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Oscillons: An encounter with dynamical chaos in 1953?

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We discuss the works of one of electronic art pioneers, Ben F. Laposky (1914–2000), and argue that he might have been the first to create a family of essentially nonlinear analog circuits that allowed him to observe chaotic attractors. © *2011 American Institute of Physics*. [doi:10.1063/1.3562545]

As any branch of science, dynamical chaos theory has no definite birth date or starting point but a certain number of milestones. Edward N. Lorenz recognized the chaotic attractor, which now bears his name, in numerical simulations somewhere around 1961,[1] while Leon Chua incarnated chaotic attractors with a specially designed electronic circuit in 1983.[2] Here we present evidence that Ben F. Laposky was able to create a family of analog circuits that allowed him to observe chaotic attractors and other trademarks of nonlinear science as early as 1953.

Although Laposky, a draftsman by profession, had received a proper recognition as a pioneer of electronic art, at no time his name has emerged in the context of dynamical chaos theory. The circuits he had implemented for generation of "oscillons" on the screen of a cathode ray tube oscilloscope remain a mystery.[3] It is known that some of his 37 circuits[4] had "as many as 70 different setting of controls"[5] and that ac-voltage has been used for the circuit feeding. Our analysis is based on the vanity press booklet with the still photos of the 56 oscillons, which were exhibited at the Sanford Museum (Cherokee, Iowa) in 1953.[4]

There are three oscillons that captured our attention [Figs. 1(a)–1(c)]. The first oscillon [Fig. 1(a), #30 in the booklet] looks very similar to the celebrated Rössler attractor[6] [Fig. 1(d)], while the second one [Fig. 1(b), #6] looks like a multi (in this case, three)-scroll attractor[7] [Fig. 1(e)], a typical output of chaotic circuits which includes nonlinear elements with nonmonotonous input/output characteristics.

The words "looks similar" stand here for the similarity of the attractor shapes only. Obviously, this observation cannot be taken as a rigorous proof of the statement that Laposky observed chaotic attractors, yet it certainly confirms the fact that the electronic systems he used were essentially nonlinear. The third oscillon [Fig. 1(c), #36] provides more substantial evidence of the last statement. It represents a peculiar limit cycle, which, we believe, demonstrates the bursting phenomenon,[8] a dynamical regime of neuronal activity where a neuron periodically fires a discrete series of spikes, and which can be reproduced with nonlinear models only. In order to substantiate this claim, we employed the Hindmarsh–Rose model,[9] with the parameters $x_R = -1.6$, $r = 0.01$, $s = 4$, $a = 2.5$, and $I = 3$. Using the shape of the model attractor in a three-dimensional space (x,y,z), we tried to find a frame transformation, $\mathbf{F} = \{F_x(x,y,z), F_y(x,y,z), F_z(x,y,z)\}$, which maps the original frame space onto a new one, $\mathbf{F} : (x,y,z) \rightarrow (x',y',z')$, so that the new coordinates of reference attractor points, (x'_r, y'_r), would maximally approach the corresponding reference points of the oscillon, (X_r, Y_r) (see Appendix A). Namely, we first digitized the image of the oscillon and distributed 26 reference points over it. Because allowable frame transformations should be smooth in order to preserve the topology of the attractor, we assumed the functions F_x, F_y, and F_z to be fourth-order polynomials and then minimized the quantity $\Delta = \sum_r (x'_r - X_r)^2 + (y'_r - Y_r)^2$ in a standard least-squares

