Real-Time Digital Signal Processing in a Mixed-Signal LSI Test System

In test subsystems based on digital signal processing, the HP 9493 test system emulates the analog and digital signals of the device under test, thereby reducing test time and increasing test coverage compared to a memory-based test system.

by Keita Gunji

Complex mixed-signal integrated circuits are used more and more frequently to realize many complex functions needed for applications such as telecommunications, servo control, and image processing. Testing of these ICs is much more difficult than for traditional ICs because of the integration of complex functions and synchronized interactions between blocks. Conventional IC testing methods cannot provide both high-test throughput and high test quality for these devices. At-speed signal processing by synchronized distributed subsystems is required to perform functional testing of complex mixed-signal devices. Also required is a programming style that is straightforward and allows flexible control of signal and data flow in the test subsystems.

DSP-based LSI testers can be classified as having one of two types of architecture according to the location of the signal processing units (SPU): centralized or distributed.[1] In the distributed type, SPUs are distributed among the individual subsystems. Usually, each SPU cannot manage a large amount of data and the processing speed of each SPU is slower than that of a centralized SPU. Programming is more difficult because the SPUs are not strongly coupled to the CPU, so the control layer between the CPU and the SPUs is more complicated. On the other hand, the distributed type makes it possible to process data in the subsystems and enables at-speed emulation of IC functions, which is required to test mixed-signal devices.

To meet the needs of complex mixed-signal testing, the HP 9493 mixed-signal LSI test system is based on distributed digital signal processors (DSPs). In each test subsystem is a Motorola DSP96002 chip, which runs at 32 MHz and performs 32-bit floating-point operations. The DSP modules are connected by data transmission paths for data sharing. A flexible programming language directs the DSPs to generate and analyze test signals.

The HP 9493 architecture allows digital and analog signal processing completion times on the order of microseconds to ensure the quality and throughput of dynamic signals and data operations for the device under test (DUT). Precise timing synchronization of all subsystems makes it possible to distribute operations among the DSP modules.

Compared to a memory-based test system, the HP 9493's distributed DSP architecture reduces test time and increases test coverage for complex mixed-signal devices. To generate an analog waveform, the conventional memory-based system must compute and store discrete time data for the entire waveform before generating it. This takes time and may require so much memory that the functions of a complex device may not be tested completely because of the memory cost. In contrast, the DSP-based HP 9493 prepares the discrete time data in real time using a much smaller amount of waveform memory.

Architecture

Fig. 1 shows the HP 9493 system architecture, which allows synchronous and asynchronous control of the analog and digital subsystems and the distributed DSP in each subsystem. This distributed architecture consists of a tester controller, which controls all test subsystems, a master clock subsystem, two test heads, and test subsystems. The test subsystems include digital subsystems, which generate and fetch digital patterns and signals, arbitrary waveform generator subsystems, and waveform digitizer subsystems.

In each test subsystem are a DSP module, a sequencer, and a memory block. Each DSP module has a data transmission path. The DSP modules operate on data or signals according to instructions loaded from the tester controller, and the start and stop operations are synchronized by the master sequencer or tester controller. The master sequencer precisely synchronizes the timing of the other sequencers.

The DSP96002 manages the memory block. Data can also be stored in high-speed memory in the DSP module to reduce memory access time, which increases the processing speed of the DSP96002. The sequencer in each subsystem controls address generation and the timing of data fetch or generation between the memory block and the signal input or output for memory-based testing.

The advantages of this architecture are real-time signal emulation and shared signal processing. Test throughput is more than double the capability of conventional LSI testers, and ICs can be evaluated by at-speed functional tests. Data can be transmitted between DSP modules without CPU intervention, which allows synchronous and concurrent operation and sharing of signals from the DUT.

