Mixed-Signal System Modeling in Ptolemy II

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Introduction

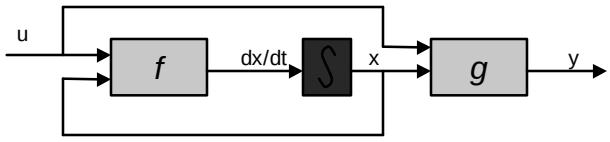
- Continuous Time Models
  - Analog Circuits
  - Mechanical Systems
  - Environments
- Event-Based Models
  - Digital Hardware (HDL)
  - Real-Time Software
  - Switches
- Mixing Continuous and Discrete Models
  - Electronic Systems with Analog and Digital Parts
  - MEMS with digital control circuitry
  - Digital Embedded System with Continuous Environments
  - Hybrid Systems

CT System Modeling (1)

- Block Diagrams of ODEs

$dx/dt = f(x, u, t), \quad x(t_0) = x_0$
$y = g(x, u, t)$

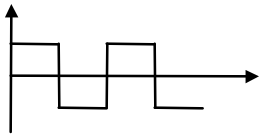
  - Integrators with Feedback Loops



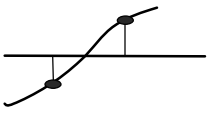
- Simulation
  - Discretization of time
  - Scheduling, evaluate functions by actor firings.
  - Fixed-point calculation.
  - Various ODE solvers.

CT System Modeling (2)

- Breakpoint Handling .



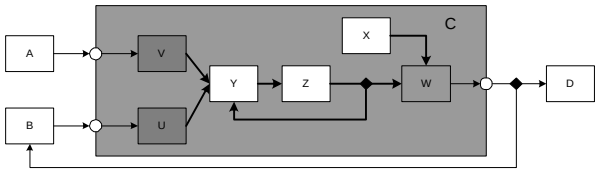
  - Predictable Breakpoints:
    - known beforehand.
    - Register to a Breakpoint Table in advance.
    - Use breakpoints to adjust step sizes.
  - Unpredictable Breakpoints:



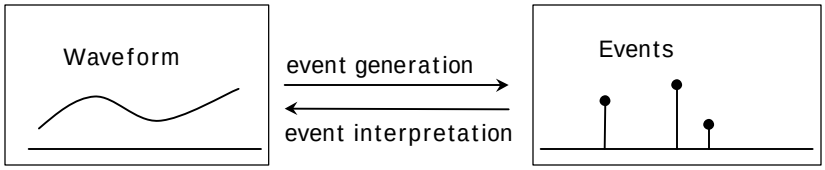
    - Prediction is not accurate enough.
    - Check after each integration step.
    - Refine the last step size if a breakpoint is missed.

Mixed-Signal Modeling

- Container-Containee Relationship



- Signal Conversions

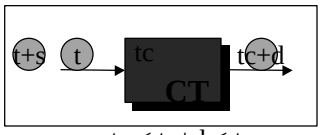


Execution: DE inside CT

- Coordination
  - Next Event: predictable breakpoint.
  - DE subsystem should not involve in the fixed point iteration of the CT system.
- Two Phase Execution
  - event phase: DE executes, report next event time
  - continuous phase: solve ODEs till next breakpoint.
    - The DE subsystem is only fired when there is an input event for it, or CT time = Next Event time
- t^--t-t^+ interpretation.

Execution: CT inside DE

- CT must run ahead of the DE (global) time!
  - CT subsystem must be causal
    $Te_{out} > Te_{in}$
  - CT can not jump in time
  - CT may generate event at any time



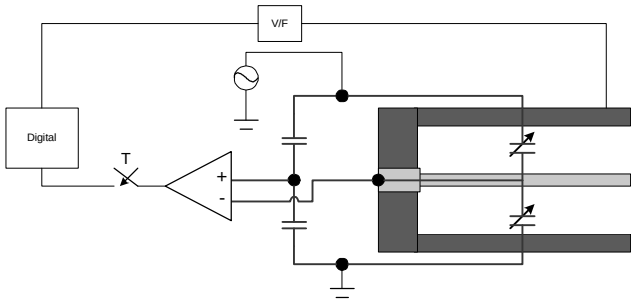
$tc < tc+d < t$

- CT must be able to rollback
  - If tc > t when CT is fired, it must rollback to t
- CT can not emit output events immediately
  - Detected event may not exist if there's another input event.

