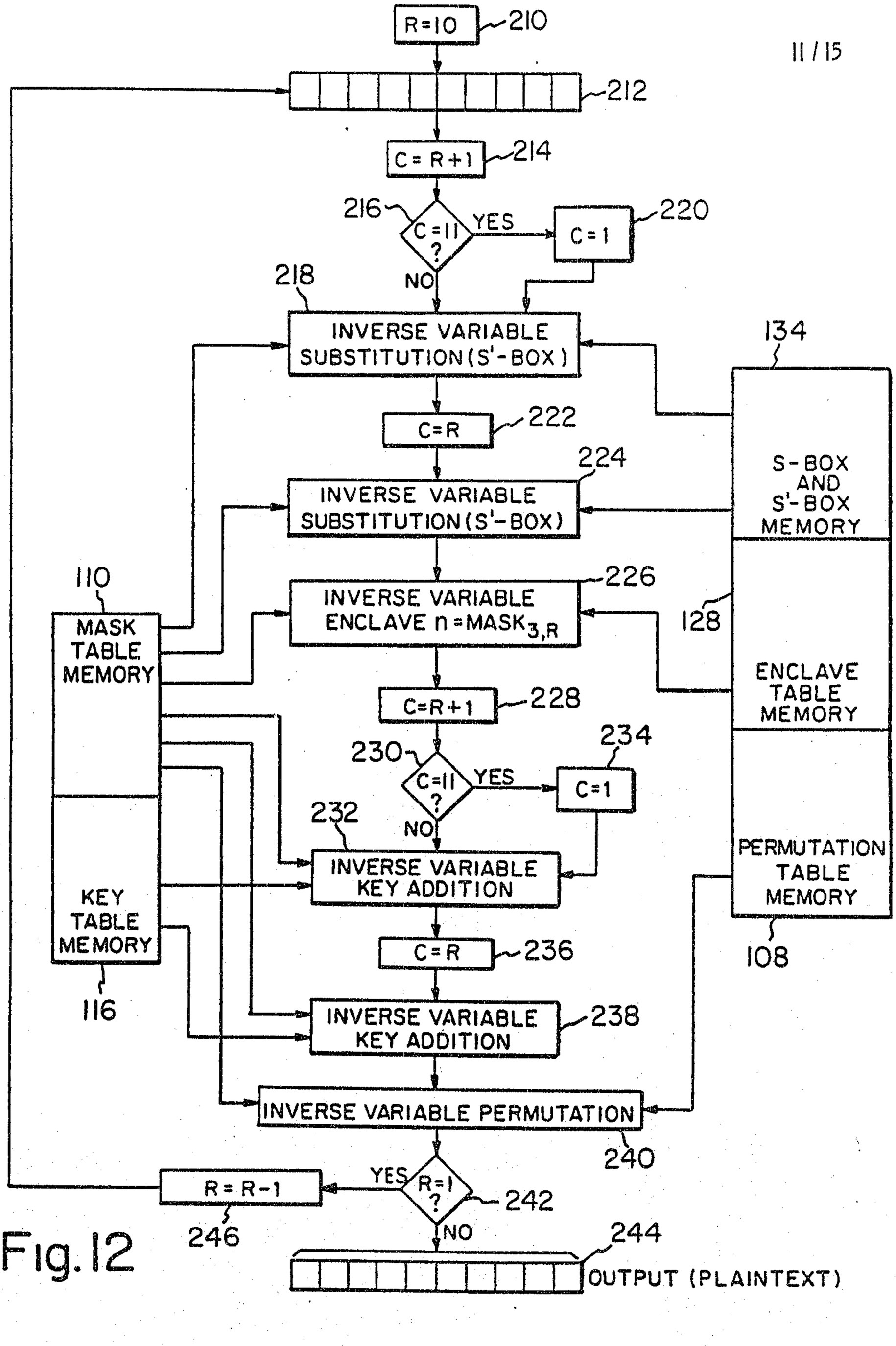

R=10
210
212
C=R+1
214
216
C=11 ?
YES
220
C=1
218
NO
INVERSE VARIABLE SUBSTITUTION (S'-BOX)
134
C=R
222
224
INVERSE VARIABLE SUBSTITUTION (S'-BOX)
S-BOX AND S'-BOX MEMORY
110
MASK TABLE MEMORY
226
INVERSE VARIABLE ENCLAVE n = MASK3,R
128
ENCLAVE TABLE MEMORY
C=R+1
228
234
230
C=11 ?
YES
C=1
232
NO
INVERSE VARIABLE KEY ADDITION
KEY TABLE MEMORY
C=R
236
PERMUTATION TABLE MEMORY
108
116
INVERSE VARIABLE KEY ADDITION
238
INVERSE VARIABLE PERMUTATION
240
YES
R=1 ?
242
R=R-1
246
NO
244
OUTPUT (PLAINTEXT)

