

# Digital Integrated Circuit Testing using Transient Signal Analysis

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## Abstract

*A novel approach to testing CMOS digital circuits is presented that is based on an analysis of  $I_{DD}$  switching transients on the supply rails and voltage transients at selected test points. We present simulation and hardware experiments which show distinguishable characteristics between the transient waveforms of defective and non-defective devices. These variations are shown to exist for CMOS open drain and bridging defects, located both on and off of a sensitized path.*

## 1.0 Introduction

Transient Signal Analysis (TSA) is a new parametric testing method for digital integrated circuits. In TSA, transients in both the voltage waveforms at selected test points as well as current transients on the power supply are analyzed to determine the presence of defects. TSA exploits the fact that the power supply is globally connected to a large fraction of the transistors in a CMOS digital integrated circuit. TSA is similar to power supply current ( $I_{DD}$ ) test methods in this way. Since power supply connections are unbuffered at the I/O pads, it is possible to measure the high frequency components of this signal without attenuation. Thus, the  $I_{DD}$  transients reflect the switching activity associated with the propagation of signals throughout the circuit. However, in larger circuits, the number of transistors which can simultaneously switch often makes it difficult to identify a defect using this single resource. TSA improves on defect detection capabilities of  $I_{DD}$  test strategies by additionally monitoring the voltage transients at a set of test points as well as on  $I_{DD}$ . The voltage test points are typically at or near the primary outputs of the device. By using a combination of voltage transients on test signal paths and  $I_{DD}$  transients on the power supply, TSA can provide improved defect resolution while maintaining a high degree of process insensitivity when compared with other  $I_{DD}$ -based testing methods.

In this paper, we present results from four experiments conducted on actual devices with intentionally inserted bridging and open drain defects. In order to demonstrate the sensitivity advantage of TSA over logic testing, we

have placed several bridging and open drain defects into separate versions of a test circuit and have conducted experiments using two-vector test sequences that do not generate logic errors at the test points. The results presented for the experiments show regional variations in the test point signals due to the presence of the defects.

The remainder of this paper is organized as follows. In Section 2 we present related research on device testing and the motivation for our research. Section 3 presents the results of hardware experiments conducted on devices with intentionally inserted bridging and open drain defects. Section 4 gives a summary and conclusions.

## 2.0 Background and Motivation

Device logic testing analyzes the logical integrity of the device by using input test vectors which are a subset of all possible stimuli. However, these subsets are generated by techniques which are based on fault models that have been shown to be inadequate to detect all forms of CMOS defects [1][2]. Parametric testing strategies [3][4], on the other hand, are based on the analysis of a circuit's parametric properties, for example, propagation delay, magnitude of supply current or transient response. While the algorithms for generating logic tests have been improved over time to handle more types of fault behaviors, parametric testing strategies offer intrinsically better solutions since they have been developed from the structural and electrical properties of CMOS circuits.

There are many types of parametric tests that have been proposed [5]. Recent research interest has focused primarily on three types:  $I_{DDQ}$  [6],  $I_{DD}$  [7], and delay fault testing [8][9].  $I_{DDQ}$  is based on the measurement of an IC's supply current when all nodes have stabilized to a quiescent value [10].  $I_{DDQ}$  has been shown to be an effective diagnostic technique for CMOS bridging defects, but is of limited applicability for some types of CMOS open defects [11]. Although defect observability is significantly improved by the addition of  $I_{DDQ}$  to logic tests,  $I_{DDQ}$  is handicapped by the necessarily slow test vector application rates, the limited resolution achievable for large ICs and the restricted class of CMOS circuits to which it is applicable.

Several dynamic supply current  $I_{DD}$ -based approaches

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