

Physical Random number generator

RPG100/RPG100F

data sheet

REV.08

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1. Outline

RPG100/RPG100F is an IC that generates physical random bit stream and random numbers at high speeds and no external components are required. Each random bit is output with the random bit generation clock continuously and each random number can be read with the high-speed shift clock. Statistical random number generator tests circuit is built into the chip and statistical tests for randomness can easily be obtained.

2. Functions

Item	Explanation
Random bit output	Continuous serial random bits, which are synchronized with the random bit generation clock, are output from serial data output terminal.
Random number output	Serial random bit stream is converted to 16 bits random numbers and are stored internally. The stored random numbers, which can be read with a shift clock, are output from data bus.
Statistical test for randomness and test data output	A statistical test for randomness [FIPS140-2(Change Notice1)Statistical random number generator tests] can be obtained. The test data and the judgment of the statistical test can be read. All internally stored random numbers are cleared when the statistical test is started and random numbers by which the statistical test for randomness was executed are newly stored. These random numbers can be used referring to the judgement of the test.

3. Specifications

3-1. Absolute maximum ratings

(VSS=RVSS=0V)

Item	Symbol	Rating	Unit
Supply voltage	VCC	VSS-0.5~+4.0	V
	RVCC	RVSS-0.5~+4.0	V
Input voltage	Vi	VSS-0.5~VCC+0.5	V
Output voltage	Vo	VSS-0.5~VCC+0.5	V
Output current	Io	±14	mA
Power dissipation	Pd	300	mW
Storage temperature	Tstg	-55~125	°C

3-2. Recommended operation conditions

(VSS=RVSS=0V)

Item	Symbol	MIN	TYP	MAX	Unit
Supply voltage	VCC	3.0	3.3	3.6	V
	RVCC	3.0	3.3	3.6	V
H level input voltage	VIH	VCC×0.8	-	VCC	V
L level input voltage	VIL	VSS	-	VCC×0.2	V
CLK_R frequency	fR	245	250	255	KHz
CLK_R duty	-	-	50	-	%
Clock input interdiction time	tRT	50	-	-	nS
Hold time of H level	tTH	50	-	-	nS
Hold time of L level	tTL	50	-	-	nS
Width of start pulse	tWT	50	-	-	nS
Operating temperature	Ta	-40	-	85	°C

3-3. DC characteristics

(VCC=RVCC=3.3±0.3V,VSS=RVSS=0V,Ta=25°C)

Item	Symbol	Condition	MIN	TYP	MAX	Unit
Supply current	ICC	CLK_R=250KHz	-	2.3	-	mA
		PSV=H	-	0.13	-	mA
		PSV=H CLK_R=STOP	-	1	5	uA
H level output voltage	VOH	IOH=4mA	VCC-0.5	-	VCC	V
L level output voltage	VOL	IOL=4mA	VSS	-	0.4	V

3-4. AC characteristics

(VCC=RVCC=3.3±0.3V,VSS=RVSS=0V,Ta=25°C)

Item	Symbol	Condition	MIN	TYP	MAX	Unit
Data output delay time 1	t _{rs}	Load 50pF	-	-	20	nS
Data output delay time 2	t _{TD}	Load 50pF	-	-	50	nS
Data output delay time 3	t _{TA}	Load 50pF	-	-	25	nS
Output enable time	t _{ZD}	Load 50pF	-	-	18	nS
Output disable time (Drive OFF time)	t _{DZ}		-	-	6	nS
Address setup time	t _{SA}		20	-	-	nS
Address hold time	t _{HA}		50	-	-	nS
Chip select setup time	t _{SC}		20	-	-	nS
Chip select hold time	t _{HC}		50	-	-	nS