Fig. 12

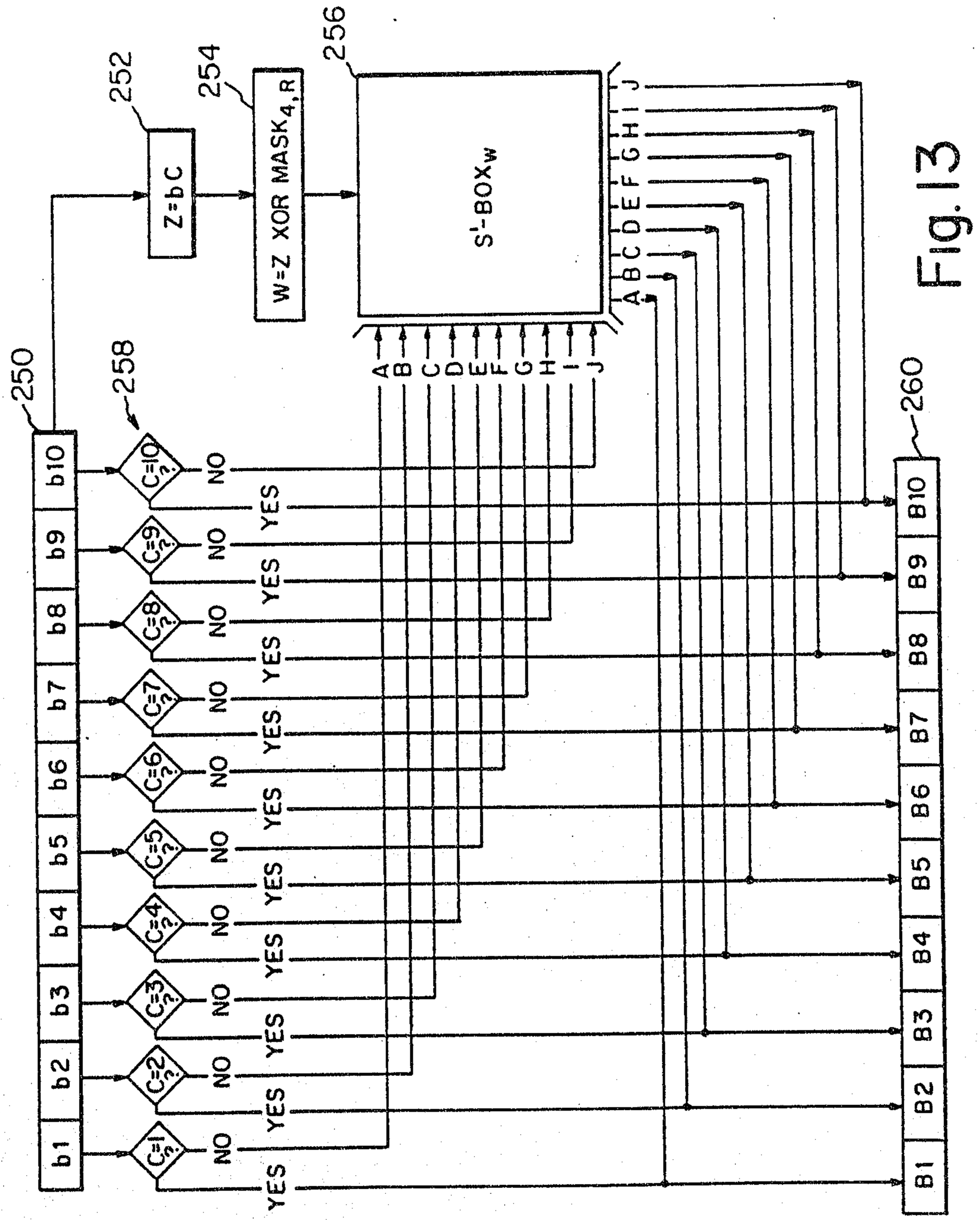

250
252
254
256
258
260
Z=bC
W=Z XOR MASK4
S'-BOXW
A B C D E F G H I J
b10 b9 b8 b7 b6 b5 b4 b3 b2 b1
C=10? C=9? C=8? C=7? C=6? C=5? C=4? C=3? C=2? C=1?
NO
YES
B10 B9 B8 B7 B6 B5 B4 B3 B2 B1

