Fault Detection for Linear Analog Circuits Using Current Injection*

J. Velasco-Medina†, Th. Calin, M. Nicolaidis

Reliable Integrated Systems Group, TIMA/INPG
46 Avenue Felix Viallet, 38031 Grenoble Cedex, France
Phone: (+33) 4 76 57 48 34, Fax: (+33) 4 76 47 38 14
e-mail: velasco@cime.inpg.fr

Abstract

A new test technique for linear analog circuits which employs current injection as input test stimulus is described. Our investigations have shown that current transitions resulting from a current injected on internal test points are significantly different for the fault free and faulty circuits. This can be used for fault detection purposes. In fact, the current injection as test input stimulus represents a powerfull alternative to the test approaches based on conventional voltage input stimulus. The new approach allows to improve the testability of various faults, which are difficult to detect or are untestable when using voltage-based test stimulus. In addition the technique has significant advantages for BIST testing purposes. The technique is illustrated by means of a modern opamp circuit and by considering catastrophic and gate-oxide-short (GOS) faults.

Mixed-signal integrated circuits can accommodate a complete system-on-a-chip, resulting in reduced demands on board space, increased reliability, lower system costs and simpler design and manufacturing processes. While demand continues to rise for complete system-on-a-chip applications, in fields as diverse as telecommunications, automotive, consumer products and industrial controllers, the design and test of complex analog and mixed-signal integrated circuits is continually a difficult and challenging task.

The analog components are often difficult to test and they can significantly increase the complexity of testing the overall mixed-signal integrated circuit or system. Circuits of small to medium complexity like operational amplifiers and filters have been conventionally tested using functional testing methods (specification-based testing), where the functionality of the circuit is verified at some pre-specified test points. Since the test effort or the testing effectiveness cannot be gauged, this method could result in either excessive or insufficient testing of the part. Fault-based approaches are aimed to test the presence of physical defects, thereby providing a quantitative estimate of the test process (fault coverage measures). Then, fault-based testing is an attractive alternative to specification-based testing.

In fault-based testing, a number of approaches have been reported for addressing the testing of analog circuits on different issues, such as fault modeling, fault simulation and test stimulus generation.

Conventional techniques presented in the literature use input test stimulus based on voltage-mode signals and solve the test stimulus generation problem efficiently for either small-medium circuits or specific classes of circuits [1][2][3][4][5].

The approach described in this work is different from the previous ones in the sense that it uses a type of test stimulus no considered previously. The basic idea consists on using current signals as input test stimuli, which are injected on well selected internal test nodes. Under these stimuli, the current transitions of the circuit nodes are very different for the fault-free and the faulty circuit cases.

The idea is illustrated in Figure 1, where a current input stimulus Iin(t) is applied to a fault-free circuit which serves as a reference and to a faulty circuit. The voltage and/or current output responses, Vout(t)/Iout(t) from the fault-free circuit and

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† He is currently an assistant professor in Electrical Engineering Department, Universidad del Valle, Cali, Colombia

Vout(t)'/Iout(t)' from the circuit under test, are then compared to find out the degree of discrepancy. The interest of the method is illustrated in a context of fault-based testing approach, which allows to quantify the effectiveness of the method by means of fault coverage measures.

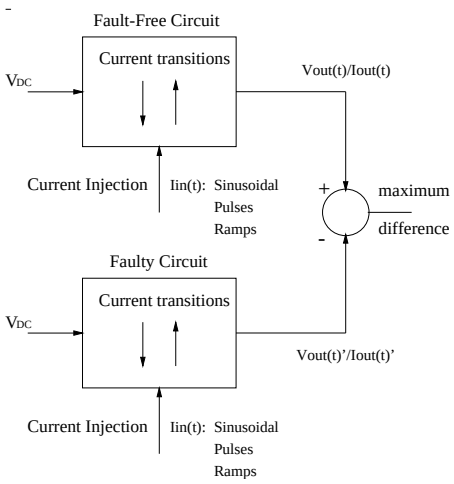

Figure 1. Current injection for fault-based testing

For the overall efficiency of the current injection based approach it is important to notice that fault simulations must be carried out during the design stage. During the testing stage, measurement values are compared with simulation results to decide whether the circuit under test is fault-free or faulty. A fault is detected if this difference is greater than a preset threshold.

In order to demonstrate the efficiency of the current injection test approach (fault coverage measures), a modern opamp circuit was simulated both in voltage-follower and inverting configuration with faults injected into it. We assume a complete set of single catastrophic (or hard) faults and gate-oxide-short (GOS) faults in the transistors of the operational amplifier. The comparison of the results with the ones obtained in the case of voltage-based test stimulus show significant advantages for the new test technique. In this case, the strategy allows to achieve high fault coverage by employing simple test patterns such as current sinusoidal waveforms.

The implementation of the method in a BIST context is easy since it will require a current generator and a current mirror for the first test point. Additional test points can be exercised by using the same current generator and adding a current mirror (a transistor) and a control signal for each new test point as is shown in Figure 2.

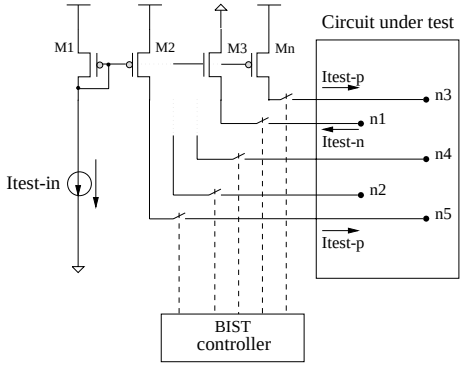

Figure 2. Current injection BIST scheme

Another decisive advantage of the technique consist on the fact that the BIST implementation does not require to insert multiplexers in the signal path of the circuit, which is a very important consideration for testing of high frequency analog circuits. Finally, current stimulus is not sensitive to noise and circuit parameters, thus allowing an easier and reliable implementation.

In the near future we scope to extend our investigation to various classes of linear analog circuits with final goal a structured analog and mixed-signal BIST technique based on current injection as input test stimulus, with improved reliability, high fault coverage, low hardware cost and reduced performance degradation.

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