3-5. Random bit & Random number specifications

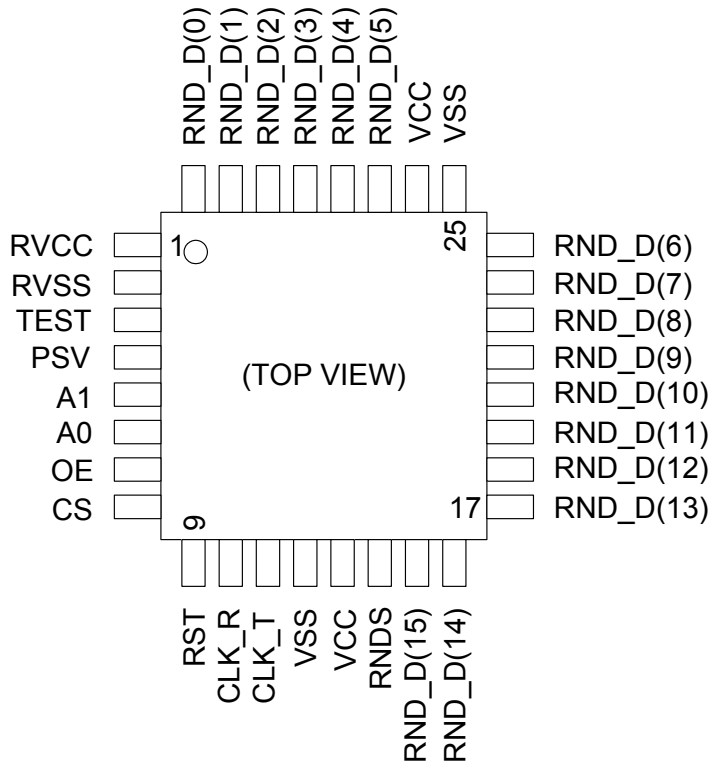
Item	Specification
Source of randomness	Noise in semiconductors
Stored maximum number of random numbers	Max 16bit×32
Quality of the random bit stream	FIPS 140-2(Change Notice1) Statistical random number generator tests corresponding

3-6. Package specifications

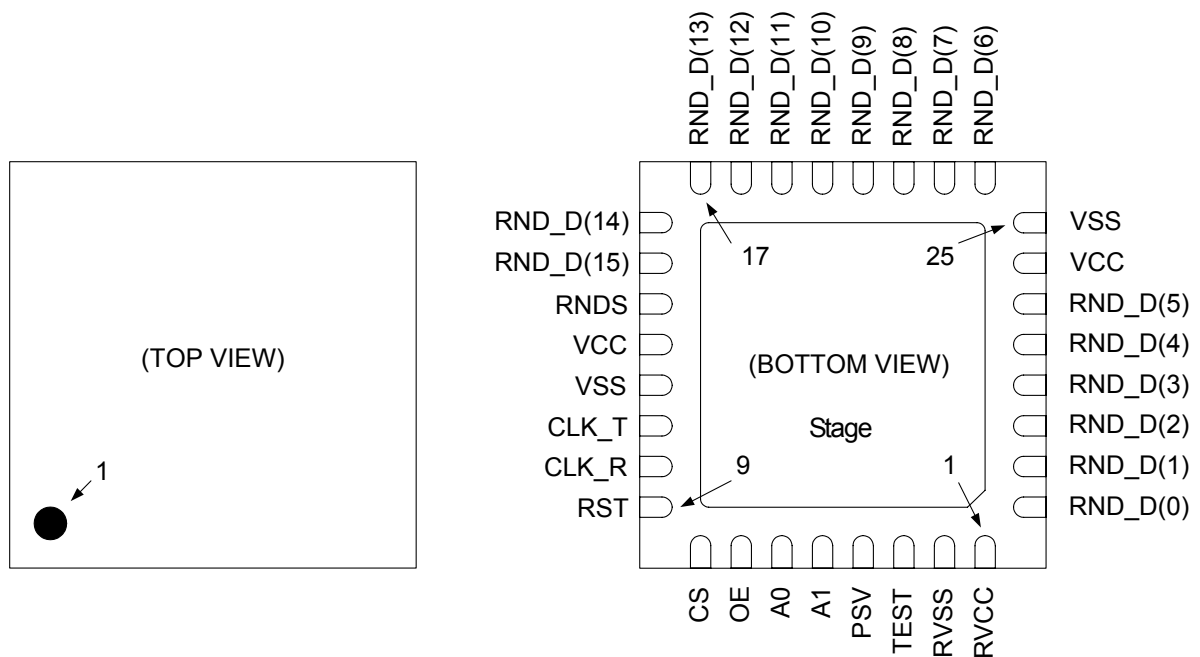
Item	RPG100	RPG100F
Package dimensional standard	Plastic LQFP	Plastic QFN
Size of package with leads	9mm×9mm	5mm×5mm
Number of pins	32 pins	32 pins
Lead pitch	0.8mm	0.5mm