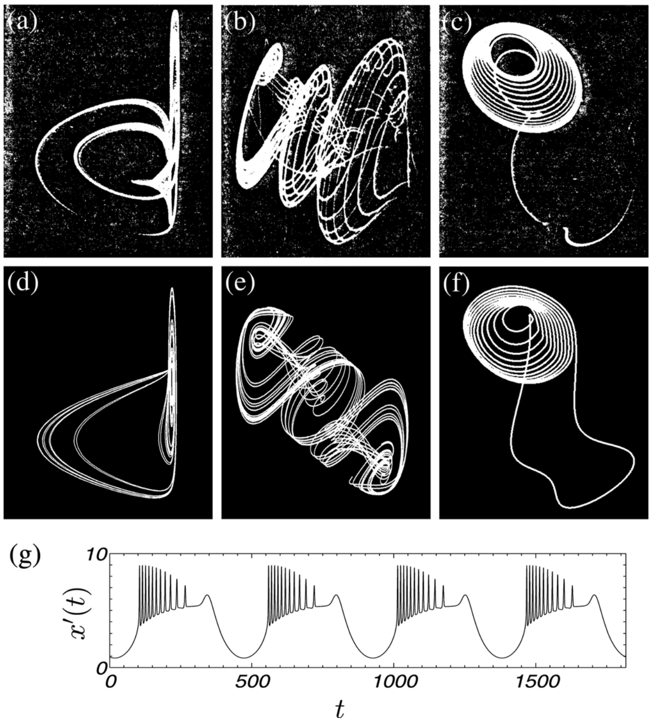

FIG. 1. Oscillons from B. F. Laposky, *Oscillons: Electronic Abstractions*, 1953. Photos courtesy of Sanford Museum and Planetarium (Cherokee, Iowa), (a) #30, (b) #6, and (c) #36. Rössler attractor, with the parameters $a = 0.2$, $b = 0.19$, and $c = 7.1$ (d), three-scroll attractor, $\dot{x} = y$, $\dot{y} = z$, $\dot{z} = -z - 5y - x^5 + 4x$ (Ref. 10) (e), and limit-cycle regime of the Hindmarsch–Rose model (f). While the last attractor was modified by a nonlinear frame transformation, the first two were obtained by a simple adjusting rotation of the original frame (x, y, z) and subsequent projection on the (x', y') plane. (g) The periodic bursting pattern, $x'(t)$, generated by the limit cycle from (c), bottom row.

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fashion, by varying the polynomial coefficients. The resulting limit cycle [Fig. 1(f)] has the shape of the original oscillon and produces a typical periodic bursting pattern [Fig. 1(g)]. Thus the oscillon #36 might be a fingerprint of an analog model of neuron, which was created even before the very first mathematical model was presented.[11] Finally, we would like to underline that the trajectory shown in Fig. 1(c) exhibits a specific type of instability[8] which is irreproducible with simple linear setups (for example, by crumpling a Lissajous curve).

Our results give substantial evidence that Ben F. Laposky had all the ingredients needed to encounter chaotic regimes of analog electronic systems, and it is quite *probable* that he had witnessed these regimes while tuning the parameters of his mysterious circuits.[12] Yet, "science starts from problems, and not from observations,"[13] so that, even if our hypothesis is correct, Laposky cannot be nominated for the discovery of chaotic attractors (although he certainly deserved to be mentioned in the curriculum vitae of electronic chaos; see Appendix B). But what is most exciting about the oscillon story is that the use of pure aesthetic criteria, which guide artists' preferences, had led to the selection of several aperiodic, chaotic attractor-like structures from more than 6000 images[4]—decades before scientists started to talk about the "beauty of chaos."[14]

APPENDIX A: FRAME TRANSFORMATION

We have used the standard routine from the MATLAB Optimization Toolbox for the solution of the optimization problem[15] (see Fig. 2).

APPENDIX B: ELECTRONIC CHAOS PREHISTORY

- 1927:[24] First encounter with electronic chaos: "Often an irregular noise is heard… [that] strongly reminds one of the tunes of a bagpipe;[16]
- 1953: Ben F. Laposky's oscillons;[4,5]
- 1957: First encounter with dynamical chaos in numerical studies (?): Two-disk dynamo model by Tsuneji Rikitake: "… the system in question performs an extremely complicated oscillation"[17] (see also Ref. 18);
- 1958:[24] Experiments with glow-lamp ring circuits: "Larger rings [of glow lamps], on the other hand, perform erratically and are always hard to adjust for a specific firing order";[19]
- Around 1961: E. Lorenz found his attractor:[1] the beginning of modern study of chaotic dynamics;
- November 16, 1961:[24] Chaotic signal from an overloaded traveling wave tube amplifier: "High power noise source employing a feedback path around a traveling wave tube";[20]
- November 27, 1961:[24] While experimenting with vacuum tube circuits, Yoshishuke Ueda noticed "randomly transitional phenomena" (though his finding was not published until 1970);[21]
- 1965:[24] An overloaded amplifier with a feedback element generates aperiodic broadband oscillations;[22]
- 1979: Experiments with a self-excited circuit: "…the results of a theoretical, numerical and experimental investigation of one of the simplest self-excited noise generators. …the statistical properties of the signal are determined… by the intrinsic dynamics of the system rather than by… the noise;[23]
- 1983: Chua's circuit: Incarnation of chaotic attractor regimes with a specially designed circuit.[2]

