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A New Design for High Throughput Linear PRNG

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ABSTRACT: As we know that pseudo random number generator is used to generate a long period random number sequence but the output random numbers of such generators are predictable due to their linear structure. When we want to design the fast circuit or fast system naturally we have to go for some solutions. To overcome this problem here presenting a new method for reseeding-mixing to extend the system period length and to enhance the statistical properties of a chaos-based pseudo random number generator (PRNG).In this model the reseeding method is used to remove the short periods of the digitized logistic map and the mixing method is for extends the system period length to 2^{253} by "XORing" with a DX generator. By that we will achieve a High throughput rate that is more than 6.4 Gb/s by producing the multiple bits per iteration and the hardware-efficiency is also validated. In this the output sequence of the RM-PRNG is used as a key to encryption and Decryption models. The simulation results are obtained by using modelsim.

Keywords*:* Mixing, period extension, pseudo random number generator (PRNG), reseeding.

I. INTRODUCTION

Many cryptographic applications don't have a reliable source of real random bits, such as thermal noise in electrical circuits. Instead, they use a cryptographic mechanism, called a Pseudo-Random Number Generator (PRNG) to generate these values. Pseudo random number generator (PRNG) has been widely used test pattern generation, cryptography, and telecommunication systems. But recently security applications have increased the need for strong (secure) random number generation like automatic password generation, encryption algorithms, on-line gambling etc. The PRNG collects randomness from various low-entropy input streams, and tries to generate outputs that are in practice indistinguishable from truly random streams. Typical PRNG consists of unpredictable input called "seed" value and a secret state "S". A good PRNG should have characteristics of long-period random number sequence, a fit in statistical properties, a high throughput rate and an unpredictability. We have several Linear PRNGs, such as linear feedback shift registers (LFSRs) linear congruential generators (LCGs) , and multiple recursive generators (MRGs),which produce long-period random number sequences. When implemented, linear PRNGs are efficient in throughput rate and hardware cost, but the output random numbers of such generators are predictable due to their linear structure. Some nonlinear PRNGs in dealt with the predictability problem, but incurred higher hardware cost and more process time. Recently, nonlinear chaos-based PRNGs (CB-PRNGs) with lower hardware cost were proposed. Chaos theory studies nonlinear systems defined on a infinite state space (e.g vectors of real numbers or infinite binary strings), whereas cryptography relies on a finite-state machine (computer). All chaos models implemented on a computer are approximations, i. e. pseudo-chaos.

In this we have propose a new system that consists of a CB-PRNG and a long-period MRG. The reseeding method removes the disadvantages of short periods in CB-PRNG while the mixing of the CB-PRNG with an MRG pushes the overall system period length to a value (>2 ^{253}in 32-b implementation) based on simple theoretical calculation. High throughput rate (>6.4 Gb/s) is achieved by outputting multiple bits per iteration and the hardware-efficiency is validated by using a modelsim simulator. good statistical qualities of the random numbers.

II. EXISTING SYSTEM

Reseeding technique is widely used in LFSR for test pattern generation Applications of LFSRs include generating pseudo-random numbers, pseudo-noise sequences, fast digital counters, and whitening sequences. and in CB-PRNG for period extension presented a reseeding method either to perturb the state value or the system
parameter of digitized logistic map (LGM) for removing the short periods of a CB-PRNG. In 1998, Sang *et al.* applied a different reseeding method in perturbing a CB-PRNG to extend its period length up to3.3672*10^{29}, and the
lower bound of the reseeded system can be calculated. Li *et al.* discovered that the reseeding technique not only removes the short periods but also improves the statistical properties of CB-PRNG.