The DSP module in the digital subsystem can fetch and generate up to 32-bit digital test data. The test data is directly connected to the data bus of the DSP96002. Data can be

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Jose Luis Huertas Díaz

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Test and Design-for-Testability in Mixed-Signal Integrated Circuits Jose Luis Huertas Díaz,2010-02-23 Test and Design for Testability in Mixed Signal Integrated Circuits deals with test and design for test of analog and mixed signal integrated circuits Especially in System on Chip SoC where different technologies are intertwined analog digital sensors RF test is becoming a true bottleneck of present and future IC projects Linking design and test in these heterogeneous systems will have a tremendous impact in terms of test time cost and proficiency Although it is recognized as a key issue for developing complex ICs there is still a lack of structured references presenting the major topics in this area The aim of this book is to present basic concepts and new ideas in a manner understandable for both professionals and students Since this is an active research field a comprehensive state of the art overview is very valuable introducing the main problems as well as the ways of solution that seem promising emphasizing their basis strengths and weaknesses In essence several topics are presented in detail First of all techniques for the efficient use of DSP based test and CAD test tools Standardization is another topic considered in the book with focus on the IEEE 1149 4 Also addressed in depth is the connecting design and test by means of using high level behavioural description techniques specific examples are given Another issue is related to test techniques for well defined classes of integrated blocks like data converters and phase locked loops Besides these specification driven testing techniques fault driven approaches are described as they offer potential solutions which are more similar to digital test methods Finally in Design for Testability and Built In Self Test two other concepts that were taken from digital design are introduced in an analog context and illustrated for the case of integrated filters In summary the purpose of this book is to provide a glimpse on recent research results in the area of testing mixed signal integrated circuits specifically in the topics mentioned above Much of the work reported herein has been performed within cooperative European Research Projects in which the authors of the different chapters have actively collaborated It is a representative snapshot of the current state of the art in this emergent field **Computer-Aided Design of Analog Integrated Circuits and Systems** Rob A. Rutenbar,Georges G. E. Gielen,2002-05-06 The tools and techniques you need to break the analog design bottleneck Ten years ago analog seemed to be a dead end 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 **Efficient Testability Design Methodology for Analog/mixed Signal Integrated Circuits** Cheng-Ping Wang,1997 Low-power HF Microelectronics Gerson A. S. Machado,1996 This book brings together innovative modelling simulation and design techniques in CMOS SOI GaAs and BJT to achieve successful high yield manufacture for low power high speed and reliable by design analogue and mixed mode integrated systems IEEE VLSI Test Symposium ,2004 Analog and Mixed-signal Test Bapiraju Vinnakota,1998 More and more chips are being designed with both analog and digital circuitry next to each other which makes testing analog circuitry even more challenging This comprehensive guide reviews all the potential testing options helping designers engineers CAD developers and researchers choose the most cost effective accurate solutions for both mixed signal and analog only testing **Information Technology** Ricardo Reis,2006-04-11 This book contains a selection of tutorials on hot topics in information technology which were presented at the IFIP World Computer Congress WCC2004 took place at the Centre de Congr s Pierre Baudis in Toulouse France from 22 to 27 August 2004 The 11 chapters included in the book were chosen from tutorials proposals submitted to WCC2004 These papers report on several important and state of the art topics on information technology such as Quality of Service in Information Networks Risk Driven Development of Security Critical Systems Using UMLsec Developing Portable Software Formal Reasoning About Systems Software and Hardware Using Functionals Predicates and Relations The Problematic of Distributed Systems Supervision Software Rejuvenation Modeling and Analysis Test and Design for Test of Mixed Signal Integrated Circuits Web Services Applications of Multi Agent Systems Discrete Event Simulation Human Centered Automation We hereby would like to thank IFIP and more specifically WCC2004 Tutorials Committee and the authors for their contribution We also would like to thank the congress organizers who have done a great job Ricardo Reis Editor QUALITY OF SERVICE IN INFORMATION NETWORKS Augusto Casaca IST INESC R Alves Redol 1000 029 Lisboa Portugal Abstract This article introduces the problems concerned with the provision of end end quality of service in IP networks which are the basis of information networks describes the existing solutions for that provision and presents some of the current research items on the subject Key words Information networks IP networks Integrated Services Differentiated Services Multiprotocol Label Switching UMTS Asian Test Symposium ,2001 *Circuits and Systems in the Information Age* Yih-Fang Huang,1997 *VLSI: Integrated Systems on Silicon* Ricardo A. Reis,Luc Claesen,2013-06-05 This book contains the papers that have been presented at the ninth Very Large Scale Integrated Systems conference VLSI 97 that is organized biannually by IFIP Working Group 10 5 It took place at Hotel Serra Azul in Gramado Brazil from 26 30 August 1997 Previous

