



US 20070271320A1

(19) **United States**(12) **Patent Application Publication****Tsuyuzaki**(10) **Pub. No.: US 2007/0271320 A1**(43) **Pub. Date: Nov. 22, 2007**

(54) **RANDOM PULSE GENERATION SOURCE,
AND SEMICONDUCTOR DEVICE, METHOD
AND PROGRAM FOR GENERATING
RANDOM NUMBER AND/OR PROBABILITY
USING THE SOURCE**

Publication Classification(51) **Int. Cl.****G06F 7/58** (2006.01)**G06F 1/02** (2006.01)**G21G 4/00** (2006.01)(76) Inventor: **Noriyoshi Tsuyuzaki, Chiba--ken (JP)**(52) **U.S. Cl.** **708/251; 250/493.1; 708/277**

Correspondence Address:

KUBOVCIK & KUBOVCIK**SUITE 710****900 17TH STREET NW****WASHINGTON, DC 20006**

(57)

ABSTRACT

The present invention provides a semiconductor device such as an IC capable of generating completely random signals and generating an authentication signal, random number, and probability by integrally setting a random pulse generation source for spontaneously generating at the inside, and also provides a method/program for generating a random number and/or probability, comprising the steps of setting a random pulse generation source (hereafter referred to as RPG) for spontaneously generating random pulses, measuring the time interval between the random pulses generated from the RPG or measuring a voltage value of the random pulse, and converting it into a digital value, and generating an exponential distribution random number and/or uniform random number having a predetermined bit length and/or a probability from random pulses as converted to digital values.

(21) Appl. No.: **11/630,678**(22) PCT Filed: **Jun. 28, 2005**(86) PCT No.: **PCT/JP05/12288**