On the other hand, the mixing technique has been used for nonlinearity enhancement of cellular automata] and for improving statistical performance of nonlinear PRNGs. For proposed a software implementation of mixing multiple spatial-temporal CB-PRNGs to obtain high security, fast encryption (decryption) speed, and reliable robustness The mixing technique is also widely applied in period extension of nonlinear PRNGs. Gammel *et al* mixed several nonlinear feedback shift registers (NLFSRs) to obtain a long-period and high-throughput-rate stream cipher. In general, mixing multiple CB-PRNGs results in higher hardware cost, lower throughput rate, and longer but unpredictable period length. Furthermore, one cannot be sure that the random numbers produced by these mixed PRNGs will have acceptable statistical properties. Since higher hardware cost is due to implementation of multiple CB-PRNGs which are more complex than linear PRNGs, mixing a CB-PRNG with a linear MRG instead of mixing two CB-PRNGs will reduced the hardware cost. In our proposed RM-PRNG, which consists of a CB-PRNG and an MRG, the period length is considerably extended because the period length of the MRG is much longer than that of the CB-PRNG while the short periods of the CB-PRNG can be removed by our reseeding algorithm. Note that the lower bound of the period length in RM-PRNG can be calculated analytically in terms of the period length of the CB-PRNG and that of the MRG. In addition, the throughput rate is enhanced using a vector-mixing technique in the proposed RM-PRNG. Finally, the statistical properties is improved because the linear structure of the MRGs is broken by mixing with a CB-PRNG. In Section III, we will introduce our proposed method in details.

III. PROPOSED SYSTEM

T o overcome the problems presents in the choas based design and multiple recursive generators here we proposed a new design of combination of these two systems Fig. 1 shows the diagram of the proposed system, which is composed of three modules: Nonlinear Module, Reseeding Module, and Vector Mixing Module. In implementation, the Nonlinear Module has a controlled 32-b state register and a Next-State construction circuitry. The controlled register stores the state value X_t which can be set to Seed1 by the Start command. The Next-State construction circuitry produces the next state value X_{t+1} according to the recursive formula $X_{t+1} = F(X_t)$. For each generated state value The RC will be reset and the reseeding operation will be activated when either the fixed point condition is detected or the RC reaches the reseeding period. When RC reaches the reseeding period Tr or the fixed point condition is detected then RC will be reset and the reseeding operation will be activated. The sate register will be loaded through the rmux, when reseeding is activated [1]. The value of Xt+1 is directly loaded into the state register if the reseeding is not activated. Vector Mixing Module is implemented by an auxiliary linear generator (ALG) and output construction. By mixing Xt+1 with the output Yt+1 from ALG in Vector Mixing Module, we obtain the output of the RM-PRNG (32-bit implementation).The models used in MPC are generally intended to represent the behavior of complex dynamical systems. The additional complexity of the MPC control algorithm is not generally needed to provide adequate control of simple systems, which are often controlled well by generic PID controllers. Common dynamic characteristics that are difficult for PID controllers include large time delays and high-order dynamics.

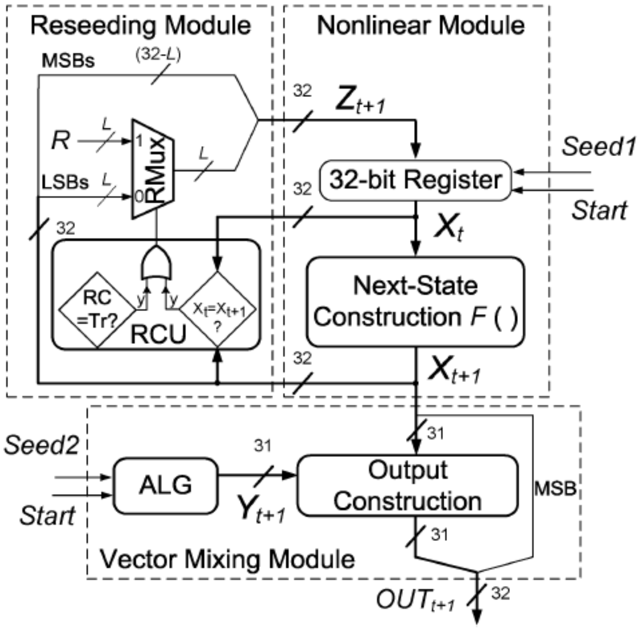


Fig. 1. Structure of the proposed RM-PRNG.

