Increasing Reliability of Programmable Mixed-Signal Systems by Applying Design Diversity Redundancy

Gabriel de M. Borges, Luiz F. Gonçalves, Tiago R. Balen, Marcelo S. Lubaszewski
Universidade Federal do Rio Grande do Sul
gabriel.borges@ufrgs.br, luizfg@ece.ufrgs.br, tiago.balen@ufrgs.br, luba@ece.ufrgs.br

***Abstract*— This work explores the concept of design diversity redundancy applied to mixed-signal (MS) circuits. Results from fault injection experiments show a very good ability of the system to tolerate double faults.**

Keywords - fault tolerance; mixed-signal; design diversity TMR.

I. INTRODUCTION

An effective technique frequently employed to add fault tolerance to electronic systems is the Triple Modular Redundancy (TMR) [1]. The present work addresses the application of the concept of TMR by design diversity [2], where the redundant copies are implemented with different architectures. The design of interest is a low-pass filter, which was prototyped in a mixed-signal programmable device, the PSoC CY8C29466, from Cypress Semiconductor [3].

II. MIXED-SIGNAL DESIGN DIVERSITY TMR

In the design diversity TMR (DTMR) the system is replicated using different architectures/domains and their outputs are delivered to a voter (Fig. 1).

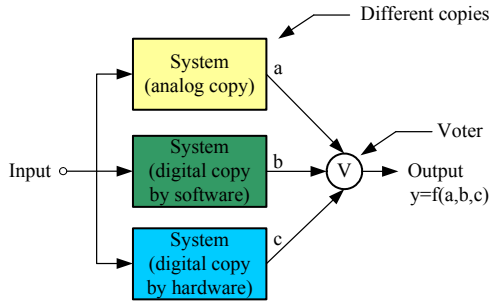

Figure 1. Mixed-Signal DTMR architecture.

In our mixed-signal case study the three copies of the filter are implemented as follows: **1) Analog low-pass filter. 2) Digital low-pass filter by software:** by using the Arithmetic and Logic Unit (ALU) from the PSoC microprocessor. **3) Digital low-pass filter by hardware:** A Multiply and Accumulate Unit is used rather than the ALU. The voter is implemented by software. Functional simulations showed the effectiveness of the method to deal with single deviations.

III. FAULT INJECTION AND RESULTS

To evaluate multiple fault effects, each redundant module is duplicated and single faults are exhaustively injected in one of the duplicated blocks. Therefore, the estimation of tolerance of the DTMR is made by calculating the number of 2-by-2 combinations of these set of faults. By using Table 1, it is possible to conclude that only 11.89% of the considered double faults are not tolerated by the proposed DTMR.

TABLE I. RESULTS OF INDIVIDUAL SINGLE FAULT INJECTION

	SW Dig. Filter	HW Dig. Filter	AN Filter
Inj. Faults	96	80	123
Errors	28	20	61
Error rate	29.16%	25%	49.59%

Fig. 2 shows that the DTMR has better results (regarding double faults) than the traditional analog TMR, although the digital filters present a slightly better tolerance level (considering the triplication in traditional TMR schemes).

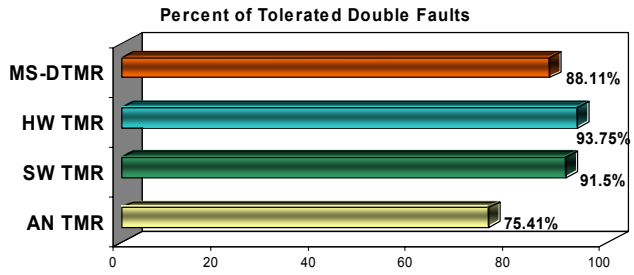

Figure 2. Comparison between the tolerance levels of the MS-DTMR scheme and traditional TMR systems.

IV. CONCLUSIONS

Since the DTMR modules are different, distinct defect mechanisms may affect the system modules in different ways. Therefore, it is possible to assume that the design diversity naturally adds an extra degree of resilience to the traditional TMR.

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