

# Research Migration Project

<https://esim.fossee.in/research-migration-project>



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The Research Migration Project is an initiative of FOSSEE, IIT Bombay that promotes the use of eSim for reproducing published research circuits originally implemented using proprietary simulation tools. The objective is to migrate these validated designs to eSim to build an open source resource database.

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**Title of the circuit :** Simulation Simple Chaotic Systems and Circuits

**Theory/Description :** This project simulates a specific third-order autonomous ordinary differential equation known as a "Jerk Equation" (involving the third time derivative,  $\dddot{x}$ ). The circuit is based on **Equation (6)** from J. C. Sprott's 2000 paper

The circuit implements this equation using an **inductor-less** topology consisting of three cascading operational amplifiers configured as integrators. The necessary nonlinearity,  $G(x)$ , is realized using a simple piecewise-linear feedback loop consisting of diodes and resistors. This system demonstrates "deterministic chaos," where the output voltage oscillates in a bounded but non-repeating (aperiodic) manner, exhibiting extreme sensitivity to initial conditions.

**Reason to reproduce with eSim :**

- 1. Inductor-less Design:** eSim and Ngspice simulate capacitors and op-amps very accurately. Avoiding inductors (which are non-ideal and bulky in real implementations) makes this simulation highly reliable and easier to match with hardware.
- 2. Educational Value:** It is an excellent example of non-linear dynamics and chaos theory, which is a growing field in secure communications and cryptography.
- 3. Open Source Validation:** Simulating this in eSim helps validate that complex mathematical chaos can be generated using standard, open-source SPICE models (like the uA741) without proprietary software.

**Expected Outcome/outputs :**

- Time Domain: The output voltage vs. time will display a chaotic waveform that never exactly repeats itself.

- Phase Portrait: When plotting the output of the first integrator ( $x$ ) against the output of the second integrator ( $\dot{x}$ ) in X-Y mode, the simulation will reveal a "Strange Attractor"—a spiraling, geometric structure.
- Verification: The shape of the attractor should match Figure 4 of the referenced research paper.

**Circuit Diagram(s) :**

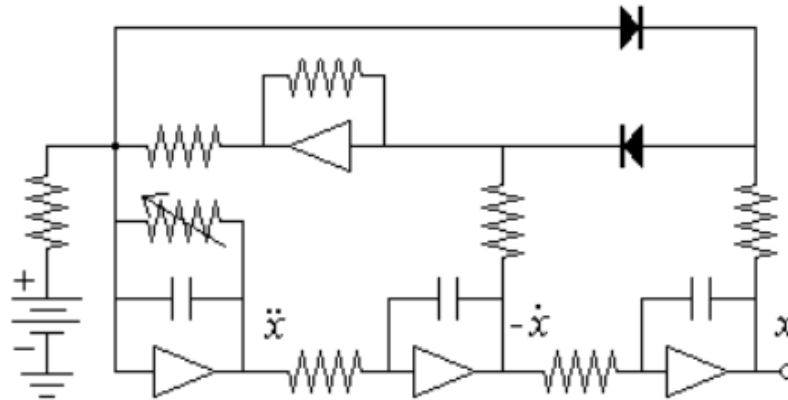


Figure-1

**Expected Results (Input, Output waveforms and/or Multimeter readings) :**

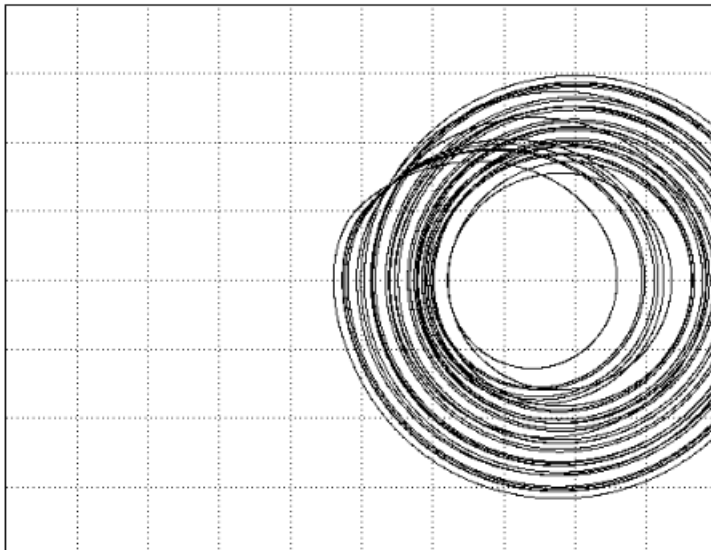


Figure 2: Expected Phase Portrait (X vs. Y plot) from the simulation. The plot shows a 'Strange Attractor' trajectory, confirming the chaotic behavior of the jerk circuit.

**Research Paper/Journal/etc. :**

- **Title** : Simple Chaotic Systems and Circuits
- **Author** : J. C. Sprott

- **Page No.** : 758-763 (Specifically Page 761, Figure 4)
  - **Link** : <https://sprott.physics.wisc.edu/pubs/paper245.htm>
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