3-7. Pin layout

<RPG100 LQFP Package>



<RPG100F QFN Package>



Note
 Stage is open circuited, connection to GND is unnecessary.
 Please do not lay the PCB signal patterns under the Stage.

4. Terminal function explanation

Terminal symbol	Terminal name	I/O	Function explanation
OE	Output enable	I	Data bus output control signal.
CS	Chip select	I	Chip enable/disable control signal.
CLK_R	Random bit generation clock	I	Random bits are generated with the rising edge of the clock.
CLK_T	Shift clock	I	Shift clock to random numbers output, data selection clock when statistical test data is read and start pulse when statistical test is started.
A1,A0	Address	I	Output data selection to data bus and enabling address to start statistical test.
PSV	Power saving	I	If 'H' power saving is enabled. (8-2 reference)
RNDS	Serial data output	O	Random bits that synchronize with the random bits generation clock are output. When the random bits generation state flag is 'L' the valid random bits can be used. If the power saving is enabled the output is 'L'.
RND_D (15~00)	Data bus	O	Random numbers and various data are output. When the random bits generation state flag is 'L', valid stored random numbers can be used.
TEST	Test	I	Connect to the same potential as VSS.
RST	Reset	I	When 'L' reset occurs. Input a 'L' level signal at power-on.
VCC	Power supply		
RVCC	Analog power supply		Connect to the same potential as VCC.
VSS	GND		
RVSS	Analog GND		Connect to the same potential as VSS.

(Truth tables)

X : H or L

CS	OE	Chip control	Data bus	Serial data output
H	X	Disable	High impedance	Output
L	L	Enable	Data output	Output
L	H	enable	High impedance	Output

A1	A0	Data in the data bus	Shift clock function	Serial data output
0	0	Random number	Random numbers shift clock	Output
0	1	Action state data	Random numbers shift clock	Output
1	0	Statistical test state data	Start pulse to Statistical test	Output
1	1	Statistical test data	Statistical test data selection clock	Output

5. Output data explanation

5-1. Random number

Output bit	Output data explanation
b15~b00	16 bits random number can be read continuously up to the number of random numbers stored.

5-2. Action state data

Output bit	Output data explanation
b05~b00	Number of random numbers stored.
b06	Presence of stored random numbers (H:Presence, L:Absence).
b07	Initialization flag (H:Initialized end, L:Initializing).After releasing reset the output becomes'L'until 512 CLK_R counts and the random bits output are invalid.
b08	Statistical test state (H:Testing, L:Test end).
b09	Random bits generation state flag.(H:Abnormal operation, L:Normal operation). When the random bits generation circuit is in normal operation mode the flag is'L'.But the flag is'H'when Initializing.
b15~b10	'L'fixation.

