Towards Wearout-aware and Accelerated Self-Healing Digital Systems
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Overview

Accelerated Self-Healing [DAC ‘14]

Main Idea
- Sleep → Active Recovery
- Some of the effects of wearout (e.g. BTI) can be reversed by several techniques (high temperature, negative voltage, UV light, reverse current, etc.), thus leading to effective self-healing.

Test Setup
- Commercial 40nm FPGA chips
- Accelerated Testing Methodology
- Knobs: V, T, AC/DC, Sleep/Active

Measurement Results

Wearout Issues
- BTI, HCI, TDBB, EM, etc.
- Increase design margin and worsen metrics
- Cross-layer issues
- Both Reversible and Irreversible Part

Previous Solutions
- Design for the worst case (Guard band)
- Dynamically adapt to wearout
- Reduce the stress during operation
- Passive Recovery

This Dissertation
- Repair wearout instead of just
- Accelerated & Active Recovery
- Circadian Rhythms for FULL recovery
- Cross-layer Implementations

“Sleep When Getting Tired” [ASPDAC ’16]

Main Idea
- The boundary between reversible & irreversible is “soft”
- Irreversible wearout can be recovered through acceleration
- Frequency dependent of accelerated wearout & recovery
- “Sleep when getting tired” to FULLY avoid the wearout
- Negative “turbo” boost at the system level

Results

On-chip implementations

Negative Voltages
- A Charge pump Neg. voltage generator

High Temperatures
- Self Reconfigurable healing tree

Solution 1: Reconfigurable self-healing tree

Solution 2: Utilize Core Redundancy & Dark Silicon

Wearout-aware Power Gating

- Power gating block
- Negative voltage

- Embedded Wearout Sensors [SELSE ’15]
- Metastable element based
- Track both wearout and (accelerated) recovery
- Track Multiple Paths
- Be aware of wearout induced path reranking
- Used together with multiple dynamic management

Core level implementations
- Utilize Core Redundancy in dark silicon era
- Optimal Scheduling/Load balancing
- Introduce Accelerated & Active Recovery as a new design knob
- Tradeoff between lifetime, power, performance

Table 1: Summary of the Accelerated Self-healing results for 6 hours (recovered portion %)

<table>
<thead>
<tr>
<th>Test Case</th>
<th>Condition</th>
<th>Measurement Results</th>
<th>Model Prediction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passive Recovery</td>
<td>20°C and 0%</td>
<td>0.66%</td>
<td>1%</td>
</tr>
<tr>
<td>Active Recovery</td>
<td>20°C and +0.3V</td>
<td>16.7%</td>
<td>14.6%</td>
</tr>
<tr>
<td>Accelerated Recovery</td>
<td>110°C and 0%</td>
<td>26.7%</td>
<td>28.6%</td>
</tr>
<tr>
<td>Accelerated Active Recovery</td>
<td>110°C and +0.3V</td>
<td>72.4%</td>
<td>70%</td>
</tr>
</tbody>
</table>

- Reduce design margin

Graph: 10X

Graph: 100X

Graph: 1000X

Graph: 10000X

Graph: 100000X

Graph: 1000000X

Graph: 10000000X

Graph: 100000000X

Graph: 1000000000X

Graph: 10000000000X

Graph: 100000000000X

Graph: 1000000000000X

Graph: 10000000000000X

Graph: 100000000000000X

Graph: 1000000000000000X

Graph: 10000000000000000X

Graph: 100000000000000000X

Graph: 1000000000000000000X

Graph: 10000000000000000000X

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Graph: 1000000000000000000000X

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Graph: 1000000000000000000000000X