Stochastic memory: getting memory out of noise

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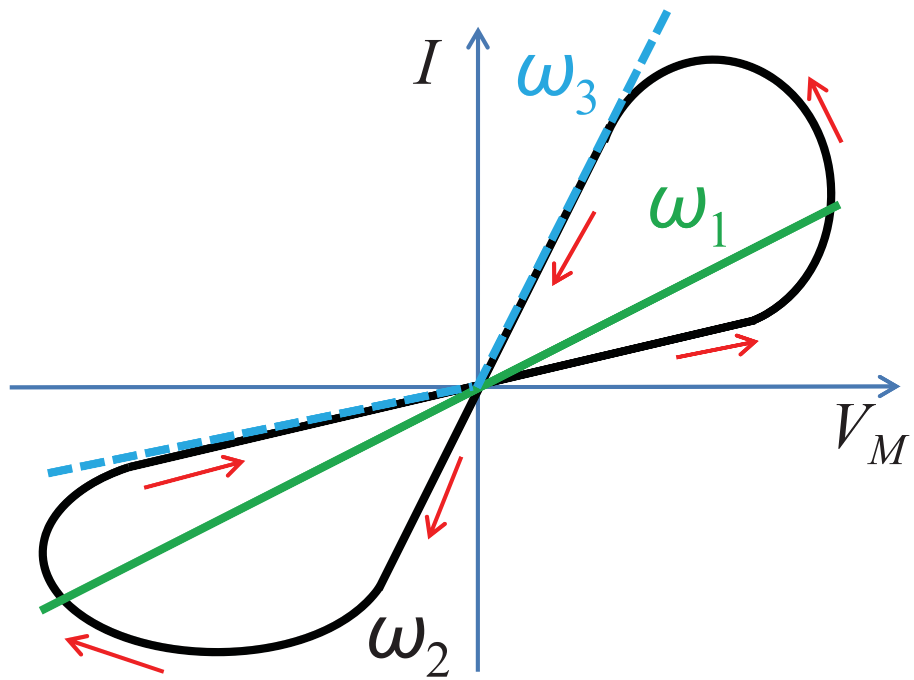
A. Stotland and M. Di Ventra, *"Stochastic memory: getting memory out of noise"*, to be submitted

Outline

- *Stochastic* memory elements
- The concept of stochastic resonance
- Example - TiO_2 memristor
- Theoretical predictions of the model



Stochastic memory elements

Definition:

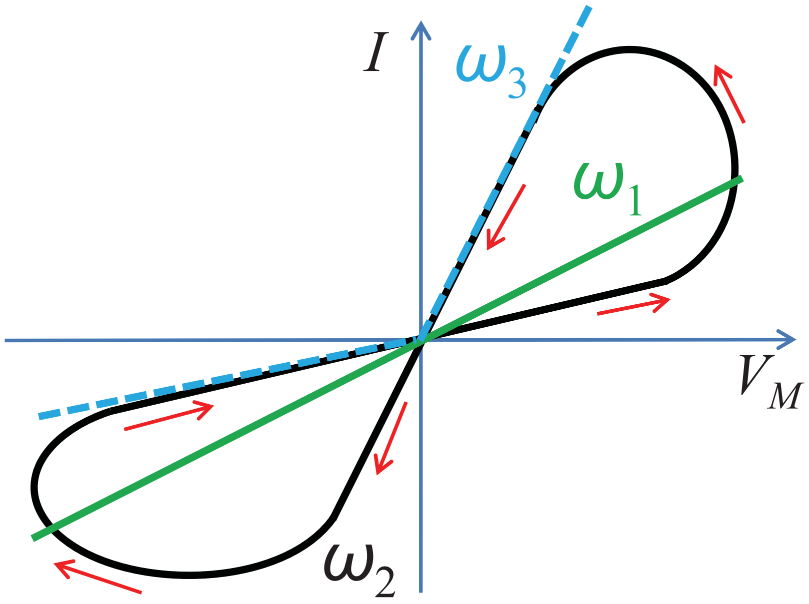
$$\{y(t)\}_{\xi} = \{g(x,u,t)\}_{\xi} u(t)$$
$$\dot{x} = f(x,u,t) + H(x,u,t)\xi(t)$$

$$\langle \xi_i(t) \rangle = 0, \quad \langle \xi_i(t)\xi_j(t') \rangle = k_{ij}(t,t')$$

