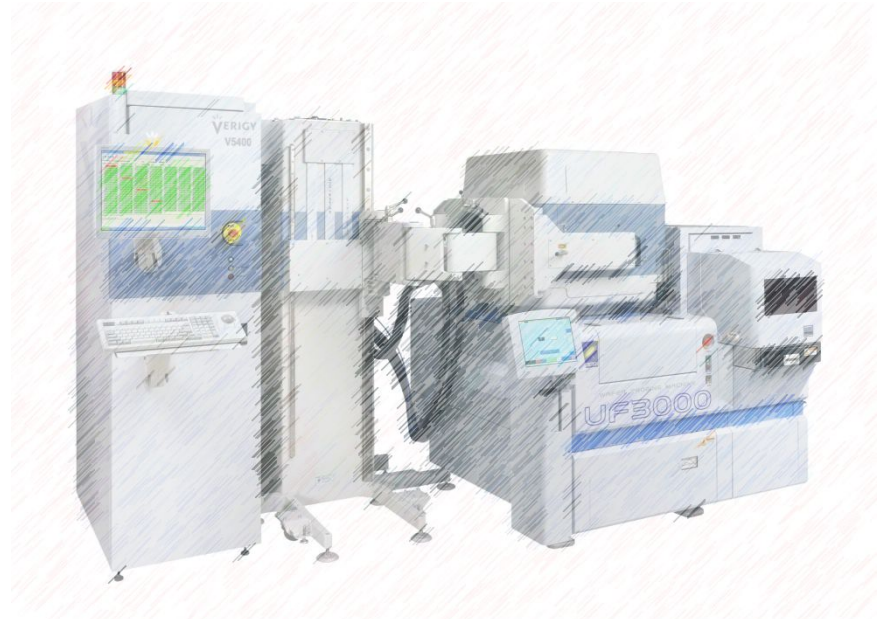


Introduction

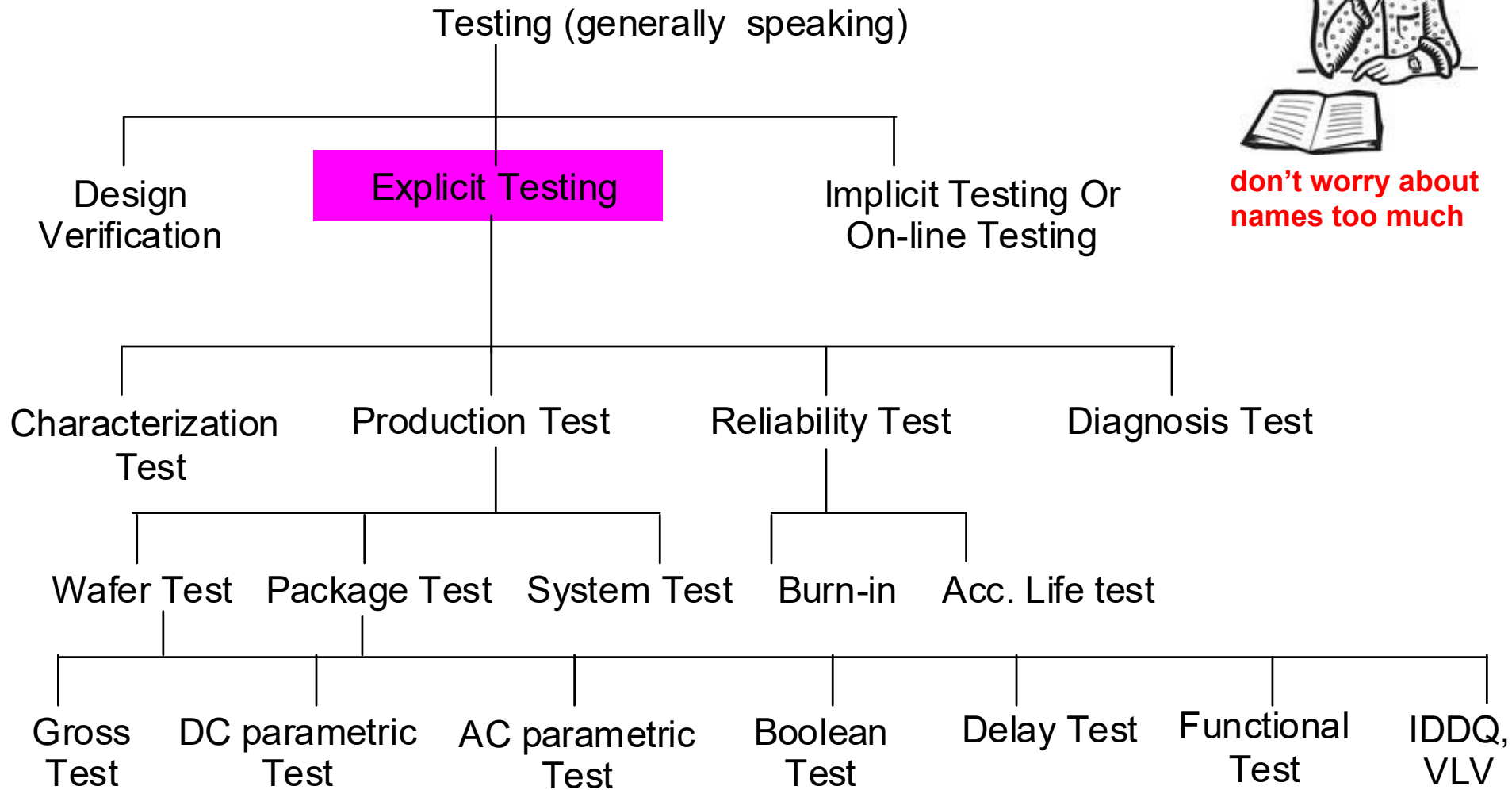
- What Is Testing
- Types of Testing
- Test Quality
- Test Economics
- Issues in Testing
- Conclusion



Types of Testing



don't worry about
names too much



Why So Many Tests?

