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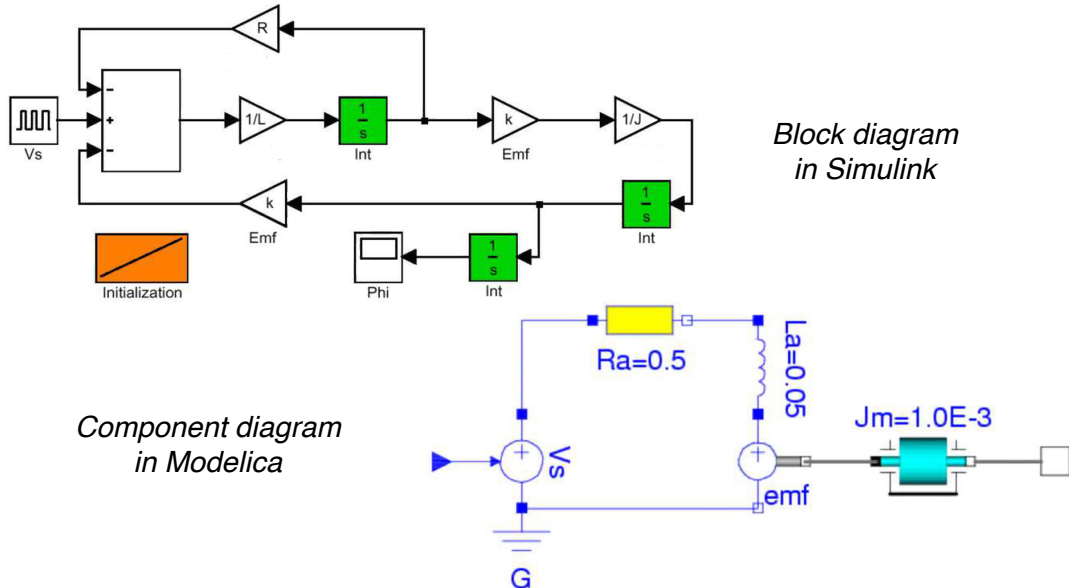
Demo: IsamDAE, an Implicit Structural Analysis Tool for Multimode DAE Systems

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DAE FOR THE MODELING OF (LARGE) CYBER-PHYSICAL SYSTEMS

Large physical systems → *Differential-Algebraic Equations (DAE)*

- Components modeled with a few differential and/or algebraic equations
- Connections: algebraic equations (balance equations, Kirchhoff laws)
- **Pros:** compositional modeling, high reusability of physical components



Non-smooth, or hybrid, systems → *Multimode DAE (mDAE)*

- In general, mDAE are poorly handled by existing tools
 - No proper *structural analysis* of mDAE at compile time

Variable dimension systems → *Variable dimension models*

- (Dis)appearance of components in a CPS would be easily handled
- Such models are not handled by existing tools

STRUCTURAL ANALYSIS OF DAE

Handling DAE systems is harder than ODE

- No direct criterion to determine whether a DAE is determined
- Simulation code cannot be generated from the original model
- Compilation relies on *Structural Analysis (SA)*

Structural analysis

- Graph-based (Pantelides method) or linear programming (Pryce's Sigma-method) algorithms
- Provides diagnosis about the model at compile time ('typechecking')
- Enables the generation of efficient simulation code:
 - equations are carefully differentiated, and grouped into the smallest possible *equation blocks*;
 - blocks are ordered ('scheduled') for the simulation of a time step

