A Chaotic Sensor with Conductivity Titration for Water Quality Measurements

Cojocaru V.P.
D. Ghitu Institute of the Electronic Engineering and Nanotechnologies of the Academy of Sciences of Moldova
Technical University of Moldova, Chisinau, Moldova
vcojocaru@nano.asm.md

***Abstract*—We present a simple sensor based on chaotic dynamics for measurements water quality. This paper is a summary of results reported by author in previous papers.**

***Index Terms*—Chaotic sensor, measurement, conductivity titration, chaotic dynamics**

I. Introduction

Contamination of the environment factors can be conducted with or without human intervention resulting in changes in the physicochemical or biological properties thereof. When these changes exceed a certain threshold and remain for a long time, environmental monitoring sensors are used in different conditions to determine pollution phenomenon [1]. Sensors (transducers) are devices (circuits) that detect changes in a parameter of the system by issuing an appropriate signal dependent on the size of the parameter measured. These circuits are designed to transform the parameters of the system in other sizes [2, 3].

For a more effective monitoring, it is desirable that these sensors are small GSM network, Bluetooth, or Wi-Fi. These sensors must have temperature stability. Considering all said above, the author of this paper proposes a new class of sensors based on nonlinear dynamics (chaos) [4-7].

In the early years of using the concept of deterministic chaos in the literature, the behaviour of chaotic systems was considered an exotic phenomenon being of interest only to mathematicians, leaving aside practical applications. Over time, chaotic dynamics has been increasingly applied in a large number of different systems from mechanics, physics, and laser communication systems based on chaos [8-10].

An important category of applications is based on the use of the concept of chaos to describe the uncertainty of the behavior of dynamic systems. Description of the chaotic uncertainty in comparison with other methods (stochastic, fuzzy, etc.) provides a specific tool to describe the uncertainty of the oscillation parameters (frequency, phase, amplitude) using a small number of parameters and by applying to a wide range of systems, namely nonlinear differential equations. Routing methods under uncertainty chaos began to develop quite recently [11-13]. This paper is only a summary of the research reported in author's previous papers.

II. Circuit

The literature presents a wide range of chaotic circuits [14-16]. A new class of chaotic circuit has been proposed in [17]. The circuit shown in Fig. 1 consists of two inverting operational amplifiers (LF 357) included in the loop. One amplifier has a nonlinear amplifier as a load resistance. In previous versions, the nonlinear element used was an electrolytic capacitor [18-19]. In our measurements, solutions composed of three salts—NaCl, $CrCl_2$, and $MgCl_2$—were used as a nonlinear element.

The sensor is based on a change in dynamics produced in a nonlinear dynamic circuit, which has a circuit element composed of the measured saline solution and electrodes. In the current implementation, the sensing element consists of two Fe/Zn electrodes immersed in a recipient (bath) containing the measured solution. The electrodes and the solution compose an electrolytic cell. The level of impurities affects the chaotic behavior of the sensor. The investigated signal is captured in points P 0 and P 1.

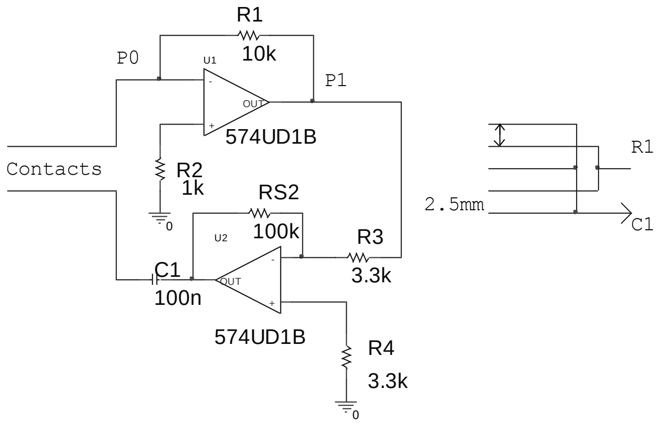

Fig. 1. Circuit schematic.

III. Experiment

In previous research, the authors have experimented with different salts, the research being reported in [20, 22]. The electrical conductivity measurement method was used.

Measurement of electrical conductivity of the solution is widely used in titrimetric analysis for the determination of equivalence (conductometric titration).