- Design errors → *Design Verification*
 - ◆ Logic design errors, physical design errors
- Manufacturing Defects → *Explicit Testing*
 - ◆ Mask problems, lithography problem
 - ◆ Particles or scratches
 - ◆ Bad manufacture recipe
- External or Environmental Disturbance → *Implicit Testing*
 - ◆ Electromagnetic interference
 - ◆ Alpha particles
 - ◆ Power supply disturbance
- Wear out → *Reliability Testing*
 - ◆ Electromigration
 - ◆ Corrosion

Focus of class

Because There Are Many Different Problems!

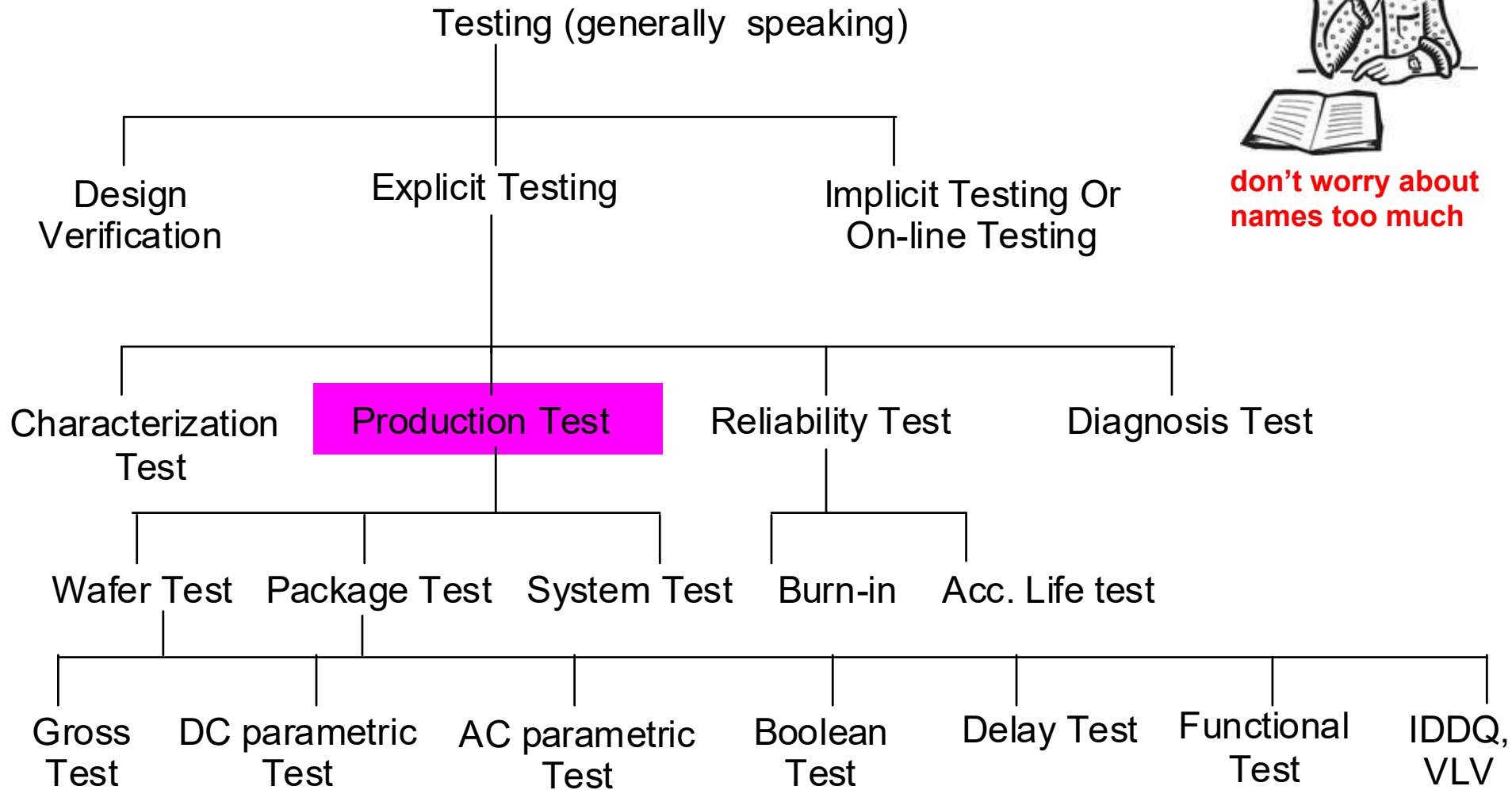
Classification of Explicit Testing

- According to **purposes**
 - ♦ **Production test**: for volume production
 - ♦ **Characterization test**: for prototype IC, silicon debug
 - ♦ **Reliability test**: for reliability defects
 - ♦ **Diagnosis test**: for identify defect location
- According to **stages**
 - ♦ **Wafer test** (aka. **Wafer sort, wafer probe**): on wafer
 - ♦ **Package test** (aka. **Final test**): after packaging
 - ♦ **System test**: in system
- According to **test techniques**
 - ♦ **DC parametric test**: V_{OH}/V_{OL}/V_{IH}/V_{IL} ...
 - ♦ **AC parametric test**: rise/fall time, operation frequency ...
 - ♦ **Boolean test** : apply test patterns at low speed for DC faults
 - ♦ **Delay test**: apply test patterns at fast speed for delay faults
 - ♦ **Functional test**: apply design verification patterns
 - ♦ **IDDQ test**: measure quiescent power supply current
 - ♦ **Low voltage test**: test at reduced power supply voltage