Applications

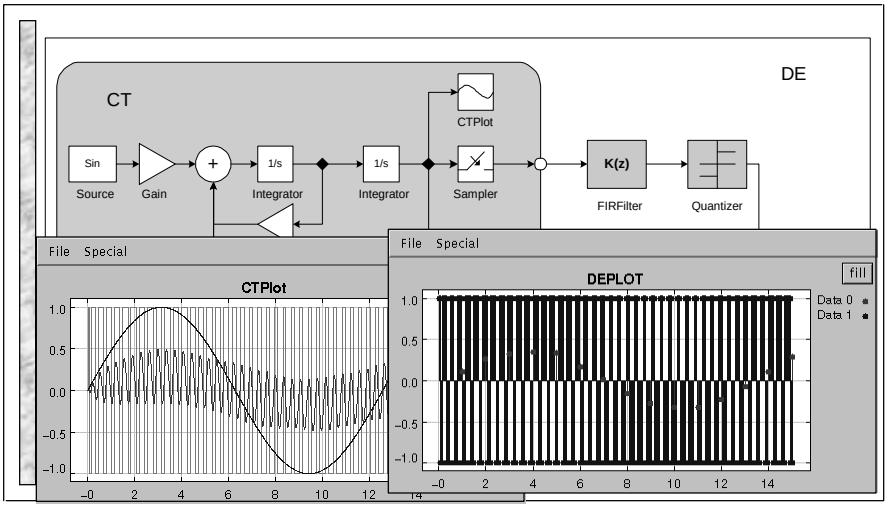
- Mixed-Signal Simulations
- Heterogeneous CAD Tool Interaction

Example: Micro Accelerometer

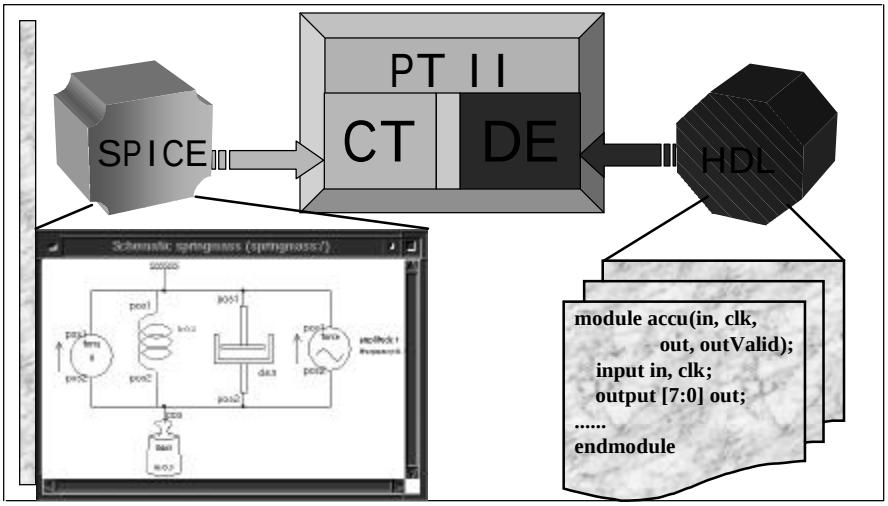


M. A. Lemkin, "Micro Accelerometer Design with Digital Feedback Control", Ph.D. dissertation, EECS, University of California, Berkeley, Fall 1997

Digital Feedback: ΣΔ



Heterogeneous Tool Interactions



Conclusion

- Signal flow model of CT & DE systems
- Breakpoint handling
- Conversion of signals and events
- Execution Coordination
  - DE inside CT: breakpoint
  - CT inside DE: rollback
- Future work:
  - Zeno Phenomena Detection
  - Hybrid System Modeling