§ 371(c)(1),

(2), (4) Date: **Dec. 27, 2006**(30) **Foreign Application Priority Data**

Jun. 30, 2004 (JP) 2004-193456

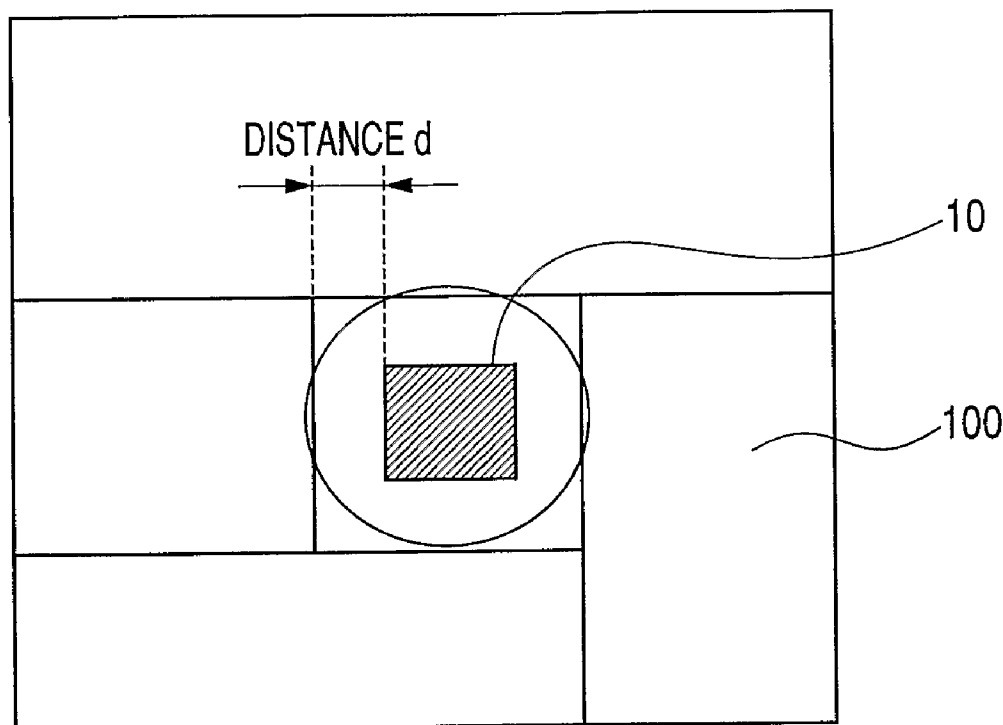


FIG. 1

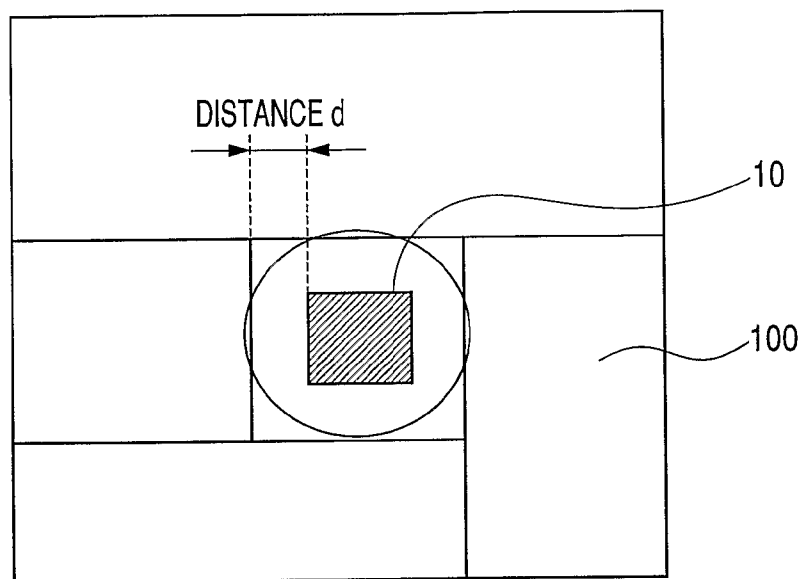


FIG. 2

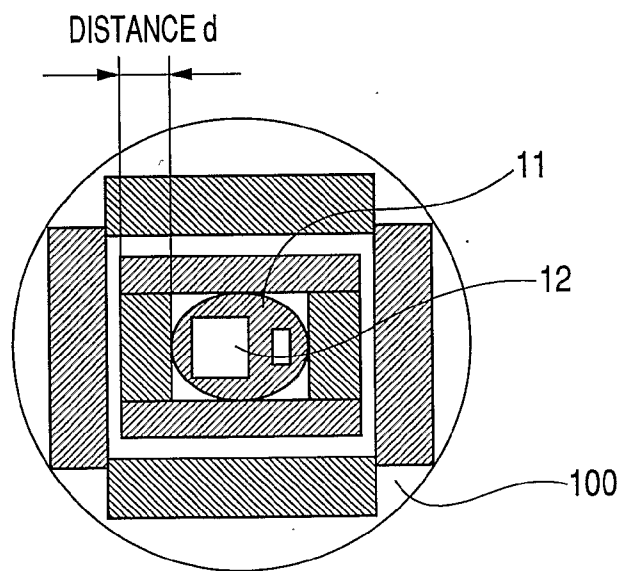


FIG. 3

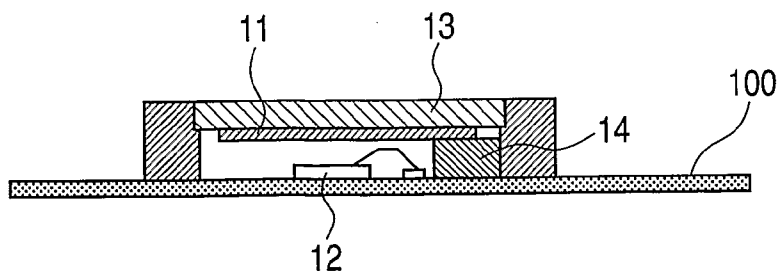


FIG. 4A

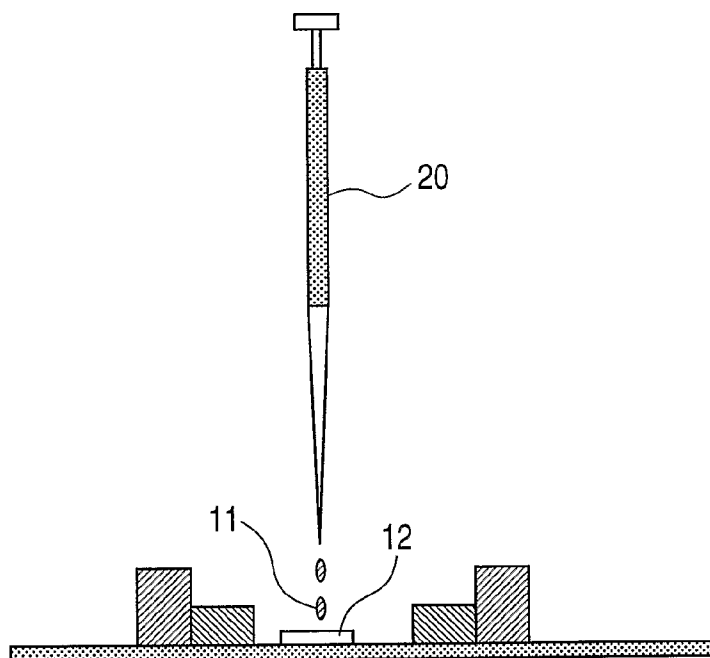


FIG. 4B

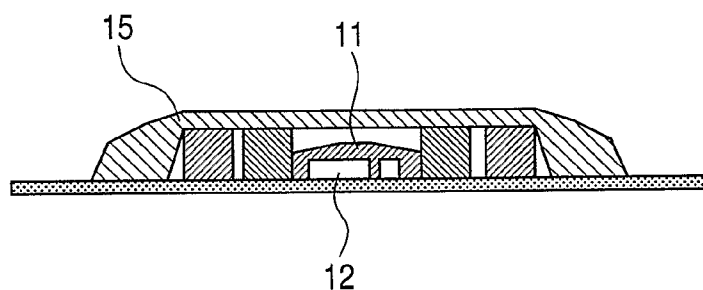


FIG. 4C

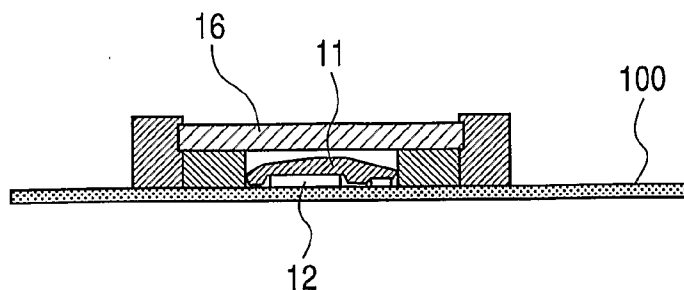


FIG. 5A

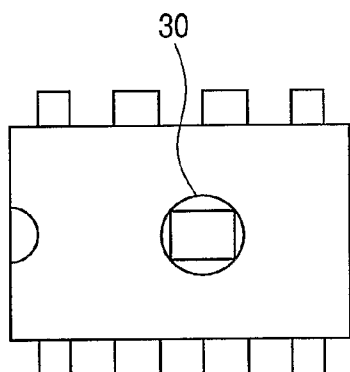


FIG. 5B

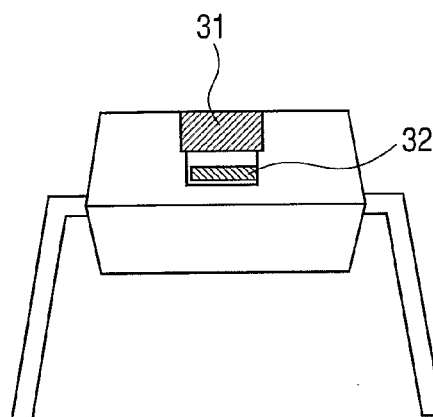
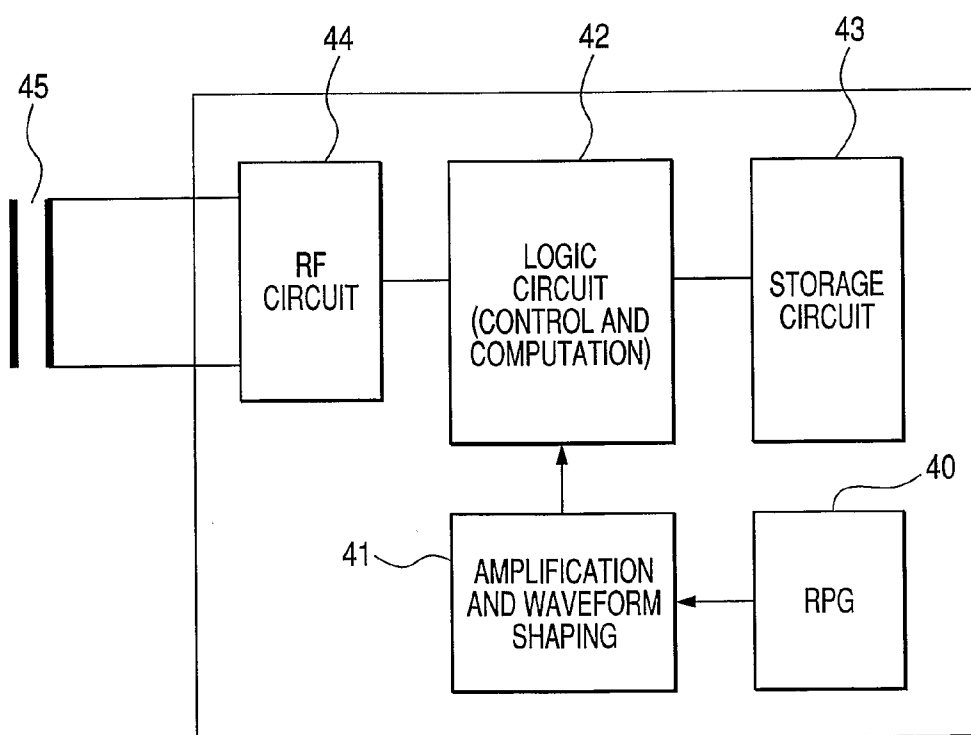


FIG. 6



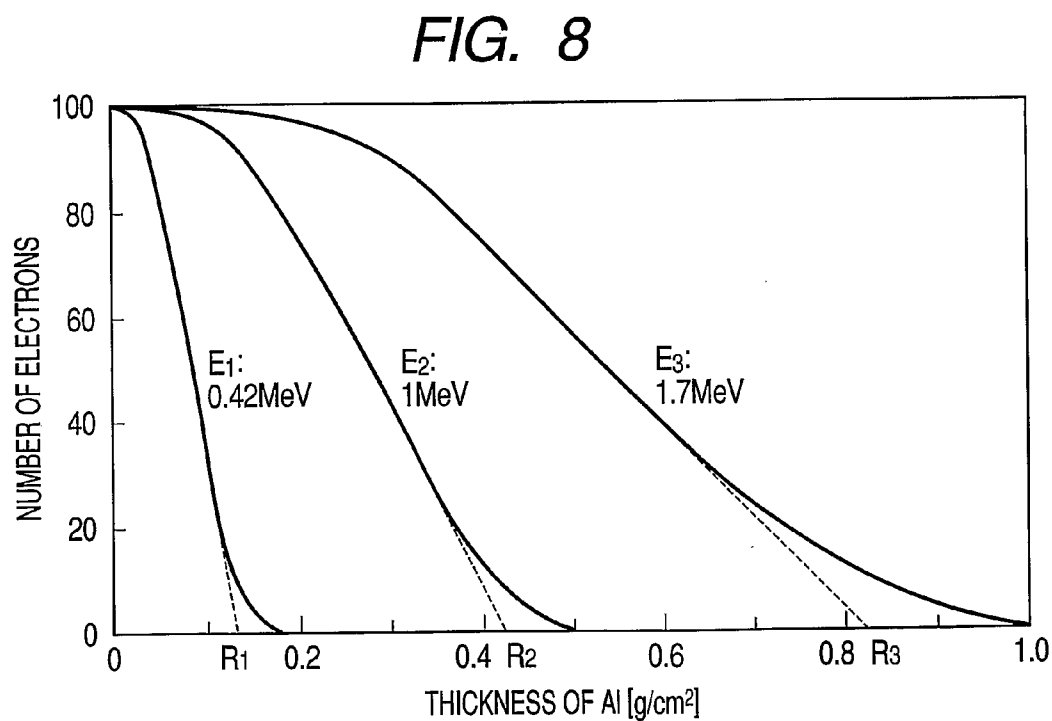
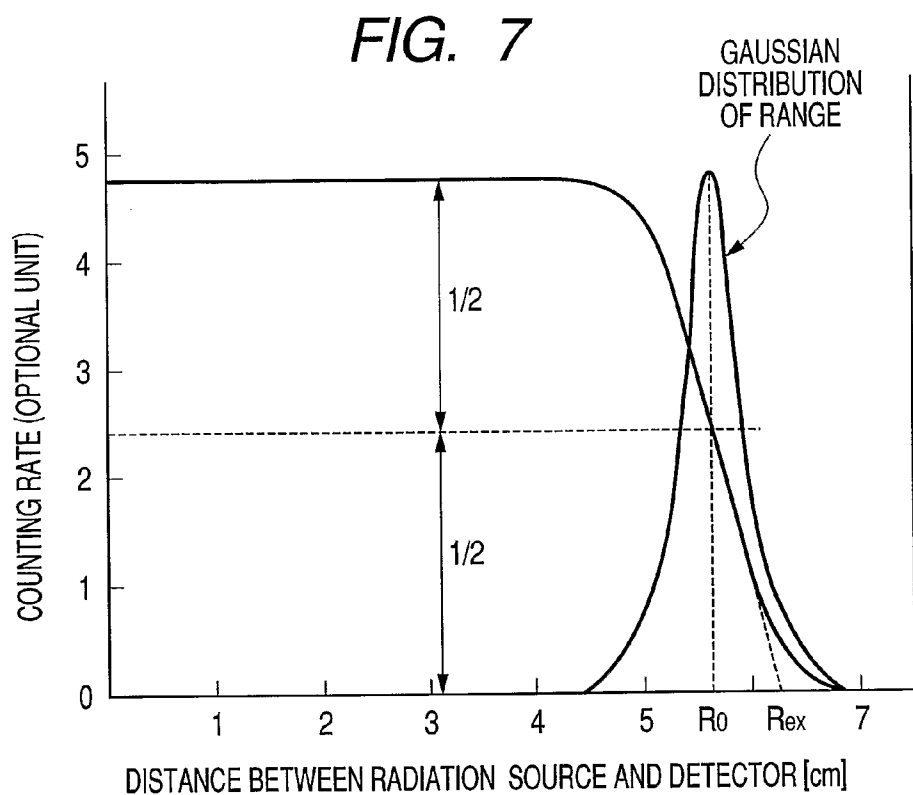