Types of Testing

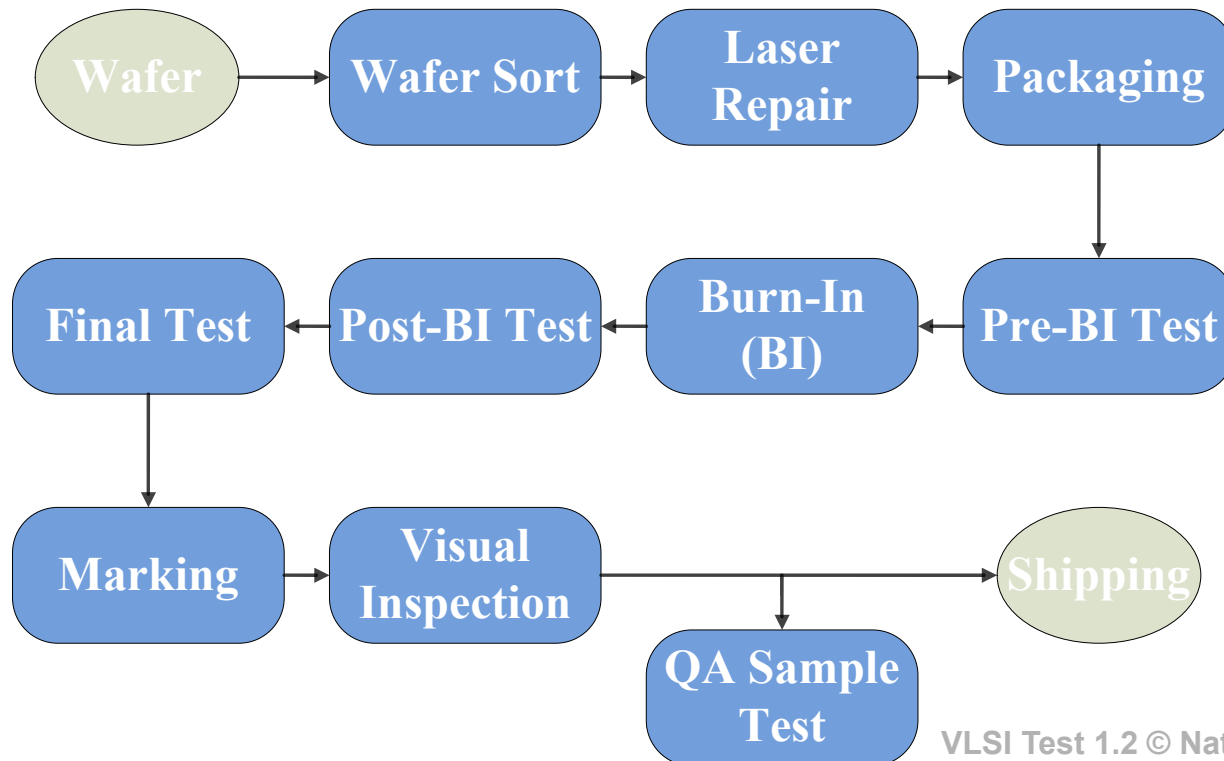


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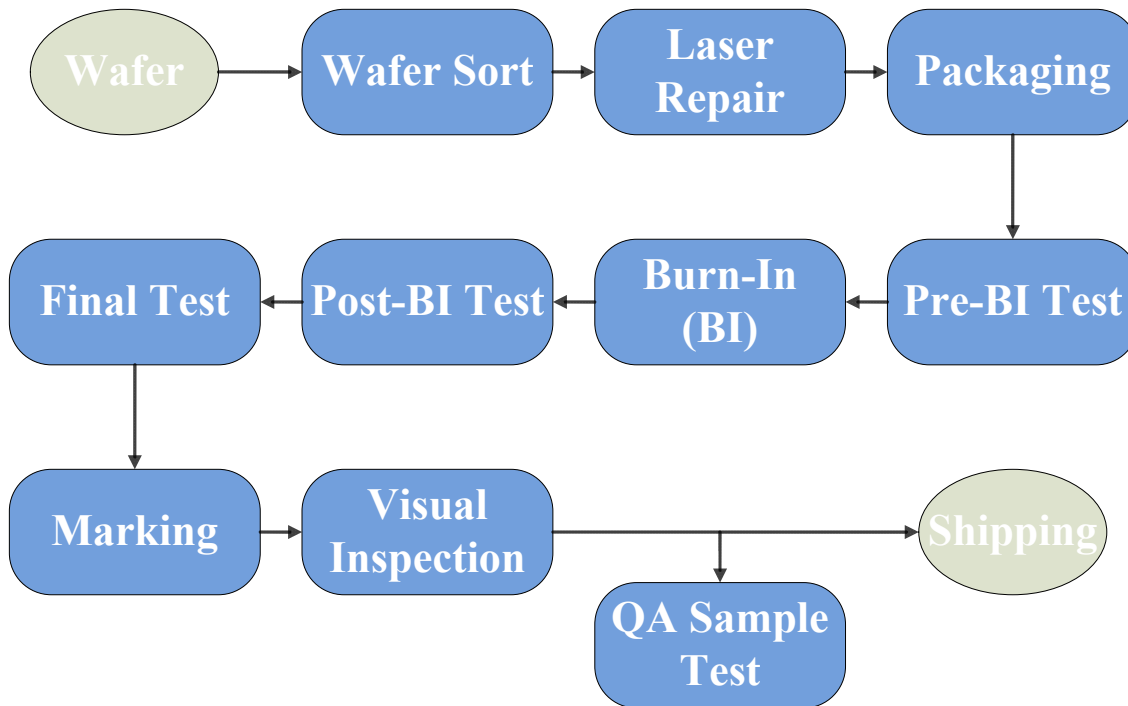
Production Tests