A. Nonlinear Module

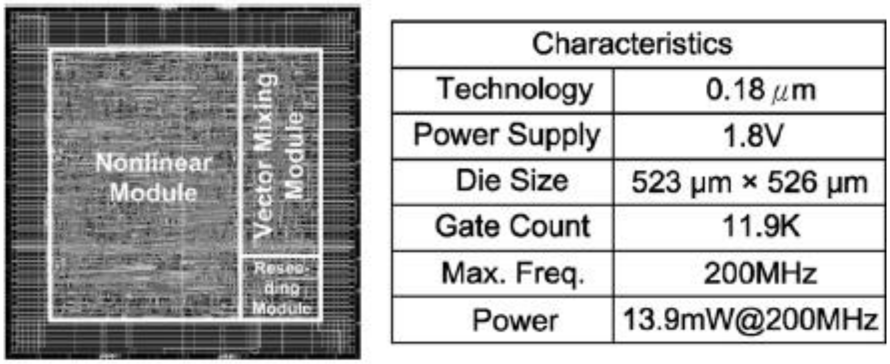
The module provides an extensive set of nonlinear structural material models, including Predefined and user-defined hyperelastic materials Small-strain and large-strain plasticity models using different hardening models. We use the LGM as the next-state construction function in the Nonlinear Module so that

$$X_{t+1} = F(X_t) = \gamma X_t(1- X_t), t\geq 0 \qquad \_\_ (1)$$

with $\gamma = 4$ and X_0 ε (0,1) as an initial seed. Choosing a value 4 for γ not only makes the LGM chaotic but also simplifies the implementation of to merely left-shifting the product of X_t and (1- X_t) by 2 b. However, the state size decreases from 32 to 31 b, because the dynamics X_t and (1- X_t) in (1) are the same. This is equivalent to a degradation of resolution by 1 b. In addition, fixed points (at X_t = 0 and 0.75) as well as short periods exist when the LGM is digitized. From exhaustive runs for all of the 2^{32} seeds, we obtain all other periods for the 32-b LGM (P_{LGM})without reseeding. They are given in Table I with the longest period (18 675) and the set of short periods T_s ($\leq$1338) listed separately along with their total occurrences. Clearly, the performance of a CB-PRNG using only the Nonlinear Module is unsatisfactory. To solve the fixed points and short-period problem, a Reseeding Module is in order.

Logistic map	Period lengths (P_{LGM})	Number of occurrences	Avg. Period ($\log_2 P_{LGM}$)
without reseeding	$T_s = \{1, 2, 3, 10, 11, 17, 23, 62, 91, 157, 1046, 1338\}$	42715656	18500.269 (14.175)
	18675	4252251640	
with reseeding $T_r = 643$ $R = 18$	1929	9212	2321423.005 (21.147)
	2572	42656	
	7073	3911606	
	10288	13524784	
	2330875	4277479038	

TABLE I
REMOVAL OF SHORT PERIODS BY THE RESEEDING METHOD



Characteristics	
Technology	0.18 μm
Power Supply	1.8V
Die Size	523 µm × 526 µm
Gate Count	11.9K
Max. Freq.	200MHz
Power	13.9mW@200MHz

Fig. 2. Core layout and characteristics of proposed nonlinear PRNG.

B. ***Reseeding Module***

When the fixed point condition is detected or the reseeding period is reached, the value Z_{t+1} loaded to the state register will be perturbed away from X_{t+1} in the RCU by the fixed pattern _ according to the formula given below

$$Z_{t+1}[j] = X_{t+1}[j], \quad 1 \leq j \leq 32 - L;$$
$$R[i], \quad 33\text{-}L \leq j \leq 32, \quad I = j + L - 32 \qquad (2)$$

where subscripts *i,j* are the bit-index, L is integer, and R≠0. In order to minimize the degradation of the statistical properties of chaos dynamics, the magnitude of the perturbation of the fixed pattern _ should be small compared with X_t. Here, we set L= 5 so that the maximum relative perturbation is only $(2^5 – 1) / 2^{32}$. Clearly, the effectiveness of removing short-periods depends on the reseeding period T, as well as the reseeding pattern R. However, choosing the optimal reseeding period and the reseeding pattern is nontrivial. Nevertheless, several guidelines to choose a suitable combination of T_r and R had been proposed and discussed in our previous work Then no effective reseeding will be realized and the system will be trapped in the short-period cycle. Hence, prime numbers should be used as the reseeding period candidates. In this study, we use T_r and R = "18(10010)", and the result is shown in Table I. One can see that the set of short periods T_s is indeed eliminated. The lowest period, the maximum period and the average period of the reseeded PRNG are, respectively, 1929, 2 330 875, and 2 321 423.005. Although the average period of the reseeded PRNG has increased more than 100 times relative to that of the non reseeded counterpart, the period can in fact be extended tremendously in the Vector Mixing Module described below.