FIG. 9

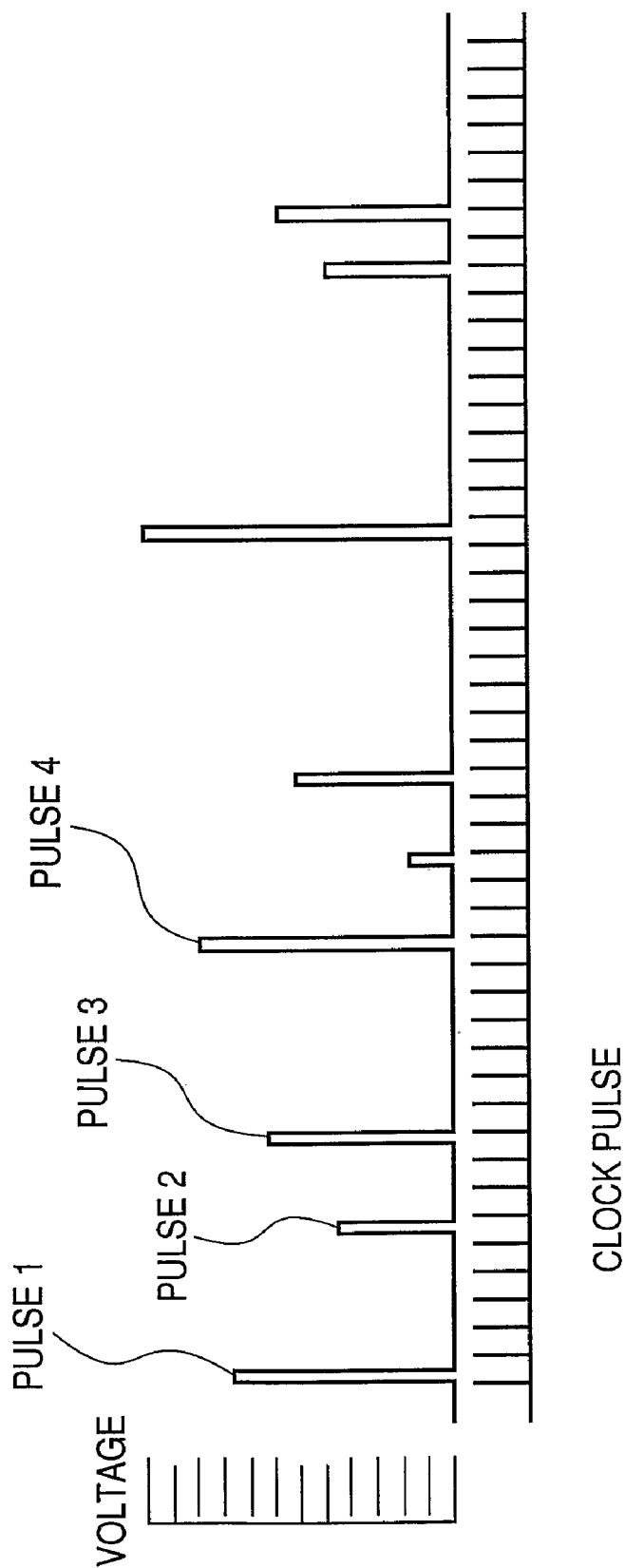


FIG. 10A

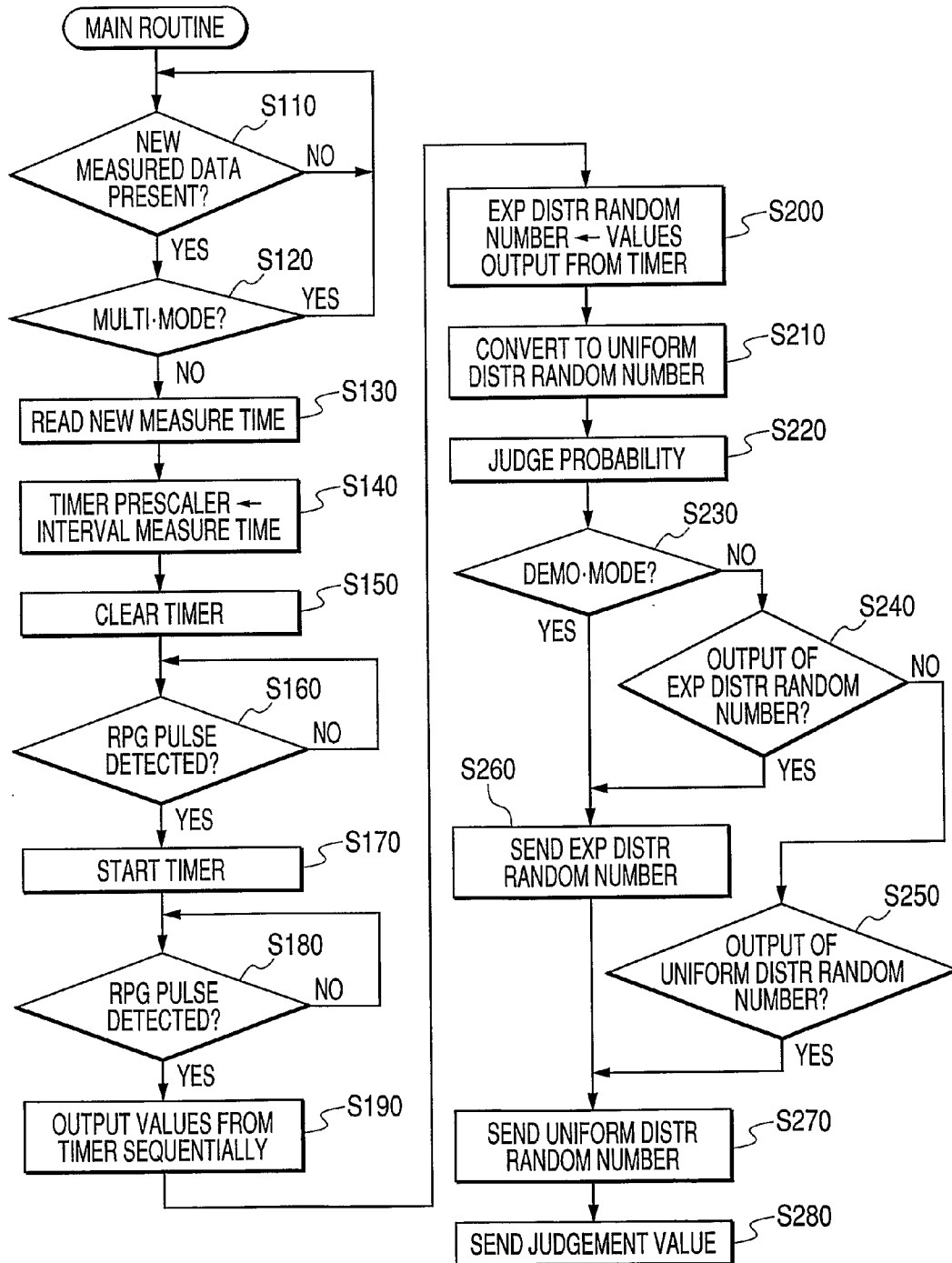


FIG. 10B

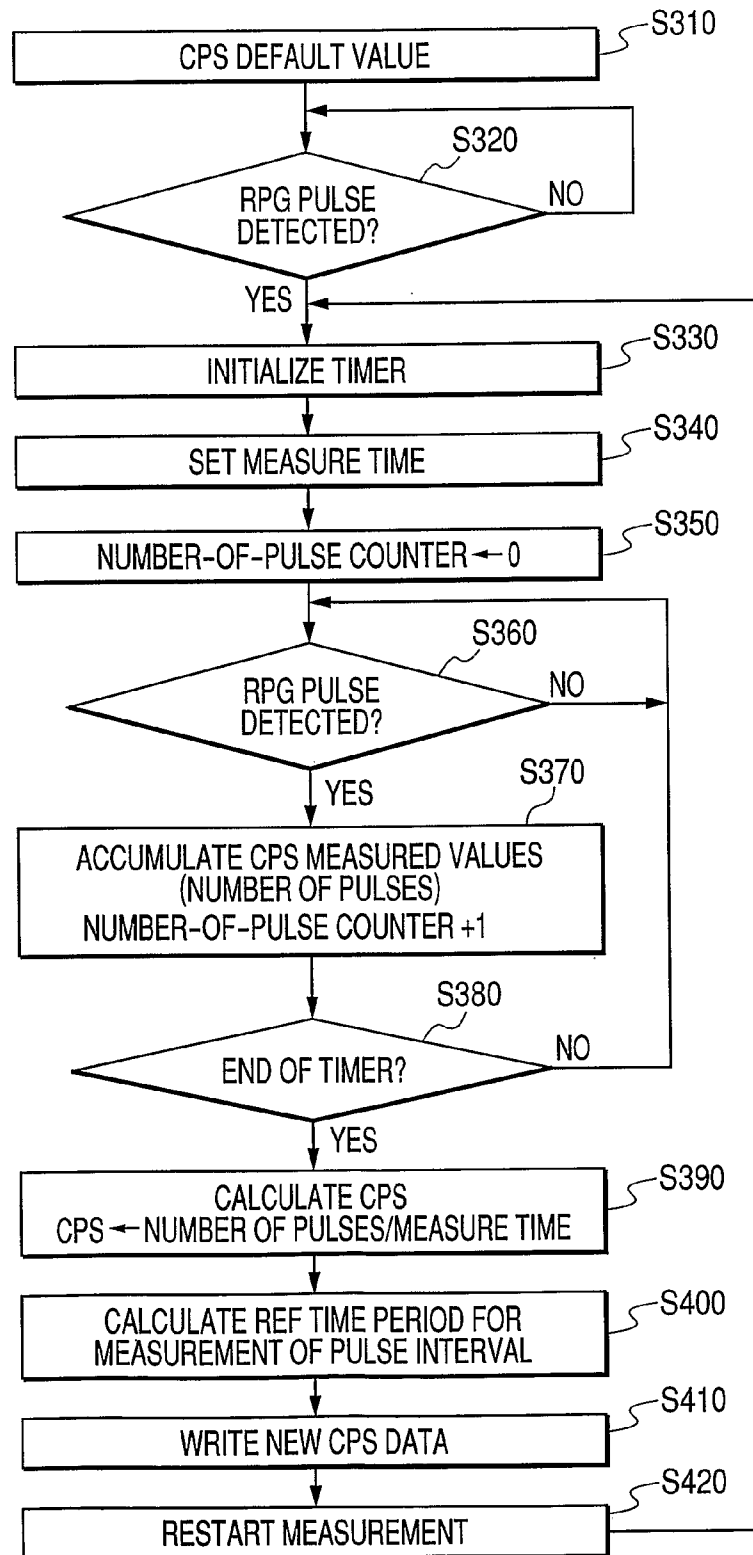
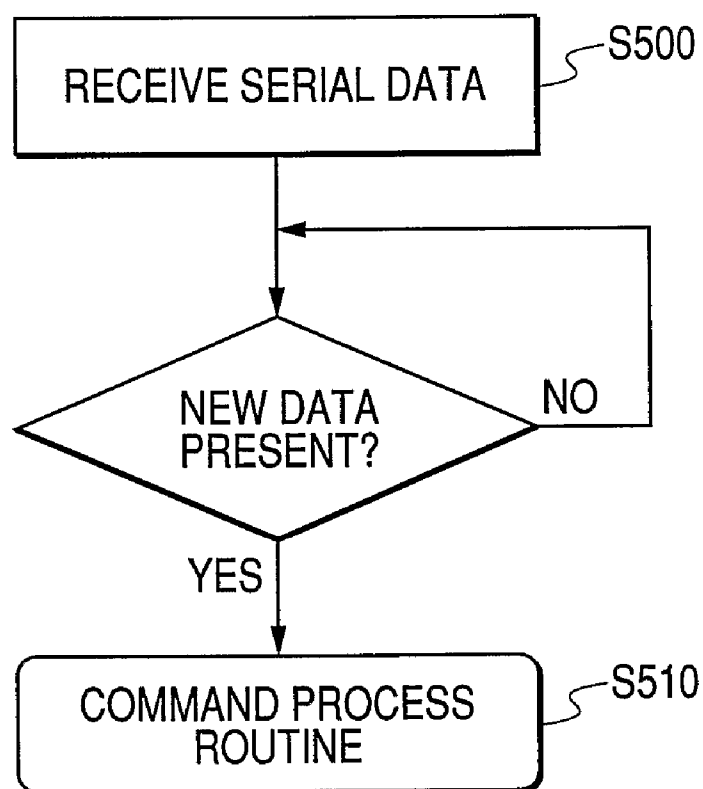


