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

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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 introduce 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.

### 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:**
    - PMOS on
    - NMOS off
    - in = 0
    - out = 1
  - **Case 1:**
    - PMOS off
    - NMOS on
    - in = 1
    - out = 0

- **Transient-fault current view in a cross section of classic CMOS inverter monitored by a NMOS-BBICS:**
  - PMOS-BBICS
  - NMOS-BBICS
  - Flag_N = 1
  - Flag_P = 0
  - in = 1
  - out = 0

### Analysis of laser-induced currents in NMOS and PMOS transistors:

- **Transistors designed with classic CMOS technology**
  - Laser-induced NMOS current Case 0
  - Laser-induced PMOS current Case 1A
  - Laser-induced PMOS current Case 1B

- **Transistors designed with triple-well CMOS technology**
  - Laser-induced NMOS current Case 0A
  - Laser-induced NMOS current Case 0B
  - Laser-induced PMOS current Case 1B

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

- **Transistors designed with triple-well CMOS technology**
  - Laser-induced NMOS current Case 0B
  - Laser-induced NMOS current Case 0A

### Conclusions and Perspectives:

- Laser-based experiments revealed:
  1) Classic PMOS transistors drive bulk currents much higher than drain currents, limiting effective 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 between the bulk current and improves the transient-fault detection sensitivity of PMOS-BBICS.

- Use of triple-well CMOS technology amplifies bulk current by an order of magnitude above drain current.

### Layout of 65-nm CMOS test chip with BBICS devices:

- NMOS in Pwell to mimic PMOS properties