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Simulation and Digital Implementation of Eight Dimensional Hyper Chaotic System for Secured Chaotic Communication

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***Abstract* - The use of hyper chaotic signals to obtain highly secure communication has been a popular research topic. Hyper chaotic system has more parameters and more complex attractors than regular chaotic system which makes the system is strong in secure data transmission. In this paper, a new eightdimensional hyper chaotic system is provided, this hyper chaotic system is simulated with specific parameters and initial conditions. The simulation results obtained in the form of timedomain noise like signals and double-scroll attractors.**

In order to overcome the problems due to analogue circuit implementation of such systems, a digital implementation of this eight-hyper chaotic system is realized, by using this digital realization we have many advantages such as easy implementation, high accuracy, and stable performance. Experiment shows that the generated attractors of the realized system are identical to simulated attractors. The purpose of this implementation is to use this hyper chaotic generator in secure digital communication field.

Keywords; Attractors, chaos, LabVIEW, realization, simulation.

I. INTRODUCTION

The chaos is achieved from nonlinear dynamic system, it is an aperiodic, deterministic, and sensitive to small changes to initial conditions and control parameters [1]. In 1963, Lorenz presented the first chaotic attractor in a three-dimensional first order differential equation systemduring studying the weatherbehavior[2].Later, many chaotic systems were introduced such as Rössler system, Qi system, Chen system, and other systems.With the rapid development of chaotic theory, the design of hyper chaoticsystem and its circuit realization problems are considered [3-4].

Hyperchaos was first reported by Rössler in1979[5], and the firstanalogue circuitsimplementation of hyperchaos wasrealized by Matsumoto et al. [6]. Hyperchaotic system is a chaotic system with more than one positive Lyapunov exponent,meaning that the chaotic dynamics of the system are expanded in more than one direction leading to more complex attractors [7]. In recent years, implementation of hyper chaotic systems by electronic circuits has become an interesting topic either in analogue way or in digital way.However, there are many methodsthat use analogue circuits for implementing chaotic systems, such as switched capacitor or analog CMOS technology [8-9]. But, those methods have some practical difficulties because of the variation of the component values are affected by the temperature and age [10-11].

In this paper, we present a new approach for real-time digital implementation of the continuous eight-dimensional hyper chaotic system by using ARM processor and FPGA integrated together on a single board based on LabVIEW, First, The eight-dimensional chaotic system is simulated by using the SIMULINK, and then digitally implemented by using National Instruments (NI) module based on LabVIEW. This new hyper chaotic signal realization approach is provided for practical applications such as secured communication and signal encryption based on chaos.

This paper is organized as follows: section 2 introduces the model and simulation of proposed eight-dimensional hyper chaotic system, implementation and experimental results are appeared in section 3, and section 4 discusses conclusion.

II. EIGHT-DIMENSIONAL HYPER CHAOTIC SIMULATON

Hyper-chaos is a special system which can reduce the disadvantages of the traditional chaos system. It has more parameters, two or more positive Lyapunov exponents and relatively complex behavior of dynamics, it also overcomes the attacking methods of general low-dimensional chaotic systems. Therefore, designing secured communication based on hyperchaos will satisfymore safety than lower one.

Mathematical modeling and numerical simulation of a nonlinear dynamical system play an important role in investigating the system and determining design parametersbefore the real implementation. SIMULINK is one of the most powerful numerical simulation tools which used in solving ordinary differential equations (ODEs), which describe the hyper chaotic system. The model ofproposed eight-dimensional hyper chaotic system is:

$$\begin{cases} \dot{x}_1 = -ax_1 + ax_8 - x_2x_3x_4x_5x_6x_7x_8 \\ \dot{x}_2 = -bx_2 - cx_1 + x_1x_3x_4x_5x_6x_7x_8 \\ \dot{x}_3 = -ax_3 + ax_2 - x_1x_2x_4x_5x_6x_7x_8 \\ \dot{x}_4 = -ax_4 + ax_1 + x_1x_2x_3x_5x_6x_7x_8 \\ \dot{x}_5 = -ax_5 + ax_8 - ex_1x_2x_3x_4x_6x_7x_8 \\ \dot{x}_6 = -dx_6 + dx_5 + x_1x_2x_3x_4x_5x_7x_8 \\ \dot{x}_7 = -dx_7 + dx_1 - x_1x_2x_3x_4x_5x_6x_8 \\ \dot{x}_8 = -ex_8 + fx_2 + x_1x_2x_3x_4x_5x_6x_7 \end{cases} \quad (1)$$

Where a, b, c, d, e and f are the parameters for this system, by choosing these parameters with a specific values the system acts as non-linear dynamic system [12]. Theseparameters values are:a=10, b=0.5, c=25, d=15, e=5, f=4.In order to solve system (1),there are many numerical methods can be used likeRunge-Kutta, Euler method, Extrapolation, and Dormand-Prince.
For computing the solutions of the system (1), we choose the fourth order Runge-Kutta (RK-4) numerical method for solving the continuous hyper chaotic system model because it is one of the well-known numerical methods for solving differential equationsand produces more accurate estimate of the solution.