FIG. 10C



**RANDOM PULSE GENERATION SOURCE, AND
SEMICONDUCTOR DEVICE, METHOD AND
PROGRAM FOR GENERATING RANDOM
NUMBER AND/OR PROBABILITY USING THE
SOURCE**

TECHNICAL FIELD

[0001] The present invention relates to a random pulse generation source provided with an α -particle emitter for spontaneously generating complete random pulses, a semiconductor device such as an IC having such a random pulse generation source integrally fitted therein and capable of generating completely random signals and preparing an authentication signal, random number, and probability, and method and program for generating random number and/or probability using the source.

BACKGROUND ART

[0002] An IC tag whose security is improved is disclosed in Japanese Patent Laid-Open Nos. 2003-337928 and 2003-16396. The IC tag disclosed in the former official gazette has a configuration of storing a power through connection with a terminal, generating a one-time password by a CPU in the IC by means of the power, holding the password in a memory, and deleting the held password when the stored power is discharged and the IC tag disclosed in the latter official gazette has a configuration of reading authentication data from the tag twice or more and using a pseudo random value as authentication data.

DISCLOSURE OF THE INVENTION

[0003] However, these IC tags do not include a generator for generating completely random signals or a function for generating such signals. In the case of this type of the authentication IC, a storage circuit is built in, authentication data is obtained by receiving a signal from the outside through radio communication or infrared communication or generated in an IC chip and the data is written in the storage circuit. Moreover, the data stored in an IC chip at the receiving side can be read from the outside and therefore, the data is weak in confidentiality and has a problem on security. Furthermore, when using random number data in order to differentiate ICs, a pseudo random number prepared by a program at the transmitting side is frequently used and therefore, holding of secret at the transmitting side is indispensable. Moreover, there is vulnerability that regularity can be estimated from random number data, the number of combinations is restricted, and it is misdoubted that a plurality of same identification numbers are mixed. When using the IC tag for pursuit, a problem occurs that individual information is accumulated at the pursuit side and the IC tag becomes a spread inhibition factor.

[0004] Moreover, in the case of an authentication device such as an electronic lock, an authentication signal generating function is not included in a chip in the case of a convention IC used to authenticate the other party. For anti-clone (anti-counterfeit), an authentication signal is sent from the outside through radio or infrared communication and this authentication data is stored in a storage device in a chip, and the other party is recognized as a correct one when the authentication data coincides with the data stored at the transmitting source. Therefore, when completely

copying the stored data, it is impossible to judge true or false by the transmitting source. Therefore, there is a problem on security similarly to the case of the above IC tag.

[0005] Moreover, there is an IC in which a random number generator using thermal noise or noises is built in. Thermal noises or noises are influenced by a change of environments such as electromagnetic waves. Therefore, it is necessary to handle not only a completely random signal but also a pseudo random number and therefore and reliability is restricted. In the case of a system using noises, random numbers generated in accordance with the noises are phenomenologically disordered. However, there is no logical corroboration about the performance of a random number other than those based on various evaluation methods.

[0006] The present invention is developed to eliminate the above-described conventional problem.

[0007] A random pulse generator (generation source) (hereafter referred to as RPG) of the present invention is constituted so as to include an emitter for discharging α particles or beta rays, or α -particles and beta rays discharged due to nuclear decay, and a detector for detecting discharged α -particles or the like, and use the emitter as a solution and drip the solution on the detection face of the detector.

[0008] An RPG of the present invention is also constituted so as to include an emitter for discharging α particles or beta rays, or α particles and beta rays discharged due to nuclear decay, and a detector for detecting discharged α particles or the like, characterized in that the emitter is used as a solution, a member on which the solution is evaporated or which is formed into a panel by e.g. the roller method is faced with the detector, spacing a predetermined distance.

[0009] Moreover, a semiconductor device including an IC, relating to the present invention is constituted so as to generate a random number and/or probability by using a random pulse generation source for spontaneously generating random pulses, measuring a time interval between random pulses generated from the RPG or a voltage value, and converting the interval or voltage value into a digital value.

[0010] For example, when applying the present invention to an authentication device, a random pulse generator (RPG) having a discharge source of α -particles endlessly discharged due to natural decay is built in an IC body and a completely random signal is obtained from the RPG to use the signal as an authentication signal. That is, an IC chip always generates an authentication signal to rewrite the signal to new authentication data for every authentication so that a copy does not make sense. In this case, almost endless combinations of authentication signals can be made without using a program, management of authentication data is made unnecessary at the IC chip fabrication side, and it is possible to establish complete security at the user side having an IC chip.

[0011] Moreover, though details will be described later, in the case of the present invention, it is possible to easily prepare a complete random number and probability from a signal of an RPG in an IC chip. Thereby, by providing the IC, a random number and probability can be easily used.

[0012] The present invention is not influenced by an environmental condition at all, an original signal generation

source which cannot be artificially controlled is built in an IC body, and a random signal generated by an IC is used as a source signal for generating an authentication signal, random number, and probability. Thereby, it is possible to construct an authentication system which cannot be artificially operated and in which safety is established.

[0013] Moreover, storage of data is unnecessary at the authentication-system supply side and it is possible to greatly decrease the cost. It is possible to handle uniform random numbers generated by the present invention as complete random numbers and the system can be used as a probability generator to which artificial dishonesty cannot be applied.

[0014] The present invention is also directed to a method/program for generating a random number and/or probability, comprising the steps of setting a random pulse generation source (hereafter referred to as RPG) for spontaneously generating random pulses, measuring the time interval between the random pulses generated from the RPG or measuring a voltage value of the random pulse, and converting it into a digital value, and generating an exponential distribution random number and/or uniform random number having a predetermined bit length and/or a probability from random pulses as converted to digital values.

[0015] The method/program is characterized in that the step of generating an exponential distribution random number and/or uniform random number having a predetermined bit length and/or a probability from random pulses, obtains a necessary number of probabilities from an exponential distribution showing a probability in which the same pulse interval occurs between pulses generated from the RPG to prepare a uniform random number in accordance with the probability.

[0016] The method/program is also characterized in that the step of generating an exponential distribution random number and/or uniform random number having a predetermined bit length and/or a probability from random pulses, recognizes, in obtaining a probability from the time interval between t_1 and t_2 by using the exponential distribution, a pulse having a predetermined probability when exceeding the time t_1 by assuming that the time t_2 is infinite time.

[0017] The method/program is also characterized in that the step of generating an exponential distribution random number and/or uniform random number having a predetermined bit length and/or a probability from random pulses, realizes, in preparing a random number from an exponential distribution, an appearance probability density distribution in which an exponential distribution random number and uniform distribution random number are stabilized, by fluctuating a basic cycle for measurement and performing the same computation even if the average discharge rate of pulses is fluctuated.

[0018] The method/program is characterized in that the step of generating an exponential distribution random number and/or uniform random number having a predetermined bit length and/or a probability from random pulses, stabilizes a distribution of exponential distribution random numbers by fluctuating a basic cycle for measurement when preparing a random number from an exponential distribution and processes generation of a uniform distribution random number and generation of a probability simultaneously.

[0019] The method/program is also characterized in that the step of generating an exponential distribution random number and/or uniform random number having a predetermined bit length and/or a probability from random pulses, automatically corrects fluctuation of an operation clock for an oscillation frequency of hardware such as microcomputer for measuring time by fluctuating a basic cycle for measurement when preparing a random number from an exponential distribution.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020] FIG. 1 is an illustration showing a setting example of an α -particle emitter to an IC tag;

[0021] FIG. 2 is an enlarged view of an α -particle emitter setting portion;

[0022] FIG. 3 is an enlarged view of an α -particle emitter setting portion (setting example when the α -particle emitter is discoid);

[0023] FIG. 4A is an illustration showing dripping of an α -particle emitter and sealing example;

[0024] FIG. 4B is an illustration showing dripping of an α -particle emitter and sealing example;

[0025] FIG. 4C is an illustration showing dripping of an α -particle emitter and sealing example;

[0026] FIGS. 5A and 5B are illustrations showing a case of setting a pulse generation source to a DIP-type IC;

[0027] FIG. 6 is a block diagram showing a RPG-RFID of the present invention;

[0028] FIG. 7 is a graph showing a relation between distance between α -particle emitter and detector and counting rate of α particles;

[0029] FIG. 8 is a graph showing decrease of the number of electrons due to increase of the thickness of aluminum;

[0030] FIG. 9 is an illustration showing a RPG output pulse; and

[0031] FIGS. 10A, 10B and 10C are flowcharts showing parts of an operation of an embodiment according to the present invention.

