HeatGen: A Vectorless Approach to Activity Generation for IC Power Analysis

EDP workshop 2004

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Outline

- Why Vectorless Power Analysis
- Existing Approaches
- Our Approach
- Implementation Description
- Testcase Description and Results
- Conclusion

Why Vectorless Power Analysis

- Power consumption crucial for performance and reliability in 130nm and 90nm process technology
  - Voltage drop
  - Delay variation
  - Electromigration
  - Temperature variation
- Need realistic worst-case scenario
  - User stimulus for simulation-based power analysis not always available
  - User stimulus usually not targeted for worst-case power consumption

Existing Vectorless Approaches

- Classical ATPG
  – Focuses on fault simulation only
- Probabilistic simulation
  – Logical and temporal correlation poorly handled
  – Widely varying accuracy
- Monte Carlo simulation
  – Very costly in terms of runtime
- User-defined worst-case
  – Subjective, difficult to prove
- Formal methods
  – Very pessimistic upper bounds
  – Exact problem is NP-complete

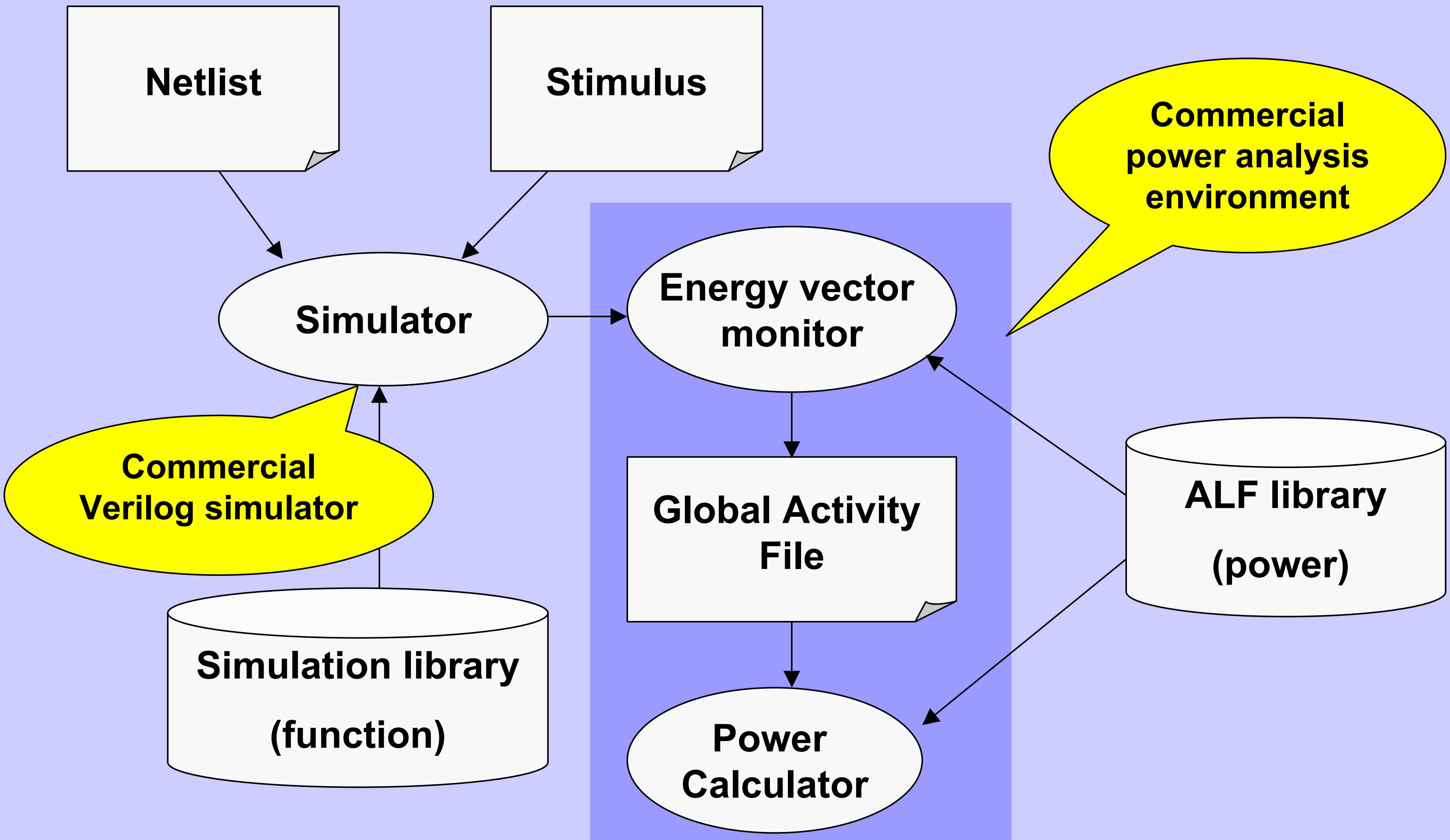
Our Approach

- Create a stimulus based on a new approach
  - Use the principle of ATPG and adapt it for power modeling
  - Understand the relationship between function and energy vectors within each library cell
  - Systematically activate the energy vectors for all instances in the design
- Method implemented in the HeatGen™ tool
  - Leverages the IEEE 1603-2003™ standard for power library description
  - Uses the Global Activity Format to record the activity of energy vectors in the design
  - Replaces simulation in existing power analysis flow

