Chaotic Signals Generated by Some Circuits – Comparative Study (Correlation Analysis)

Stoitscho V. Manev[1]and Vladimir Iv. Georgiev[2]

Abstract – **In this paper correlation analysis of chaotic signals, generated by some circuits, has been made. These circuits have been developed in practice. The signals, obtained at the outputs of the circuits, have been digitized and analyzed.**

Keywords – **chaotic circuits, chaotic attractors**

I. Introduction

The study of the autocorrelation functions of the chaotic signals is of great interest. This is the first step toward the qualitative and quantitative estimation of the chaotic signals. The determination of the Ljapunov exponents, using an algorithm, based on the algorithm of Eckmann, Kamphorst, Ruelle and Ciliberto (EKRC algorithm), requires the precise estimation of some parameters, concerning the autocorrelation analysis. In the proposed paper some practical developed circuits have been used, in terms of obtaining chaotic signals. Graphics of the autocorrelation functions of the discussed signals have been presented.

II. Classification

In the presented work signals, obtained from the following circuits, have been discussed [3-4]:

1) H-generator.

2) 4-D generator

3) Circuits, based on the canonical realization of Chua's circuit.

These circuits have been developed in practice. The signals, obtained at the outputs of the circuits, have been digitized by means of oscilloscope interface and after that the obtained results have been used as basis for further investigations. One of the main goals of the discussed paper is, to show the relationship between the structure and the parameter values of each of the analyzed variants and the form of the obtained signals. The analysis has been made in time domain.

The precise determination of the Ljapunov's exponents is from great importance for the understanding the dynamical behaviour of the analyzed circuits. The necessary condition for this aim requires analysis, based on the autocorrelation functions (ACF) of the obtained signals.

[1]Stoitscho Velizarov Manev, Dept. of Radiotechnique in Faculty of Communication and Communication Technologies in TU-Sofia, Bulgaria

[2]Vladimir Ivanov Georgiev, Dept.of Theoretical Electrotechnic in TU-Sofia, Bulgaria

III. Experimental Results

The circuits, discussed in [3-4], have been practical developed. Using the lab prototypes, a number of experiments have been carried out.

Most realistic notion about the nature of the generated chaotic signals can be obtained by inspection of the photos from the trajectory pictures, observed on oscilloscope in the phase plane.There are not any restrictions, resulting from the analog - digital transforms.

A. H-generator [3]

In [3] a LC-generator from H-type, designed to produce chaotic signals, has been discussed. For different values of the circuit parameters a variety of chaotic signals has been obtained. The signals, observed in the phase plane, have been presented on Fig. 1 [3].

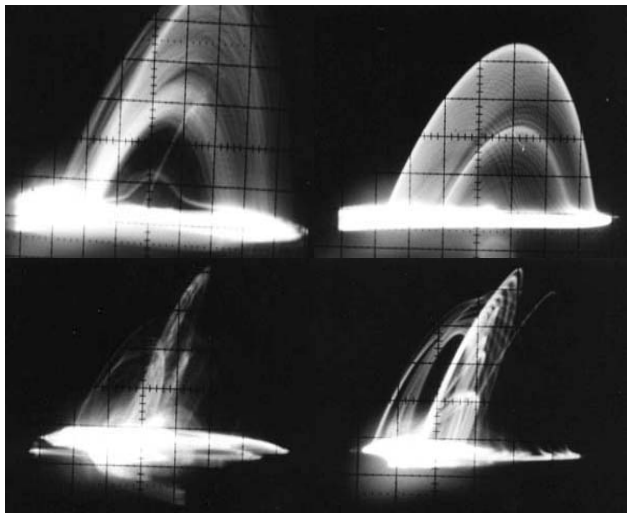

Fig. 1. Photos of output signals, observed in the phase plane[3]

For a fixed set of values of the parameters a chaotic signal has been produced. This signal has been digitized. The

Fig. 2. Time domain presentation

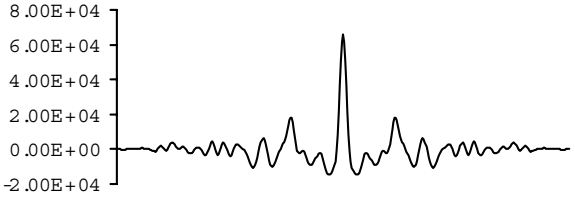

Fig. 3. ACF of the obtained chaotic signal

obtained digital values have been used as basis for further investigations. The time domain presentation and the auto-correlation function (ACF) of the signal have been shown respectively on Figs. 2 and 3.

The value of τ for the discussed signal has been obtained after computations, based on the ACF. The computed value for τ is $\tau = 6$.

Another set of parameter values of the analyzed circuit lead, as expected, to different experimental results (Figs. 4 and 5).