Fig. 13

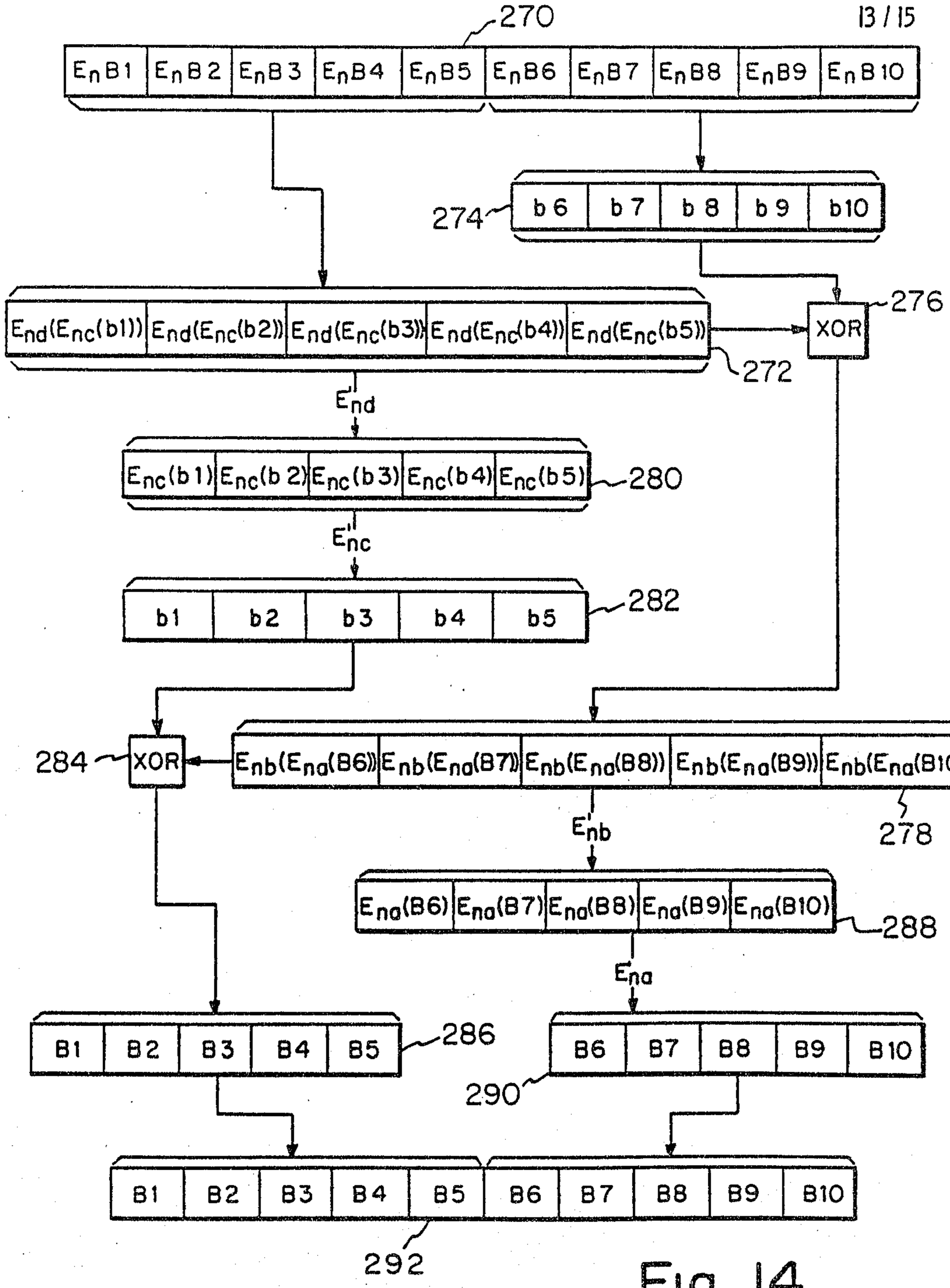

270
EnB1 EnB2 EnB3 EnB4 EnB5 EnB6 EnB7 EnB8 EnB9 EnB10
274
b6 b7 b8 b9 b10
276
XOR
End(Enc(b1)) End(Enc(b2)) End(Enc(b3)) End(Enc(b4)) End(Enc(b5))
272
E'nd
Enc(b1) Enc(b2) Enc(b3) Enc(b4) Enc(b5)
280
E'nc
b1 b2 b3 b4 b5
282
284
XOR
Enb(Ena(B6)) Enb(Ena(B7)) Enb(Ena(B8)) Enb(Ena(B9)) Enb(Ena(B10))
278
E'nb
Ena(B6) Ena(B7) Ena(B8) Ena(B9) Ena(B10)
288
Ena
B1 B2 B3 B4 B5
286
B6 B7 B8 B9 B10
290
B1 B2 B3 B4 B5 B6 B7 B8 B9 B10
292