Maintaining proper water quality is a goal of the utmost importance to prevent any outbreak of infection. Systems for on-line water quality monitoring and early warning are a necessity for water distribution systems (WDS). The authors of [23-25] describe a set of sensors and pH-based conductometric interdigitated electrodes (the form of combs) for on-line water monitoring. Tests show that the sensors can perform accurately even at a high rate of water flow of 30 ml/min. The authors compare these sensors and industrial sensors; the former are cheaper.

An efficient and highly accurate method is titration. Until recently, a disadvantage of this method has been used only in laboratories given that the method uses liquid titrant. The authors of [26-28] use the methods and the equipment that allows very fast accurate acid-base measurements with a probe based on a solid material. Two titration methods with a probe based on a solid material are described: Coulometric titration and The Orion FLASH.

The results are explained with the images of the nonlinear dynamics of the measuring cell immersed in a solution for three different salts. The samples were prepared of 12 ml of H_2O with a salt solution. The solution concentration ranged from 0.2 to 1.8 ml. The solution was made of 0.5 g of the used salt per liter of H_2O with steps of 0.2 ml.

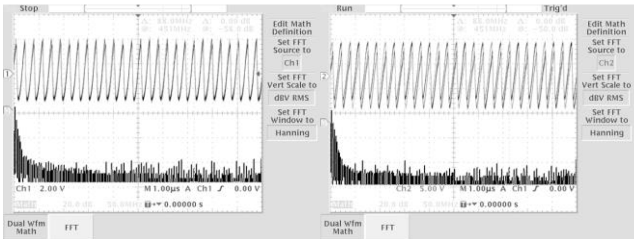

Fig. 2. Solution of 12 ml of H_2O + 0.2 ml of NaCl ground 0.5 g per liter of H_2O, t = 20°.

Figure 2 shows signals X (P0), Y (P1) and FFT of the NaCl sample. The chaotic signal was measured using a Tektronix TDS 3012B oscilloscope.

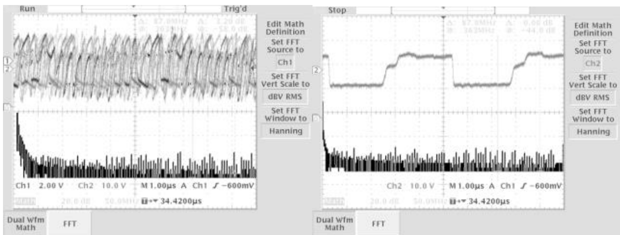

Fig. 3. Solution of 12ml of H2O + 0.2 ml of MgCl2 ground 0.5 g per liter of H2O, t = 20°.

Figure 4 shows signals X (P0), Y (P1) and FFT for these signals. Analysis of the signals reveals that the visualized signals are non-periodic and FTT spectrum has a similar noise "colour", which indicates a well defined chaotic behaviour.

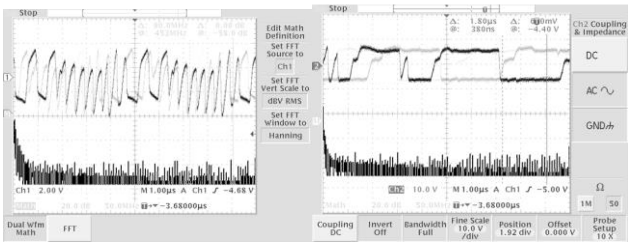

Fig. 4. Solution of 12 ml of H2O + 0.2 ml of CrCl2 ground 0.5 g per liter of H2O, t = 20°.

Figure 2 shows signals X (P0), Y (P1) and FFT for the CrCl sample. Comparison of the results of measurements at two different temperatures does not reveal changes in the chaotic signal. Comparison of the signals obtained with the CrCl2 solution to the signals obtained with the NaCl and MgCl2 solutions shows the difference. Signals may vary due to changes in the electric strength of the chemical potentials

Fig. 5. Design sensor.

Figure 5 shows the sensor used for measurements. It is made of available materials, is compact, and has sizes of 100 mm x 19 mm. The sensor must be completely submerged in the solution. Signals generated by the nonlinear circuit are sent for processing in a computer.