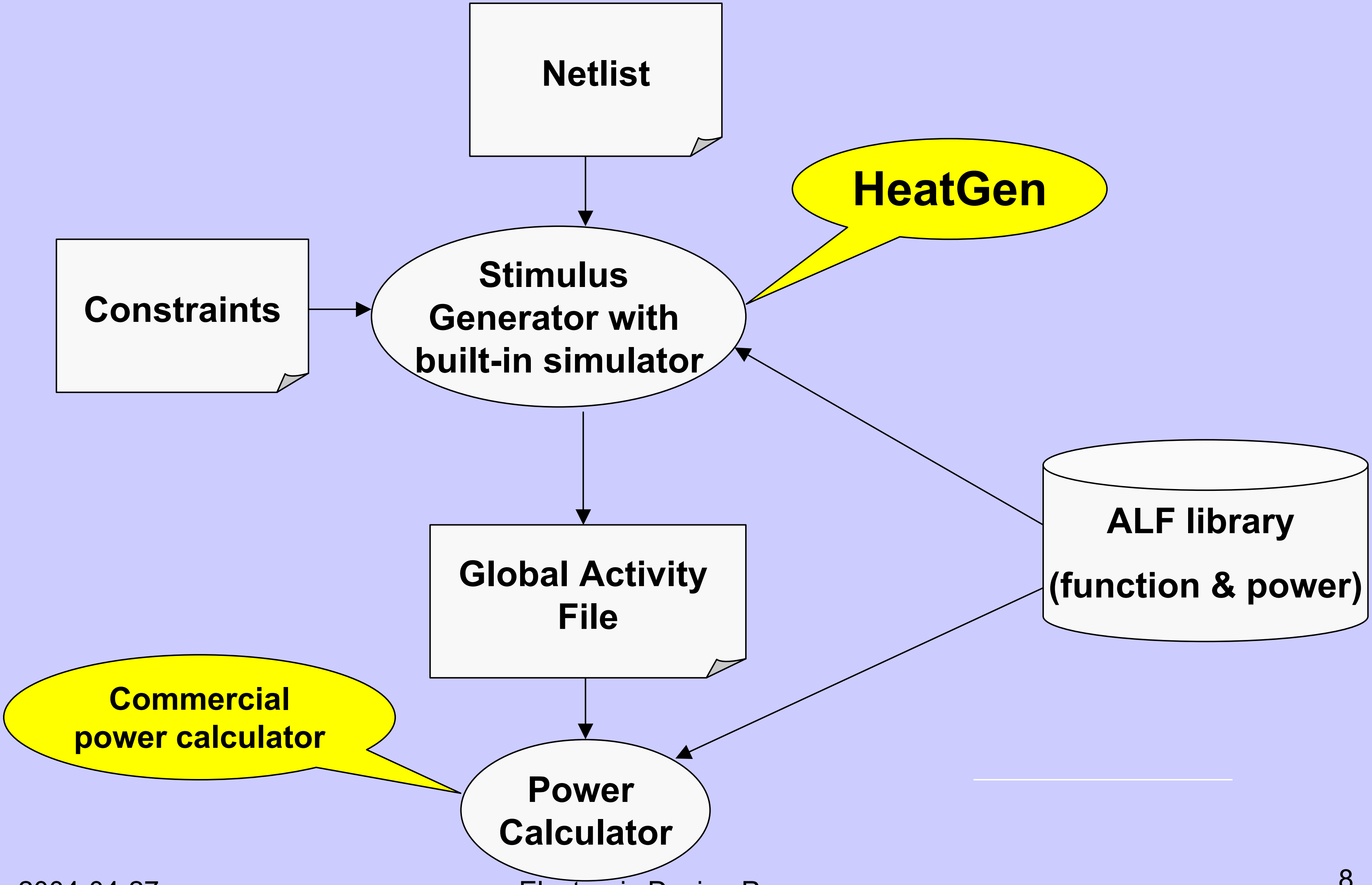
Implementation description

- Existing simulation-based power analysis flow
- Vectorless power analysis flow with HeatGen
- HeatGen algorithm
- Sample contents of ALF Library
- Sample contents of Global Activity File