Fig. 14

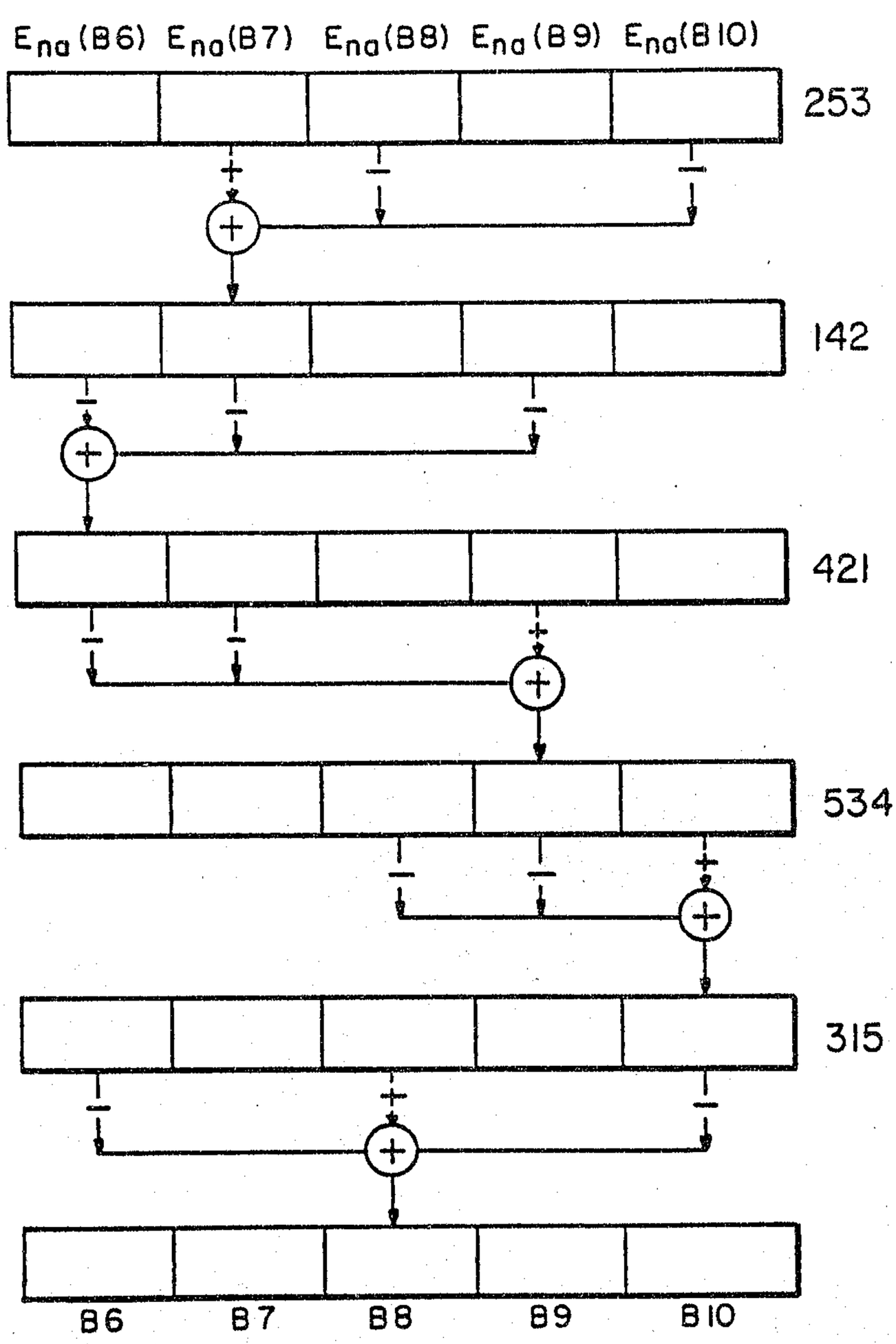

Ena(B6) Ena(B7) Ena(B8) Ena(B9) Ena(B10)
253
142
421
534
315
B6
B7
B8
B9
B10

Fig. 15

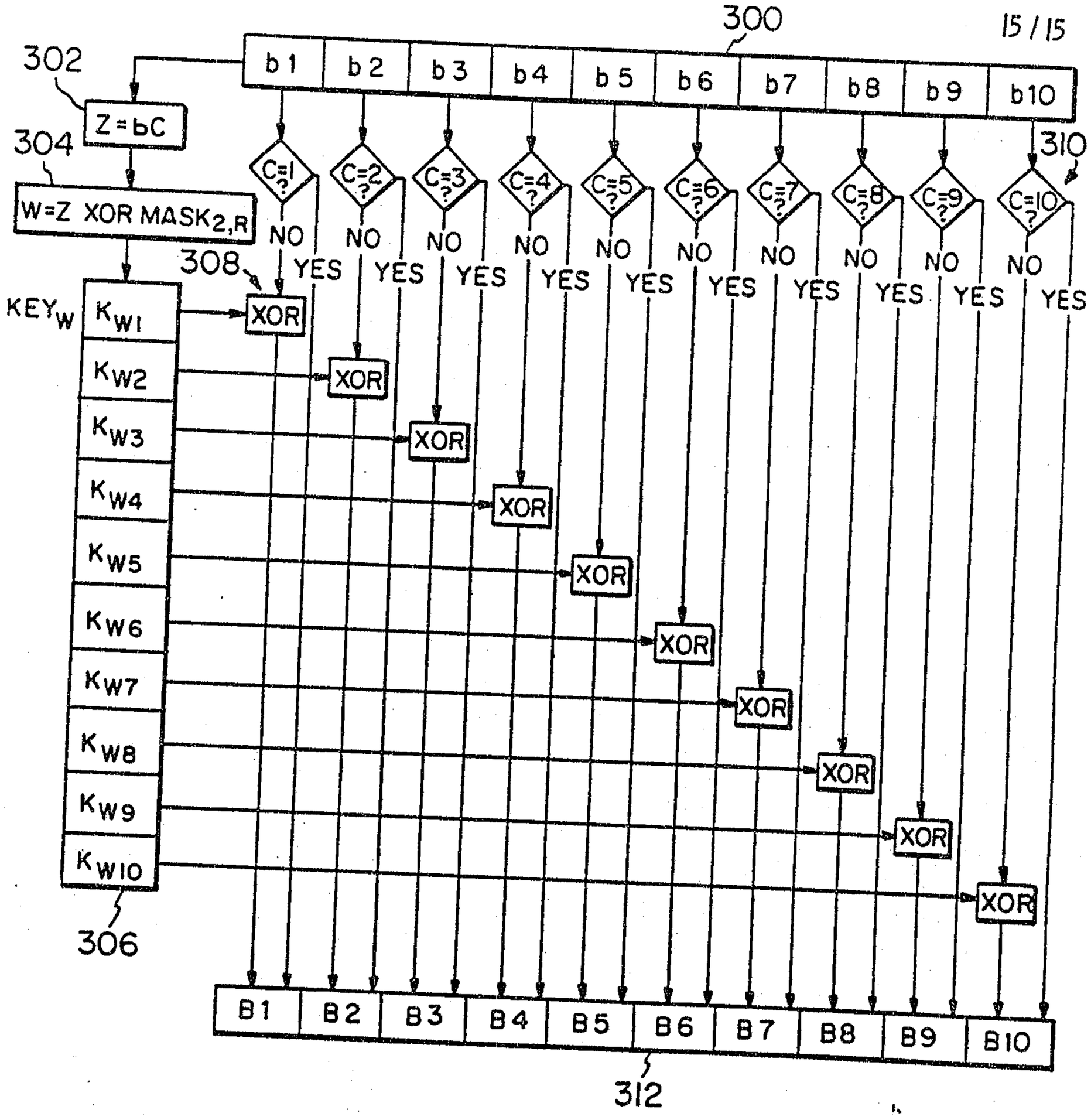

300
302
b1
b2
b3
b4
b5
b6
b7
b8
b9
b10
Z=bC
304
W=Z XOR MASK2,R
C=1?
C=2?
C=3?
C=4?
C=5?
C=6?
C=7?
C=8?
C=9?
C=10?
310
NO
YES
308
KEYW
KW1
KW2
KW3
KW4
KW5
KW6
KW7
KW8
KW9
KW10
XOR
306
B1
B2
B3
B4
B5
B6
B7
B8
B9
B10
312

Fig. 16