$H(x,u,t) \equiv 0 \Leftrightarrow$ deterministic element

$\boldsymbol{u(t)}$	$\boldsymbol{y(t)}$	**system**
current	voltage	memristive
charge	voltage	memcapacitive
current	flux	meminductive

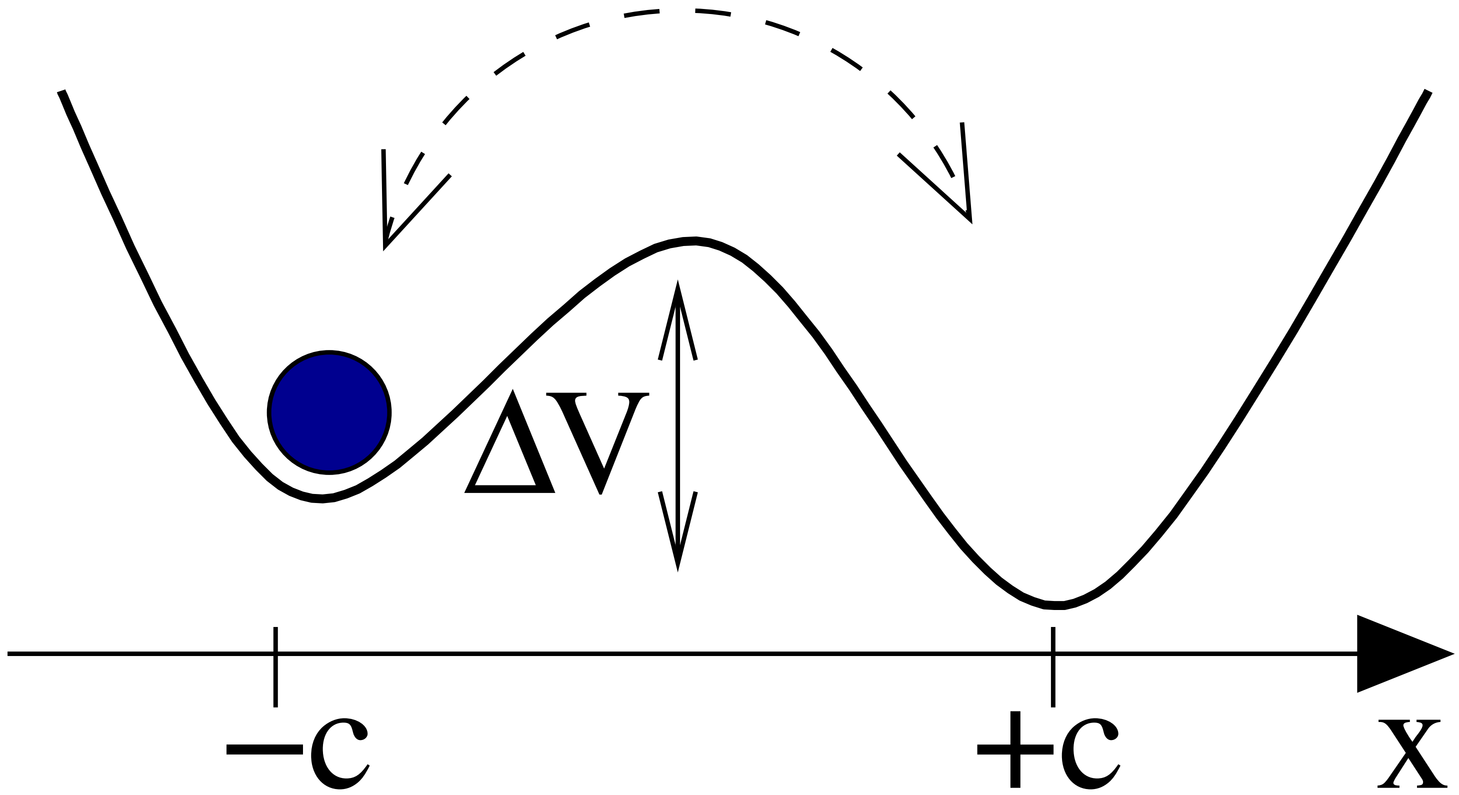
Hysteresis loop



$\omega_1 \gg \omega_2 \gg \omega_3$

Y. V. Pershin and M. Di Ventra, Advances in Physics, 60, 145 (2011)

Stochastic resonance



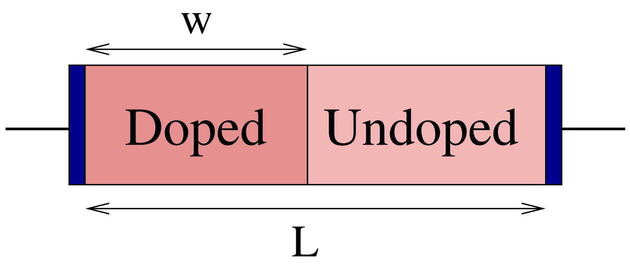