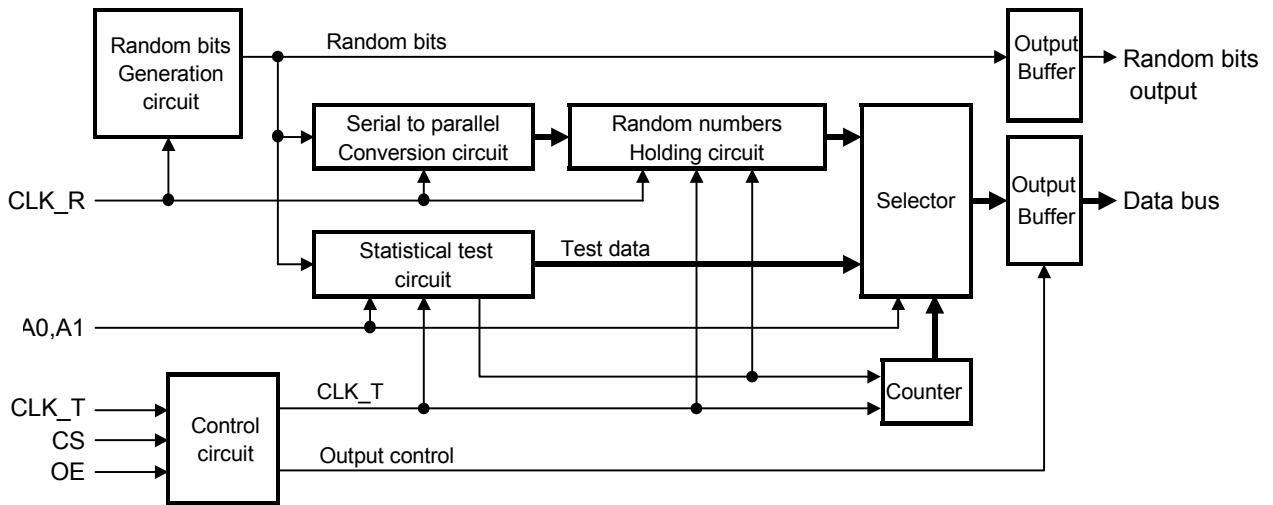
5-3. Statistical test state data * timing chart 7-3 and 7-4 references.

Output bit	Output data explanation
b05~b00	Statistical test data selection address.
b06	Region of random bits for statistical test.
b07	Statistical test state(H:Testing, L:Test end).
b08	Statistical test result(H:Fail, L:Pass). * Same as statistical test data00(b15).
b12~b09	Data for test.
b15~b13	Data for test.

5-4. Statistical test data * timing chart 7-3 and 7-4 references.

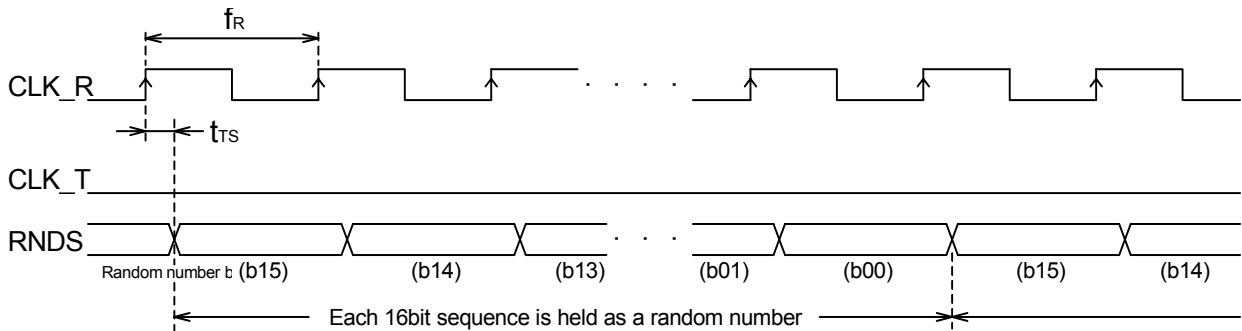
Statistical test data selection address (Test data)	Output bits	Output data explanation		
		Statistical test result (H:Fail) (L:Pass)	b00:Data 02 judgment b01:Data 03 judgment b02:Data 04 judgment b03:Data 05 judgment b04:Data 06 judgment b05:Data 07 judgment b06:Data 08 judgment b07:Data 09 judgment	b08:Data 10 judgment b09:Data 11 judgment b10:Data 12 judgment b11:Data 13 judgment b12:Data 14 judgment b13:Data 15 judgment b14:Data 16,17 judgment b15:Total judgment
00 (Data 00)	b15~b00			
01 (Data 01)	b15~b00	The total number of random bits for statistical test		
02 (Data 02)	b15~b00	The monobit test data (Number of 'H' bits)		
03 (Data 03)	b15~b00	The long runs test data (Maximum number of consecutive bits)		
04 (Data 04)	b15~b00	FIPS 140-2(Change Notice1) Statistical random number generator tests	The runs test data	
05 (Data 05)	b15~b00		Number of continuous'L'bit length 1	
06 (Data 06)	b15~b00		Number of continuous'H'bit length 1	
07 (Data 07)	b15~b00		Number of continuous'L'bit length 2	
08 (Data 08)	b15~b00		Number of continuous'H'bit length 2	
09 (Data 09)	b15~b00		Number of continuous'L'bit length 3	
10 (Data 10)	b15~b00		Number of continuous'H'bit length 3	
11 (Data 11)	b15~b00		Number of continuous'L'bit length 4	
12 (Data 12)	b15~b00		Number of continuous'H'bit length 4	
13 (Data 13)	b15~b00		Number of continuous'L'bit length 5	
14 (Data 14)	b15~b00		Number of continuous'H'bit length 5	
15 (Data 15)	b15~b00		Number of continuous'L'bit length 6 ≤	
16 (Data 16)	b15~b00		Number of continuous'H'bit length 6 ≤	
17 (Data 17)	b15~b00		The poker test data	
18 (Data 18)	b15~b00		Calculated value $(\sum [f(i)]^2)$	
19 (Data 19)	b15~b00	* f (i) is Data 18-33.		
20 (Data 20)	b15~b00	Low bits		
21 (Data 21)	b15~b00	High bits		
22 (Data 22)	b15~b00	Number of 4bits value'00'		
23 (Data 23)	b15~b00	Number of 4bits value'01'		
24 (Data 24)	b15~b00	Number of 4bits value'02'		
25 (Data 25)	b15~b00	Number of 4bits value'03'		
26 (Data 26)	b15~b00	Number of 4bits value'04'		
27 (Data 27)	b15~b00	Number of 4bits value'05'		
28 (Data 28)	b15~b00	Number of 4bits value'06'		
29 (Data 29)	b15~b00	Number of 4bits value'07'		
30 (Data 30)	b15~b00	Number of 4bits value'08'		
31 (Data 31)	b15~b00	Number of 4bits value'09'		
32 (Data 32)	b15~b00	Number of 4bits value'10'		
33 (Data 33)	b15~b00	Number of 4bits value'11'		
		Number of 4bits value'12'		
		Number of 4bits value'13'		
		Number of 4bits value'14'		
		Number of 4bits value'15'		