C. Vector Mixing Module

An efficient MRG, called the DX generator , serves as the ALG in Vector Mixing Module. Specifically, we choose the DX generator with the following recurrence equation:

$$Y_{t+1} = Y_t + B_{dx} . Y\ t\text{-}7 \bmod M \qquad \_\_\ \_\ \_\_ \ (3)$$

Using an efficient search algorithm , we find that the particular choice of $B_{dx} = 2^{28} + 2^{8}$ and $M= 2^{31} – 1$ gives the maximum period of the DX generator. The LSBs of and that of Y_{t+1} are mixed in the Output Construction unit using a XOR operation to obtain the least significant bits of the output according to the equation

$$OUT_{t+1}\ [1:31] = X_{t+1}\ [1:31]\ XOR\ Y_{t+1} \qquad \_\ \_\ \_\_\_\_ \ (4)$$

Then, the most significant bit (MSB) of X_{t+1} is attached to OUT $_{t+1}$ [1:31] to form the full 32-b output vector OUT .

D. DX Generator (ALG)

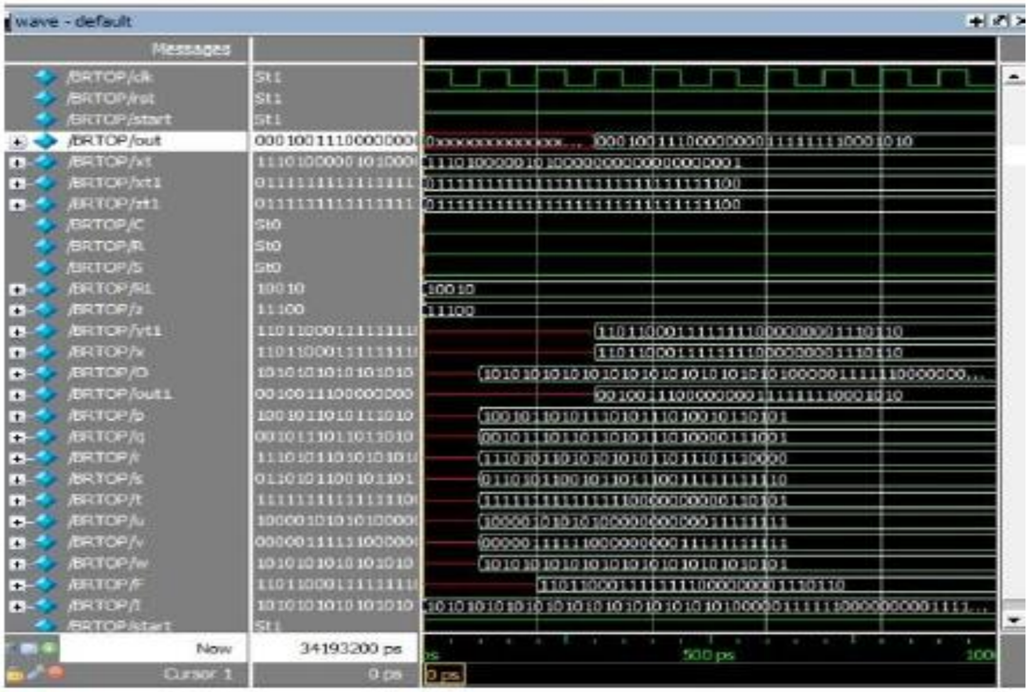
The implementation of the DX generator is (the ALG) done by using 8-word registers, circular-left-shift (CLS), circular 3-2 counter and End Around Carry- carry look ahead adder (EAC-CLA). By using flip-flops the eight-word register was implemented. For generating two partial products signal Yt-7 is circular-left-shifted 28 and 8 b , using the modules CLS-28 and CLS-8 respectively. To combine these three 31-b operands into two 31-b operands a circular 3-2 counter is used, which consumes 247 gates. To evaluate Yt+1 31-b EAC-CLA is used with 348 gates. The schematic design of the 31-b EAC-CLA. The schematic design of the 31-b EAC-CLA includes four modules they are propagation and generation (PG) generators, end-around-carry (EAC) generator, internal carry (IC) generator, and CLAs.

IV. RESULTS AND SIMULATION

Pseudo Random Number Generator, Encryption and Decryption were designed using Verilog language in ModelSim 6.3. All the simulations are performed using ModelSim 6.3 simulator. The simulated output of Pseudo Random Number Generator, Encryption and Decryption are shown in Figure 3&4.