- Purposes:
 - ♦ 1. Enforce quality requirements before selling to customers
 - ♦ 2. Sort parts for different specifications
 - * e.g. different speeds of CPU
- Example: a typical **production test flow**
 - ♦ actual flow modified according to **test cost** and **test quality** requirements



Food for Thought, FFT

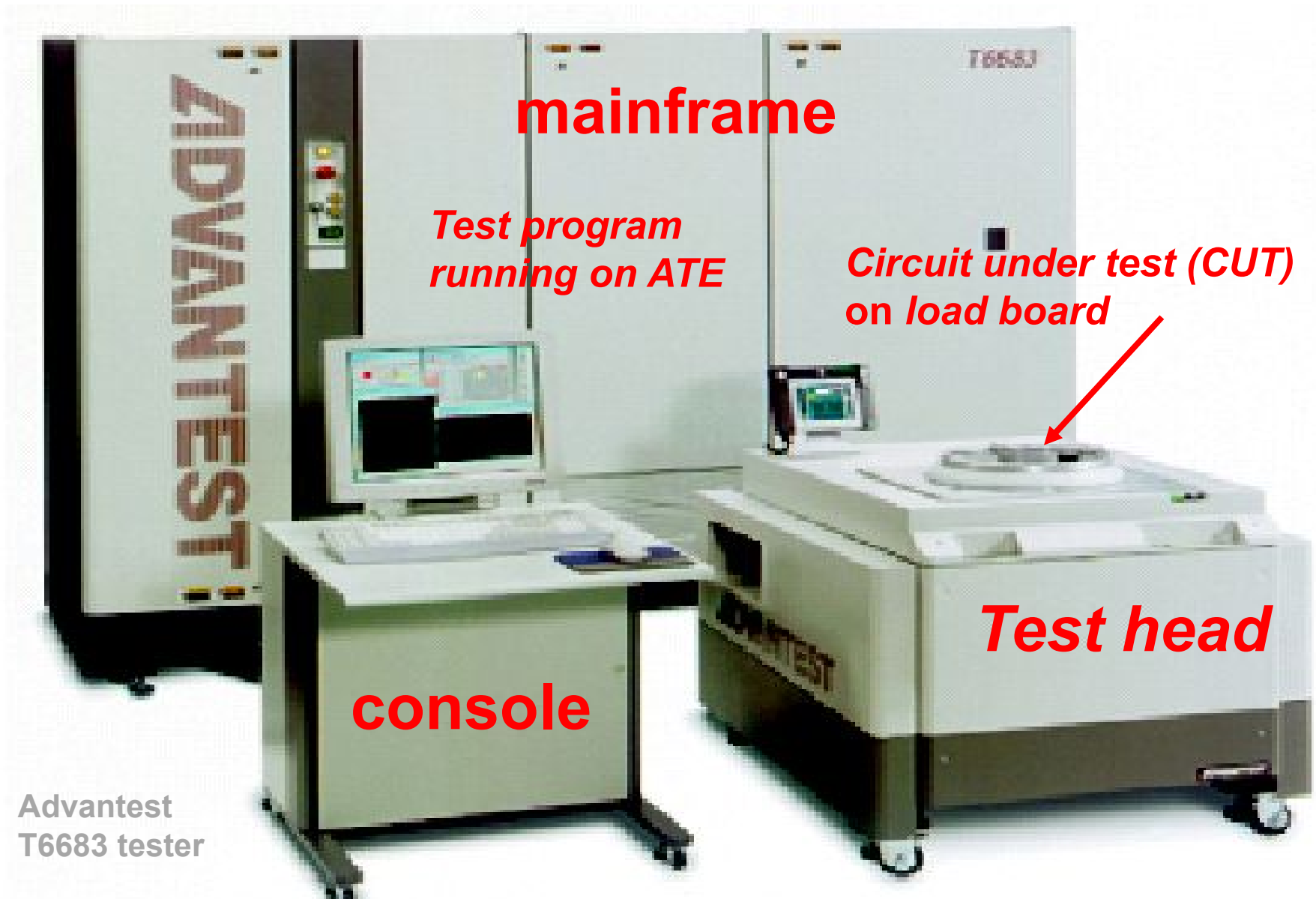
- Q: If we already have wafer test, why package test again?