IV. Conclusions

The use of the conductometric method for measurements in diverse areas of the environment shows that this method is effective and has good prospects for the future. This type of sensor can be used in the near future as the basis for a biosensor to be implanted in different biological tissues for monitoring salt levels in the blood.

Acknowledgments

The author acknowledges three research exchanges supported by the Romanian Academy. The experiments were developed during V.C.’s stay at the Institute for Computer Science, Romanian Academy. The researches were conducted in Gheorghe Asachi Technical University of Iasi during the inter-academy exchange visits between AS Moldova Republic and AR Romania. We thank Prof. H.-N. Teodorescu for advice and critics on several versions of the article. Prof. H.-N. Teodorescu developed the method for detecting harmful substances using this kind of chaotic sensor, verified and analyzed the results. All the measurements were made under the guidance (together) of Prof. H.-N. Teodorescu.

References

[1] Anas Ghadouani, Liah X. Coggins Science, technology and policy for Water Pollution Control at the Watershed Scale: Current issues and future challenges Original Research ArticlePhysics and Chemistry of the Earth, Parts A/B/C, Volume 36, Issues 9–11, 2011, Pages 335-341

[2] Hiromitsu Sakai, Satoru Iiyama, Kiyoshi Toko, Evaluation of water quality and pollution using multichannel sensors Original Research Article, Sensors and Actuators B: Chemical, Volume 66, Issues 1–3, 25 July 2000, Pages 251-255

[3] Karl Cammann, Continuous pollution control by chemical sensorsOriginal Research Article, Sensors and Actuators B: Chemical, Volume 6, Issues 1–3, January 1992, Pages 19-24

[4] Teodorescu, H.N., Characterization of nonlinear dynamic systems for engineering purposes – a partial review, International Journal of General Systems, Volume 41, Issue 8, 2012 pages 805-825

[5] Kobayashi Y., Nakano H., Saito T., „A Simple Chaotic Circuit with Impulsive Switch Depending on Time and State", Nonlinear Dynamics (2006) 44 pp. 73–79, Springer 2006.Teodorescu, H.N., Method for measuring at least one parameter and device for carrying this method. European patent application, EP 0 981 038 A1, date of publication 23.02.2000 Bulletin 2000/08, date of filing 19.08.1998. Patent Application #988-10802.3, Aug. 1998/23.02.2000, EP0981038 (A1) Priority number(s): EP19980810802 19980819, patent: EP 981 038 A1 / 23.02.2000)

[6] Teodorescu, H.N., Method for measuring at least one parameter and device for carrying this method. European patent application, EP 0 981 038 A1, date of publication 23.02.2000 Bulletin 2000/08, date of filing 19.08.1998. Patent Application #988-10802.3, Aug. 1998/23.02.2000, EP0981038 (A1) Priority number(s): EP19980810802 19980819, patent: EP 981 038 A1 / 23.02.2000

[7] V.Z. Tronciu, I.V. Ermakov, P. Colet, C.R. Mirasso, "Chaotic dynamics of a semiconductor laser with double cavity feedback: Applications to phase shift keying modulation", Optics Communications, 281, 4747–4752, 2008.

[8] V.Z. Tronciu, C.R. Mirasso, and P. Colet, "Chaos Based Communications using On-Off Shift Keying Method", Physical Review E 78, 066202 (1-11) (2008).

[9] Ermakov I. V., Tronciu V. Z., Colet P., Mirasso C., " Controlling the unstable emission of a semiconductor laser subject to conventional optical feedback with a filtered feedback branch", Optics Express 17, 8749-8755 (2009)

[10] .Teodorescu, H.-N.; Mlynek, D.; Kandel, A.; Zimmermann, H.-J., Intelligent Systems and Interfaces, Series: International Series in Intelligent Technologies, Vol. 15, 2000, XXXI, 452 p.

