

**THURSDAY
OCTOBER 30, 2003**

**Scaife Hall Auditorium
Room 125**

**4:00 PM
Refreshments—3:30 PM**



ARTHUR DAVIDSON
CARNEGIE MELLON UNIVERSITY

Dr. Arthur Davidson is the Executive Director of the Center for Highly Integrated Information and Storage Systems (CHIPS) in the ECE Department. He came to Carnegie Mellon in 2000 after a career in superconductivity and low power CMOS at IBM, Westinghouse, and Northrop Grumman. CHIPS' goal is to produce a MEMS based mass storage device that is dense, small, fast, cool, and cheap. MEMS based mass storage is a multidisciplinary research area and Dr. Davidson's multidisciplinary background is well suited for it. He has had extensive cleanroom experience in photolithography, film deposition, and semiconductor processing, all of which are integral to MEMS. He has had experience designing superconductive digital circuits, so that he is familiar with both digital requirements and the analog nature of small signal detection in magnetic systems. His work on solitons and Josephson parametric amplifiers has prepared him for dealing with non-linear problems, a key feature in cantilevered probe actuation and control. Finally, his background in the theory of superconductivity as a magnetic phenomenon gives him an understanding of magnetism, which is how bits will be stored and retrieved in the CHIPS probe array.

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For more information:
<http://www.ece.cmu.edu/seminar>

THE STRANGE BEHAVIOR OF A NONLINEAR MEMS CANTILEVER

Work at CHIPS on designing electrostatically actuated MEMS cantilevers for probe storage devices has taken us beyond the well known snapping instability. We have simulated a MEMS cantilever system modeled as a linear spring and mass coupled to a moving parallel plate capacitor. A voltage applied across the capacitor stretches the spring, and closes the gap between the parallel plates. We have developed dynamical equations for this system, and a related system in which we incorporate a control loop with a capacitive sensor. The voltage actuation and capacitive sensing contain all the nonlinearities.

Our open loop simulations show the well-known snapping instability of the electrostatically actuated MEMS cantilever. However, careful study of the open loop system under small and large disturbances show subharmonic generation and a cascade of period doubling bifurcations leading to chaotic motion in a small range of parameters before the cantilever snaps.

When we close the loop, we can extend the range of motion without snapping, as has been experimentally observed. However, we find several additional phenomena occurring in this system: multiple stable operating points at low loop gain; spontaneous development of oscillations around the operating point; and quasi periodic responses to a sinusoidal disturbance leading again to chaos, all before the gap snaps closed.

We will illustrate these non-linear dynamic phenomena along with our method of simulation. Finally, we will share our thoughts on how to improve controlled electrostatically actuated cantilevers.