Production Test Floor

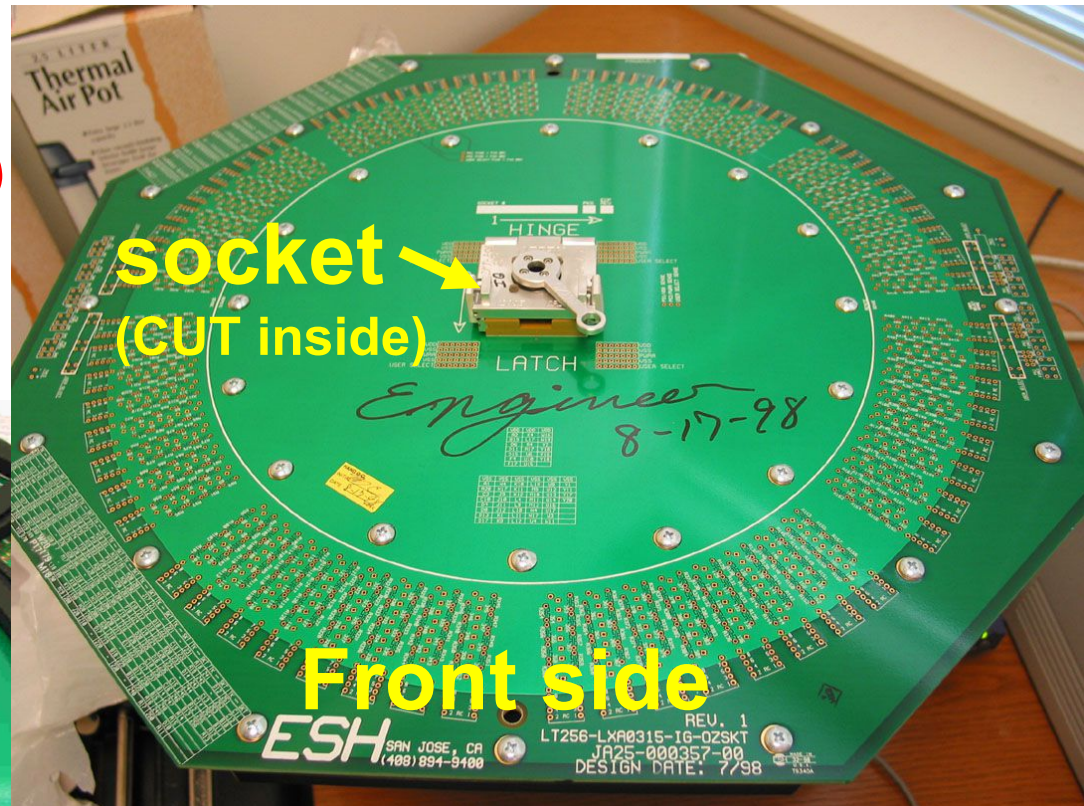
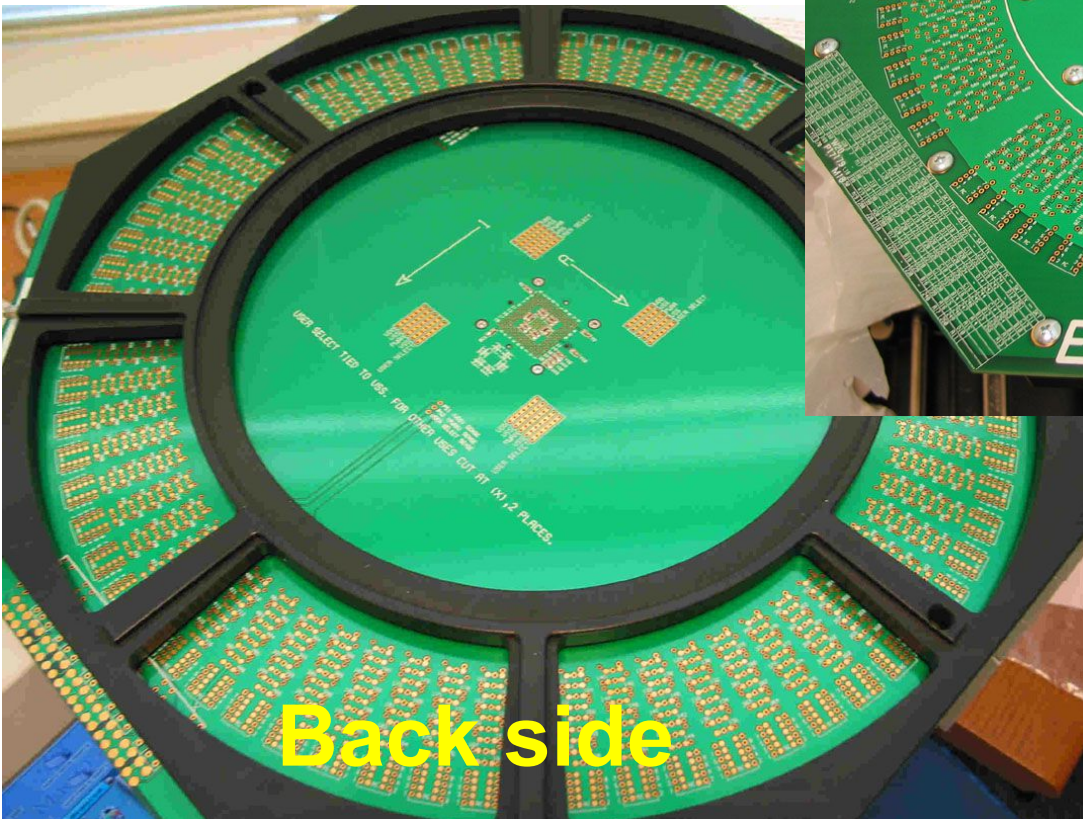


