Simultaneous amplitude and frequency noise analysis in Chua's circuit.

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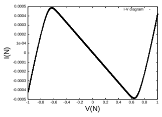
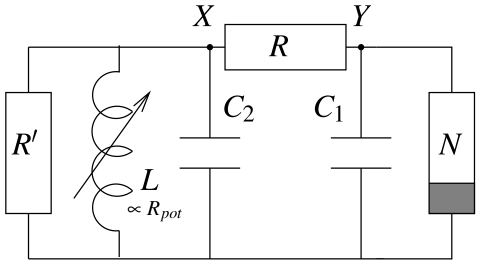
Introduction

Chua's circuit :
– simple circuit (parallel LC and CN circuits connected by a resistor, N being a negative resistor characterized by two slopes)
– bifurcation parameter : the inductor L, simulated by an operational amplifier based circuit. Its value is set by a variable resistor controlled by a computer
– the non-linearity is isolated to the negative resistor N (segment-wise linear)

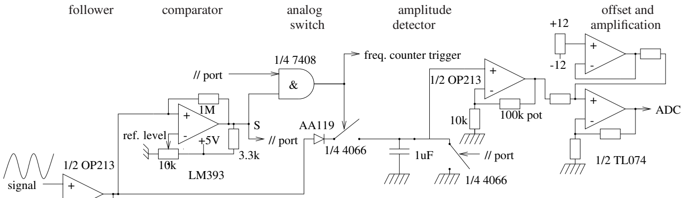
$$\begin{cases} C_1\frac{dv_{C_1}}{dt} = \frac{1}{R}(v_{C_2}-v_{C_1}) - g(v_{C_1}) \\ C_2\frac{dv_{C_2}}{dt} = \frac{1}{R}(v_{C_1}-v_{C_2}) + i_L - \left(\frac{v_{C_2}}{R'}\right) \\ L\frac{di_L}{dt} = -v_{C_2} - (i_L R_L) \end{cases}$$





Experimental setup

– Chua's circuit is an oscillator whose behavior is modified by changing the value of the inductor L from a periodic to a chaotic (Rössler like) oscillation mode following a period doubling pattern. Three of these bifurcations can be observed.
– a circuit for signals shaping: detection and isolation of a single period, measurement of the "instantaneous" parameters of this period (amplitude and frequency)



– 12 bit analog to digital conversion card with a conversion time of less than 500 μs
– commercial frequency counter (HP 5334B) for a statistical analysis of the signal (slow GPIB communication) or fast custom frequency counter

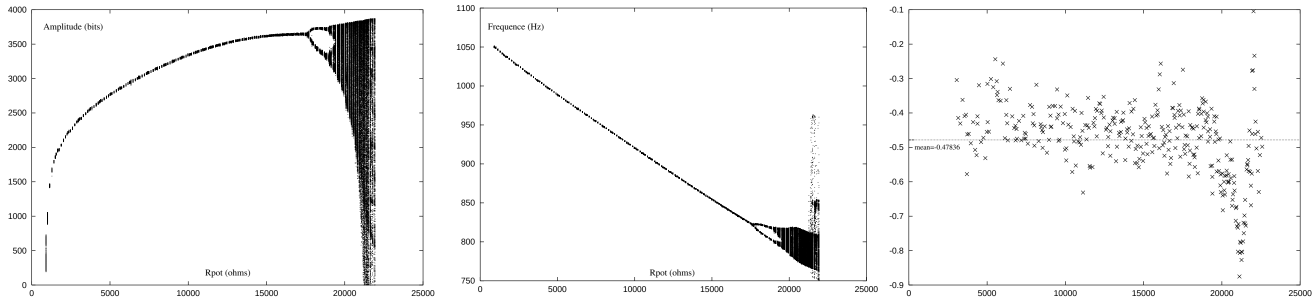
Data acquisition algorithm :

`while S is high, wait`	wait the end of the current period
`set the ''AND'' gate triggering the frequency counter`	get ready for a measurement
`while S is low, wait`	end of the low half-period
`while S is high, wait`	end of the high half-period, measurement in progress
`read amplitude and frequency measurements`	data acquisition
`capacitor reset`	

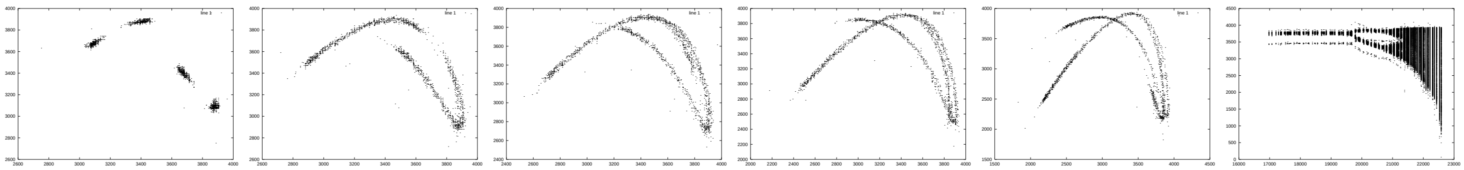
This algorithm is repeated for each new period to be analyzed.
Amplitude must be read *first*, followed by frequency reading, in order to avoid noise due to leakage currents.

Results

• Statistical measurements (periods are chosen randomly in the signal)
– Observation of the bifurcation diagram, validating our data acquisition methodology (left: amplitude, middle: frequency)



• Sequential measurements (all periods in a given time lapse are observed)
– Plot of the return maps for parameter values of L of (from left to right): 16.91 mH, 16.99 mH, 17.06 mH, 17.14 mH and 17.21 mH



– Allan variance computation for amplitude data (whose behavior is expected to be close to that of the frequency data): noise characteristics evolve when the circuit shifts from periodic oscillations to a chaotic behavior (figure at the right of the bifurcation diagrams)

Future work

Our fast frequency counter greatly modifies the behavior of the chaotic circuit: we must eliminate these disturbances in order to be able to compute Allan variances on experimental frequency data and compare these results with the measurements done on the amplitude.
Prediction of the experimental chaotic series using neural networks.