6. Block diagram



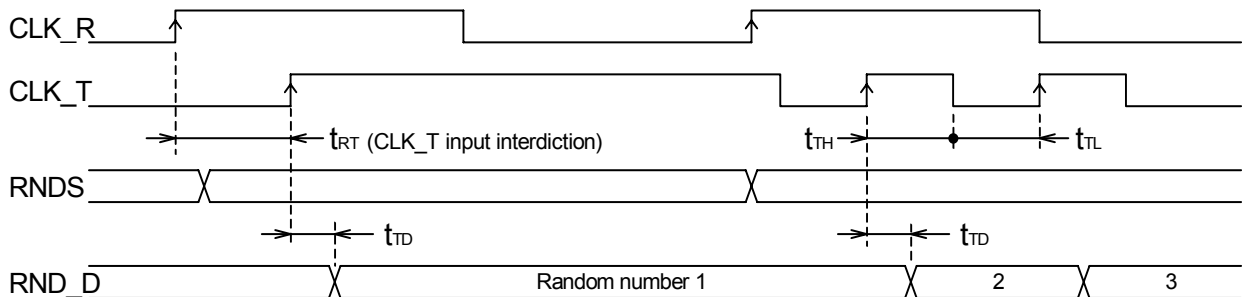
7. Timing chart

7-1. Random bits output (RST=H,PSV=TEST=L)



7-2. Random numbers output (RST=H,TEST=OE=CS=A0=A1=L)

*Possible to read continuously up to the number of random numbers stored



Note:Data Bus use

This IC can store 32steps 16bit random number and you can read them continuously up to the number of stored. You can check the number of 16bit random nuber stored, and get them by reading and sifting register with CLK_T. If you want to check the number of 16bit random number stored, please set address A1=0, A0=1, and read output b05 - b00 of RND_D. And if register stores 16bit random number, please change address A1=0, A0=0 to read them.