Automatic Test Equipment (ATE), Tester



Load Board

- Test fixture to interface
 - ♦ ATE and
 - ♦ *circuit under test (CUT)*



Handler

- Robotic arm (inside) for moving packaged IC
- <Video demo>

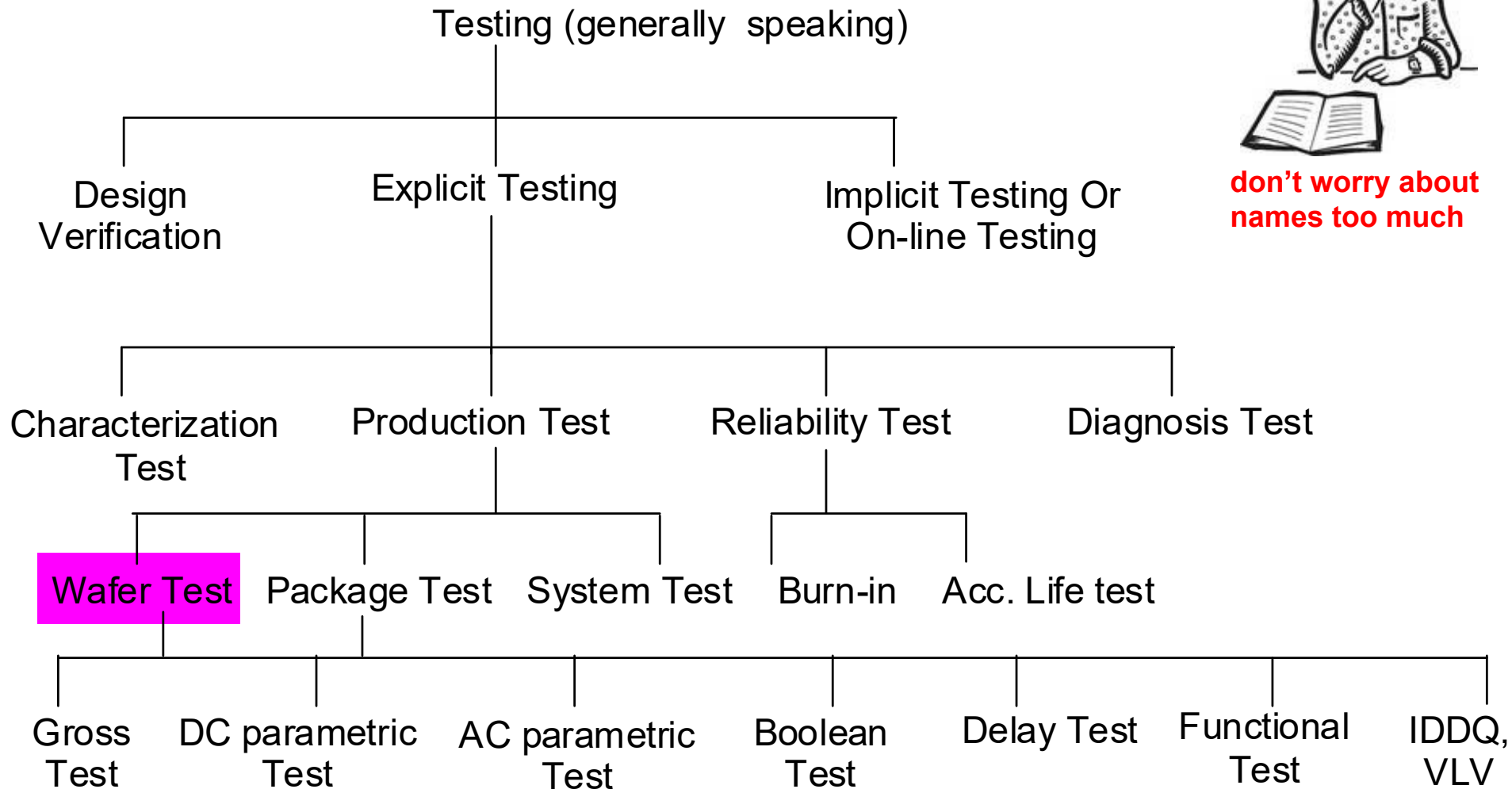


Advantest
M4541A handler

Types of Testing



don't worry about
names too much



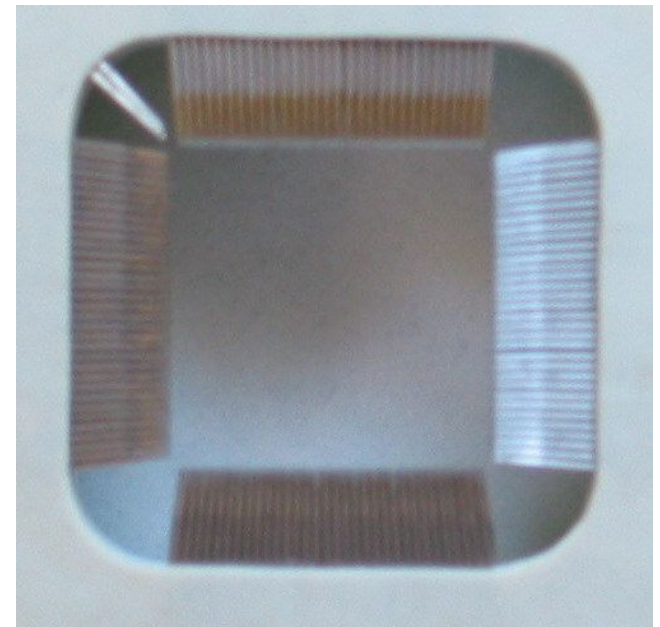
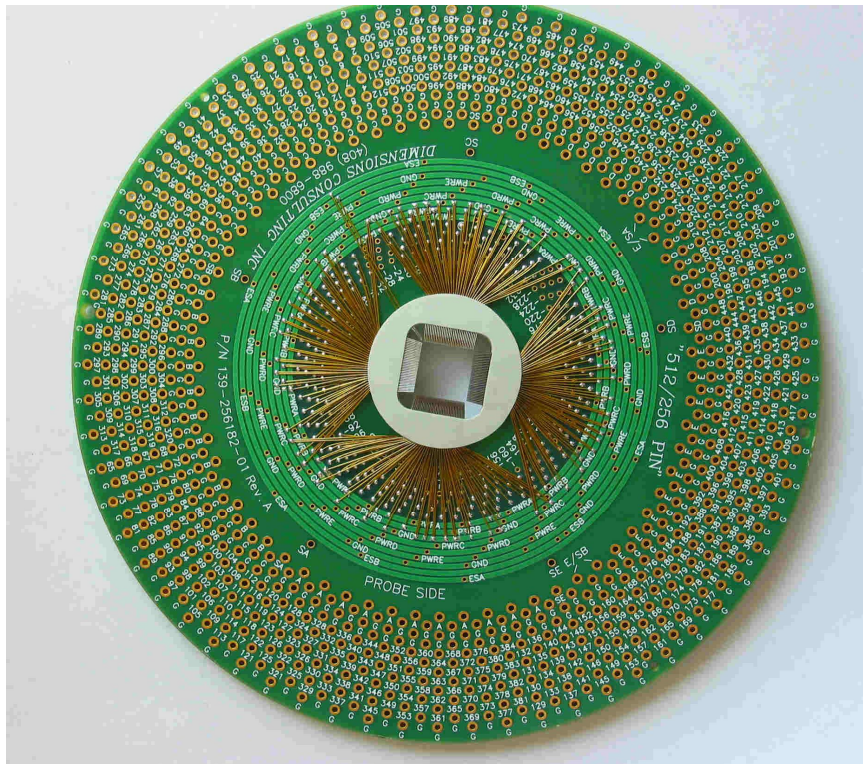
Wafer Test Setup