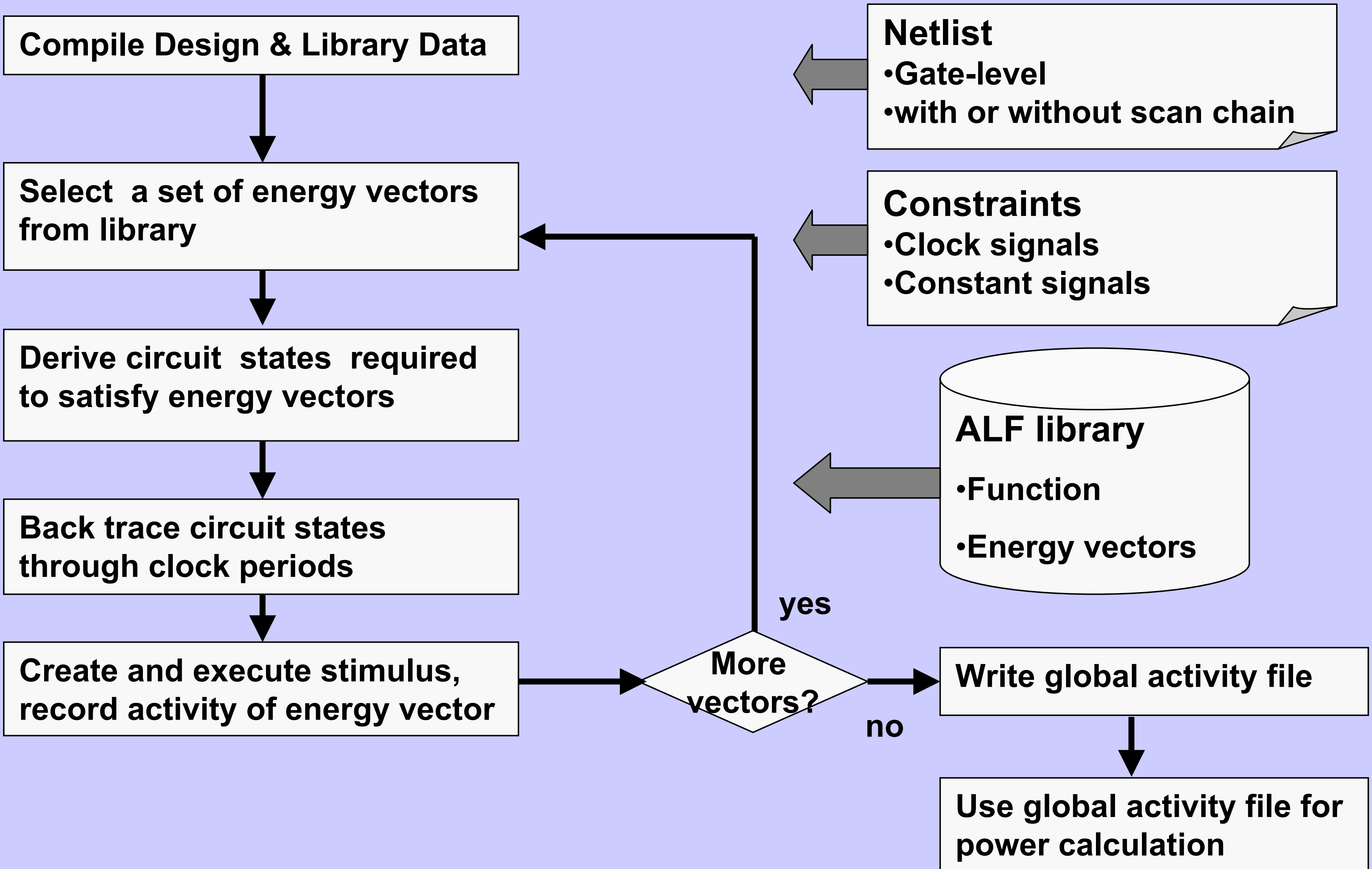
Simulation-based Power Analysis Flow



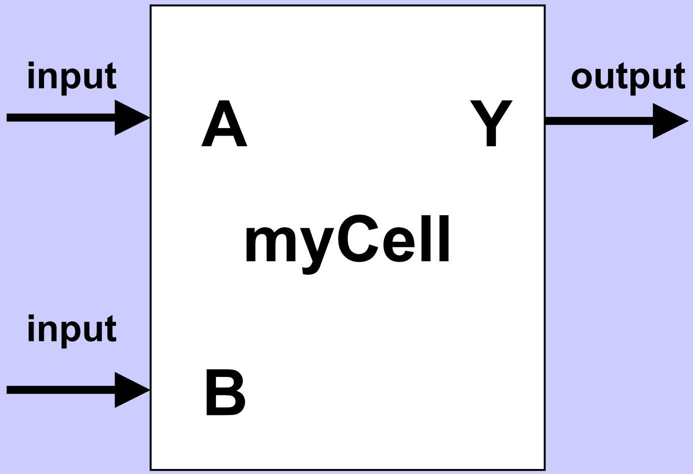
Vectorless Power Analysis Flow



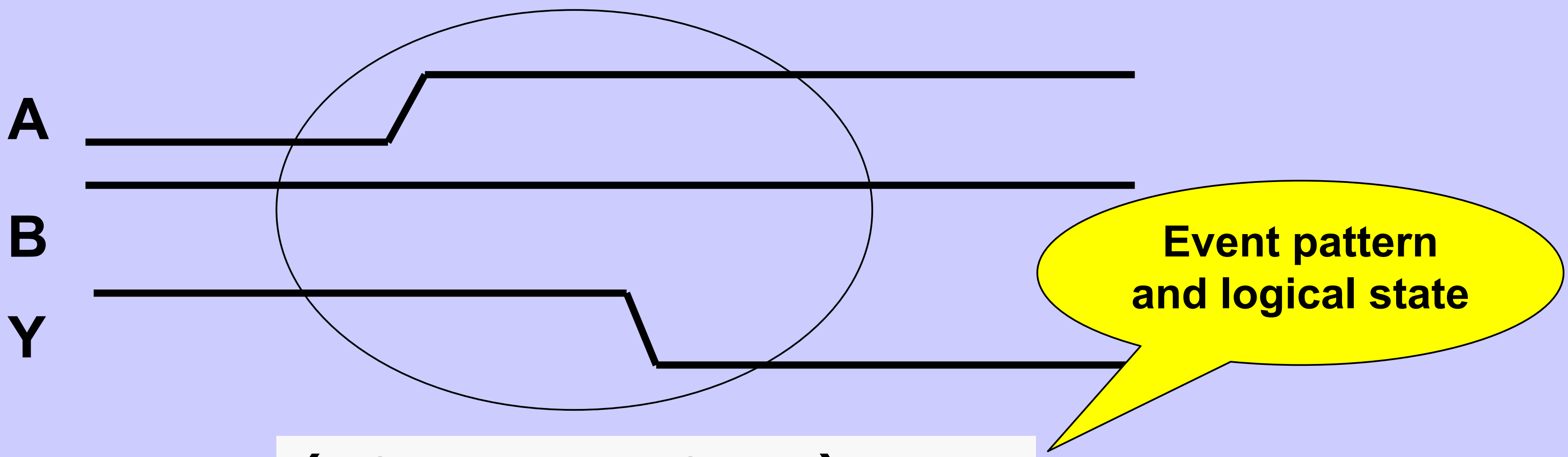
HeatGen Algorithm



Sample Contents of ALF Library




```
CELL myCell {
  PIN A { DIRECTION = input ; }
  PIN B { DIRECTION = input ; }
  PIN Y { DIRECTION = output ; }
  FUNCTION { BEHAVIOR { Y = !(A&&B); }
  VECTOR ( ( 01 A -> 10 Y ) && B ) {
    /* put ENERGY data here */
  }
  /* put more ENERGY vectors here */
}
```




```
( 01 A -> 10 Y ) && B
```

