Testing of Digital Systems

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http://www.ida.liu.se/~zebpe/teaching/test/index.html
Contents

☞ Basic principles and practice of digital system testing.

☞ Design for testability techniques.

☞ Integration of test consideration with system synthesis.

☞ Testing of system-on-chip.
Course Organization

☞ General lectures.
  - Lecture notes and selected papers.

☞ Seminars and discussions, led by the participants.
  - Seminar notes by the participants.
Lecture I: Introduction

1. Basic definition and terminology
2. Classification of test
3. Test process
4. Test cost and its reduction
Design versus Test
What is Testing?

☞ Process of exercising a product and analyzing its resulting response to check whether faults are introduced during the *manufacturing* or *operation* phase.

☞ Process of exercising a product and analyzing its resulting response to check whether it *functions* correctly.

☞ Process of determining whether a product functions correctly.
Hardware Life Cycle

- Specification
- Design
- Implementation
- Manufacturing
- Production Test
- System Integration
- System Test
- Operation and Maintenance

- Validation
- Verification
- Review
- Inspection
- Simulation

- Test Preparation

- Testing
Causes of Incorrect Function of Digital Systems

- Design errors — usually consistent

- Fabrication (manufacturing) errors
  - often consistent, e.g., wrong components
  - usually operator errors

- Fabrication (manufacturing) defects
  - inconsistent, e.g., impurity of materials

- Physical failures
  - wear-out
  - environmental factors

Physical faults
Classification of Physical Faults

☞ Permanent — always present after their occurrence.

☞ Intermittent — existing only during some intervals.

☞ Transient — a one-time occurrence caused by a temporary change in some environmental factor.
Another Classification

- Logic (functional) faults — the logic function of CUT (circuit under test) is wrong.

- Parametric — the magnitude of a CUT parameter is changed (e.g., power and current).
Principles for Digital Test
A Board Testing Example
Test Head Fixtures

- Edge-connector — via the normal input/output pins.

- Bed of nails.

- Wafer prober — a set of micro-probes arrange so as to make contact with the bonding pads of a chip.
  - Bare chip test for known-good die (for MCM application).
  - Wafer-level screening.

- Probes:
  - Mechanical probe.
  - Electron-beam probe.
Main Difficulties in Testing

- Miniaturization -> Physical access difficult or impossible.
- Increasing complexity -> Large amount of test data.
- Number of access ports remains constant -> Long test application time.
- High speed -> High demand on tester’s driver/sensor mechanism and more complicated failure mechanism.

-> Testing accounts up to 50% of product development efforts.

☞ The key to successful testing lies in the design process.
Design for Testability (DFT)

☞ To take into account the testing aspects during the design process so that more testable designs will be generated.

☞ The design is changed to make it more testable.

☞ Advantages of DFT:
- Reduce test efforts.
- Reduce cost for test equipments (ATE).
- Shorten turnaround time.
- Increase product quality.
**Test vs. Diagnosis**

- **Test** — Detection of faults.

- **Diagnosis** — Detection and location of faults (fault site and fault type).
  - Repair.
  - Manufacturing process optimization (reduce manufacturing errors).
  - Re-design.

- **Cause-effect analysis** (external fault location):
  - Build a fault dictionary.
  - Use dictionary look-up to determine the possible faults.

- **Effect-cause analysis** (internal fault location): based on the erroneous response, determine directly the faults that could produce it.
  - Ex. guided-probe testing.
Types of Testing

- Production (manufacturing) test — test individual products to check whether faults are introduced during the manufacturing phase.

- System test — test a product in its operating environment to ensure that it works correctly when interconnected with other components.

- Operation and maintenance test — test a product in the field for diagnostic or "preventive" purpose.

- Prototype test — testing to check for design faults during the system development phase. Diagnosis is required.

- Different levels: chip, board, or system.

- On-line, off-line, or concurrent testing.
Types of Testing (Cont’d)

• Functional test — validating the correct operation with respect to its functional specification.

• Structural test — testing of structural defects, such as open, stack-at, and short-circuit.

• Static v. at-speed testing.

• In-circuit test — the tester gains access to the internal nodes.

• Parametric test — testing of technology-dependent parameters, such as power consumption.

• IDDq test — testing the entire circuit by making analog measurements of IDD which is the current flows in a CMOS circuit when all nodes are in the quiescent state.
Test Classification
Test Classification (Cont’d)
A Typical Testing Process

1. Test Strategy Selection
2. Test Generation
3. Test Evaluation
4. Test Application
5. Analysis and Diagnosis

- Manufacturing
- Design
- Test Mechanism
Composition of Testing Costs

- Cost of test equipment (hardware):
  - A test controller (usually a computer).
  - Interface drivers/receivers and cable-connections.
  - System of probe-contacts.
  - A controlled environment.

- Cost of software supports:
  - Test pattern generation programs.
  - Test evaluation procedures (fault simulation and analysis).

- Testing time
  - Test development time.
  - Test application time (maybe very long for "burn-in" purpose).
Cost of Finding Defects ("Rule of Tens")

- Chip: $0.50
- Board: $5.00
- System: $50.00
- Field: >$500.00
Methods for Test Cost Reduction

- DFT simplifies/automates test pattern generation, which decreases development cost and lead times.

- DFT facilitates more efficient production test, i.e., lower fault levels and shorter test application times.

- BIST can reduce the need for expensive test equipment and supports field test.

- Better design verification reduces the need for functional test which has long test application time.

- Statistics-based methods reduces overall test cost.
Testing is an expensive and complex task, and is becoming more difficult with the development of more complex chips, especially systems-on-chip.

It takes typically 30% of the total production cost.

Hardware testing is mainly used to find physical faults introduced during the manufacturing and operation phases.

Testing does not guarantee the absence of faults!