T. Wellens, V. Shatokhin, and A. Buchleitner, Reports on Progress in Physics 67, 45 (2004)

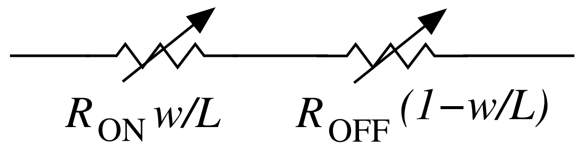
Example - Pt–TiO$_{2-x}$–Pt

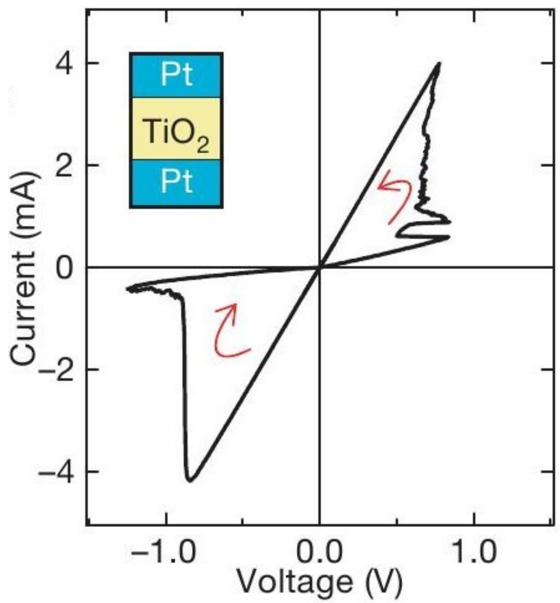
$$M(w) = \frac{w}{L}R_{\mathrm{ON}} + \left(1 - \frac{w}{L}\right)R_{\mathrm{OFF}}$$

$$I(t) = \frac{V(t)}{M(w)}$$

$$\frac{\mathrm{d}w}{\mathrm{d}t} = \frac{\mu_{\mathrm{D}} R_{\mathrm{ON}}}{L} I(t) + L\xi(t)$$