conferences have taken place in Edinburgh Trondheim Vancouver Munich Grenoble and Tokyo The papers in this book report on all aspects of importance to the design of the current and future integrated systems The current trend towards the realization of versatile Systems on a Chip require attention of embedded hardware software systems dedicated ASIC hardware sensors and actuators mixed analog digital design video and image processing low power battery operation and wireless communication The papers as presented in Jhis book have been organized in two tracks where one is dealing with VLSI System Design and Applications and the other presents VLSI Design Methods and CAD The following topics are addressed VLSI System Design and Applications Track VLSI for Video and Image Processing Microsystem and Mixed mode design Communication And Memory System Design Cow voltage Low power Analog Circuits High Speed Circuit Techniques Application Specific DSP Architectures VLSI Design Methods and CAD Track Specification and Simulation at System Level Synthesis and Technology Mapping CAD Techniques for Low Power Design Physical Design Issues in Sub micron Technologies Architectural Design and Synthesis Testing in Complex Mixed Analog and Digital Systems *Analog VLSI* Mohammed Ismail,Terri Fiez,1994 This book presents the first comprehensive treatment of analog VLSI design for signal and information processing applications by blending the basic design concepts of both traditional and contemporary analog VLSI The breadth and level of details of topics covered are unique reflecting the birth of a new generation of analog VLSI circuits Each chapter provides basic introductory material in a tutorial manner with examples or case studies at the circuit and or system level Outstanding features of the text include coverage of the latest in analog VLSI putting students and practicing engineers on the cutting edge of this exciting field thorough coverage of topics unique to this book including low voltage BiCMOS current mode and neural information processing oversampled data converters statistical design analog testability analog CAD analog layout and analog VLSI interconnects avoids lengthy coverage of device physics and IC fabrication and goes straight to the design and applications of analog VLSI circuits extensive use of SPICE in numerous examples and problem sets worked examples from a realistic silicon chip and end of chapter problems assist reader comprehension and an instructor s manual containing a complete listing of problem solutions and SPICE netlists Tenth International Conference on VLSI Design ,1997 **Proceedings, ... International Symposium on VLSI Design** ,2000 **Integrated Circuit Design, Fabrication, and Test** Peter Shepherd,1996 All aspects of chip realization for both digital and analog circuits are covered Electronics engineers are shown how to choose appropriate technololgy and circuit architecture and plan the IC design They ll gain expert information on power consaiderations the advantages and disadvantages of each IC architecture and aspects of design for testability **Evaluation Engineering** ,1992 **Proceedings** ,1997 *An Introduction to Mixed-signal IC Test and Measurement* Mark Burns,Gordon W. Roberts,2001 Integrated circuits incorporating both digital and analog functions have become increasingly prevalent in the semiconductor industry Mixed signal IC test and measurement has grown into a highly specialized field of electrical engineering It has become harder to hire and train new