Fig. 4. Time domain presentation

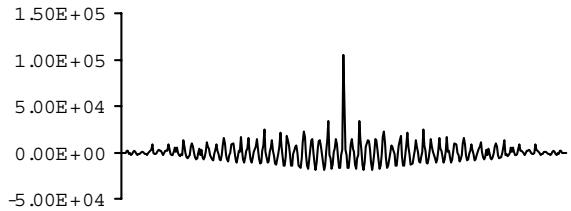

Fig. 5. ACF of the obtained chaotic signal

After computations, based on the ACF, the value of τ for the discussed signal has been obtained: $\tau = 2$.

Another set of values of the parameters of the analyzed circuit causes a corresponding change in the form of the obtained signals, as indicated on Figs. 6 and 7.

Fig. 6. Time domain presentation

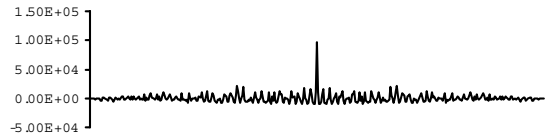

Fig. 7. ACF of the obtained chaotic signal

The value for τ obtained for the discussed signal after some computations is equal to 2.

The presence of close relationship between the set of the values of the parameters and the form of the chaotic signal, analyzed at the output of the circuit, can be shown.

B. Four-dimensional chaotic generator [3]

In [3] a 4-D chaotic generator with modified external driven nonlinearity has been presented. The trajectories in the phase plane have been presented on Fig. 8 [3].

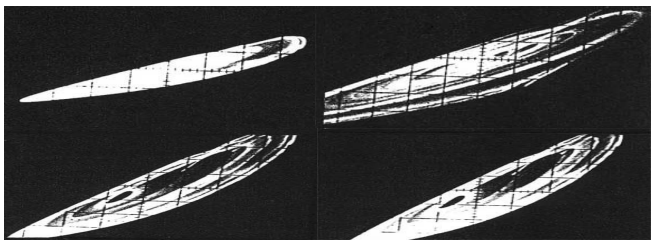

Fig. 8. Photos of output signals observed in the phase plane

By a fixed set of values of the parameters the following chaotic signal has been obtained (Figs. 9, 10).

Fig. 9. Time domain presentation

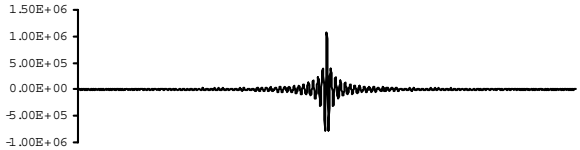

Fig. 10. ACF of the obtained chaotic signal

After some computations $\tau = 4$ has been obtained.

Fig. 11. Time domain presentation

Fig. 12. ACF of the obtained chaotic signal

By different conditions, concerning the set of values of the parameters of the 4-D generator, discussed in [3], a different signal has been obtained (Figs. 11, 12).

The computed value for τ is: $\tau = 9$.

A first version of Chua's circuit. In [4] a version, based on the well known Chua's circuit, has been discussed. The trajectories of different output signals have been presented in the phase plane on Fig. 13 [4].

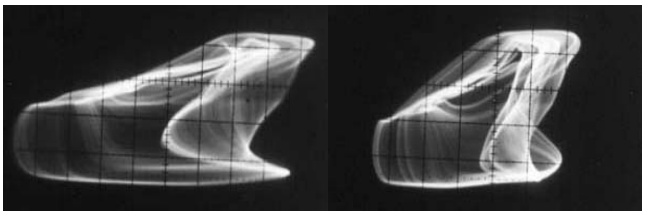

Fig. 13. Photos of output signals observed in the phase plane

For the experiments an appropriate signal has been chosen. The signal presented in time domain has been shown on Fig. 14. The corresponding ACF has been presented on Fig. 15. The value for τ of the discussed signal obtained after computations is: $\tau = 2$.

Fig. 14. Time domain presentation

Fig. 15. ACF of the obtained chaotic signal

A second version of Chua's circuit. In [4] another version, based on the Chua's circuit, has been presented. The circuit, discussed there, includes external driven nonlinearity. Different output signals, observed in the phase plane, have been shown on Fig. 16 [4].

For the calculations an appropriate signal has been chosen. The generated signal has been presented in time domain on Fig. 17.