BEST MODE FOR CARRYING OUT THE INVENTION

[0032] Specific description is made by taking an RPG-RFID (Radio Frequency Identification) chip to which a function of a radio tag is added as an example. However, the present invention is not restricted to the example. It is a matter of course that the present invention can be applied to another semiconductor device such as an IC for generating an authentication signal, random number, or probability.

[0033] Moreover, it is possible to apply the present invention to an IC card, IC tag, PC connectable unit, unit built-in module, etc. including a random pulse generation source (RPG) to be described below and moreover apply the present invention to an IC card, IC tag, PC connectable unit, unit built-in module, etc. including a semiconductor device constituted so as to generate a random number and/or probability by measuring a time interval between random

pulses generated from the RPG or voltage value and converting the value into a digital value.

[0034] An IC tag of the present invention has the following structure. An RPG (random pulse generator) for generating complete random pulses is used by improving a pulse generator using α particles disclosed in Japanese Patent No. 2926539 obtained by the present inventor. An α -particle emitter uses one of ^{241}Am , ^{244}Cm , ^{210}Pb , ^{210}Po , ^{210}Po , etc. which are naturally decayed. More specifically, it is possible to use all nuclear species of uranium series, all nuclear species of thorium series, and all nuclear species of ^{210}Pb - ^{210}Po , etc. forming the radioactive-equilibrium between these nuclear species, ^{244}Cm , or ^{241}Am . Moreover, it is allowed to use an RPG for generating random pulses by using beta rays or gamma rays as long as an IC tag is used for a portion having a shield setting space at an IC tag use destination.

[0035] Because α particles, beta rays, and gamma rays are not influenced by an environment such as temperature, pressure, humidity, or electromagnetic waves, it is impossible to artificially operate them. This specific IC cannot be realized by other method and the IC is important factor to secure safety. An IC tag used for a portion for which complete safety is not requested can use an RPG using a thermal noise or jitter of a semiconductor as a random pulse generation source.

[0036] An RPG-RFID chip of an IC tag includes an RPG, electronic circuit for making it possible to use a random pulse transmitted from the RPG as an authentication signal, circuit for storing the authentication signal, storage device, circuit for transmitting an authentication signal corresponding to the conformation of communication, antenna, communication device, etc. As for power supply, RF energy is supplied from the antenna in the case of the RPG-RFID chip. However, it is also allowed to use a terminal and supply a power via the terminal when there is a setting space for the terminal.

[0037] In the case of an authentication procedure of the RPG-RFID chip, random signals (generation time and time interval between pulses) from the built-in RPG are written, as authentication signals of the RPG-RFID chip, in an inside storage device. The stored signals are fetched from the outside by using communication means with the RPG-RFID chip or through connection by direct contact to confirm that there is not a combination of same authentication signals in the same lot.

[0038] When an RPG-RFID chip to be shipped is used for specific commodity management and a distribution range is comparatively restricted in management of moving information or the like since the time of shipment, the authentication signal of each RPG-RFID chip is read through communication before shipment, stored, and used.

[0039] The authentication procedure and storage of authentication data are performed for every communication to replace the authentication data with random signals generated by the RPG-RFID chip.

[0040] An embodiment of an RPG-RFID chip provided with a random pulse generator (RPG) of the present invention is described in detail by referring to the accompanying drawings.

[0041] First, a random pulse generator (RPG) for spontaneously generating random pulses is described.

[0042] The RPG is constituted of an α -particle emitter, and PN-type semiconductor, PNP-type semiconductor, PIN photodiode, phototransistor, photodiode or the like at the central portion of the RPG-RFID chip shown in FIG. 1. The device of the pulse generator is selected in accordance with the safety level requested for the RPG-RFID chip. In FIG. 1, reference numeral 10 denotes a position where an α -particle emitter and a detector are set, and 100 denotes a base substance (silicon base).

[0043] FIG. 2 shows a structure around the α -particle detector of the RPG-RFID chip to which the α -particle emitter is set. The α -particles (He atoms) discharged from the α -particle emitter are not influenced by an environment such as temperature, pressure, or electromagnetic waves, a power supply is also unnecessary, and α particles are semi-permanently discharged in accordance with the half-life. That is, this system is characterized in that it is possible to use a signal source which cannot be artificially operated at all for an original signal used for authentication. Therefore, this system becomes a signal generation source which cannot be changed at all from the outside. When complete safety is not requested for the setting portion of this IC, it is also allowed to use e.g. a diode for generating noises for a pulse generator. In FIG. 2, reference numeral 11 denotes an evaporated or dripped α -particle emitter and 12 denotes a detector.

[0044] To incorporate an α -particle emitter into an IC, there are the following two methods: a method using a member on which an α -particle emitter is evaporated or which is formed like a disk by a roll method and a method of dripping the solution of an α -particle emitter (also including injection by ink jet system).

[0045] In the case of the method for incorporating the α -particle emitter formed like a disk, the α -particle emitter is set immediately above an α -particle detection diode. There are the following two setting methods: a method for setting a spacer so that the distance between the detection diode and the α -particle emitter becomes a predetermined distance and mounting the α -particle emitter on the spacer and a method for setting the α -particle emitter by adhering it to a sealing plate. FIG. 3 shows a set structure. In FIG. 3, reference numeral 11 denotes an α -particle emitter, 12 denotes a detector, 13 denotes a sealing plate, and 14 denotes a spacer for setting the distance between the emitter and the detector.

[0046] The following is a method for constituting a detector by dripping the solution of an α -particle emitter. (Refer to FIGS. 4A to 4C.)

[0047] The volume including the circumference of a detector to which the solution is dripped is first calculated to obtain a volume of the solution which does not flow to the outside. The quantity of the solution to be dripped is made equal to the volume. The number of atoms of the α -particle emitter included in the dripping quantity is obtained so that a predetermined pulse number is obtained and a concentration is adjusted before dripping the emitter so that the concentration is obtained.

[0048] A necessary quantity is absorbed by a dripping jig such as a microsyringe 20 and the solution 11' of a previ-

ously-decided quantity of an α -particle emitter is extruded to drip the solution 11' on the surface of the detector 12 (refer to FIG. 4A). After dripping the solution 11', the detector 12 is sealed by a sealing material 15 such as epoxy (refer to FIG. 4B) or sealed by a sealing disk 16 (refer to FIG. 4C). The same procedure is used for a case in which the solution is dripped in accordance with injection of the solution by using an ink jet system.

[0049] The distance between the α -particle emitter and the circuit portion (distance d in FIGS. 1 and 2) is taken larger than the range of α particles obtained by the following expression in order to prevent a malfunction due to α particles.

[0050] FIG. 7 shows a general range of α particles in air. The axis of abscissa denotes the distance between α -particle emitter and detector and the axis of ordinate denotes discrete value (optional unit). The calculation when using ^{210}Pb - ^{210}Po for an α -particle emitter is shown below.

[0051] A relation between energy E (MeV) of α particles and range R (cm) in air is well examined and is shown by the Geiger's expression.

$$E = 2.12R^{2/3} \quad (4 < E < 7)$$

$$R = 0.323E^{3/2} \quad (3 < R < 7)$$

Thus, the range of Po α particles is shown below.

$$\begin{aligned} R &= 0.323 \times (5.305)^{3/2} & [\text{Formula 1}] \\ &= 0.323 \times 12.2188 \\ &= 3.94667 \text{ cm} \end{aligned}$$

[0052] The range Rs (cm) of α particles in a solid substance is obtained from the following Bragg-Kleeman's expression when the range in air is already known.

$$Rs = \frac{3.2 \times 10^{-4} RA^{1/2}}{\rho} \quad [\text{Formula 2}]$$

[0053] A: Atomic weight of a solid substance

[0054] ρ : Density

[0055] The range of α particles in Si is shown by the following expression.

$$\begin{aligned} Rs &= \frac{3.2 \times 10^{-4} \times (3.94667) \times (28.0855)^{1/2}}{2.33} & [\text{Formula 3}] \\ &= 0.002873 \text{ cm} \\ &= 0.0287 \text{ cm} \\ &= 28.7 \text{ } \mu\text{m} \end{aligned}$$

[0056] Therefore, when using a shielding material (shielding wall) of Si in order to separate from a circuit, it is allowed to set 29 μm or more.

[0057] Moreover, ^{210}Pb - ^{210}Po discharges very weak beta rays. In the case of the beta ray, the number of reached electrons is exponentially decreased with a distance as shown in FIG. 8 differently from α particles. A beta ray is an electron but it does not influence an internal IC circuit at all. However, it is necessary to use a structure from which beta rays do not leak to the outside so as not to be misunderstood. A necessary thickness of a shielding material is obtained from the following expression. In FIG. 8, the axis of abscissa denotes thickness of Al and the axis of ordinate denotes the number of electrons.

[0058] Because the maximum energy Em of the Pb-210 beta ray is 0.061 MeV, the maximum range Rm is calculated in accordance with the Willson's expression.

$$Rm = \frac{2400(Em)^2}{8.9304 \text{ mg/cm}^2} = \frac{2400 \times (0.061)^2}{8.9304 \text{ mg/cm}^2} = 2400 \times 0.003721 =$$

[0059] Moreover, from Isotope Handbook (Revised Third Edition, Maruzen, April, 1985), the range in Al is 6 mg/cm^2 at 60 KeV. Because the density of Al is 2.7 g/cm^3 , the following expression is obtained.

$$\begin{aligned} Rm &= \frac{8.9304 \text{ mg/cm}^2}{2700 \text{ mg/cm}^3} & [\text{Formula 4}] \\ &= 3.308 \times 10^{-3} \text{ cm} \\ &= 3.308 \times 10^{-2} \text{ mm} \\ &= 0.03308 \text{ mm} \\ &= 33 \text{ } \mu\text{m} \end{aligned}$$

[0060] Thus, it is enough that the sealing material shown in FIG. 1 necessary for a RPG-RFID chip is 33 μm or more.

[0061] The present invention can be easily built in not only a RPG-RFID chip but also a general IC. FIGS. 5A and 5B show layouts when building the present invention in a DIP-type IC. It is unnecessary to set the position at which an α -particle emitter is built in to the center like FIGS. 5A and 5B but the position can be changed in accordance with a design of an IC circuit. (The same is also applied to an MM chip.) In the illustrations, reference numeral 30 denotes an α -particle emitter setting portion, 31 denotes a sealing cap or pitch, and 32 denotes a diode chip on which an α -particle emitter is dripped.