- Source: Verigy.com



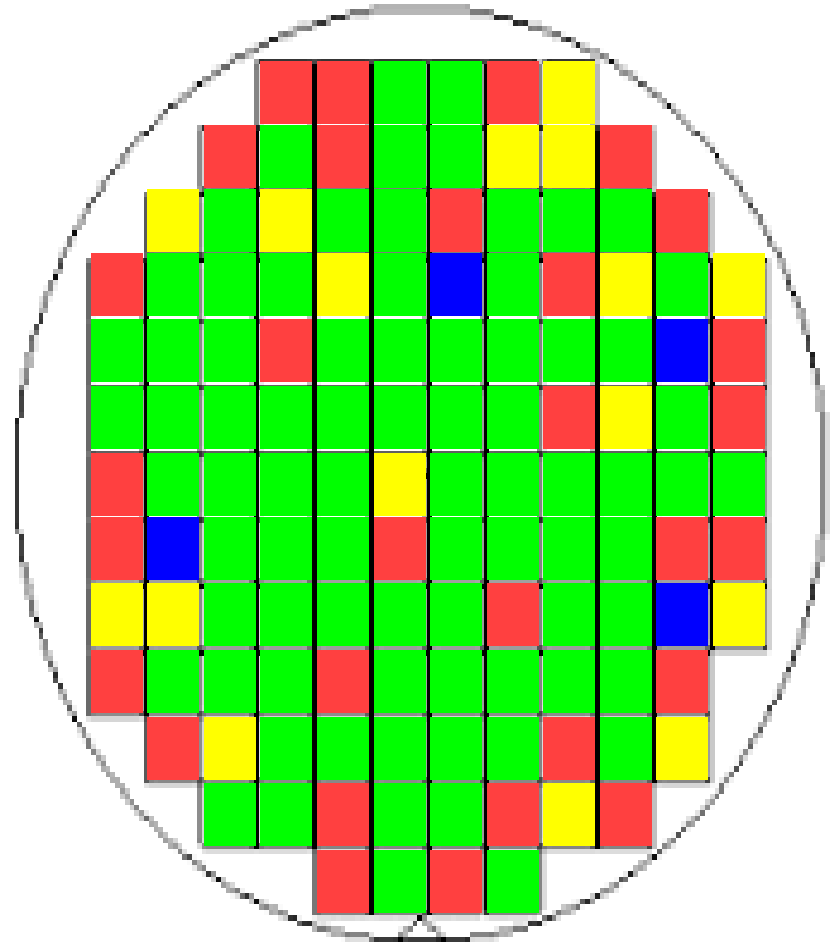
Probe Card

- Test fixture to interface load board and die
- Signal integrity is a big concern
 - ♦ Many **tiny needles** contacting die, cannot probe at fast speed
 - ♦ Must carefully balance inductance and capacitance of each pin
 - ♦ Need regular **cleaning** after a numbers of **touch downs**
- Probe card wears out quickly so it should be replaced regularly



