



INSTITUTE FOR RESEARCH IN
ELECTRONICS
& **APPLIED PHYSICS**

Implementation of a Time-Delayed Nonlinear Feedback System with Tunable Delay

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TREND 2009



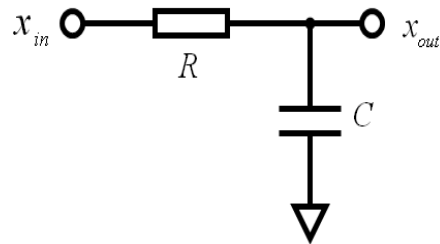
Introduction

Time-delayed nonlinear feedback systems can:

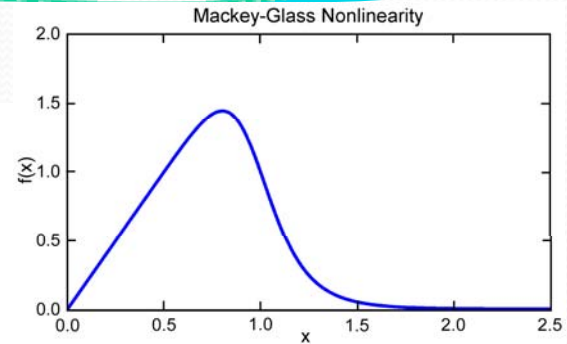
- Produce rich varieties of chaotic behavior
- Synchronize and communicate privately when coupled (if they have similar parameters)

New developments in these systems could lead to new sensor and communication platforms.

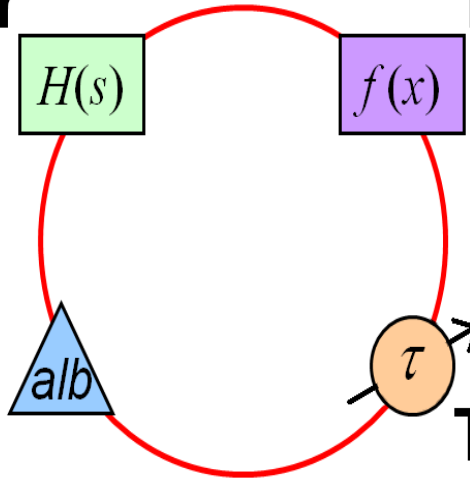
Mackey-Glass System



Filter

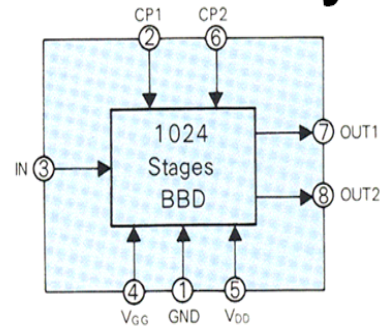
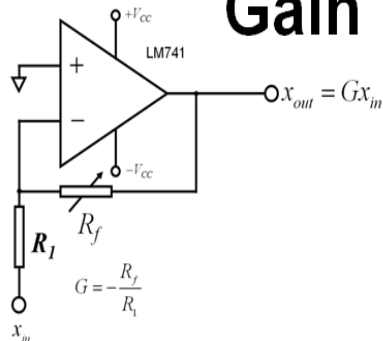