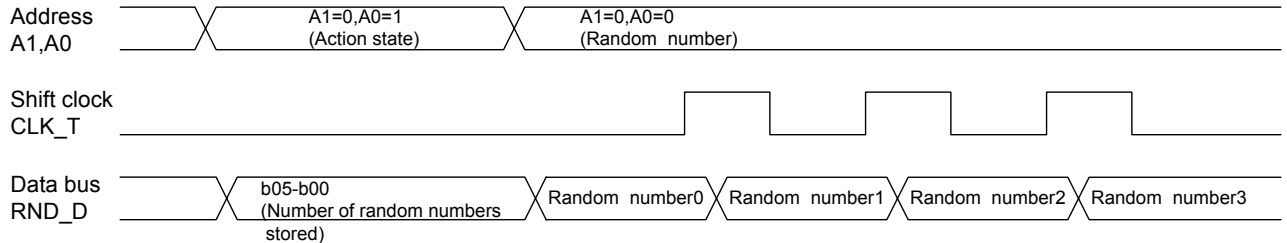
Then the first 16bit random nuber is comming to output of RND_D with changing address.

If you want to read all random numbers stored, please input CLK_T with "the number of 16bit random number stored - 1" times.

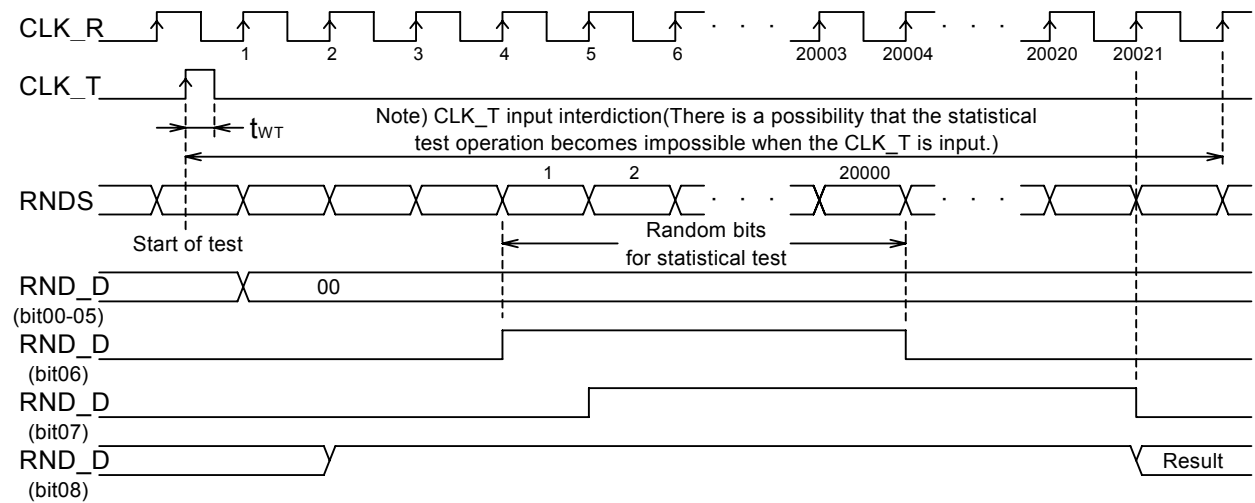
Please note that if you input CLK_T with same as the number of 16bit random number stored, the last output of RND_D is '0000000000000000' and this is not random number.

Checking the number of 16bit random number stored and output them.