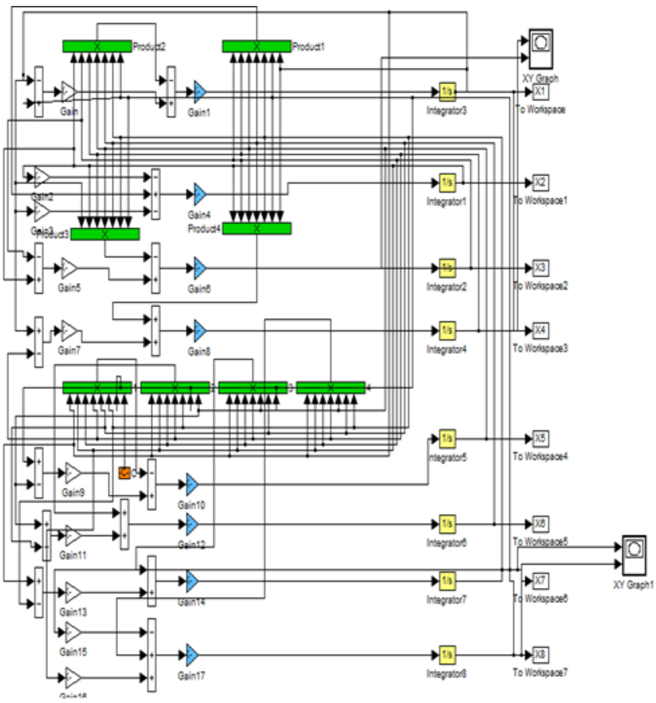
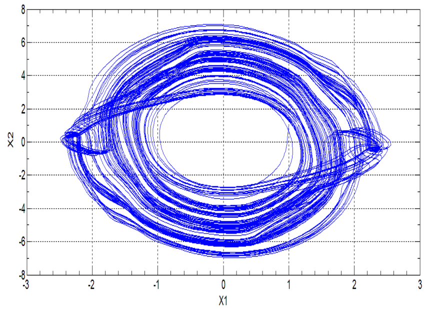
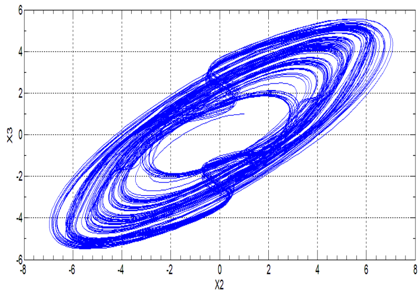


Fig. 1.SIMULINK model for eight-dimensional hyper chaotic system

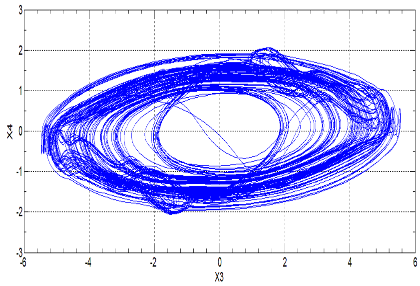
The system (1) solved by using SIMULINK function blocks as illustrated in Fig.1,by adjusting the simulation configuration parameters of SIMULINK model like choosing suitable solver, selecting initial conditions and adjusting step size,we can solve the continuous hyper chaotic system (1).The phase portraits of this eight-dimensional hyper chaotic system are shown in Fig.2.