Nonlinearity



Gain

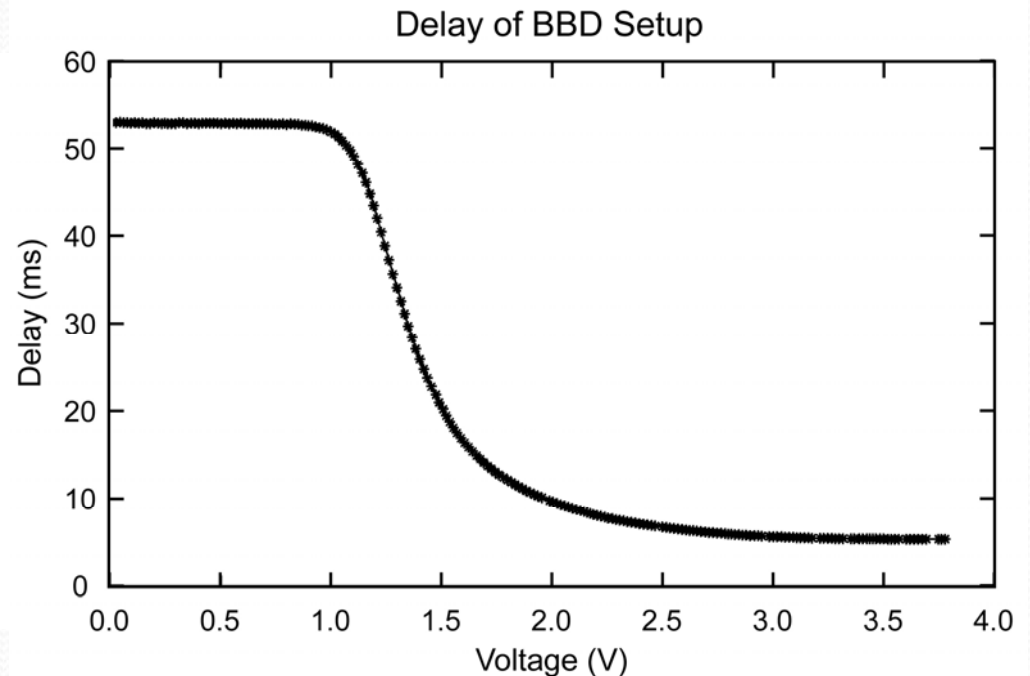
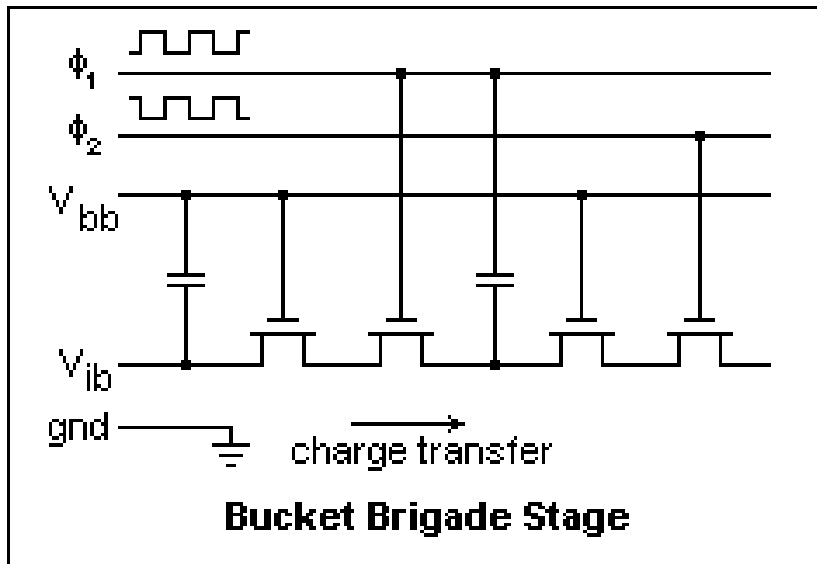
Time Delay



[Mackey, M. C. and Glass, L., *Science* **197** (1977), pp. 287-289]

VCO-Driven Bucket Brigade Device

- Controlled by driving frequency (generated by VCO)
- Continuously tunable time delay
- Moves charge from one capacitor to the next at each clock cycle

