Mixed mode and chaotic oscillations in Newtonian jerk circuits

Wiesław Marszałek (DeVry University), Zdzislaw Trzaska (Warsaw University of Ecology and Management, Poland)

Mixed-mode and chaotic behavior are important features of many nonlinear systems not only in physics, biology and chemistry but also in nonlinear processes in economics, dusty plasma, arrhythmias of human hearts and synchronization of massive population of neurons in human brains leading to the epileptic brain cell diseases [1].
Based on a singularly perturbed system of three ODEs with a cubic nonlinear term, we propose two *jerk* circuits that can generate mixed-mode oscillations of various sequences. The circuits are realized using operational amplifiers, passive R and C elements and one voltage-controlled voltage source. The circuits' responses comprise both the large (L) and small (s) amplitude oscillations which result in a periodic L^s sequence. The L^s patterns follow the Farey arithmetic of coprime integers when the circuits' parameters bifurcate in certain intervals [2]. One of the two *jerk* circuits has a Newtonian form as its mathematical model can be derived from the second Newton's law $x'' = F/m$, with $x'' = d^2x/dt^2$ being an "acceleration" variable. This allows for a mechanical interpretation of the electrical variables of the circuits as position, velocity and acceleration. The second *jerk* circuit obtained from the same set of singularly perturbed ODE system is not Newtonian. The third variable in the ODE system does not yield any *jerk* circuit. Several PSPICE and Matlab simulation results are included.

References

[1] H. Podhaisky, W. Marszalek, Bifurcations and synchronization of singularly perturbed oscillators: an application case study, Nonlinear Dynamics, 2012, (DOI) 10.1007/s11071-011-0316-8.
[2] W. Marszalek, Circuits with oscillatory hierarchical Farey sequences and fractal properties, Circuits, Systems, Signal Processing, 2012, (DOI) 10.1007/s00034-012-9392-3.