Fig. 16. Photos of output signals observed in the phase plane

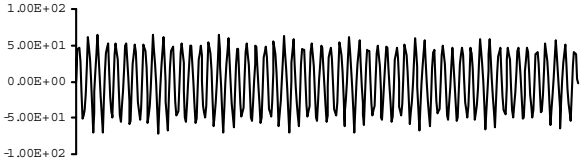

Fig. 17. Time domain presentation

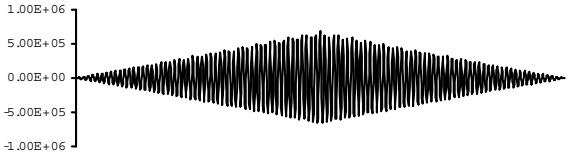

Fig. 18. ACF of the obtained chaotic signal

The corresponding ACF has been shown on Fig. 18. The value for τ, obtained after computations, is: $\tau = 3$.

A third version of Chua's circuit. In an another circuit, presented in [4], a different way of design of the nonlinear element has been chosen.

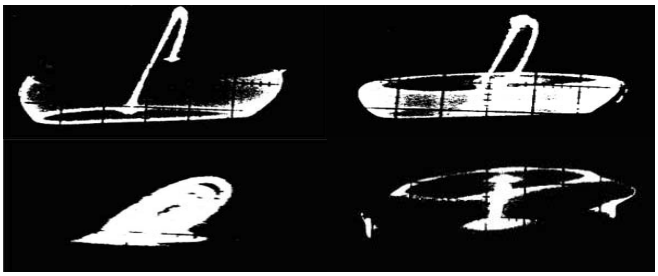

Fig. 19. Photos of output signals observed in the phase plane

The trajectories in the phase plane have been shown on Fig. 19 [4]. A several types of signals, obtained by different sets of values of the parameters of the circuit, analyzed in [4], have been presented. For a fixed set of values of the parameters a chaotic signal has been produced (Figs. 20, 21).

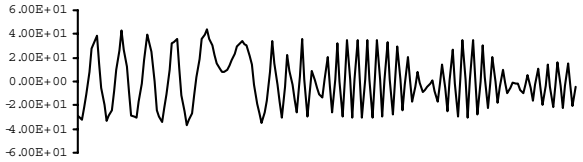

Fig. 20. Time domain presentation

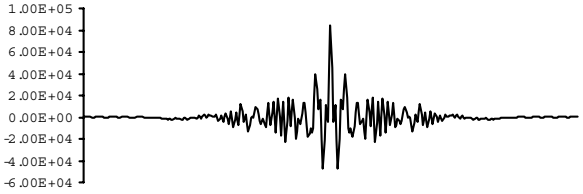

Fig. 21. ACF of the obtained chaotic signal

The value for τ, obtained after computations, is: $\tau = 2$.

Changing the set of values of the parameters, another signal at the output of the discussed circuit, presented in [4], has been obtained (Figs. 22, 23).

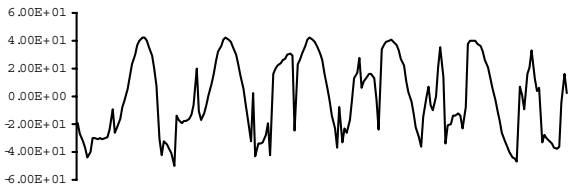

Fig. 22. Time domain presentation

Fig. 23. ACF of the obtained chaotic signal

The value for τ, obtained after computations, is: $\tau = 8$.

The next change in the parameter values leads to a corresponding change in the form of the generated signal (Fig. 24).

Fig. 24. Time domain presentation

The corresponding ACF has been presented on Fig. 25.

Fig. 25. ACF of the obtained chaotic signal

For the discussed signal, by means of computations, based on the ACF, $\tau = 2$ has been obtained.

IV. Conclusions

- Some circuits, designed to generate chaotic signals, have been investigated.
- The discussed circuits have been developed in practice.
- Experiments on the lab prototypes have been made.
- The dependence between the change in the sets of the values of their parameters and the corresponding change in the form of the obtained chaotic signals has been shown.
- Signals, obtained from the discussed circuits, have been digitized and presented in the time domain.
- The corresponding ACF have been shown.
- Based on the obtained ACF, computations, necessary for the determination of the Lyapunov exponents, have been carried out.

References

[1] Stoycho Panchev, “Theory of chaos” (with Examples and Applications), Academic Publishing House “Prof. Marin Drinov”, 1996 (in Bulgarian).

[2] Antonis Karantonis, M. Pagistas, “Comparative study for the calculation of the Lyapunov spectrum from nonlinear experimental signals”, pp. 5428-5444, Phys. Rev. E, Vol. 53, 1996.

[3] Stoitscho V. Manev and Vladimir Iv. Georgiev, “Chaotic Signals in Radiocommunication Generated by some Circuits”, pp. 627-630, ICEST Niš 2002.

[4] Stoitscho V. Manev and Vladimir Iv. Georgiev, “Study of some Circuits in Radio Communication Designed to Generate Chaotic Signals”, pp. 631-634, ICEST Niš 2002.