THE ISAMDAE TOOL

Structural analysis for mDAE, in an 'all-modes-at-once' fashion

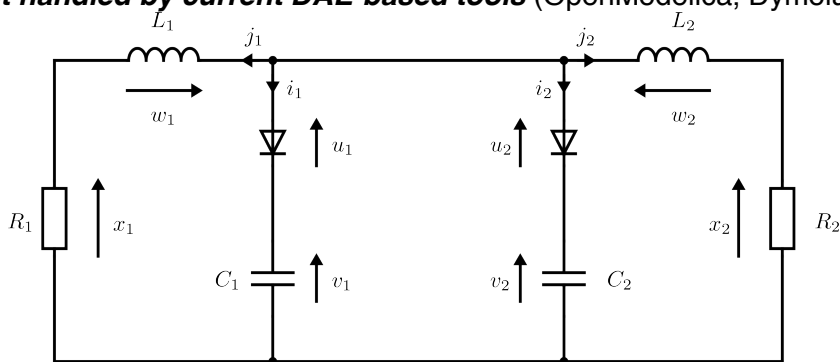
- **Input:** Ad hoc equation language used for declaring mDAE models
 - Implicit representation with BDD (preserves sparsity)
 - Structural analysis (from the Sigma-method) and block scheduling: adaptation of existing methods and novel algorithms
- **Output:** Detailed (but condensed) description of the simulation blocks and their dependencies, in all modes

Implementation

- About 16,000 lines of OCaml code
- Libraries: menhir, mlbdd, OCaml-Tools, pprint, xml-light
- Software package: GraphViz

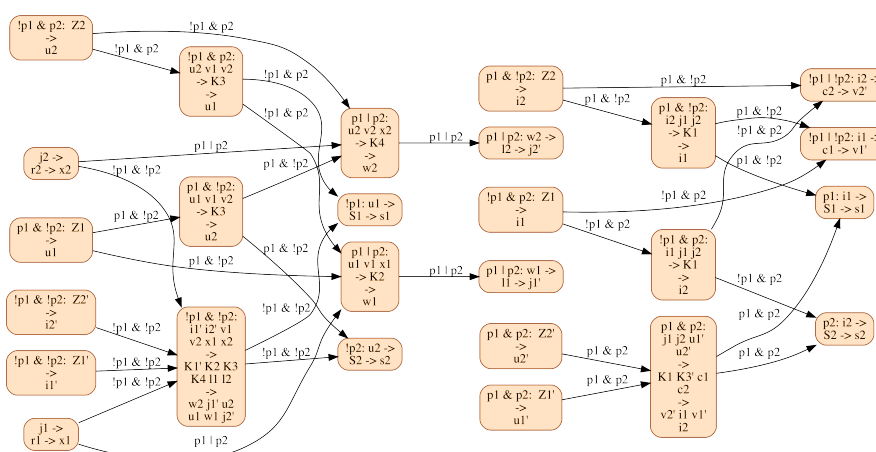
THE RLDC2 EXAMPLE

- Two RLC circuits with ideal diodes, in parallel
- Mode-dependent structure: differentiation orders for the equations, as well as the resulting equation blocks, depend on the mode
- **Not handled by current DAE-based tools** (OpenModelica, Dymola)



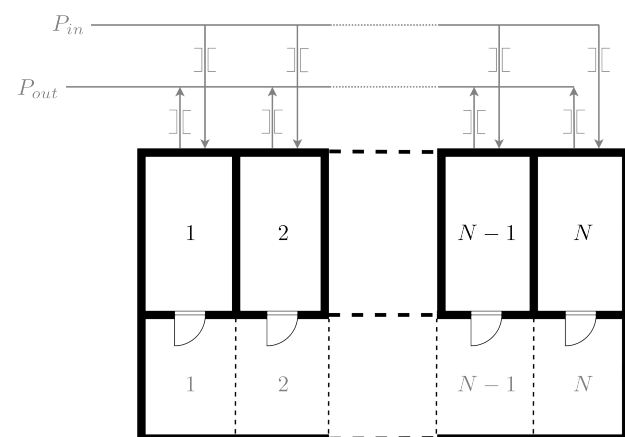
Mode-dependent structural analysis by IsamDAE

- Checks that the model is determined in all modes
- Generates the mode-dependent scheduling graph shown below
- In each mode: description of the (*ODE-like*) blocks to be compiled into simulation code + dependencies (for their scheduling)
 - ✓ Same results, in each mode, as those of standard structural analysis



THE BUILDING EXAMPLE

- **Scalable model:** single-story building with N rooms and doors
- Instantaneous mode transitions when a door is opened or closed
- Variables taken into account: pressures, temperatures →, air masses, enthalpies, heat and mass flows (compressible air)
- For N rooms : $16N+5$ equations and variables, $6^{N/2}$ modes



Scaling-up of the structural analysis by IsamDAE

- The total number of blocks is an affine function of N
- Experimental computation times: about $O(N^3)$