[0062] FIG. 6 shows the whole block circuit of a RPG-RFID chip of the present invention. The RPG-RFID chip is constituted of a waveform-shaping amplifying circuit 41, logic circuit (control processing) 42, storage circuit 43, RF circuit 44, and antenna 45.

[0063] The waveform-shaping amplifying circuit 41 is used to form a cusp waveform output from the RPG 40 into a shaped rectangular waveform which can be digital-processed. The logic circuit 42 is a processing circuit for handling a random pulse signal as a purposed signal. The storage circuit 43 is a circuit for storing data after signal processing. The RF circuit 44 is a circuit for performing communication with the outside through the antenna 45.

[0064] As shown in FIG. 9, to digitalize and store a signal from a RPG, the peak value and pulse interval of a random pulse of the RPG are random. Therefore, it is possible to

measure the pulse interval or sample-hold the voltage of the peak value to digital-convert the voltage, and bring the measured or converted value into a random number. Moreover, it is possible to use a combination between voltage and the number of clock pulses.

[0065] Then, when using a pulse generated by the RPG as an authentication signal, the probability in which completely the same pulse interval occurs is obtained.

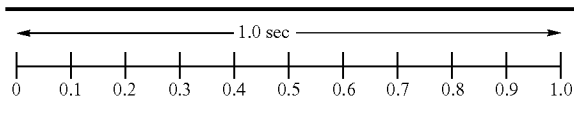
[0066] A case is obtained in which an average discharge rate $n=10$ of normally used pulses as an example.

[Formula 5]

$$P(t_1, t_2) = \frac{A \int_{t_1}^{t_2} e^{-nt} dt}{A \int_0^{\infty} e^{-nt} dt} = e^{-nt_1} - e^{-nt_2} \quad (1)$$

[0067] When the average discharge rate of the RPG is n 10, it is assumed to use an average number of pulses of 10 for 1 sec as an authentication signal.

TABLE 1



[0068] When it is assumed that 10 pulse intervals appear as an average pulse interval of 0.1 sec, the probability in which 10 pulses appear next time at the same time interval is shown by the calculation result of the following table.

TABLE 2

	Average number of pulses	Average (sec)	t1 (sec)	t2 (sec)	$e^{-n \cdot t_1}$	$e^{-n \cdot t_2}$	P	1/P	Total 1/P
1	10	0.1	0	0.1	1	0.367879	0.632121	1.581977	
2	10	0.1	0.1	0.2	0.367879	0.135335	0.232544	4.300259	5.882235
3	10	0.1	0.2	0.3	0.135335	0.049787	0.085548	11.68931	68.7593
4	10	0.1	0.3	0.4	0.049787	0.018316	0.031471	31.77485	2184.817
5	10	0.1	0.4	0.5	0.018316	0.006738	0.011578	86.373	188709.2
6	10	0.1	0.5	0.6	0.006738	0.002479	0.004259	234.7862	44306299
7	10	0.1	0.6	0.7	0.002479	0.000912	0.001567	638.215	2.83E+10
8	10	0.1	0.7	0.8	0.000912	0.000335	0.000576	1734.848	4.91E+13
9	10	0.1	0.8	0.9	0.000335	0.000123	0.000212	4715.806	2.31E+17
10	10	0.1	0.9	1	0.000123	4.54E-05	7.8E-05	12818.89	2.97E+21

[0069] From the calculation results of the above table, the probability in which 10 pulse strings at the same interval appear is $1/2.97E+21$.

[0070] Therefore, in the case of a method using this system, the probability in which at most 10 pulses realize the same combination is $1/2.97E+21$ or less. This probability is a probability in the same pulse generator but an individual pulse generator respectively has different n value. Therefore, the probability in which different pulse generators have the same pulse string become $(1/3E+21)^2$ or less.

[0071] It is possible to select a pulse number to be used in accordance with the purpose of an IC using this system for authentication and improve the safety.

[0072] Then, a method for preparing uniform random numbers is described below.

[0073] The probability of pulses appearing at a time interval from t_1 to t_2 is obtained from the above expression (1).

[0074] When transforming the above expression, the following expression (2) is obtained.

$$t_2 = -1/n \cdot \log(e^{-nt_1} - P). \quad (2)$$

[0075] wherein $t_2 > t_1$, therefore the above expression is replaced with $t_k = t_2$, $t_{k-1} = t_1$, and $t_1, t_2, \dots$ are successively obtained from $t_0 = 0$, and thereby, it is possible to obtain the threshold value of a time width (Δt) having $1/p$ ways of uniform appearance probabilities.

$$t_{k+1} = -1/n \cdot \log(e^{-nt_k} - p) \quad (3)$$

[0076] wherein, $t_0 = 0$

[0077] In the case of this expression (3), by fixing n and p , it is possible to univocally decide each t_k value. When performing pulse time interval measurement by a 16-bit length (0-65535) and considering the effective number of digits after conversion, it is necessary to set the data length to be replaced with the above threshold value to approx. 8-bit length. Otherwise, it is impossible to ignore the influence of an error in a short time interval. Therefore, the above p is set to 256 and the interval of 0-65535 (16-bit length) is converted to the interval of 0-255 (8-bit length) by the above threshold value. When 16 bits are required as a bit length, it is possible to generate 16 bits by connecting two 8-bit-length data values.

[0078] In the case of this method, when the n value increases, the appearance time interval relatively decreases. When keeping a time interval measuring resolution constant, an error becomes a problem. However, when the n value decreases, a time interval relatively increases. When keeping the time interval measurement resolution constant, a rounding error (overflow) occurs in an upper value.

[0079] Therefore, fluctuating the basic cycle of time measurement is made to correspond to the fluctuation of n value. That is, when the measured n value is small, the basic cycle

of measurement is increased, while when the n value is large, the basic cycle of measurement is decreased. Thereby, the distribution of value data as a measured result is always constant and, it is possible to simplify a subsequent arithmetic processing circuit. Moreover, because the fluctuation of the basic cycle of time measurement depends on only the average number of discharges for unit time, the fluctuation of the reference operation frequency of an arithmetic circuit is corrected in a scope which that the operation speed of the arithmetic circuit follows from the viewpoint of throughput. Therefore, the accuracy of the frequency of an oscillation circuit for generating clocks of the arithmetic circuit is not requested. Specifically, the following expression (4) is obtained.

$$t_{k+1} = -1/n * \log(e^{-ntk} - p). \quad (4)$$

[0080] wherein, $t_0 = 0$.

[0081] However, when assuming the fluctuation component of n as m and $n = n \times m$, the following expression (5) is obtained.

$$t_{k+1} = -1/nm * \log(e^{-nmtk} - p) \quad (5)$$

[0082] wherein, $t_0 = 0$.

[0083] In this case, by fluctuating the basic cycle of measured time in accordance with m ($tk = t1/m$), the following expression (6) is obtained.

$$t_{k+1} = -1/n * \log(e^{-nt1} - p) \quad (6)$$

[0084] wherein, $t_0 = 0$.

[0085] Therefore, a basic arithmetic expression can be directly applied.

[0086] When assuming the operation frequency used for the arithmetic circuit as approx. 25 MHz, the basic cycle clock is 40 ns. When assuming n value as 10, an average pulse interval is 100 ms. Measurement of the average pulse interval is made by assuming the measurement basic cycle as 100 μ s. The number of divisions for generating the measurement basic cycle becomes 100 μ s/40 ns=2500 counts. Therefore, the minimum value (resolution) of the above fluctuation value m becomes 0.4/100=0.004(0.4%) and the resolution of the fluctuation of measured reference time to the fluctuation of n value does not matter.

[0087] The measurement time necessary to obtain 256 values in accordance with this system increases as n decreases. For example, the 255th threshold value becomes 1.386 sec when n is equal to 4, 1.848 sec when n is equal to 3, and 2.773 sec when n is equal to 2. Therefore, it is necessary to continue counting up to this time. It is possible to round a time width more than that time in the maximum value (65535) of time measured data. (Even if rounding the time, the appearance frequency of the maximum data 255 does not greatly change.) Therefore, the maximum value of measurement is fluctuated due to n value.

[0088] Then, a method for preparing a probability is described below.

[0089] The probability using natural decay can be obtained by the following expression (1). The expression (1) can be shown by the following expression (7).

$$p = e^{-nt1} - e^{-nt2} \quad (7)$$

[0090] Therefore, it is only necessary to decide t_1 and t_2 for satisfying a probability value to be generated and judge

whether a pulse is present between t_1 and t_2 . In this case, when infinitely increasing t_2 , e^{-nt2} at the second item can be ignored because it becomes 0 and it is possible to judge a hit by comparing a measured time width with t_1 . By infinitely increasing t_2 , a region in which the appearance frequency of e^{-nt} is small is used. Therefore, it is possible to widely take a resolution. Therefore, it is possible to minimize a rounding error for probability calculation.

[0091] An expression when assuming that t_2 is infinite is shown by the following expression (8).

$$p = e^{-nt1} \quad (8)$$

[0092] When applying logarithm to the both sides of the expression (8) to obtain t_1 , the following expression (9) is obtained.

$$t_1 = -\log(p)/n \quad (9)$$

[0093] Thus, the value of t_1 can be obtained from a set probability-value (p) and the number of pulses (n) per sec.

[0094] Also in this case, necessary measurement time is fluctuated due to the fluctuation of n value. Particularly when a probability value is small, it is necessary to make long-time measurement effective. Therefore, by fluctuating the basic cycle of measurement similarly to the case of the computation of uniform random numbers, it is possible to solve the problem of overflow or insufficient accuracy of a counter. This method can correspond to a very small probability value. However, when a probability value is small, the maximum value of measurement increases and a case in which measurement time is lengthened occurs. However, by using a mechanism or structure for storing a past measured value in an arithmetic circuit, the problem of response time can be avoided.

