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Periodically varied initial offset boosting behaviors in a memristive system with cosine memductance

Key words: Initial offset boosting; Memristive system; Memductance; Line equilibrium set

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Motivation

- With the small size and low power consumption, memristor-based chaotic oscillating circuits and neuromorphic computing circuits have wide potential application prospects.
- The cosine or sine functions are commonly used as the external forcing terms of non-autonomous systems or special nonlinear terms for the generation of multi-scroll attractor and initial offset boosting behaviors.

Main idea

- The cosine function is treated as memductance nonlinearity in the proposed memristive system, which could be an effective way to implement the initial offset-boosted behaviors with more complex extreme multi-stability.
- The stabilities of the line equilibrium set periodically evolve along the coordinate of the memristor’s inner state variable, and thus infinitely many topologically different attractors are readily revealed. Moreover, the position offset boosting and topological structural variations are triggered by three of all the four initial conditions.

Method

1. Mathematical model of the memristive system is expressed as:

$$\begin{cases} \dot{x} = y + z - ky\cos\varphi, \\ \dot{y} = z, \\ \dot{z} = -x - z, \\ \dot{\varphi} = y, \end{cases} \qquad (4)$$

in which a novel ideal flux-controlled memristor with cosine memductance is used. Its dimensionless voltage-current relation is described as

$$\begin{cases} i = W(\varphi)v = v\cos\,\varphi, \\ \dot{\varphi} = v, \end{cases}$$

The memductance $W(\varphi) = \cos\varphi$ is nonlinear and periodically multi-valued.

2. Equivalent realization circuit

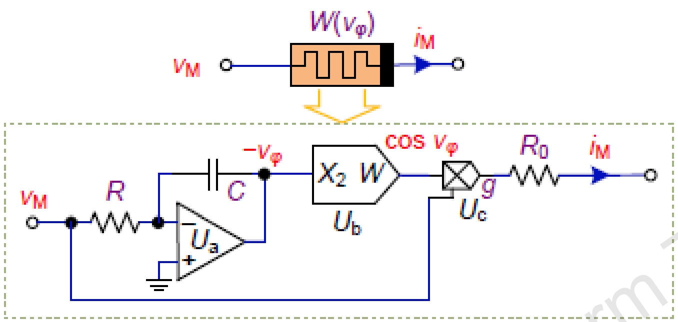

Fig. 1 Circuit schematic of the ideal memristor emulator implemented by op-amps, a trigonometric function chip, and a multiplier

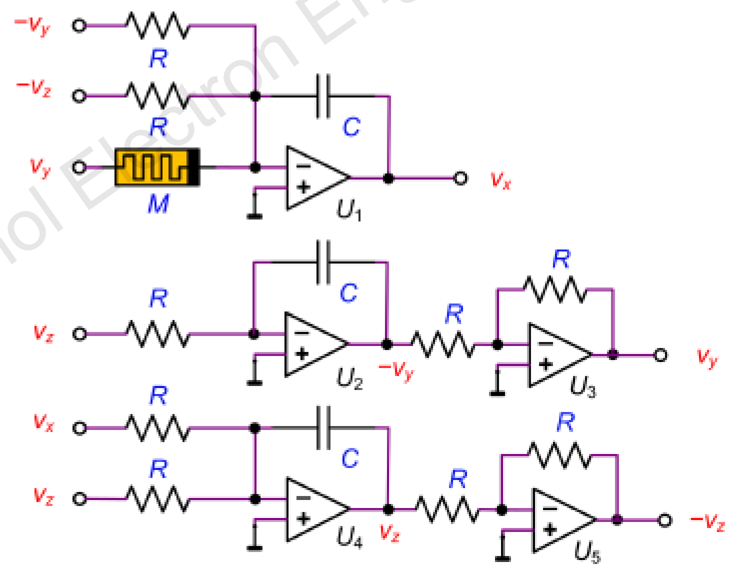

Fig. 7 Equivalent realization circuit of system (4)