[11] .Teodorescu, HN; Yamakawa, T., Applications of chaotic systems: An emerging field. International Journal Of Intelligent Systems Volume: 12 Issue: 4 Pages: 251-253

[12] . Teodorescu, HN; Stoica, A; Mlynek, D; Nonlinear dynamics sensitivity analysis in networks and applications to sensing Source: Large Scale Systems: Theory And Applications 2001 (LSS'01) Book Series: IFAC Symposia Series Pages: 333-338 Published: 2002

[13] Mandal S., Banerjee S., „An Integrated CMOS Chaos Generator", Proc. 1st Indian National Conf. on Nonlinear Systems & Dynamics, 2003; also S. Mandal, S. Banerjee, Analysis and CMOS Implementation of a Chaos-Based Communication System, IEEE Trans. Circ. & Systems, 51(9) pp. 1708-1722, 2004.

[14] Mitsubori K. and Saito T., „Dependent Switched Capacitor Chaos Generator and Its, Synchronization", IEEE Transactions Circuits and Systems-L: Fundamental Theory and, Applications, Vol. 44, No. 12, pp. 1122-1128, December 1997.

[15] Algaba A., Freire E., Gamero E., Rodrнguez-Luis A.J., „Analysis of Hopf and Takens–Bogdanov Bifurcations" in a Modified van der Pol–Duffing Oscillator., Nonlinear Dynamics 16: 369–404, 1998. Kluwer Academic Publ.

[16] Mishagin K.G., Matrosov V.V., Kuzmin L.V., Kletsov A.V., „Multi-band Chaotic Oscillator with Phase-locked Loop", Piers Online, 5, 6, pp. 531-535, 2009.

[17] H.N. Teodorescu, A New Class of Chaotic Circuits based on Capacitive Feedback. Proc. ITEI, Kishnew, R. Moldova, May 20-22, 2010.

[18] Teodorescu H.N., Cojocaru V., "Complex Signal Generators based on Capacitors and on Piezoelectric Loads", Chaos theory Modeling, Simulator and Application, World Scientific Publishing 2011 pp.423-430.

[19] Teodorescu, H.-N.; Iftene, E.-F., Efficiency of a Combined Protection Method against Correlation Power Analysis Side-Attacks on Microsystems. International Journal of Computers Communications & Control, Vol. 9, Issue 1, pp. 79-84, Feb 2014

[20] Teodorescu, H.N. L.; Cojocaru, Victor P. Biomimetic Chaotic Sensors for Water Salinity Measurements and Conductive Titrimetry Emerging Security Technologies (EST), 2012 Third International Conference on Portugal, Lisbon 5-7 Sept. 2012 pp182 – 185.

[21] Victor P. Cojocaru, „Sensors Based on Chaotic Systems for Environmental Monitoring" Improving Disaster Resilience and Mitigation - IT Means and Tools Proceedings of the NATO Advanced Research Springer ISBN 978-94-017-9138-0 (PB) 2014,pp 323-334

[22] V. Cojocaru, Chaotic generator-based sensor for environment conductometric measurements, submitted, 2015.

[23] Grysiński, T., Moroń, Z., Planar sensors for local conductivity measurements in biological objects—Design, modelling, sensitivity maps Sensors and Actuators B: Chemical, 158, 1, 15 November, 2012, pp.190-198.

[24] Naderi-Boldaji, M., Sharifi A., Hemmat, A., Alimardani, R., Keller, T., Feasibility study on the potential of electrical conductivity sensor Veris® 3100 for field mapping of topsoil strength Biosystems Engineering, 2014 pp.126, 1-11.

[25] Banna, M.H., Najjaran. H., Sadiq, R., Imran, S. A., Rodriguez, M. J., Hoorfar, M., Miniaturized water quality monitoring pH and conductivity sensors, Sensors and Actuators B: Chemical, 193, 31 March, 2014, pp 434-441.

[26] Van der Schoot, B., Van der Wal, P, De Rooij, N., West, S., Titration-on-a-chip, chemical sensor–actuator systems from idea to commercial product, Sensors and Actuators B: Chemical, 105, 1, 14 February, 2005, pp.88-95.

[27] Llorent-Martínez, E.J., Ortega-Barrales, P., Fernández-de Córdova, M.L., Ruiz-Medina, A., Trends in flow-based analytical methods applied to pesticide detection: A review Analytica Chimica Acta, 684, 1–2, 17 January, 2011, pp. 30-39).

[28] Steinberg, M. D., Žura, I., Murkovic, I., Wireless smart tag with on-board conductometric chemical sensor Sensors and Actuators B: Chemical, 196, June, 2014, pp. 208-214.