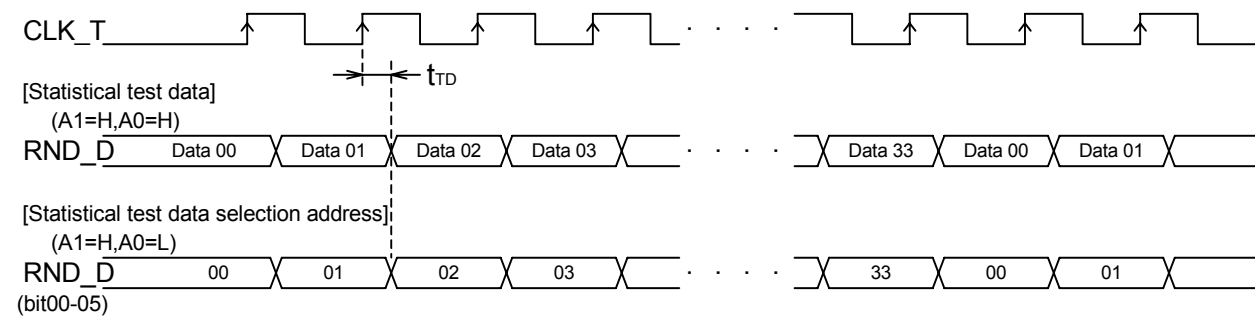
(RST=H,TEST=OE=CE=L)



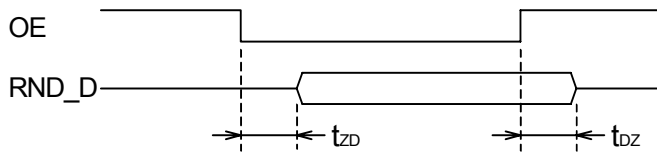
7-3. Statistical test (RST=A1=H,PSV=TEST=OE=CS=A0=L)



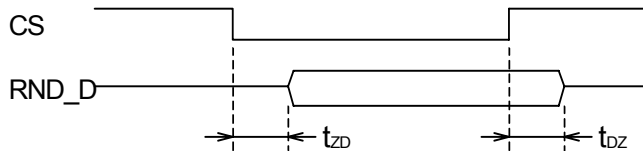
7-4. Statistical test data output (RST=H,TEST=OE=CS=L)



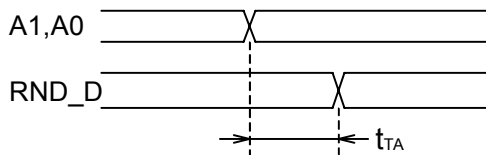
7-5. Output enable / disable time 1(CS=L)



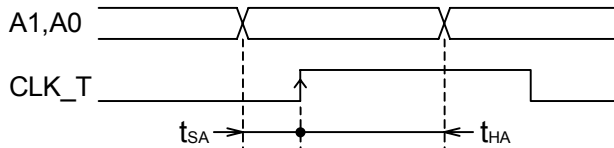
7-6. Output enable / disable time 2(OE=L)



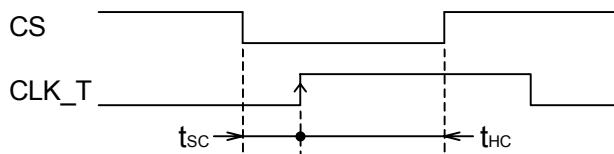
7-7. Data output delay time 3 (CS=OE=L)



7-8. Address setup / hold time



7-9. Chip select setup / hold time



8. Reference material

8-1. FIPS 140-2 (Change Notice1) Statistical random number generator tests

(1) The monobit test

X denotes the number of 'H' bits in a 20,000 random bits stream. The test is passed if $9,725 < X < 10,275$.

(2) The long runs test

X denotes the maximum number of consecutive bits of either all 'H' or all 'L' in a 20,000 random bits stream. The test is passed if $X < 26$.

(3) The runs test

X_i denotes the number of consecutive bits of same kind of length i ($1 \leq i \leq 6$) in a 20,000 random bits stream. If $i \geq 6$ considered to be of $i = 6$. The test is passed if the X_i lies within the specified required intervals in the table given below. This must hold for both 'H's and 'L's.

Length of Run	Required Interval
1	$2,315 \leq X_1 \leq 2,685$
2	$1,114 \leq X_2 \leq 1,386$
3	$527 \leq X_3 \leq 723$
4	$240 \leq X_4 \leq 384$
5	$103 \leq X_5 \leq 209$
$6 \leq$	$103 \leq X_6 \leq 209$

(4) The poker test

Divide the 20,000 random bits stream into 5,000 consecutive four bits segments. Let $f(i)$ be the number of occurrences of the i th ($0 \leq i \leq 15$) type of four bits segment.

