

# 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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IC Test Using the Energy Consumption Ratio Wanli Jiang,2000 **Proceedings, International Test Conference 1996**,1996 ITC is the World s largest premier technical conference on the testing and total quality of integrated electronics and the assenblies and systems that are based on them **IEEE VLSI Test Symposium** ,2004 **18th IEEE VLSI Test Symposium** ,2000 Proceedings of a spring 2000 symposium highlighting novel ideas and approaches to current and future problems related to testing of electronic circuits and systems Themes are microprocessor test validation low power BIST and scan technology trends scan related approaches defect driven techniques and system on chip test techniques Other subjects are analog test techniques temperature and process drift issues test compaction and design validation analog BIST and functional test and verification issues Also covered are STIL extension IDDQ test and on line testing and fault tolerance Lacks a subject index Annotation copyrighted by Book News Inc Portland OR 19th IEEE VLSI Test Symposium ,2001 Collects 58 papers from the April May 2001 symposium that explore new approaches in the testing of electronic circuits and systems Key areas in testing are discussed such as BIST analog measurement fault tolerance diagnosis methods scan chain design memory test and diagnosis and test data compression and compaction Also on the program are sessions on emerging areas that are gaining prominence including low power testing testing high speed circuits on low cost testers processor based self test techniques and core based system on chip testing Some of the topics are robust and low cost BIST architectures for sequential fault testing in datapath multipliers a method for measuring the cycle to cycle period jitter of high frequency clock signals fault equivalence identification using redundancy information and static and dynamic extraction and test scheduling for minimal energy consumption under power constraints No subject index c Book News Inc **Proceedings** ,2002

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technology Today System on Chip SoC designs are increasingly mixed signal designs With the advent of application specific integrated circuits ASIC technologies that can integrate both analog and digital functions on a single chip analog has become more crucial than ever to the design process Today designers are moving beyond hand crafted one transistor at a time methods They are using new circuit and physical synthesis tools to design practical analog circuits new modeling and analysis tools to allow rapid exploration of system level alternatives and new simulation tools to provide accurate answers for analog circuit behaviors and interactions that were considered impossible to handle only a few years ago To give circuit designers and CAD professionals a better understanding of the history and the current state of the art in the field this volume collects in one place the essential set of analog CAD papers that form the foundation of today s new analog design automation tools Areas covered are Analog synthesis Symbolic analysis Analog layout Analog modeling and analysis Specialized analog simulation Circuit centering and yield optimization Circuit testing Computer Aided Design of Analog Integrated Circuits and Systems is the cutting edge reference that will be an invaluable resource for every semiconductor circuit designer and CAD professional who hopes to break the analog design bottleneck

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**International Workshop on Electronic Design, Test and Applications** Michel Renovell,2002 A collection of the 78 oral presentations and 24 poster papers from the January 2002 international workshop which brought together specialists from a broad area of electronic design manufacturing test and advanced system applications in the hope that the conference would integrate design test and application as cross dependent disciplines The contributions are organized into sessions focusing on analog test communications digital signal processing and architectures low to high level fault simulation and identification high level design memory power issues in design and test sensor and analog design electrical engineering education electromagnetics and control fault tolerant digital systems image processing robotics submicron technology test

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## **Table of Contents Digital Integrated Circuit Testing Using Transient Signal**

1. Understanding the eBook Digital Integrated Circuit Testing Using Transient Signal
  - The Rise of Digital Reading Digital Integrated Circuit Testing Using Transient Signal
  - Advantages of eBooks Over Traditional Books
2. Identifying Digital Integrated Circuit Testing Using Transient Signal
  - Exploring Different Genres
  - Considering Fiction vs. Non-Fiction
  - Determining Your Reading Goals
3. Choosing the Right eBook Platform
  - Popular eBook Platforms
  - Features to Look for in an Digital Integrated Circuit Testing Using Transient Signal
  - User-Friendly Interface
4. Exploring eBook Recommendations from Digital Integrated Circuit Testing Using Transient Signal
  - Personalized Recommendations
  - Digital Integrated Circuit Testing Using Transient Signal User Reviews and Ratings
  - Digital Integrated Circuit Testing Using Transient Signal and Bestseller Lists
5. Accessing Digital Integrated Circuit Testing Using Transient Signal Free and Paid eBooks

- Digital Integrated Circuit Testing Using Transient Signal Public Domain eBooks
  - Digital Integrated Circuit Testing Using Transient Signal eBook Subscription Services
  - Digital Integrated Circuit Testing Using Transient Signal Budget-Friendly Options
6. Navigating Digital Integrated Circuit Testing Using Transient Signal eBook Formats
    - ePub, PDF, MOBI, and More
    - Digital Integrated Circuit Testing Using Transient Signal Compatibility with Devices
    - Digital Integrated Circuit Testing Using Transient Signal Enhanced eBook Features
  7. Enhancing Your Reading Experience
    - Adjustable Fonts and Text Sizes of Digital Integrated Circuit Testing Using Transient Signal
    - Highlighting and Note-Taking Digital Integrated Circuit Testing Using Transient Signal
    - Interactive Elements Digital Integrated Circuit Testing Using Transient Signal
  8. Staying Engaged with Digital Integrated Circuit Testing Using Transient Signal
    - Joining Online Reading Communities
    - Participating in Virtual Book Clubs
    - Following Authors and Publishers Digital Integrated Circuit Testing Using Transient Signal
  9. Balancing eBooks and Physical Books Digital Integrated Circuit Testing Using Transient Signal
    - Benefits of a Digital Library
    - Creating a Diverse Reading Collection Digital Integrated Circuit Testing Using Transient Signal
  10. Overcoming Reading Challenges
    - Dealing with Digital Eye Strain
    - Minimizing Distractions
    - Managing Screen Time
  11. Cultivating a Reading Routine Digital Integrated Circuit Testing Using Transient Signal
    - Setting Reading Goals Digital Integrated Circuit Testing Using Transient Signal
    - Carving Out Dedicated Reading Time
  12. Sourcing Reliable Information of Digital Integrated Circuit Testing Using Transient Signal
    - Fact-Checking eBook Content of Digital Integrated Circuit Testing Using Transient Signal
    - Distinguishing Credible Sources
  13. Promoting Lifelong Learning
    - Utilizing eBooks for Skill Development

- Exploring Educational eBooks
14. Embracing eBook Trends
- Integration of Multimedia Elements
  - Interactive and Gamified eBooks

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