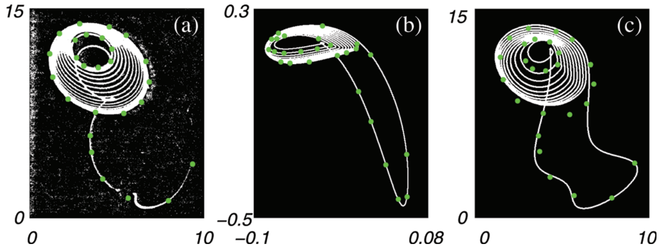

FIG. 2. (Color online) Phase-space transformation. (a) Oscillon #36 with 26 reference points (X_r,Y_r) from B. F. Laposky, *Oscillons: Electronic Abstractions*, 1953. Photo courtesy of Sanford Museum and Planetarium (Cherokee, Iowa), (b) original limit cycle of the Hindmarsch–Rose model with reference points (x_r,y_r), and (c) limit cycle after a frame transformation with superimposed reference points (X_r,Y_r).

[1] E. N. Lorenz, J. Atmos. Sci. **20**, 130 (1963).

[2] L. O. Chua, M. Komuro, and T. Matsumoto, IEEE Trans. Circuits Syst. **33**, 1072 (1986).

[3] We did not find any information concerning circuits used by Laposky (circuit diagrams, elements, regimes). We doubt that such information exists and is available at all.

[4] B. F. Laposky, *Oscillons: Electronic Abstractions* (1953). See http://www.vasulka.org/archive/Artists3/Laposky,BenF/.

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[11] A. Hodgkin and A. Huxley, J. Physiol. **117**, 500 (1952); Reprinted in Bull. Math Biol. **52**, 1 (1990).

[12] Strictly speaking, we should not exclude the possibility that, by feeding the vertical and horizontal control inputs of an oscilloscope with specially devised quasiperiodic signals, one could get something similar to the oscillons shown in Figs. 1(a) and 1(b).

[13] K. Popper, *Conjectures and Refutations: The Growth of Scientific Knowledge* (Routledge, New York, 2002), p. 301.

[14] J. Briggs, *Fractals: The Patterns of Chaos: Discovering a New Aesthetic of Art, Science, and Nature* (Simon and Schuster, NY, 1992); R. Chapman and J. C. Sprott, *Images of a Complex World: The Art and Poetry and Chaos* (World Scientific, Singapore, 2005).

[15] See documentation at www.mathworks.com/access/helpdesk_r13/help/toolbox/optim/fminunc.html.

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[18] K. Ito, Earth Planet. Sci. Lett. **51**, 451 (1980).

[19] R. L. Ives, Electronics **31**, 108 (1958).

[20] C. A. Ries and J. E, Zellens, U.S. patent 3,178,655 (16 November 1961).

[21] Y. Ueda, C. Hayashi, N. Akamatsu, and H. Itakura, Electron. Commun. Jpn. **53**, 31 (1970) (in Japanese); English translation in Y. Ueda, *The Road to Chaos* (Aerial Press, Santa Cruz, CA, 1992).

[22] E. A. Kotyrev and L. E. Pliss, Radiotekh. Elektron. (Moscow) **10**, 1628 (1965) (original in Russian).

[23] S. V. Kiyashko, A. S. Pikovskii, and M. I. Rabinovich, Radio Eng. Electron. Phys. **25**, 74 (1980).

[24] All these researchers did not attribute the observed phenomena to the underlying chaotic dynamics of the employed systems. They interpreted chaotic signals as the result of amplification of "inevitable" internal fluctuations.