[0095] It is only necessary to compute the expression (9) $t_1 = -\log(p)/n$ when a probability value is set from the outside, and a computation does not occur at the time of measurement. Therefore, the influence on actual operations is very small even if a computation time is required to a certain extent. To flexibly correspond to a set probability value and make it possible to select various probability values by external inputs, it is possible to compute the above logarithm operations by a microcomputer without using a table for omitting calculations.

[0096] Then, setting a reference measurement time in relative to n value for fluctuating a basic cycle is described below.

[0097] In the expression

$$p = e^{-nt1} - e^{-nt2} \quad (7)$$

[0098] wherein assuming t_0 as 0, the time interval of the maximum threshold value (255) can be obtained from the following expression (10) from $p = 255/256 = 1 - e^{-nt255}$.

$$t_{255} = -(1/n) * \log(1/256) = 5.545177/n \quad (10)$$

[0099] When setting the above 255th threshold value+5% as the time at which a 16-bit timer overflows, by taking some allowance, the maximum time interval which can be counted by the 16-bit timer is shown by the following expression (11).

$$t_{max} = 5.545177 * 1.05/n = 5.822436/n \quad (11)$$

[0100] Thereby, the cycle of the counting reference clock of the timer becomes

$$t_{\text{clk}} = (5.822436/65536)/n = 88.84333 \text{ } \mu\text{s}/n.$$

[0101] When assuming the basic operation frequency of an arithmetic circuit as 25 MHz, the cycle of a system clock becomes

$$t_{\text{sys}} = 40 \text{ ns}$$

[0102] and the value of a prescaler for generating a reference clock t_{clk} of the above timer becomes

$$t_{\text{pres}} = (88843.33/40.816)/n = 2176.7/n.$$

[0103] By fluctuating the counting reference cycle of the timer in accordance with the value of n, it is only necessary to use the expression (4) in order to obtain a threshold value for generating a uniform random numbers and the following expression is obtained.

$$t_{k+1} = -1/n * \log(e^{-nt_k} - p); \text{ wherein } t_0 = 0$$

[0104] In the above expression, when calculating each t_k when n is equal to 5.822436, threshold values from 1 to 255 can be calculated and they are shown in the table below.

TABLE 3

Data	Threshold value
0	0
1	44
2	88
3	133
4	177
5	222
6	267
7	312
8	357
9	403
10	448
11	494
12	540
13	587
14	633
15	680
16	726
17	773
18	821
19	868
20	916
21	963
22	1011
23	1060
24	1108
25	1157
26	1205
27	1254
28	1304
29	1353
30	1403
31	1453
32	1503
33	1553
34	1604
35	1655
36	1706
37	1757
38	1809
39	1860
40	1912
41	1965
42	2017
43	2070
44	2123
45	2176

TABLE 3-continued

Data	Threshold value
46	2229
47	2283
48	2337
49	2391
50	2446
51	2501
52	2556
53	2611
54	2667
55	2722
56	2779
57	2835
58	2892
59	2949
60	3006
61	3064
62	3121
63	3180
64	3238
65	3297
66	3356
67	3415
68	3475
69	3535
70	3595
71	3656
72	3717
73	3778
74	3840
75	3902
76	3964
77	4027
78	4090
79	4154
80	4217
81	4282
82	4346
83	4411
84	4476
85	4542
86	4608
87	4674
88	4741
89	4808
90	4876
91	4944
92	5012
93	5081
94	5150
95	5220
96	5290
97	5361
98	5432
99	5503
100	5575
101	5648
102	5720
103	5794
104	5868
105	5942
106	6017
107	6092
108	6168
109	6244
110	6321
111	6398
112	6476
113	6555
114	6633
115	6713
116	6793
117	6874
118	6955
119	7037

TABLE 3-continued

Data	Threshold value
120	7119
121	7202
122	7286
123	7370
124	7455
125	7541
126	7627
127	7714
128	7802
129	7890
130	7979
131	8069
132	8159
133	8250
134	8342
135	8435
136	8528
137	8622
138	8717
139	8813
140	8910
141	9007
142	9106
143	9205
144	9305
145	9406
146	9508
147	9610
148	9714
149	9819
150	9924
151	10031
152	10139
153	10248
154	10357
155	10468
156	10580
157	10693
158	10808
159	10923
160	11040
161	11158
162	11277
163	11397
164	11519
165	11642
166	11766
167	11892
168	12019
169	12148
170	12278
171	12410
172	12543
173	12678
174	12814
175	12952
176	13092
177	13234
178	13377
179	13522
180	13669
181	13818
182	13969
183	14123
184	14278
185	14435
186	14595
187	14757
188	14921
189	15088
190	15257
191	15429
192	15604
193	15781

TABLE 3-continued

Data	Threshold value
194	15961
195	16144
196	16330
197	16519
198	16712
199	16907
200	17107
201	17309
202	17516
203	17726
204	17941
205	18159
206	18382
207	18610
208	18842
209	19079
210	19321
211	19568
212	19821
213	20080
214	20345
215	20616
216	20894
217	21179
218	21471
219	21771
220	22080
221	22397
222	22723
223	23059
224	23405
225	23763
226	24132
227	24513
228	24908
229	25318
230	25742
231	26184
232	26643
233	27122
234	27623
235	28146
236	28696
237	29273
238	29881
239	30525
240	31207
241	31934
242	32710
243	33544
244	34445
245	35425
246	36497
247	37683
248	39009
249	40512
250	42247
251	44299
252	46811
253	50049
254	54613
255	62414

[0105] When obtaining that measured data is included between any threshold values, the result becomes an 8-bit uniform random number.

[0106] A method for obtaining that measured data is included between any threshold values includes two types of methods. One is a method for performing magnitude comparison by binary search after measurement is completed and the other is a method for checking a present measured

value is included in any area in the course of measurement. Each of the methods is described below.

Binary Search Method

[0107] In the case of the present conversion, condition for binary search is perfect because measured data becomes 16-bit length and converted data becomes 8-bit length, so a program can be greatly simplified. A sample of algorithms specified under this condition is shown below.

[0108] BitInd I Cator=10000000b;

[0109] Result=BitInd I Cator;

[0110] Repeat

[0111] If MeasuredValue<DataTable(Result) then
Result=Result xor BitInd I Cator;

[0112] BitInd I Cator=RightLotate(BitInd I Cator, 1
bit);

[0113] Result=Result xor BitInd I Cator;

[0114] Until BitInd I Cator. bit7="1";

[0115] In the case of this conversion, comparison of 16-bit length, bit processing(xor), and reference of a data table are performed eight times.

Judgment in Measurement Course

[0116] In the above threshold value table, a numerical value increases in order of 0 to 255. Therefore, by performing comparison with data table whenever measuring a pulse interval, processing is greatly simplified. Further, since conversion into uniform random number is completed when measurement is completed (or the next pulse arrives), response is also greatly improved. Therefore, a certain determined time is not required to arithmetic processing, unlike the above method using binary search. When using a microcomputer for arithmetic processing, the algorithm may effectively work. Specific algorithm is shown below.

[0117] In the case of this method, it is assumed that data for 1 to 255 in the above table is stored in 0 to 254.

<Initial Processing>

[0118] Result=0; Head of table

<For Every Prescaler Overflow>

[0119] if MeasuredValue=DataTable(Result) then Result=Result+1;

[0120] Therefore, because this is a very simple method and threshold value searches are performed dispersedly, a load for the throughput (processing capacity) of the arithmetic processing portion is very small.

[0121] Then, a processing procedure of a device/method for generating a random number and probability of the present invention is described below more minutely.

[0122] The method to be described below has three modes such as normal (stand alone) mode, demonstration mode, and multi-module mode (multimode) and the following features.

[0123] The normal mode is a mode to be connected with a host computer one to one, which outputs exponential distribution random number string and uniform random number string and outputs a probability judgment result in

accordance with input of a probability judgment read command. The demonstration mode is a mode prepared for demonstration, which outputs an exponential distribution random number string, uniform distribution random number string, and probability judgment result, for each measurement of pulses. The multimode can connect a plurality of modules, increase a random number generation speed, in which an exponential distribution random number string, uniform distribution random number string, and probability judgment result are respectively output in accordance with a command.

[0124] FIGS. 10A to 10C are flowcharts showing algorithm when processing a device/method of the present invention by using a microcomputer.

[0125] First, as shown in FIG. 10A, initializing operations such as clearing of a RAM, initialization of various registers, and reading of the default value of a flash memory are performed and the main routine is started.

[0126] In the main routine, it is checked whether unprocessed new measured time data is present (step S110). When the data is present, the data is called (read) (step S130) by premising that the present mode is not the multimode (step S120). Then, a prescaler of a timer for measuring an inter-pulse time (pulse time interval, pulse interval) is set (step S140) and the timer is cleared (step S150). When a RPG pulse is detected (step S160), the timer is started (step S170). Every time the RPG pulse is detected (step S180), the timer outputs measured data (step S190) and the data is stored as exponential random number (step S200). Then, the data is converted into a uniform distribution random number (step S210) to judge a probability (hit or failure) (step S220). Then, it is judged whether an operation mode is the demonstration mode (step S230). When the operation mode is the demonstration mode, an exponential distribution random number is transmitted to the host computer without condition (independently of presence or absence of selection of random number output) (step S260), a uniform distribution random number is transmitted (step S270), and moreover a probability judgment-value is transmitted (step S280).

[0127] When the operation mode is not the demonstration mode (that is, the normal mode), an exponential distribution random number is transmitted when the output of the random number is selected (step S240) and when the output of the uniform distribution random number is selected (step S250).

[0128] On the other hand, as shown in FIG. 10B, for measurement of CPS values (number of pulses), the default value is set (step S310), and when RPG pulse is detected (step S320), a timer for setting a measurement time is initialized (step S330) to set the measurement time (step S340). Then, a number-of-pulse counter is cleared (step S350), and every time the RPG pulse is detected (step S360), the measured values are integrated (step S370). This is repeated up to a set measured time (e.g. 64 seconds or 1 hour). When the measurement set time comes (step S380), the CPS value of the set measured time is calculated (step S390). Then, a reference time period for measurement of pulse interval is calculated (step S400), and new CPS data is written in a flash memory (step S410) to start measurement (step S420).

