TLM-ADI Simulator
--- A Linear-Time Power Grid Transient Simulator

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Characteristics of the TLM-ADI Simulator

- A Transient Power Grid Simulator
- Linear Runtime and Memory requirement
- Unconditionally Stable
- Powered by Transmission-Line-Modeling Alternating-Direction-Implicit (TLM-ADI) Method for Fast Simulation
- Deal with Inhomogeneous Cases.

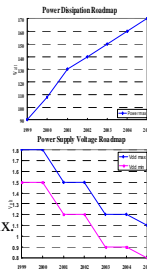## Motivation

- **Trend of VLSI Technology**
  - Increasing power dissipation
  - Decreasing supply voltage
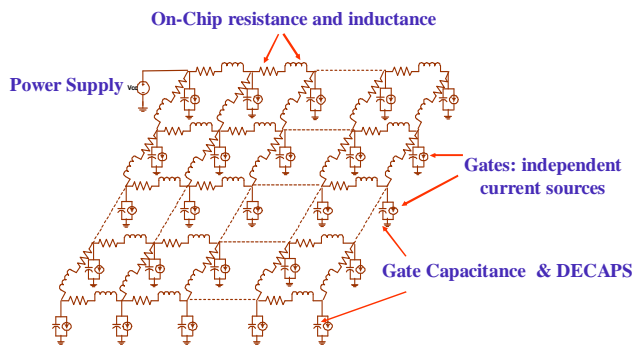- **Power Fluctuation Sources Increase Significantly**
  - IR-drop: $\Delta V = I \times R = (P / Vdd) \times R$
  - L di/dt: $\Delta V = L\, di/dt \sim L\,(P \times f / Vdd)$
  - Other noises such as resonance and electromigration
- **Power Grids Analysis Challenges**
  - More than 40-million transistors on a chip
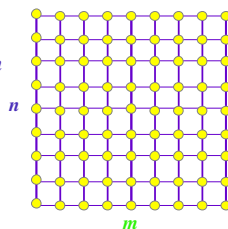 - Sparse direct method takes super linear time to solve a matrix.

Power Dissipation Roadmap

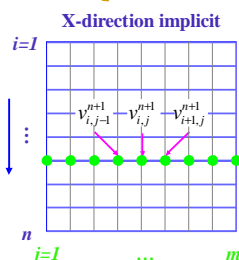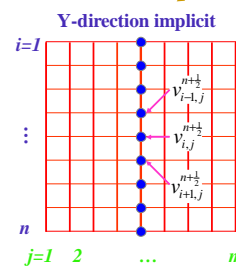Power Supply Voltage Roadmap

Power Grid Modeling

On-Chip resistance and inductance

Power Supply

Gates: independent current sources

Gate Capacitance & DECAPS

Key Idea: ADI Method

Total Runtime: $O(2mn) = O(N)$

Total nodes: $N = mn$

n

m

Step I → Y-direction implicit

Step II → X-direction implicit

Y-direction implicit
$i=1$
$v_{i-1,j}^{n+\frac{1}{2}}$
$v_{i,j}^{n+\frac{1}{2}}$
$v_{i+1,j}^{n+\frac{1}{2}}$
n
$j=1$ 2 ... m

X-direction implicit
$i=1$
$v_{i,j-1}^{n+1}$ $v_{i,j}^{n+1}$ $v_{i+1,j}^{n+1}$
n
$j=1$ ... m

Runtime for solving each x: $O(n)$ Runtime for solving each y: $O(m)$

Linear Runtime

Runtime of TLM-ADI, SPICE, and PCG vs. Node Number

Runtime of TLM-ADI, and PCG vs. Node Number
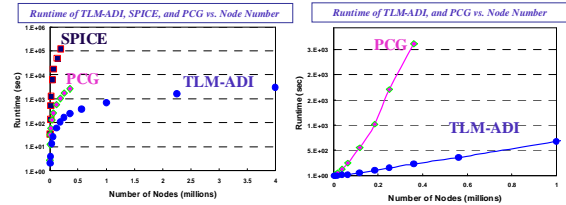
**TLM-ADI is over 1000 times faster than SPICE, and 10 times faster than PCG**

- Runtime Comparison based on the TLM-ADI, SPICE, and Preconditioned Conjugate Gradient (PCG)
- The runtime of the TLM-ADI Simulator is linearly proportional to the number of the discretization nodes.

Memory Usage

Memory Usage of TLM-ADI, SPICE, and PCG vs. Node Number
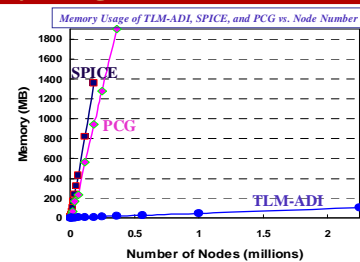
- Memory Usage Comparison based on the TLM-ADI, SPICE, and PCG.
- The memory usage of the TLM-ADI Simulator is linearly proportional to the number of nodes.
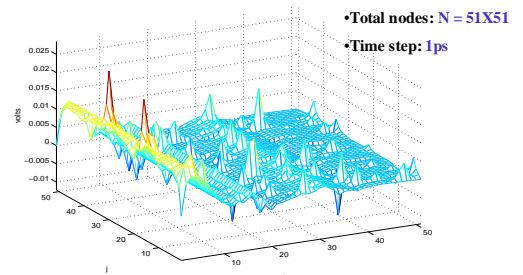
Unconditionally Stable

TLM-ADI with Different Time Steps

# of nodes: 100
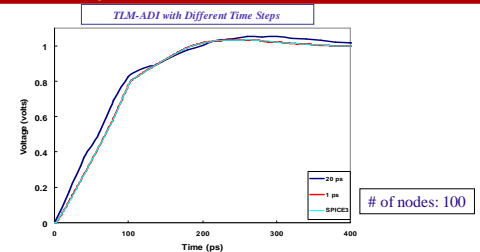
The Courant stability constraint is *1.9442* ps

- The time step of TLM-ADI is not limited by any stability constraint

A Snapshot of Transient Response

- **Total nodes: N = 51X51**
- **Time step: 1ps**

Contact Information

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Download TLM-ADI
http://vlsi.ece.wisc.edu/TLM-ADI.htm