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

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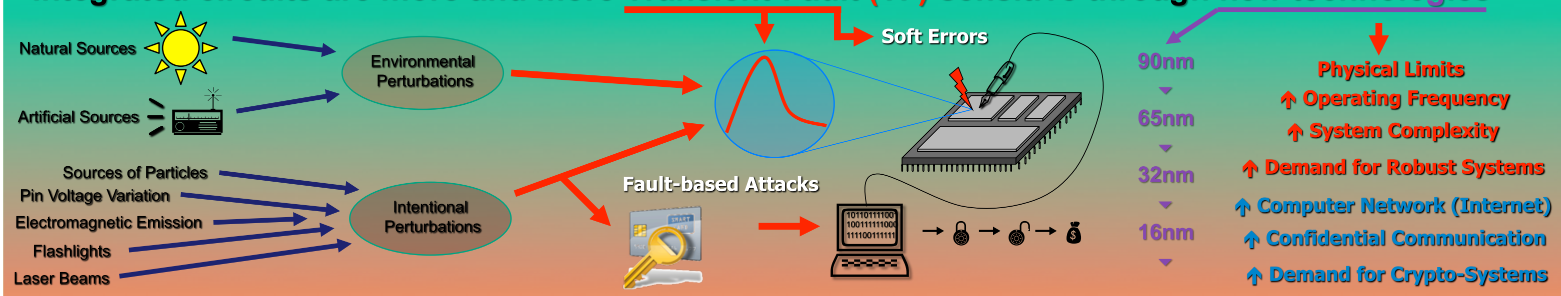
Bulk Built-In Current Sensors (BBICS) are fault detection mechanisms embedded in integrated systems. BBICS are able to monitor anomalous transient currents like the so-called single event effects induced by radiation or even malicious injection sources. This work reviews BBICS principles and introduce 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.

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



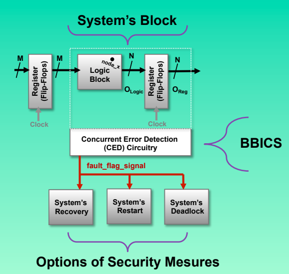
The today's trend in efficient protections against transient faults:

Concurrent Error Detection (CED) mechanisms → Lower abstraction levels

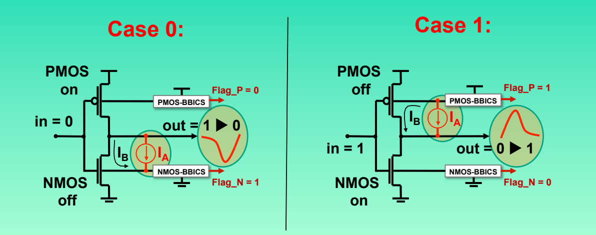
Recovery-based Error Correction Procedures → Higher abstraction levels

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

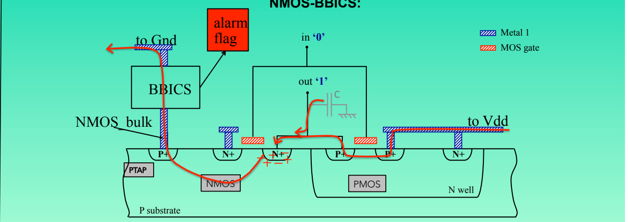
Mitigation of Transient faults by using CED schemes based on Bulk Built-In Current Sensors (BBICS):



Cases of Transient Faults in an Inverter Protected by a PMOS-BBICS and a NMOS-BBICS:



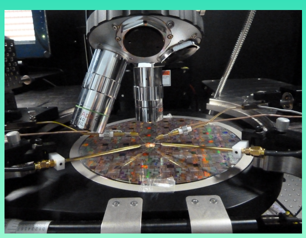
Transient-fault current view in a cross section of classic CMOS inverter monitored by a NMOS-BBICS:



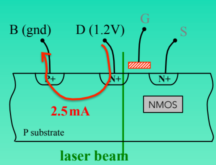
Analysis of laser-induced currents in NMOS and PMOS transistors:

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

Experiment settings: measure of laser-induced currents at λ = 1064 nm, laser spot Ø = 5 µm, pulse duration = 20 µs, 1.25 W

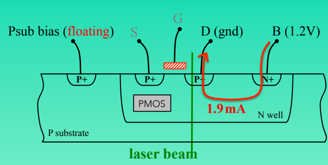


Transistors designed with classic CMOS technology

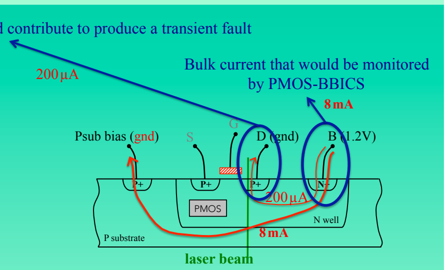


Laser-induced NMOS current Case 0

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



Laser-induced PMOS current Case 1A

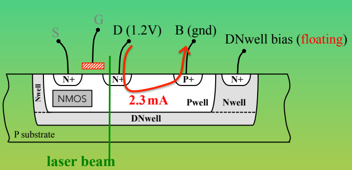


Laser-induced PMOS current Case 1B

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

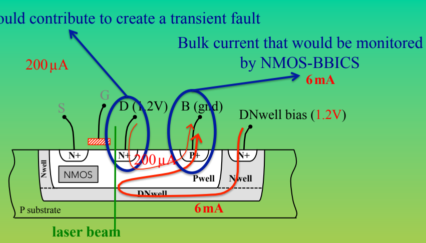
Improving the transient-fault detection sensitivity of BBICS by using triple-well CMOS technology:

Transistors designed with triple-well CMOS technology



Laser-induced NMOS current Case 0A

NMOS in Pwell to mimic PMOS properties



Laser-induced NMOS current Case 0B

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

Conclusions and Perspectives:

+ Laser-based experiments revealed:

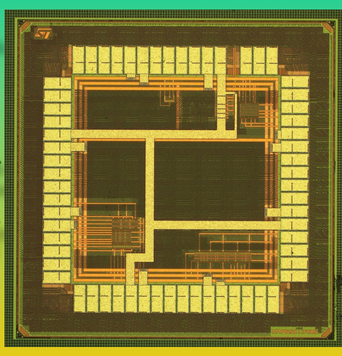
1) Classic PMOS transistors drive bulk currents much higher than drain currents, hinting efficient transient-fault detection sensitivity of PMOS-BBICS;

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 NMOS-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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