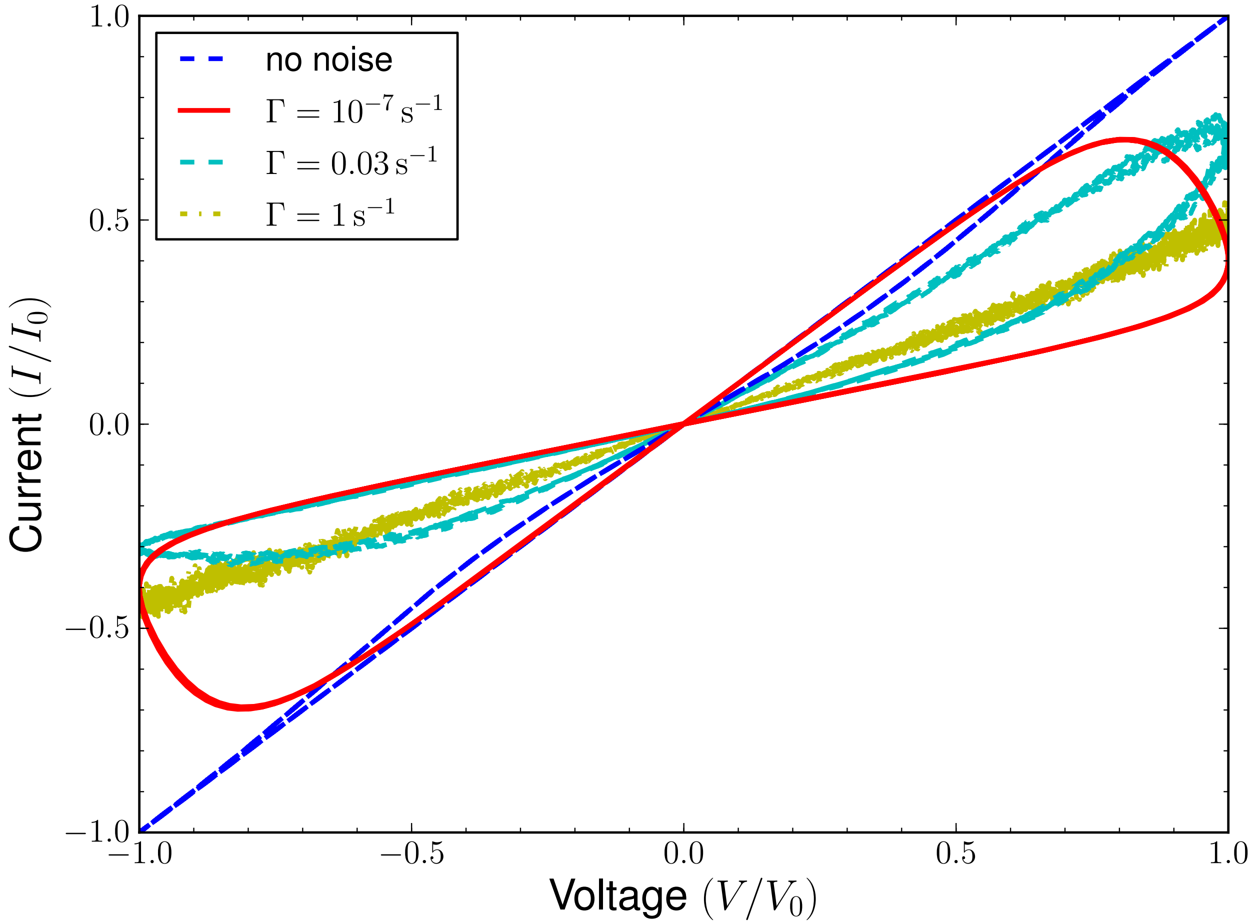
White Gaussian Noise:

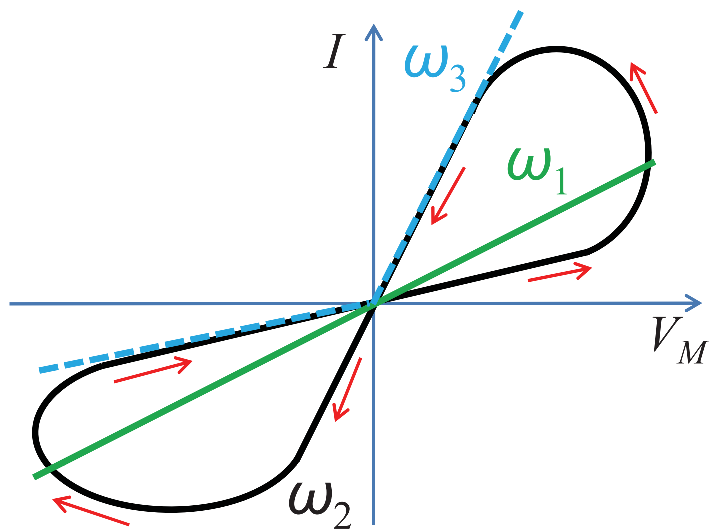
$$\langle \xi(t) \rangle = 0, \qquad \langle \xi(t)\xi(t') \rangle = \Gamma\delta(t - t')$$

D.B. Strukov, G.S. Snider, D.R. Stewart and R.S. Williams, Nature 453, 80 (2008)