Major results

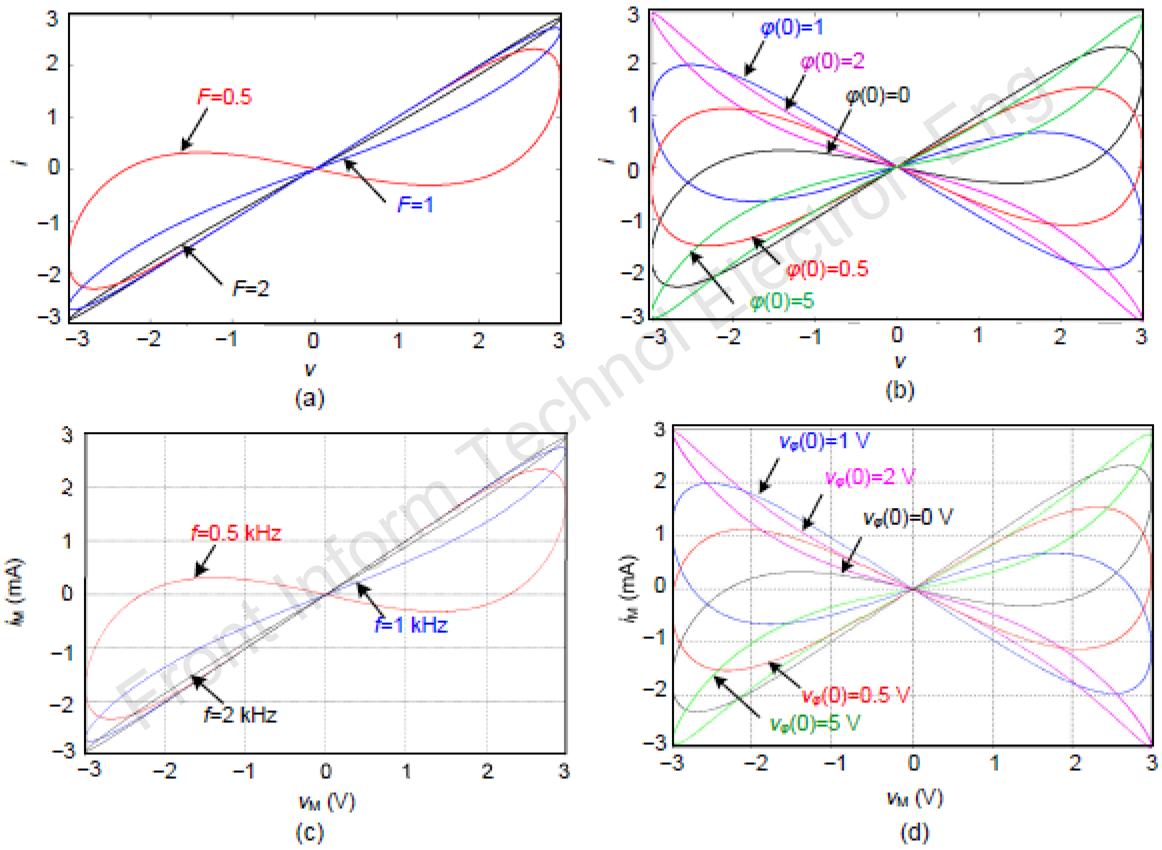

Fig. 2 Pinched hysteresis loops of the ideal memristor model and emulator: (a) memristor model-based numerical simulation with A=3 and $\varphi(0)$=0; (b) memristor model based numerical simulation with F=0.5 and A=3; (c) memristor emulator based circuit simulation with H=3 V and $v_\varphi(0)$=0 V; (d) memristor emulator based circuit simulation with f=0.5 kHz and H=3 V

References to color refer to the online version of this figure

Major results (Cont'd)

