Robust Modular Bulk Built-In Current Sensors for Detection of Transient Faults

Frank Sill Torres+, Rodrigo Possamai Bastos*

+ Department of Electronic Engineering, Federal University of Minas Gerais, Belo Horizonte, Brazil

* LIRMM, Université Montpellier II / CNRS UMR 5506 Montpellier, France
Outline

- Preliminaries
- Modular Bulk Built-In Current Sensors
- Results
- Conclusion
Preliminaries

Transient-Faults in Integrated Circuits (IC)

- Increasing susceptibility of CMOS IC to radiation effects due to decreasing technology sizes
- Environmental (\(\alpha\)-particles, neutrons, …) and intentional (laser beams, …) sources
- Can cause transition faults
Preliminaries

Solutions for Transient Fault Detection

- Redundancy (Time, Logic)
  - Well known approach
  - Strong *increase* in *area*, *power* and/or *delay*

- Shadow Latches (*Razor*)
  - Moderate area increase
  - *Useless* against long-duration TF

- Built-In Current Sensors (BICS)
  - Good for Memory block
  - Not appropriate for logic
Preliminaries

Bulk Built-In Current Sensors

- At particle strikes transistor in off mode → generation of current between transistor’s reverse-biased drain-bulk pn-junction
- Idea: Current sensor between Bulk and ground → Bulk BICS (BBICS)

Neto, Micro, 26/5, p. 10, 2006
Modular Bulk Built-In Current Sensors

Origination of Approach

Common problems of existing Bulk-BICS

- High area effort
- Strong susceptibility to parameter / temperature variations
- Offset on bulk voltage → increased leakage (sub-threshold) of monitored circuits

Proposed solution

- Functionality sharing (reduction of power/area)
- Bulk connected directly with VDD/GND via a high ohmic transistor (as proposed in “Wirth, in Mic. Rel., v.48/5, 2008”)
- Implementation of positive feedback structure (increase of stability / decrease of sensor response time)
Modular Bulk Built-In Current Sensors

Architecture (only NMOS)
Modular Bulk Built-In Current Sensors

Mode of Operation (NMOS)

1. Particle Strike
2. Current through Nh1 → voltage peak on $bulk_{NMOS}$
3. Nh2 starts to conduct → voltage drop on $head_{NMOS}$
4. State of $inv_{out}$ changes → pos. feedback
5. Error flag set
Results

Simulation Environment

- **BUT** (Block Under Test): 6 chains of 10 inverter
- 2 groups of PMOS mBBICS (*load equalization* w/ NMOS mBBICS)
- Particle strike via current source connected to 5th inverter of 1st chain
- Predictive 16 nm technology (Bulk CMOS, Berkeley)
## Results

### Detection Capability (6 Heads, nominal case)

<table>
<thead>
<tr>
<th>Q&lt;sub&gt;f&lt;/sub&gt;</th>
<th>t&lt;sub&gt;f&lt;/sub&gt; [ (t_r = 1, ps) ]</th>
<th>PMOS</th>
<th>NMOS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 fC</td>
<td>5 ps</td>
<td>O×</td>
<td>O×</td>
</tr>
<tr>
<td>2 fC</td>
<td>5 ps</td>
<td>⋆✓</td>
<td>⋆✓</td>
</tr>
<tr>
<td>3 fC</td>
<td>5 ps</td>
<td>⋆✓</td>
<td>⋆✓</td>
</tr>
<tr>
<td>4 fC</td>
<td>5 ps</td>
<td>⋆✓</td>
<td>⋆✓</td>
</tr>
<tr>
<td>1 fC</td>
<td>10 ps</td>
<td>O×</td>
<td>O×</td>
</tr>
<tr>
<td>2 fC</td>
<td>10 ps</td>
<td>⋆✓</td>
<td>⋆✓</td>
</tr>
<tr>
<td>3 fC</td>
<td>10 ps</td>
<td>⋆✓</td>
<td>⋆✓</td>
</tr>
<tr>
<td>4 fC</td>
<td>10 ps</td>
<td>⋆✓</td>
<td>⋆✓</td>
</tr>
<tr>
<td>1 fC</td>
<td>20 ps</td>
<td>O×</td>
<td>O×</td>
</tr>
<tr>
<td>2 fC</td>
<td>20 ps</td>
<td>⋆✓</td>
<td>⋆✓</td>
</tr>
<tr>
<td>3 fC</td>
<td>20 ps</td>
<td>⋆✓</td>
<td>⋆✓</td>
</tr>
<tr>
<td>4 fC</td>
<td>20 ps</td>
<td>⋆✓</td>
<td>⋆✓</td>
</tr>
</tbody>
</table>

TF – Transient Fault, t<sub>resp</sub> – Sensor Response Time

\[
I_{\text{fault}} = \frac{Q_f}{t_f - t_r} \ldots \left( e^{\frac{t}{t_f}} - e^{\frac{t}{t_r}} \right)
\]

〇× - no TF no detection
〇✓ - no TF detection
⋆✓ - TF detection
⋆× - TF no detection
Results

Influence of Heads Amount (Nominal Models, $Q_f = 2 \text{ fC}, t_f = 5 \text{ ps}$)
Results

Temperature Analysis (Nominal Models, $Q_f = 2 \text{ fC}$, $t_f = 5 \text{ ps}$)
Results

Monte Carlo Analysis ($t_f = 5$ ps)
Conclusions

- Bulk Built-In Current Sensors (BBICS) promising solution to detect soft errors in current CMOS technologies
- Main problems: susceptibility to variations, area, power
- Proposed modular BBICS (mBBICS) combines functional block sharing and positive feedback
- Simulations (16 nm PTM)
  - All injected transition faults detected for nominal and MonteCarlo (MC) case
  - Max. response times of ca. 500 ps (nominal) and ca. 1 ns (MC)
  - Area offset of 25 %
  - Very low increase in power dissipation
Thank you!

franksill@ufmg.br
bastos@lirmm.fr

OptMA$^{\text{lab}}$ / ART
www.asic-reliability.com