Sample Contents of Global Activity File

Total activity recording time

% of time signal is logic 1

# of times signal rises

# of times signal falls

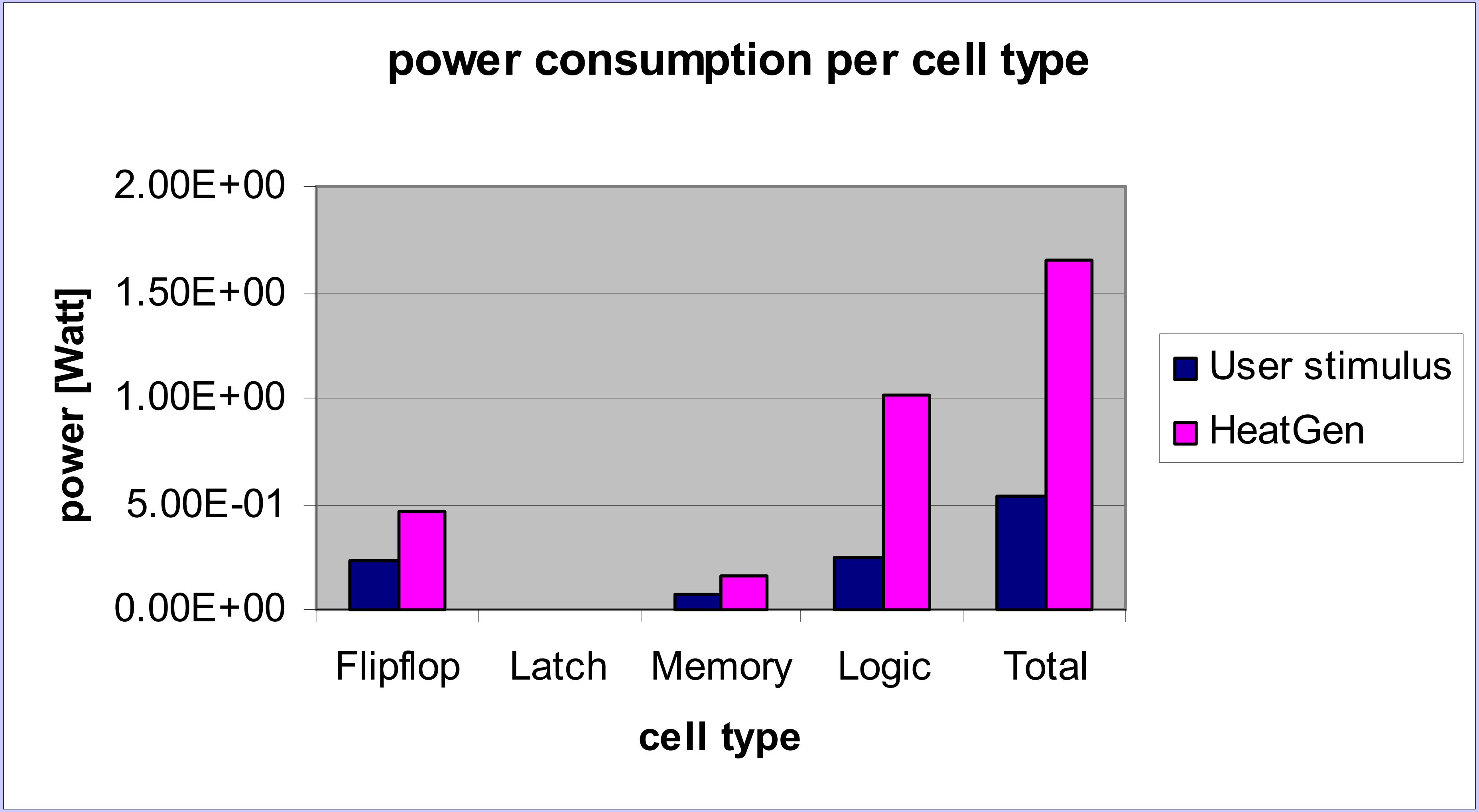
```
SimTime 1e-6
…
myDesign.U1.node1 0.3   10    10
myDesign.U1.node2 0.8   7     7
…
myDesign.U1.inst1.((01A->10Y)&&B) 0 5
myDesign.U1.inst1.((10A->01Y)&&B) 0 9
…
```