engineers to become skilled mixed signal test engineers The slow learning curve for mixed signal test engineers is largely due to the shortage of written materials and university level courses on the subject of mixed signal testing While many books have been devoted to the subject of digital test and testability the same cannot be said for analog and mixed signal automated test and measurement This book was written in response ot the shortage of basic course material for mixed signal test and measurement The book assumes a solid background in analog and digital circuits as well as a working knowledge of computers and computer programming A background in digital signal processing and statistical analysis is also helpful though not absolutely necessary This material is designed to be useful as both a university textbook and as a reference manual for the beginning professional test engineer The prerequisite for this book is a junior level course in linear continuous time and discrete time systems as well as exposure ot elementary probability and statistical concepts Chapter 1 presents an introduction to the context in which mixed singal testing is performed and why it is necessary Chapter 2 examines the process by which test programs are generated from device data sheet to test plan to test code Test program structure and functionality are also discussed in Chapter 2 Chapter 3 introduces basic DC measurement definitions including continuity leakage offset gain DC power supply rejection ratio and many other types of fundamental DC measurements Chapter 4 covers the basics of absolute accuracy resolution software calibration standards traceability and measurement repeatability In addition basic data analysis is presented in Chapter 4 A more thorough treatment of data analysis and statistical analysis is delayed until Chapter 15 Chapter 5 takes a closer look at the architecture of a generic mixed signal ATE tester The generic tester includes instruments such as DC sources meters waveform digitizers arbitrary waveform generators and digital pattern generators with source and capture functionality Chapter 6 presents an introduction to both ADC and DAC sampling theory DAC sampling theory is applicable to both DAC circuits in the device under test and to the arbitrary waveform generators in a mixed signal tester ADC sampling theory is applicable to both ADC circuits in the device under test and to waveform digitizers in a mixed signal tester Coherent multi tone sample sets are also introduced as an introduction to DSP based testing Chapter 7 further develops sampling theory concepts and DSP based testing methodologies which are at the core of many mixed signal test and measurement techniques FFT fundamentals windowing frequency domain filtering and other DSP based testing fundamentals are covered in Chapter 6 and 7 Chapter 8 shows how basic AC channel tests can be performed economicaly using DSP based testing This chapter covers only non sampled channels consisting of combinations of op amps analog filters PGAs and other continuous time circuits Chapter 9 explores many of these same tests as they are applied to sampled channels which include DACs ADCs sample and hold S H amplifiers etc Chapter 10 explains how the basic accuracy of ATE test equipment can be extended using specialized software routines This subject is not necessarily taught in formal ATE tester classes yet it is critical in the accurate measurement of many DUT performance parameters Testing of DACs is covered in Chapter 11 Several kinds of DACs are studied including traditional binary weighted resistive ladder pulse

with modulation PWM and sigma delta architectures Traditional measurements like INL DNL and absolute error are discussed Chapter 12 builds upon the concepts in Chapter 11 to show how ADCs are commonly tested Again several different kinds of ADC s are studied including binary weighted dual slope flash semi flash and sigma delta architectures The weaknesses of each design are expalined as well as the common methodologies used to probe their weaknesses Chapter 13 explores the gray art of mixed signal DIB design Topics of interest include component selection power and ground layout crosstalk shielding transmission lines and tester loading Chapter 13 also illustrates several common DIB circuits and their use in mixed signal testing Chapter 14 gives a brief introduction to some of the techniques for analog and mixed signal design for test There are fewer structured approaches for mixed signal DfT than for purely digital DfT The more common ad hoc methods are explained as well as some of the industry standards such as IEEE Std 1149 1 and 1149 4 A brief review of statistical analysis and Gaussian distributions is presented in Chapter 15 This chapter also shows how measurement results can be analyzed and viewed using a variety of software tools and display formats Datalogs shmoo plots and histograms are discussed Also statistical process control SPC is explained including a discussion of process control metrics such as Cp and Cpk Chapter 16 examines the economis of production testing The economics of testing are affected by many factors such as equipment purchase price test floor overhead costs test time dual head testing multi site testing and time to market A test engineer s debugging skills heavily impacts time to market Chapter 16 examines the test debugging process to attempt to set down some general guidelines for debugging mixed signal test programs Finally emerging trends that affect test economics and test development time are presented in Chapter 16 Some or all these trends will shape the future course of mixed siganl test and measurement   *10th Anniversary Compendium of Papers from Asian Test Symposium* ,2001   **International Test Conference, 1993** ,1993   **VLSI Circuits and Systems** ,2005

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