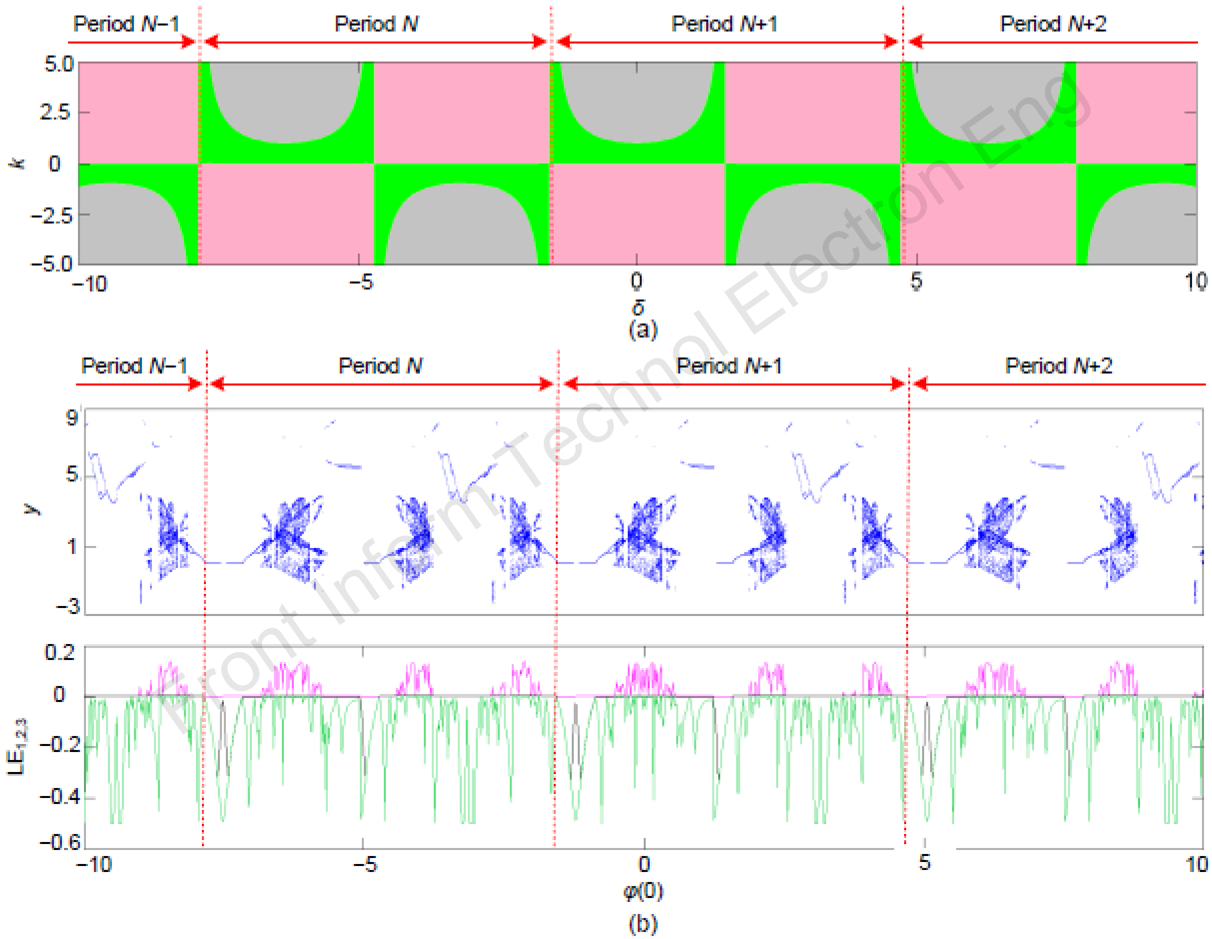

Fig. 3 Initial-condition-dependent dynamics of the memristor of system (4): (a) stability distribution of the line equilibrium set E in the δ-k plane; (b) bifurcation diagram and Lyapunov exponent spectra for k=3, $x(0)=10^{-6}$, and $y(0)=z(0)=0$
References to color refer to the online version of this figure