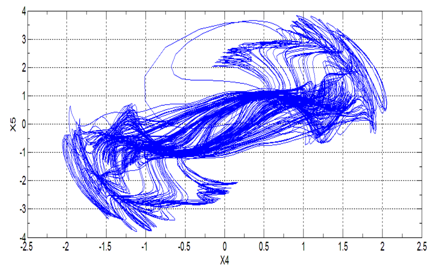
(a) X1-X2



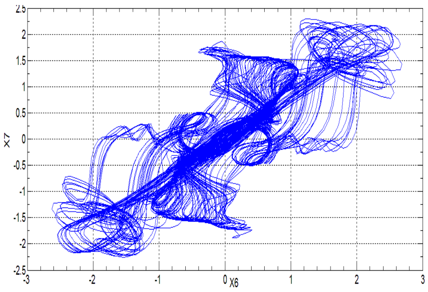
(b) X2-X3



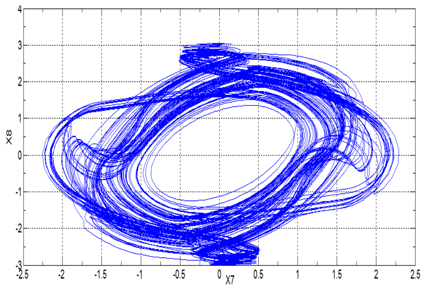
(c) X3-X4



(d) X4-X5



(e) X6-X7



(f) X7-X8

Fig.2.SIMULINK phase portraits of eight-dimensional hyper chaotic system

The simulation results can also be obtained in form of time series illustrated noise-like waveforms which were unpredictable even after a long interval of time as shown in Fig.3.

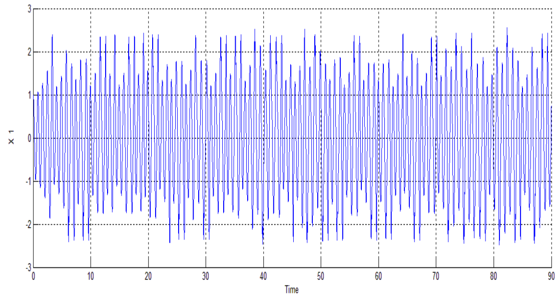


Fig. 3.Noise-like waveform chaotic signal

III.HARDWARE IMPLEMENTATION OF THE SYSTEM

To overcome the problems related to analogue implementation of chaotic systems such as sensitivity to external conditions like humidity, temperature, ripples, and any small variations of related parameters which make the system state change from the unpredicted state to the predicted state, and to obtain an efficient implementation of the chaotic generator, a digital implementation of hyper chaotic system is proposed in this paper by using hardware moduleincluding FPGA and ARM processor integrated together based on LabVIEW. The field programmable Gate Array (FPGA) is an integrated circuit designed to be configured by a designer, FPGA considered as aprogrammable device which includes general-purpose chips that can be configured for a numerous variety of applications. To realize hyper chaotic system on the digitalboard we represented this system by a set of nonlinear equations represented by LabVIEW code (VI code) which consisting of some blocks describing the system of differential equationsand a system-based model is then realized on FPGAto realize these equations directly.

LabVIEW is developed by National Instruments (NI) Company, it has graphical programming language and strong mathematical computations[13],theproposed digital board based on LabVIEWprovides analogue input (AI), analogue output (AO), digital input and output (DIO), audio, and power output in a compact embedded device, it has FPGA and ARM processor integrated in one board. This board connects to a host computer over USB or wireless. Fig.4 shows its block diagram.

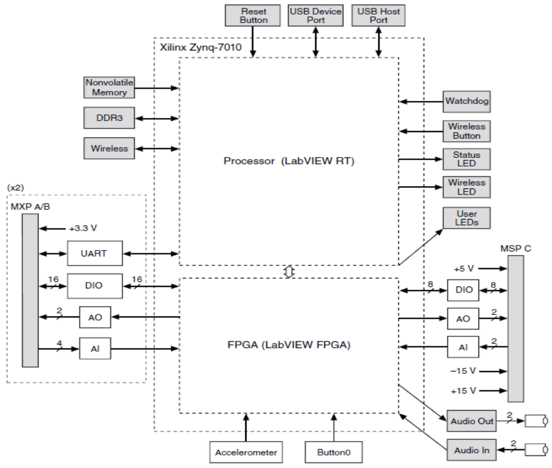


Fig. 4. NI hardware block diagram

The VI code representing hyper chaotic generator is shown in the Fig.5which presents a solution of the system (1) of each signal x1, x2, x3, x4, x5, x6, x7 and x8.

