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An Integrated Diagnostic Reconfiguration (IDR) Design Approach for Fault Tolerant Mixed Signal Integrated Systems

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Abstract

An Integrated Diagnostic Reconfiguration (IDR) approach is presented that is compatible with a range of mixed signal circuits and sensors used in high dependability systems. The technique achieves improved testability, diagnostic capabilities and fault tolerance through reconfiguration.

The approach has been used to implement a prototype fault-tolerant interface ASIC for a piezoresistive silicon pressure sensor. This paper will describe the technique, an application and present results from measurements on the silicon implementation.

Summary

Deep sub-micron technology together with rapid advances in micromachining techniques are making the concept of fully integrated intelligent Microsystems practical. Many of these devices are required for safety critical and high dependability systems hence in these applications on-line data validation and fault tolerance are as important or in some cases more important specifications than production test coverage. An example here is the need for mixed signal IC's and Smart sensors in the automotive industry where low cost and radical quality levels are demanded and where failure may either endanger human life or require the replacement of a complete panel. This is specifically relevant if the concept of for example, injection moulding electronics into the chassis becomes realistic.

This paper describes a new approach referred to as integrated Diagnostic Reconfiguration[1,2,3](IDR) and presents results on an experimental device. The technique utilises interchangeable circuit blocks such as half bridges in the case of resistive bridge sensors or gain / filter stages for analogue signal conditioning circuits, together with appropriately designed reconfiguration switches operating under digital logic or microprocessor control.

Principle of IDR

To achieve diagnostics and reconfigurability without excessive computational effort some form of comparative test must be made. This may take the form of spatial redundancy where a physical copy or a duplicate device is included in the circuit as in multiple sensor fusion[4,5,6]. Analytic redundancy can be used which[7,8,9] uses a real-time computational model to provide a best estimate of the circuit output from a combination of previous outputs and measurements taken from other parts of the system. This is however overly complex at the silicon level. Triplex systems are an approach used extensively in the aerospace industry however this approach is not practical at the microsystem level due to cost and silicon overhead. In addition, the technique will not detect a range of subtle faults that may effect

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secondary parameters such as power consumption, harmonics etc, that may indicate imminent catastrophic failure or time dependent degradation.

The techniques used for IDR exploits the inherent regularity in many functions used in fully integrated microsystems such as half bridges, pipelined structures such as converters, switched current designs and a range of filter and multi-stage amplification functions. Fig. 1 demonstrates the theoretical basis for the technique. A diagnostic algorithm controls the connectivity of the two or more interchangeable functional blocks F_1 & F_2 – F_x. The diagnostic algorithm compares the response from each configuration and if the difference exceeds a pre-set threshold, uses the results to detect and initiate normal functionality or in the case of an error condition:

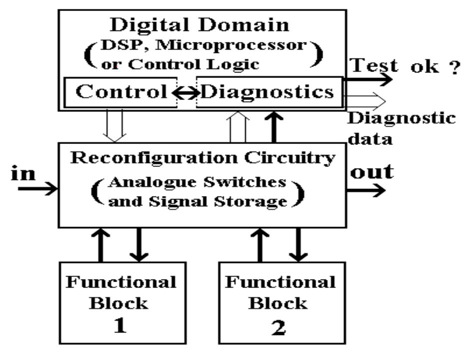

Fig. 1 The IDR Methodology

1. Initiate a diagnostic algorithm
2. Mask out the defective block and re-use the functional block through the use of a buffer or depending on the design;
3. Substitute a redundant identical block for the faulty one.

In addition, as the relative position of functional blocks in the signal path are switched, soft faults that are masked from the primary output due to the position of the faulty component in the signal path will have a drastically different effect on the output when the component occupies a different position in the signal chain. This has been shown to be a valid assumption in the majority of cases. This property of IDR automatically improves the coverage of on-line faults over the triplex system concept.

The Experiment

IDR has been theoretically evaluated on a number of different mixed signal functions however, this paper will focus on the experimental evaluation of the technique on a Smart pizoresistive pressure sensor. Fig. 2 illustrates the experiment.

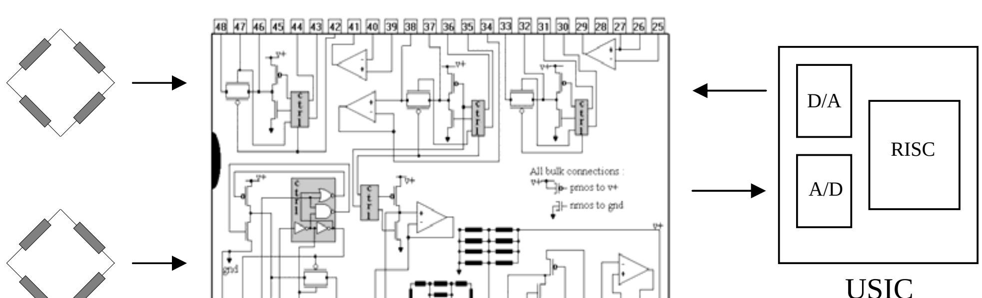

Fig. 2 Experiment to characterise the IDR concept

Two silicon micromachined pressure sensors are used to simulate a single sensor with two additional dummy half bridges fabricated into the device. The ASIC fabricated on the AMS 1.2um process contains the reconfiguration switches and a number of structures used to evaluate noise performance essential to validate the performance impact in terms of loss of accuracy in the primary measurand. The USIC which contains amongst other functions an A-D, D-A and a RISC processor is being used to run the diagnostic algorithms required for fault detection and switch control. Note the technique assumes that future microsystems will contain some form of processor on board that will run the diagnostics.

Results

The paper will present the results to date relating to the performance degradation caused by the reconfiguration switches, the software overhead for the diagnostic algorithms and the projected limitations on a real implementation. In addition, a projection of the applicability of the technique to a range of mixed signal systems will be presented.

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