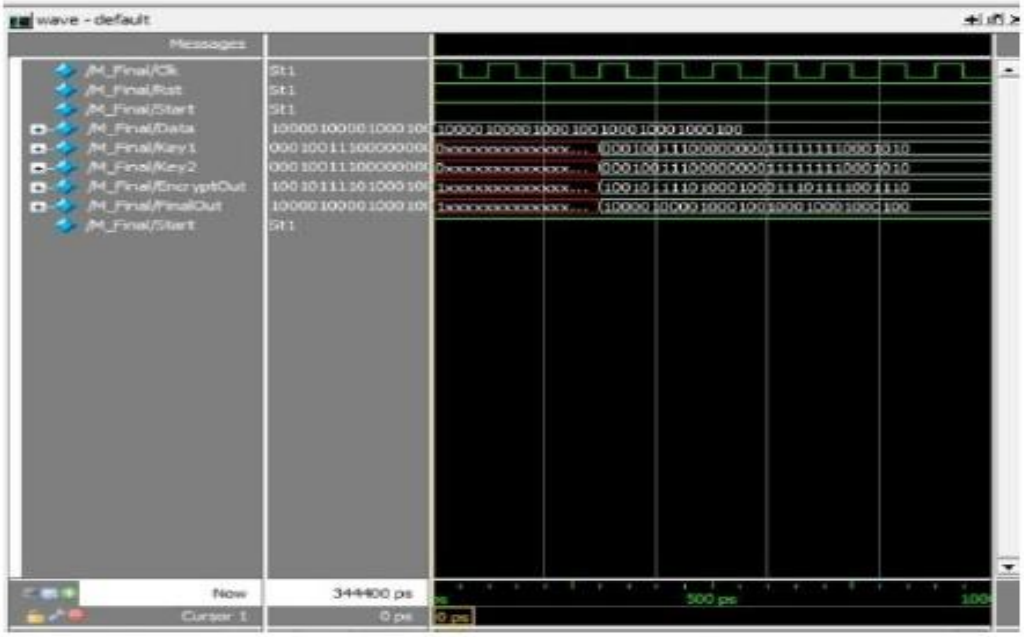
V.CONCLUSION

In this paper, we proposed a cryptographic algorithm using RM-PRNG to ensure secure communication. This Cryptographic algorithm allows people to carry over the confidence found in the physical world to the electronic world, thus allowing people to do business electronically without worry of deception. With these secure communications, the proposed cryptographic algorithm using RM-PRNG can a good candidate for protect the data in ATM cards, computer passwords and electronic commerce.



```
wave - default
Messages
/BRTOP/clk       St1
/BRTOP/rst       St1
/BRTOP/start     St1
/BRTOP/out       000100111000000000
/BRTOP/xt        1110100000 1010000
/BRTOP/xt1       0111111111111111
/BRTOP/zt1       0111111111111111
/BRTOP/C         St0
/BRTOP/R         St0
/BRTOP/S         St0
/BRTOP/R1        10010
/BRTOP/z         11100
/BRTOP/yt1       1101100011111111
/BRTOP/x         1101100011111111
/BRTOP/D         1010101010101010
/BRTOP/out1      00100111000000000
/BRTOP/p         1001011010111010
/BRTOP/q         0010111011011010
/BRTOP/r         1110101101010101
/BRTOP/s         0110101100101101
/BRTOP/t         1111111111111110
/BRTOP/u         1000010101010000
/BRTOP/v         0000011111100000
/BRTOP/w         1010101010101010
/BRTOP/F         1101100011111111
/BRTOP/I         1010101010101010
/BRTOP/start     St1
Now              34193200 ps
Cursor 1         0 ps
```

Figure 3. Simulation results for RM-PRNG



```
wave - default
Messages
/M_Final/Clk         St1
/M_Final/Rst         St1
/M_Final/Start       St1
/M_Final/Data        10000100001000100
/M_Final/Key1        000100111000000000
/M_Final/Key2        000100111000000000
/M_Final/EncryptOut  100101111101000100
/M_Final/FinalOut    10000100001000100
/M_Final/Start       St1
Now                  344400 ps
Cursor 1             0 ps
```

Figure 4. Simulation results for cryptography

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