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.
  - M. Abramovici, M. A. Breuer and A. D. Friedman, “Digital System Testing and Testable Design,” Computer Science Press, 1990.
  - 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

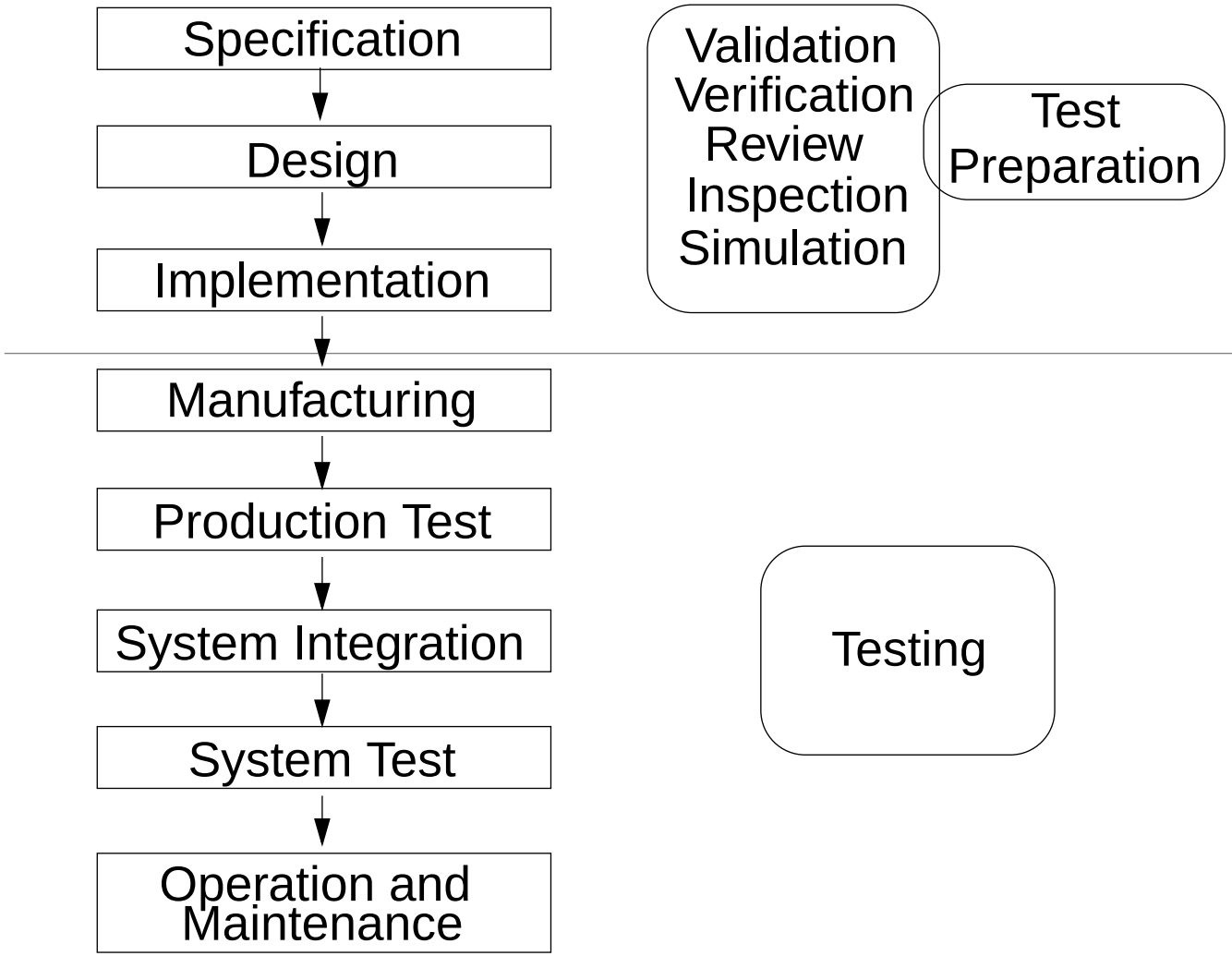
What is Testing?

- 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



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 cased 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 filed for diagnosis 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.