[0129] The measurement processes shown in FIGS. 10A and 10B are conducted in parallel and simultaneously, and the measurement of pulse interval is conducted over the whole pulse period.

[0130] In the present embodiment, as shown in FIG. 10C, when receiving serial data (step S500), a command processing routine is started only when there is new data (step S510).

[0131] Processing of an operation condition setting command, processing of an internal status reading command, processing of a probability setting command, processing of an operation command, and comparison between a module address and a designated address are performed so that the command processing routine describes data in a program describing a processing procedure (algorithm) to be described later.

[0132] The program shown below describes a processing algorithm in a microcomputer when processing a device for generating a uniform random number and probability of the present invention by using a microcomputer.

1. A random pulse generation source including an emitter for discharging α particles or beta rays, or α particles and beta rays discharged due to nuclear decay, and a detector for detecting discharged α particles or the like, characterized in that the emitter is used as a solution and the solution is dripped on the detection face of the detector.

2. A random pulse generation source including an emitter for discharging α particles or beta rays, or α particles and beta rays discharged due to nuclear decay, and a detector for detecting discharged α particles or the like, characterized in that the emitter is used as a solution, a member on which the solution is evaporated or which is formed into a panel by e.g. the roller method is faced with the detector, spacing a predetermined distance.

3. The random pulse generation source according to claim 1, characterized in that all nuclear species of uranium series, all nuclear species of thorium series, all nuclear species of ^{210}Pb - ^{210}Po or the like forming the radioactive equilibrium between these nuclear species, ^{244}Cm , or ^{241}Am are used as the emitter for discharging α particles or the like.

4. The random pulse generation source according to claim 1, characterized in that the detector includes a PN-type semiconductor, PNP-type semiconductor, PIN photodiode, phototransistor, or photodiode.

5. The random pulse generation source according to claim 1, further comprising a shielding wall for shielding the emitter, characterized in that the shielding wall shields at least the distance of the range of α particles or the like to be used.

6. A semiconductor device constituted so as to generate a random number and/or probability by setting a random pulse generation source (hereafter referred to as RPG) for spontaneously generating random pulses, measuring the time interval between the random pulses generated from the RPG or measuring a voltage value of the random pulse, and converting it into a digital value.

7. The semiconductor device according to claim 6, characterized in that

the RPG includes an emitter for discharging α particles or beta rays, or α particles and beta rays (particles) discharged due to nuclear decay.

8. The semiconductor device according to claim 7, characterized in that

all nuclear species of uranium series, all nuclear species of thorium series, all species of ^{210}Pb - ^{210}Po or the like forming the radioactive equilibrium between these nuclear species, ^{244}Cm , or ^{241}Am are used as the emitter for discharging α particles or the like.

9. The semiconductor device according to claim 6, characterized in that

the RPG further includes a detector for detecting discharged α particles or the like, the emitter is used as a solution, and the solution is dripped on the detection face of the detector, or a member on which the solution is evaporated or which is formed into a panel by e.g. the roller method is faced with the detector, spacing a predetermined distance.

10. The semiconductor device according to claim 9, characterized in that

the detector includes a PN-type semiconductor, PNP-type semiconductor, PIN photodiode, phototransistor, or photodiode.

11. The semiconductor device according to claim 6, characterized in that

the RPG further includes a shielding wall for shielding the emitter and the shielding wall shields at least the distance of the range of α particles to be used.

12. The semiconductor device according to claim 6, characterized in that

the RPG is constituted so as to amplify thermal electrons, noises, or jitter to generate random pulses.

13. The semiconductor device according to claim 6, characterized in that

an exponential distribution random number and/or uniform random number having a predetermined bit length and/or a probability are generated from random pulses generated from the RPG.

14. The semiconductor device according to claim 13, characterized in that

a necessary number of probabilities are obtained from an exponential distribution showing a probability in which the same pulse interval occurs between pulses generated from the RPG to prepare a uniform random number in accordance with the probability.

15. The semiconductor device according to claim 14, characterized in that

when obtaining a probability from the time interval between t_1 and t_2 by using the exponential distribution, a pulse having a predetermined probability is recognized when exceeding the time t_1 by assuming that the time t_2 is infinite time.

16. The semiconductor device according to claim 13, characterized in that

when preparing a random number from an exponential distribution, an appearance probability density distribution in which an exponential distribution random number and uniform distribution random number are stabilized is realized by fluctuating a basic cycle for measurement and performing the same computation even if the average discharge rate of pulses is fluctuated.

17. The semiconductor device according to claim 6, characterized in that a random number generated from the RPG is stored as an identification signal or anticlone signal and a signal input from the outside is compared and authenticated with the stored signal.

18. The semiconductor device according to claim 17, characterized in that

a new random number is rewritten as authentication data whenever the comparison and authentication are performed.

19. The semiconductor device according to claim 17, characterized in that

authentication data is transmitted and received.

20. The semiconductor device according to claim 19, characterized in that

transmission and reception of the authentication data is performed through radio communication, infrared data communication, or communication of circuit connection method by contact.

21. An IC card, IC tag, PC connectable unit, or unit built-in module including the random pulse generation source according to claim 1.

22. The IC card, IC tag, PC connectable unit, or unit built-in module including the semiconductor device according to any claim 6.

23. The semiconductor device according to claim 16, characterized in that

a distribution of exponential distribution random numbers is stabilized by fluctuating a basic cycle for measurement when preparing a random number from an exponential distribution and generation of a uniform distribution random number and generation of a probability are simultaneously processed.

24. The semiconductor device according to claim 16, characterized in that

fluctuation of an operation clock for an oscillation frequency of hardware such as microcomputer for measuring time is automatically corrected by fluctuating a basic cycle for measurement when preparing a random number form an exponential distribution.

25. A method for generating a random number and/or probability, comprising the steps of:

setting a random pulse generation source (hereafter referred to as RPG) for spontaneously generating random pulses,

measuring the time interval between the random pulses generated from the RPG or measuring a voltage value of the random pulse, and converting it into a digital value, and

generating an exponential distribution random number and/or uniform random number having a predetermined bit length and/or a probability from random pulses as converted to digital values.

26. The method according to claim 25, characterized in that the step of generating an exponential distribution random number and/or uniform random number having a predetermined bit length and/or a probability from random pulses, obtains a necessary number of probabilities from an exponential distribution showing a probability in which the

same pulse interval occurs between pulses generated from the RPG to prepare a uniform random number in accordance with the probability.

27. The method according to claim 26, characterized in that the step of generating an exponential distribution random number and/or uniform random number having a predetermined bit length and/or a probability from random pulses, recognizes, in obtaining a probability from the time interval between t_1 and t_2 by using the exponential distribution, a pulse having a predetermined probability when exceeding the time t_1 by assuming that the time t_2 is infinite time.

28. The method according to claim 25, characterized in that the step of generating an exponential distribution random number and/or uniform random number having a predetermined bit length and/or a probability from random pulses, realizes, in preparing a random number from an exponential distribution, an appearance probability density distribution in which an exponential distribution random number and uniform distribution random number are stabilized, by fluctuating a basic cycle for measurement and performing the same computation even if the average discharge rate of pulses is fluctuated.

29. The method according to claim 25, characterized in that the step of generating an exponential distribution random number and/or uniform random number having a predetermined bit length and/or a probability from random pulses, stabilizes a distribution of exponential distribution random numbers by fluctuating a basic cycle for measurement when preparing a random number from an exponential distribution and processes generation of a uniform distribution random number and generation of a probability simultaneously.

30. The method according to claim 29, characterized in that the step of generating an exponential distribution random number and/or uniform random number having a predetermined bit length and/or a probability from random pulses, automatically corrects fluctuation of an operation clock for an oscillation frequency of hardware such as microcomputer for measuring time by fluctuating a basic cycle for measurement when preparing a random number form an exponential distribution.

31. A program for executing a method for generating a random number and/or probability, said method comprising the steps of:

setting a random pulse generation source (hereafter referred to as RPG) for spontaneously generating random pulses,

measuring the time interval between the random pulses generated from the RPG or measuring a voltage value, and converting it into a digital value of the random pulse, and

generating an exponential distribution random number and/or uniform random number having a predetermined bit length and/or a probability from random pulses as converted to digital values.

32. The program according to claim 31, characterized in that the step of generating an exponential distribution random number and/or uniform random number having a predetermined bit length and/or a probability from random pulses, obtains a necessary number of probabilities from an exponential distribution showing a probability in which the

same pulse interval occurs between pulses generated from the RPG to prepare a uniform random number in accordance with the probability.

33. The program according to claim 32, characterized in that the step of generating an exponential distribution random number and/or uniform random number having a predetermined bit length and/or a probability from random pulses, recognizes, in obtaining a probability from the time interval between t1 and t2 by using the exponential distribution, a pulse having a predetermined probability when exceeding the time t1 by assuming that the time t2 is infinite time.

34. The program according to claim 31, characterized in that the step of generating an exponential distribution random number and/or uniform random number having a predetermined bit length and/or a probability from random pulses, realizes, in preparing a random number from an exponential distribution, an appearance probability density distribution in which an exponential distribution random number and uniform distribution random number are stabilized, by fluctuating a basic cycle for measurement and performing the same computation even if the average discharge rate of pulses is fluctuated.

35. The program according to claim 31, characterized in that the step of generating an exponential distribution random number and/or uniform random number having a predetermined bit length and/or a probability from random pulses, stabilizes a distribution of exponential distribution random numbers by fluctuating a basic cycle for measurement when preparing a random number from an exponential distribution and processes generation of a uniform distribution random number and generation of a probability simultaneously.

36. The program according to claim 35, characterized in that the step of generating an exponential distribution random number and/or uniform random number having a predetermined bit length and/or a probability from random pulses, automatically corrects fluctuation of an operation clock for an oscillation frequency of hardware such as microcomputer for measuring time by fluctuating a basic cycle for measurement when preparing a random number form an exponential distribution.

* * * * *