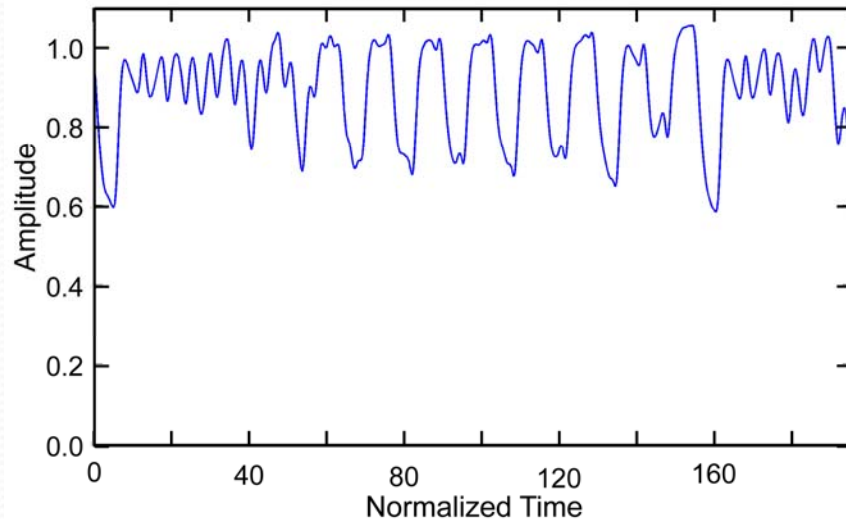


Mackey-Glass System Results

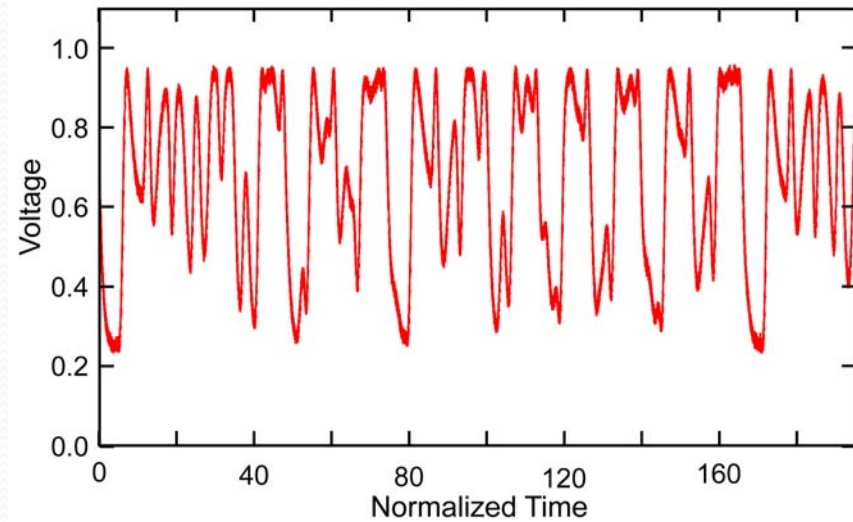
Simulation

Experiment

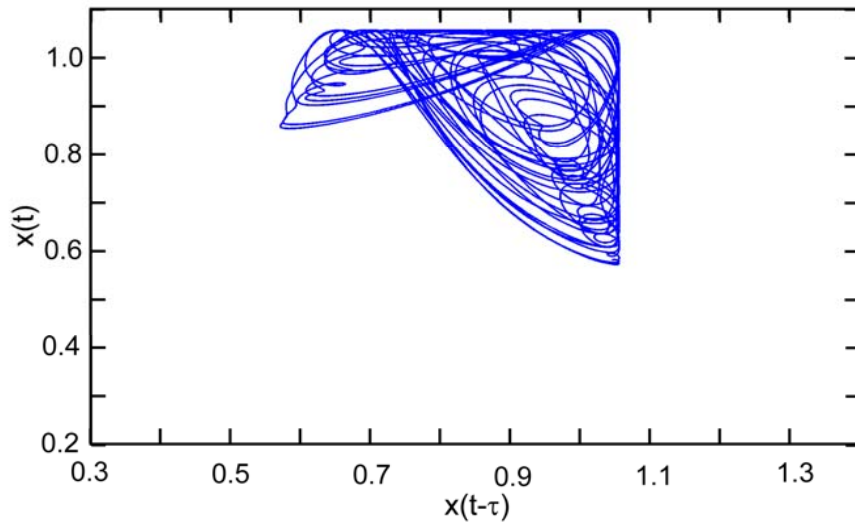
Time Series, $\tau = 5.756$



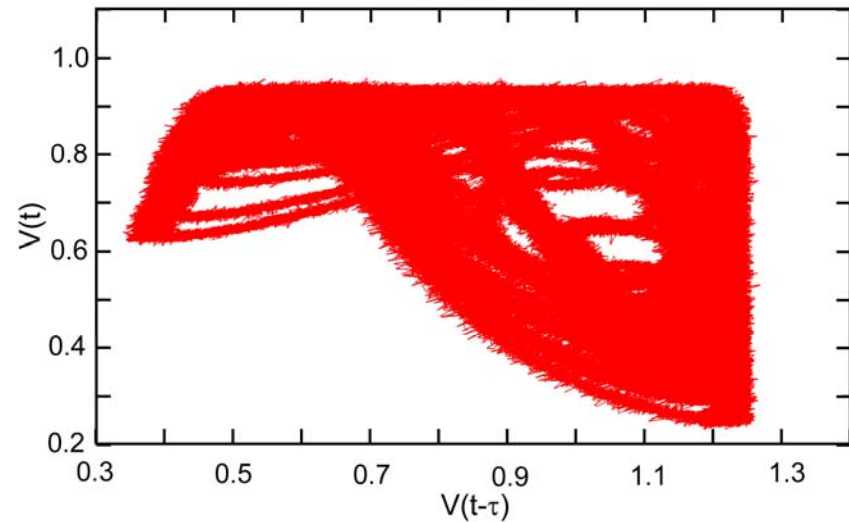
Time Series, $\tau = 5.756$



$\tau = 5.756$



$\tau = 5.756$



Main Conclusions and Future Work

- Demonstrated operation of electrically tunable time delay for nonlinear dynamical systems
- Great correspondence with simulations of Mackey-Glass numerical model
- Create an experimental τ -bifurcation diagram
- Investigate adaptive schemes that maintain synchronization with time-varying time delay

Acknowledgements and Thanks

- Adam Cohen, Bhargava Ravoori, Caitlin Williams, Rachel Kramer
- Professor Wes Lawson and everyone that made the TREND program possible
- National Science Foundation