Evaluate the following :

$$X = (16/5000) \cdot \left(\sum_{i=0}^{15} [f(i)]^2 \right) - 5000$$

The test is passed if $2.16 < X < 46.17$.

Let modify the inequality.

$$1,563,175 < \sum_{i=0}^{15} [f(i)]^2 < 1,576,928$$

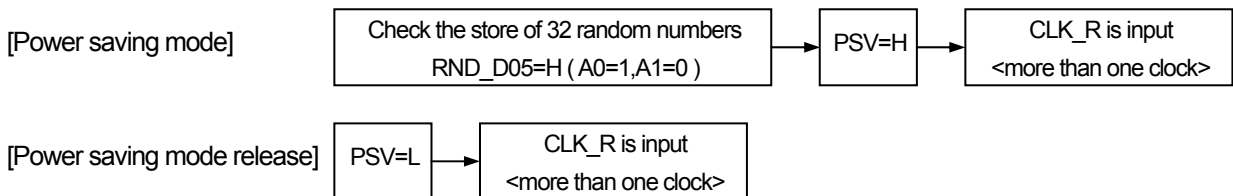
The poker test is judged from this inequality.

8-2. Notes when power saving (PSV) is used

The power saving is a function to stop the internal random bit generation circuit operation, and to reduce the power supply current. The following attention is necessary to use the power saving so that an internal random bit generation circuit stops when changing to the power saving mode.

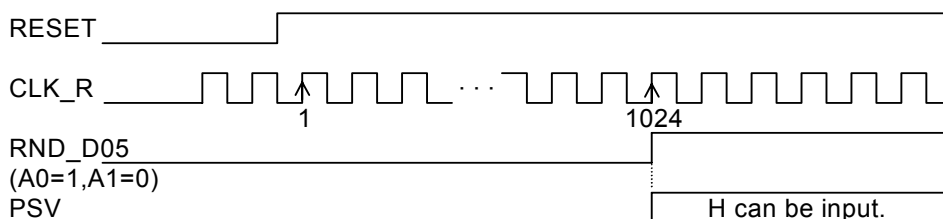
(1) Power saving mode and mode release

The power saving mode and the mode release are executed by the following sequences.



(2) PSV input after releasing reset

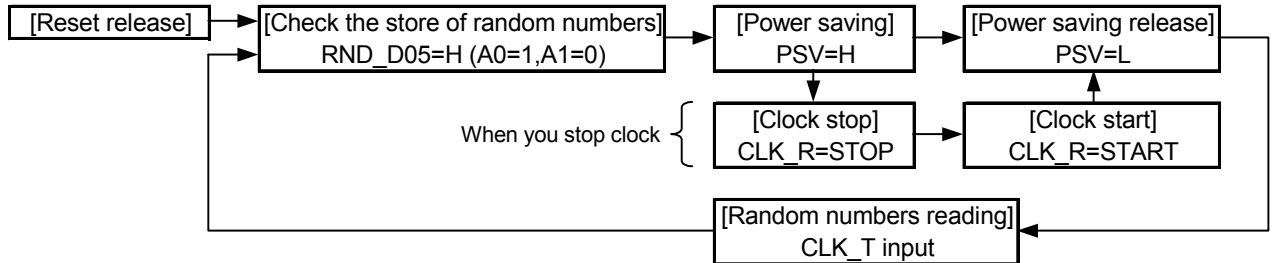
After releasing reset, the first section of 1024 clocks (CLK_R) period is used for initialization and to store first 32(16bit×32) random numbers. If PSV=H in this section, the random bit generation stops, and the stored random numbers become "0". Please execute the power saving mode after inputting 1024 clocks.



(3) Random numbers reading when power saving (CLK_T input with A1=0)

When random numbers are read, random numbers are automatically added only as for the read amount. There is a possibility that "0" is stored because the random bit generation stops at PSV=H when random numbers are read other than the undermentioned sequences. Please avoid the reading of random numbers other than the undermentioned sequences.

[Sequence 1]



[Sequence 2]

