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**Design of Bulk Built-In Current Sensors to Detect Single Event Effects and Laser-Induced Fault Injection Attempts**

J.-M. Dutertre1, R. Possamal Bastos2, O. Potin1, M.-L. Flottes2, G. Di Natale3, and B. Rouzeyre3

Bulk Built-In Current Sensors (BBICS) are fault detection mechanisms embedded in integrated systems. BBICS are able to monitor anomalous transient currents like the so-called single event effects induced by radiation or even malicious injection sources. This work reviews BBICS principles and introduces new sensor architectures that improve the transient-fault detection sensitivity. In addition, a test chip is presented for the validation of the sensor concept under the laser-induced effects.

**Integrated circuits are more and more Transient-Fault (TF) sensitive through new technologies**

The today’s trend in efficient protections against transient faults:
- Concurrent Error Detection (CED) mechanisms
- Recovery-based Error Correction Procedures
- Lower abstraction levels
- Higher abstraction levels

It allows higher detection capability at the expense essentially of CED devices.

**Mitigation of Transient faults by using CED schemes based on Bulk Built-In Current Sensors (BBICS):**

| Cases of Transient Faults in an Inverter Protected by a PMOS-BBICS and a NMOS-BBICS: |
|------------------|------------------|
| **Case 0:**      | **Case 1:**      |

PMOS on

<table>
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<tr>
<th>in = 0</th>
<th>out = 1</th>
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</thead>
</table>

PMOS off

<table>
<thead>
<tr>
<th>in = 1</th>
<th>out = 0</th>
</tr>
</thead>
</table>

NMOS on

<table>
<thead>
<tr>
<th>in = 0</th>
<th>out = 1</th>
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</thead>
</table>

NMOS off

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<th>in = 1</th>
<th>out = 0</th>
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**Analysis of laser-induced currents in NMOS and PMOS transistors:**

Test chip composed of single NMOS and PMOS transistors designed with classic and triple-well 90-nm CMOS technology.

**Transistors designed with classic CMOS technology**

- Laser-induced NMOS current
  - Case 0
  - Case 0A
  - Case 0B

- Laser-induced PMOS current
  - Case 1A
  - Case 1B

**Transistors designed with triple-well CMOS technology**

- Laser-induced NMOS current
  - Case 8A
  - Case 8B

- Laser-induced PMOS current
  - Case 4A
  - Case 4B

**Laser-induced current that would contribute to produce a transient fault**

- Drain current

- Bulk current

Bulk current monitored by a NMOS-BBICS would have the same order of magnitude than drain current

Bulk current monitored by a PMOS-BBICS would be an order of magnitude above drain current

**Improving the transient-fault detection sensitivity of BBICS by using triple-well CMOS technology:**

**Conclusions and Perspectives:**

1. Classic PMOS transistors drive bulk currents much higher than drain currents, limiting efficient transient-fault detection sensitivity of PMOS-BBICS.

2. Structural weakness in classic NMOS transistors that precludes NMOS-BBICS efficiently identifying anomalous bulk currents.

3. Use of triple-well CMOS technology allows a distinction of the bulk current and improves the transient-fault detection sensitivity of BBICS.

A 65-nm CMOS test chip is being tested to validate BBICS approach in such a technology.

**Layout of 65-nm CMOS test chip with BBICS devices**

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