Controller Architectures for Fully-Integrated Micro/Nano-Systems

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Goals and Potential Impact if Successful

Theme: Sophisticated Control based on Simple Elements

Goals: 1) develop generic *analog* controller architectures suitable for a diverse range of micro/nano nonlinear systems using basic micro/nano-electronic devices; 2) propose theory and implementation strategies for efficient realization of controllers; 3) identify methods for dealing with substantial plant and controller uncertainty.

Broader Impact: Facilitate Design of Complex Nano-Systems

Enable the cost-effective implementation of controlled, single-chip autonomous micro/nano-systems. We specifically address control system complexity and develop both theory and practical techniques to keep hardware cost to a minimum. Please see Figure 1 for the general framework.

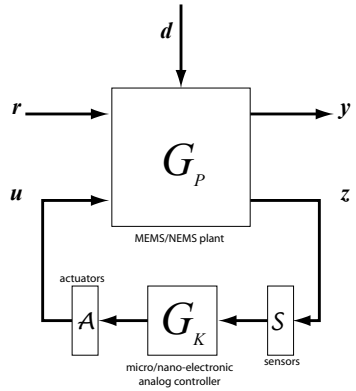

Figure 1: Closed-loop micro/nano-system featuring analog electronic control. A digital control paradigm is generally not suited to full integration of plant and controller.

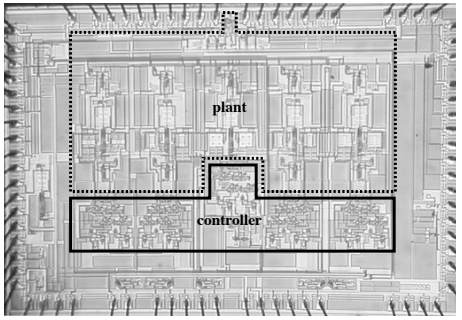

Figure 2: A fifth-order nonlinear control system implemented in a 350-nanometer silicon-based technology. The controller is an analog switching-type design that provides robust stabilization.

Approach and/or Accomplishments

Theory

We have developed tunable analog controller architectures for the stabilization of arbitrary-order plants based on low-cost elements using Lyapunov and variable-structure toolsets. Our current aim is the development of low-complexity robust switching controllers for use on nonlinear micro/nano-system models with significant parametric uncertainty.

Implementation/Experimental Work

We have developed a variable-structure control system in microelectronic form using a silicon-based technology with 350-nanometer feature sizes (shown in Figure 2). We are currently designing controllers using technologies approaching 100-nanometer feature resolutions for electronic systems; experimental verification pending.

Bottlenecks and Open Research Questions

1) How will the choice of substrate material and device structure affect the realization of analog electronic controllers? How should the characteristics of the fabrication technology affect the development of control algorithms?

2) What are classes of "important" problems/models with which to address control system research for nano-scale systems? *A clear need exists for dialogue/collaboration between control theory specialists and nano-technology (modeling) experts*.

3) Nano-system control identifies a "language barrier" amongst system theorists, modeling experts and experimentalists--- we need to educate ourselves about each other's fields (which requires considerable effort); how can we facilitate the learning process?