# of times energy vector is activated

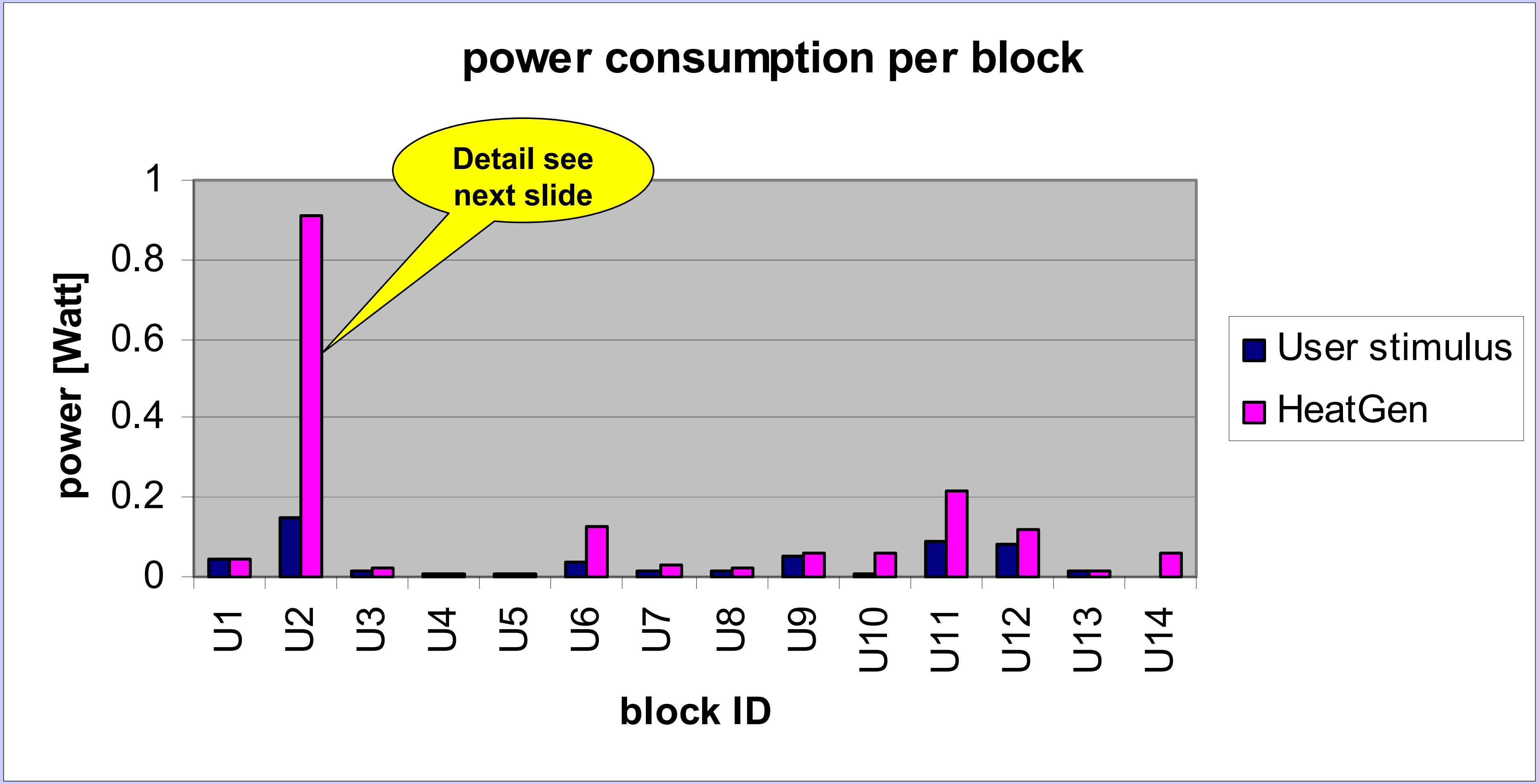
Testcase description

- Design size
  - 15,000 standard cells total
    - 5,500 Flip flops
    - 48 latches
    - 9,452 combinatorial
  - 24 RAM instances
- Clock domains
  - 2 functional clocks (excluding test clocks)
    - 100 MHz
    - 200 MHz
- Power model statistics
  - 8,900 energy vectors in library
  - 800,000 instances of energy vectors in design

