A General Purpose Design-For-Test Methodology at the Analog-Digital Boundary of Mixed-Signal VLSI

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Received September 1, 1995; Revised January 12, 1996
Editors: B. Kaminska and B. Courtois

Abstract. A general-purpose modular-based scan chain between the analog-digital boundary of a mixed analog/digital design is proposed. This general-purpose Design-For-Test methodology is oriented towards the test of the mixed-signal modules within the design. Implementing this structure improves the controllability and observability of these modules and the reusability of the test software at a minimum cost.

Keywords: mixed-signal DFT, mixed-signal boundary scan, modular mixed-signal test

1. Introduction

For current mixed-signal designs, no well-defined and efficient Design-For-Test (DFT) methodology for the analog and mixed-signal blocks exists. Testing the digital logic can be done with mature digital test techniques such as combinational ATPG [1] and built-in-selftest (BIST) for embedded RAMS and ROMS [2]. Testing the analog part and in particular the AD-DA conversions is still a challenge. Not only every test engineer has his own way of solving these problems, but even test strategies from the same engineer created for designs with different functionalities can differ completely. It is clear that this methodology does not encourage reusability. As time-to-market is heavily under pressure it is no longer acceptable to generate from scratch new DFT and test software for each new design.

This paper proposes a general DFT methodology for testing the analog part, referred to as ASCAN, concentrating on the digital-analog boundary.

The ASCAN is designed to facilitate both characterization and production testing of complex mixed-signal designs. In particular designs with a large number of analog-digital interface signals with complex dependencies will benefit from this Design-For-Test methodology.

Traditionally mixed-signal Design-For-Test techniques are developed ad-hoc bases by altering or reusing the digital part. This often resulted in a limited observability and controllability of the analog and mixed-signal portion leading to high test program development efforts with poor results.

Furthermore this methodology often could not offer the flexibility necessary for both characterization and production test optimization of dynamic blocks.

1.1. Characterization

In the design phase of a component, maximal controllability and observability is required, not only for exploring all corners of the specification, but also for diagnostics. All conditions capable of affecting the test result must be fully under control.

As the sample size and the frequency content of a waveform are highly deterministic for the quality and accuracy of a dynamic measurement (e.g., quantization
noise, harmonic distortion), it is essential they can be chosen without any constraints.

1.2. Production Test Time

The production test time optimization process requires the same flexibility as described in 1.1, but for different reasons. The goal of this process is to have maximal coverage at minimum cost in test time. A classical example of test time reduction is to make all frequency dependent measurements with one multitone. Better coverage can be attained by carefully choosing the most critical testpoint(s) of the specification.

ASCAN offers a general interface for all possible mixed signal building blocks, putting no constraints on the nature of the input stimuli whatsoever. The test stimuli can be anything a test engineer can imagine, leaving the processing of the data to the external hardware linked with a wide range of powerful hardware and software tools.

2. Divide and Conquer

In order to be successful, a general-purpose mixed-signal DFT scheme must satisfy following requirements:

1. The methodology must encourage test software reusability.
2. It must be possible to determine fault coverage of a test setup and to predict the response of given stimuli by simulation.

Modular parametric testing is still the only realistic way to achieve all goals and to maximize reusability of the existing know-how regarding previous designs as well as the test software:

—A lot of work has been spent to determine the fault coverage of analog circuits [3–5] but as mixed signal designs evolve towards higher complexities with high transistor counts, simulation times become too high for performing fault simulations on complete designs. It is feasible, though, to perform this exercise on typical building blocks like filters, amplifiers and DA-converters and to maximize the coverage for these modules with a minimum cost. The effort spent in terms of fault simulation and development of test software can then be reused for devices using the same analog modules.

—Some DFT methodologies concentrate on altering the analog circuit for attaining maximal coverage, in similarity with the ATPG method for digital circuits. This strategy has not been very successful. Analog designers don't feel comfortable adding extra hardware into critical blocks because of parasitic effects on the circuit. Even when this test hardware can be implemented, there would still be a necessity to write parametric test programs in function of system specifications for characterization purposes during the design/qualification phase. Also the tendency to use Statistical Process Control (SPC) throughout all steps of the production flow of a product, correlating data between the production stages, forces the test engineer to orient the test program towards parametric testing.

An analog-bus based approach, together with a structure separating digital and analog part with Boundary Scan cells controlled via the IEEE 1149.1 TAP controller has already been proposed [6]. This technique is satisfactory for the analog part, but the Boundary Scan cells do not allow operation of converters at functional speed and create a large overhead in number of gates when a lot of signals go from the digital to the analog part and vice versa and/or Boundary Scan is not a system requirement. The proposed chain considers all signals as equal and as a consequence, is not suited for implementing a modular-based test strategy.

In present mixed-signal designs the digital part is often reused for generating and/or capturing analog signals to test the analog part and in particular for the digital-analog interface. This methodology has a number of disadvantages:

—Poor flexibility in generating test signals. A digital function controlling a D/A-converter often generates dedicated waveforms without any controllability over phase and frequency content of that waveform. Furthermore, data produced by a A/D-converter can be processed by a digital signal processor which alters or masks important properties of the initial data. This puts a burden on characterization and troubleshoot possibilities and production test time reduction. In addition the reusability is often very low. Modern DSP-based test systems allow complex time-saving test techniques [7], but they can only be applied when the input of the block-under-test is fully controllable.