Modeling Deterministic Chaos: A Case Study of Chua's Circuit

Nika Tugushi [a]

e-mail: nika.tughushi107@ens.tsu.edu.ge

[a] Physics Department, Faculty of Exact and Natural Sciences, Tbilisi State University

1 Ilia Chavchavadze Avenue, Tbilisi, 0179, Georgia

The present work aims to investigate the deterministic chaos established in dynamical systems by analyzing several key characteristics. The systems under consideration are those with the potential for a transition to a chaotic state. The analysis focuses on: the equilibrium state (stability analysis), the mechanisms of transition into a chaotic state (bifurcation), the characteristic quantities of the established chaotic state (Lyapunov exponents), its geometric properties (strange attractors), and the characteristic measures of these properties (attractor dimension). This investigation allows for the prediction of the dynamics of such systems over time for specific initial conditions.

The central subject of the work is the investigation of an electronic circuit with chaotic dynamics - Chua's circuit. A stability analysis of the Chua's circuit has been conducted (calculation of equilibrium points, their classification, and a qualitative analysis of these points using numerical methods). We have studied different types of transitions (bifurcation) from an equilibrium state to a new state, such as the local Hopf and saddle-node bifurcations, and the global homoclinic bifurcation. We have performed an analysis of the dynamical system's transition to a chaotic state and the emergence of the strange attractor, as well as a quantitative characterization of the chaos. For this purpose, we have calculated the maximal Lyapunov exponent using Rosenstein's algorithm, the spectrum of Lyapunov exponents by the QR decomposition method, and the dimension of the strange attractor by the Kaplan-Yorke method.

Numerical calculations were performed using the MATLAB software.

To validate the mathematical modeling against real experimental data, we have constructed a physical version of Chua's circuit with electronic components and have modeled it using the virtual laboratory software (LTspice).