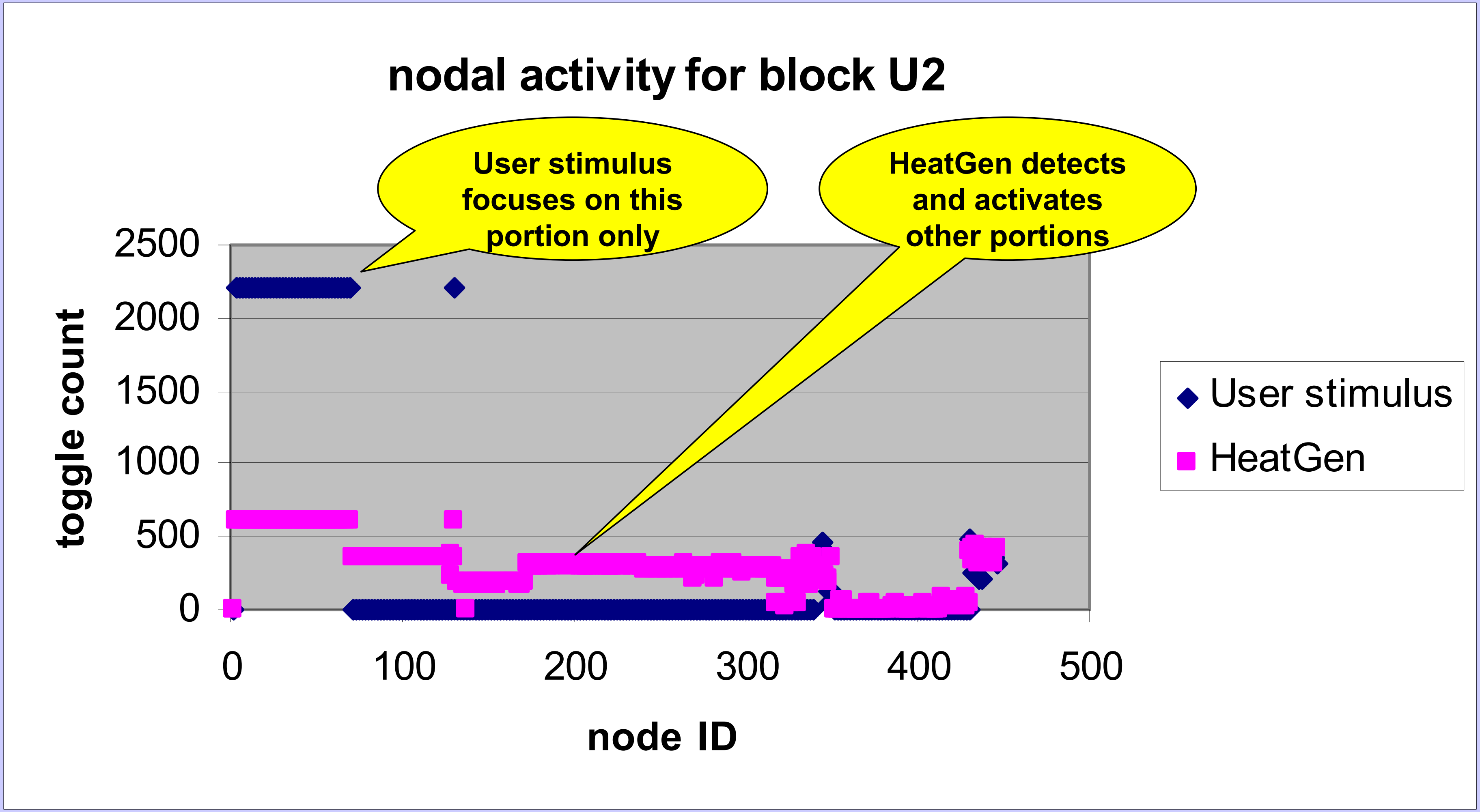
Testcase results (1 of 3)



Testcase results (2 of 3)



Testcase results (3 of 3)



Discussion of testcase results

- HeatGen created higher power consumption than user-acclaimed worst case stimulus
  - Higher power per cell type
  - Higher power per block
  - Results validated by simulation of HeatGen stimulus
- Explanation
  - User stimulus focused only on portion of design
  - HeatGen stimulus systematically activates all possible portions of design

More results

All power numbers are post-layout

Details see previous slides

	# of std cell instances	HeatGen runtime	HeatGen power [W]	User stimulus power [W]
1	15K	2H	1.65	0.54
2	45K	12H	1.2	0.5
3	123K	6H 12H	3.77 3.97	N/A
4	224K	6H 12H	0.95 0.95	N/A

Periodical power monitor applied (6H, 12H …)

Result stabilized within 6H

Conclusion

- HeatGen is the first energy vector activity generation tool in the industry
  - Deployed on real-life designs
  - Higher power consumption than typical user stimuli
  - More reliable than probabilistic simulation
- Future work
  - Integration with static and transient voltage drop analysis
  - Explore other applications involving ALF vectors
    - Power macro model characterization
    - Electromigration analysis
    - Stimulus generation for delay and crosstalk testing