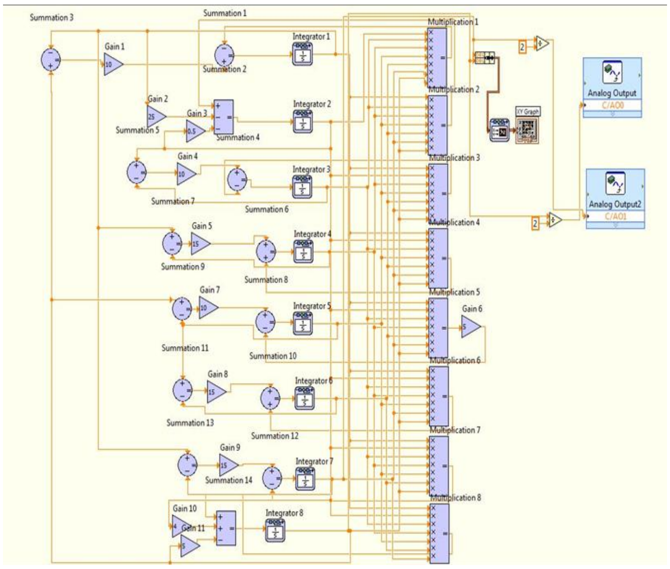
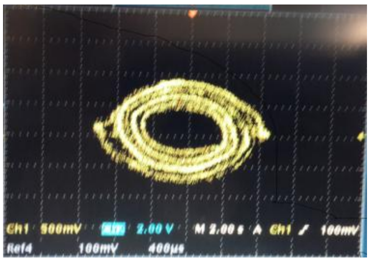
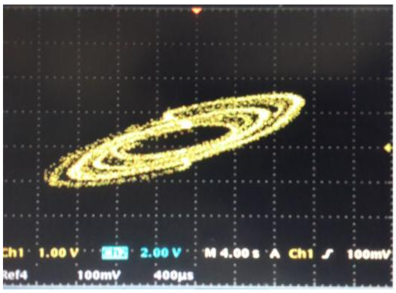


Fig. 5. Designed program based on LabVIEW

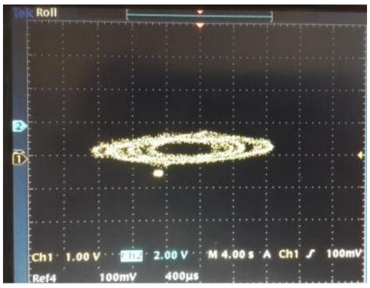
The real time measured results using the National Instruments module are shown in Fig.6.We took two signals output (x1-x2), (x2-x3), (x3-x4), (x4-x5), (x6-x7) and (x7-x8) from digital circuit and measure those couple of signals by using oscilloscope. The results illustrate that by using the proposed hard ware method, the simulation results and the measured results are identical. This method has good experimental results and has many advantages such as ease of implementation, high accuracy and good real-time capability.



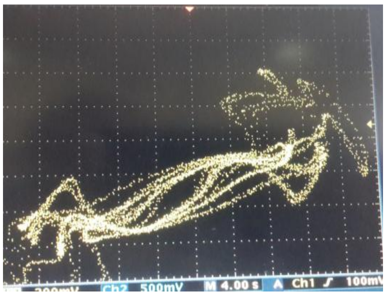
(a) X1-X2



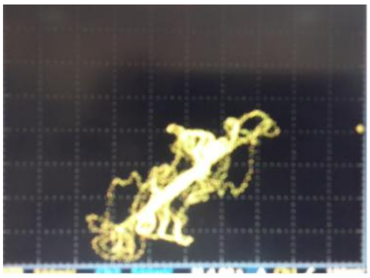
(b) X2-X3



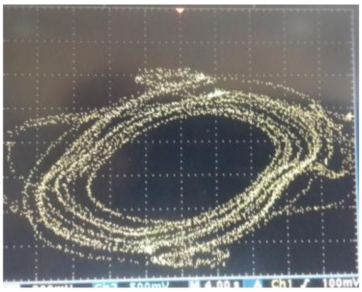
(c) X3-X4



(d) X4-X5



(e) X6-X7



(f) X7-X8

Fig. 6. Hardware measured results

IV. CONCLUSION

With the rapid development of chaotic theory and its practical applications, hyper chaotic system becomes a new approach by building higher dimensional chaotic system and designing its circuit realization.This paper presented the simulation of a new hyper chaotic system with a certain initial conditions and parameters. This model is simulated by using SIMULINK, the simulated attractors are shown. Then a digital implementation of this hyper chaotic system is presented, it is a new method for implementing hyper chaotic systems, the results of the real implementation are identical to those obtained with simulation. The digital implementation solves many problems related to analog implementation. The proposed method for generating hyper chaotic signals can be used for many applications used in secured communication.

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