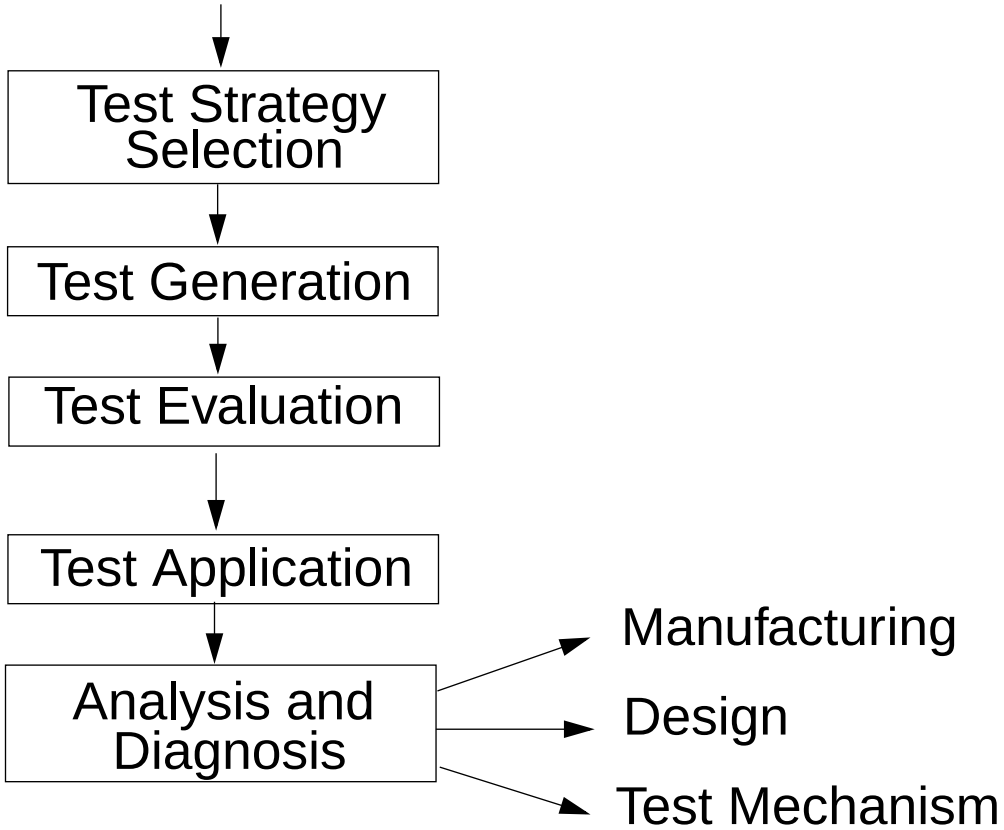
Types of Testing (Cont'd)

- 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



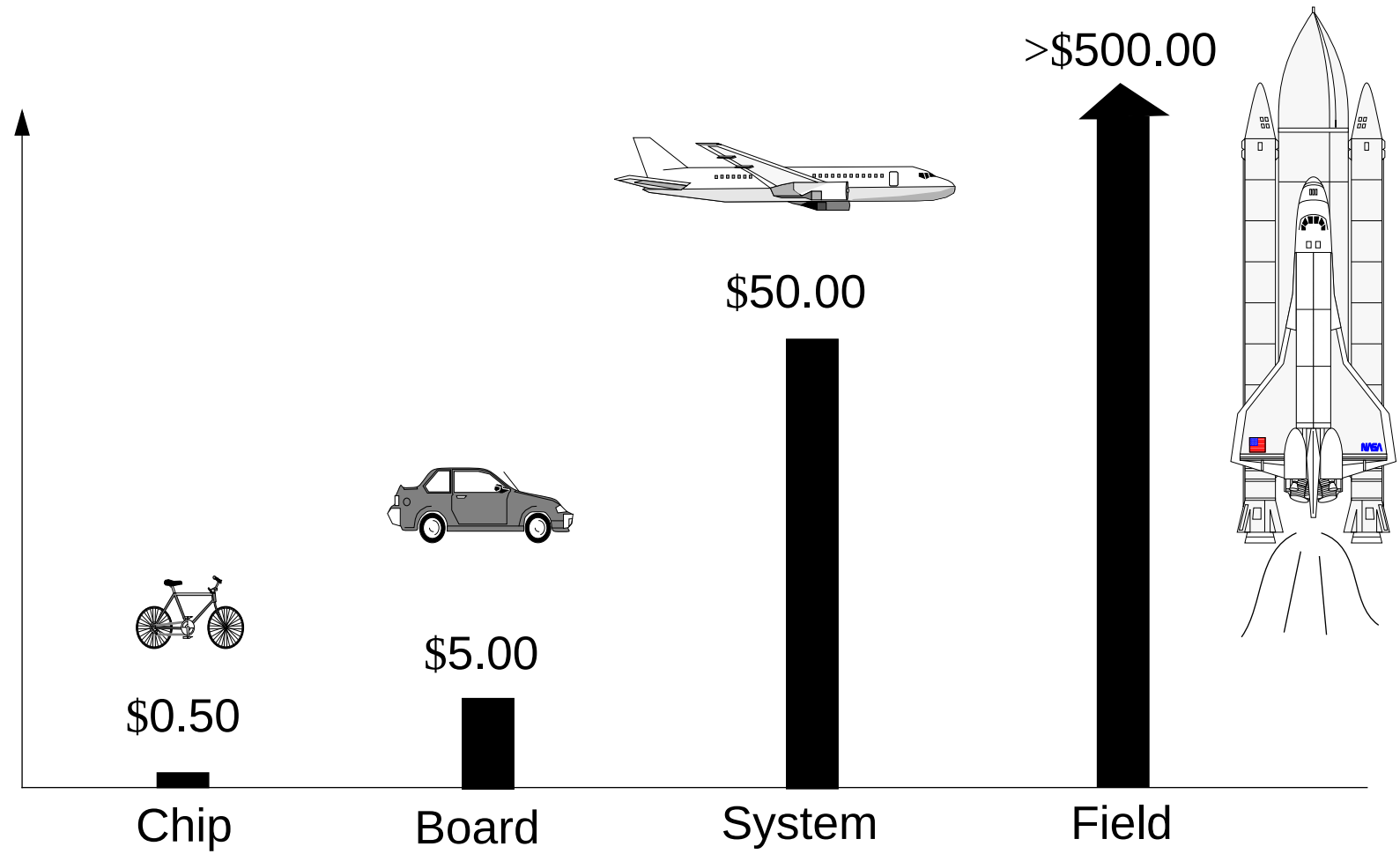
Composition of Testing Costs

- 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”)



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.

Summary

- 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 absent of faults!