Results - Pt–TiO_{2-x}–Pt

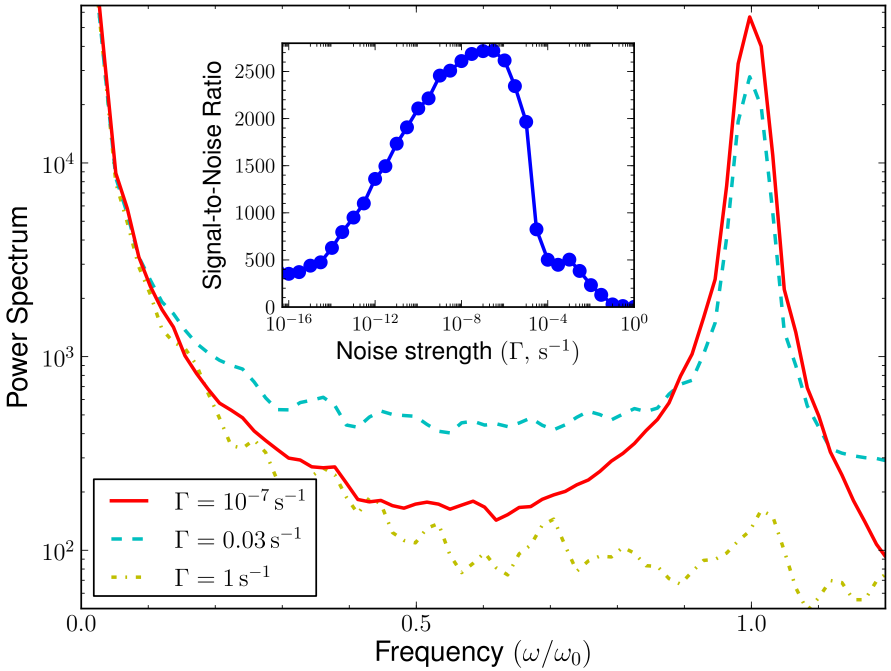
Applied voltage: $V(t) = V_0 \sin \omega t$

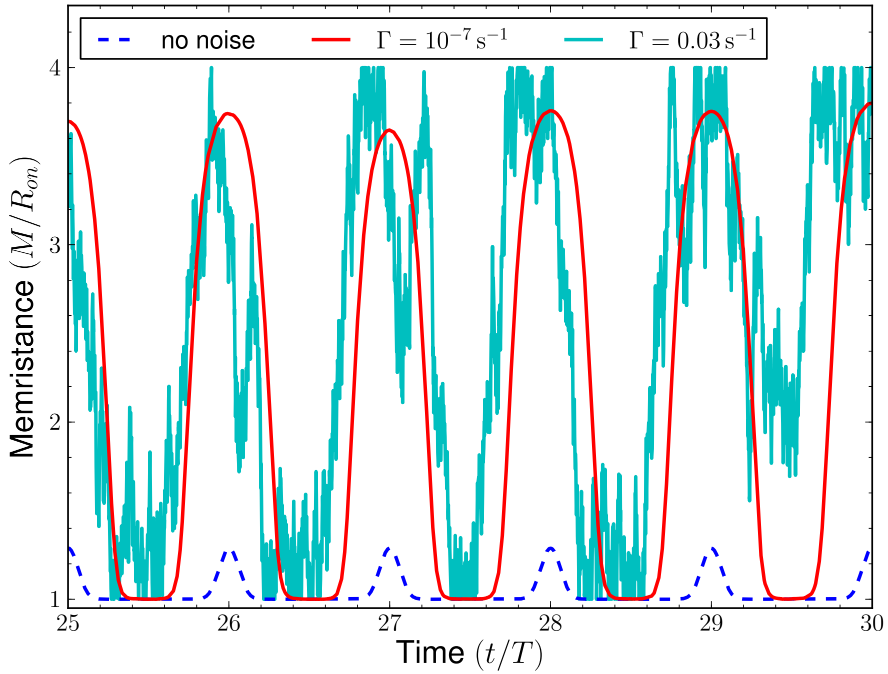




Noise can be used to enhance memory effects!

Results - Pt–TiO_{2-x}–Pt





- Maximum memory effect enhancement is achieved for the maximum Signal-to-Noise Ratio

Theoretical predictions of the model

- Memory effects can be enhanced by tuning **frequency** and/or **noise**
- To see the memory effect enhancement experimentally in Pt–TiO_{2-x}–Pt device one can reduce the frequency and vary the external temperature.