Major results (Cont'd)

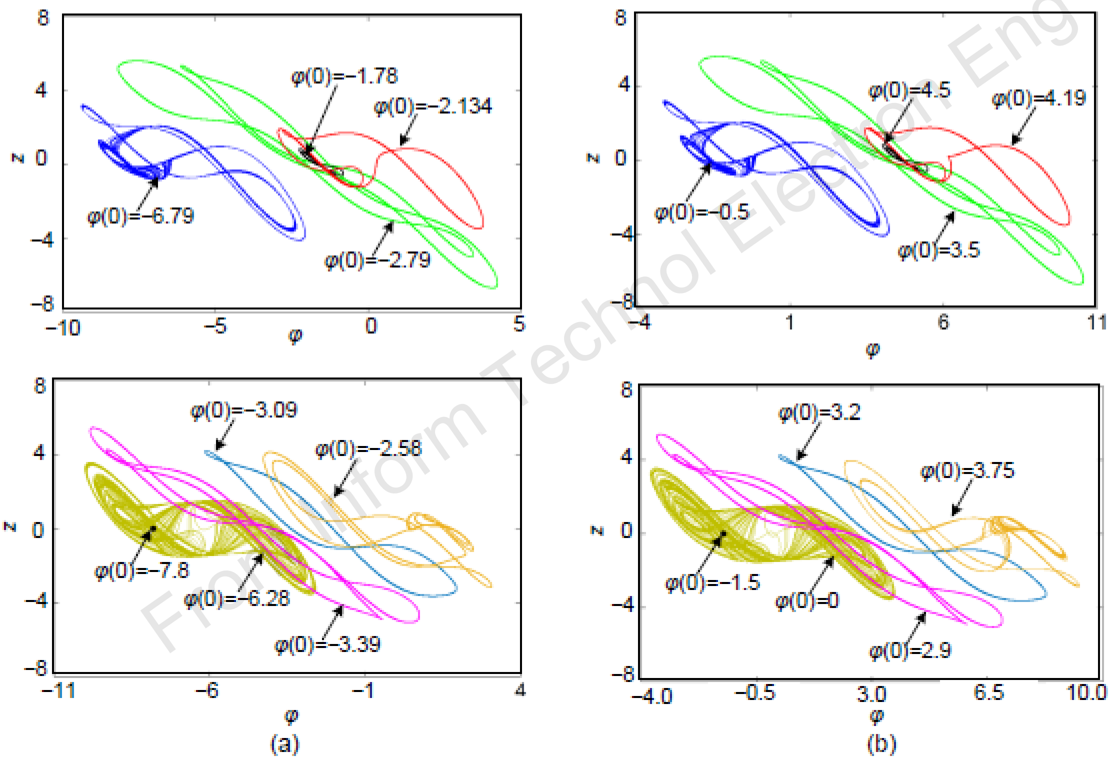

Fig. 4 Coexisting attractors in the φ-z plane with $x(0)=10^{-6}$, $y(0)=0$, and $z(0)=0$ for the initial conditions in periods N (a) and N+1 (b)

Conclusions

- A 4D memristive system has been constructed using a novel ideal memristor with cosine memductance.
- With the variation of three initial conditions, i.e., $x(0)$, $y(0)$, and $\varphi(0)$, periodically varied initial offset boosting dynamics has been uncovered.
- Diversiform point and chaotic and periodic attractors have been uncovered along the φ-coordinate through numerical simulations and PSIM circuit simulations.
- These sensitive initial-condition-dependent behaviors can be realized in an analog electronic circuit through incremental integral mapping of the state variables, or in a digital electronic circuit using a microcontroller-, FPGA-, or DSP-based platform.