Wafer Map

- Why we call it *wafer sort*?
- **Wafer map** shows test results
 - ♦ Die are sorted into different **Bins**
- Example:
 - ♦ **Bin #1:** PASS ALL
 - ♦ **BIN #2:** FAIL FUNCTION test
 - ♦ **BIN #3:** FAIL IDDQ test
 - ♦ **BIN #4:** FAIL DC parametric test
- Wafer map very useful for
 - ♦ pass/fail decision
 - ♦ diagnosis
 - ♦ yield improvement



Yield=Bin#1/total = 78/130=60%

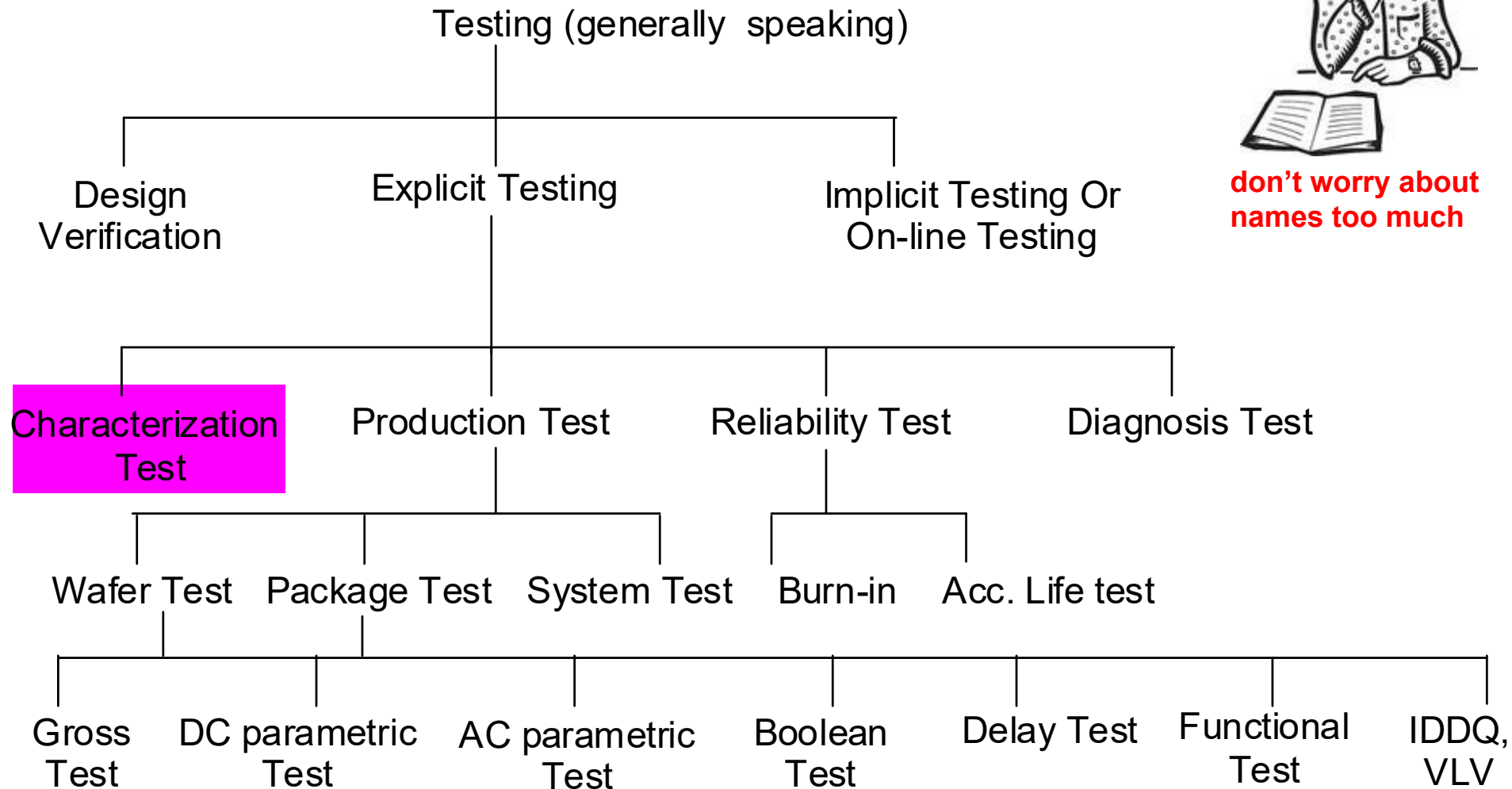
Video Clip

- You can see a typical production test environment
- youtube video
 - ◆ “DELTA Test solutions since 1976”
 - ◆ <https://www.youtube.com/watch?v=yKI71IX8Zc0>
- Terminology
 - ◆ Probe Station = Wafer prober
 - ◆ Component test = Package test
 - ◆ Electro Anti-static

Types of Testing



don't worry about
names too much

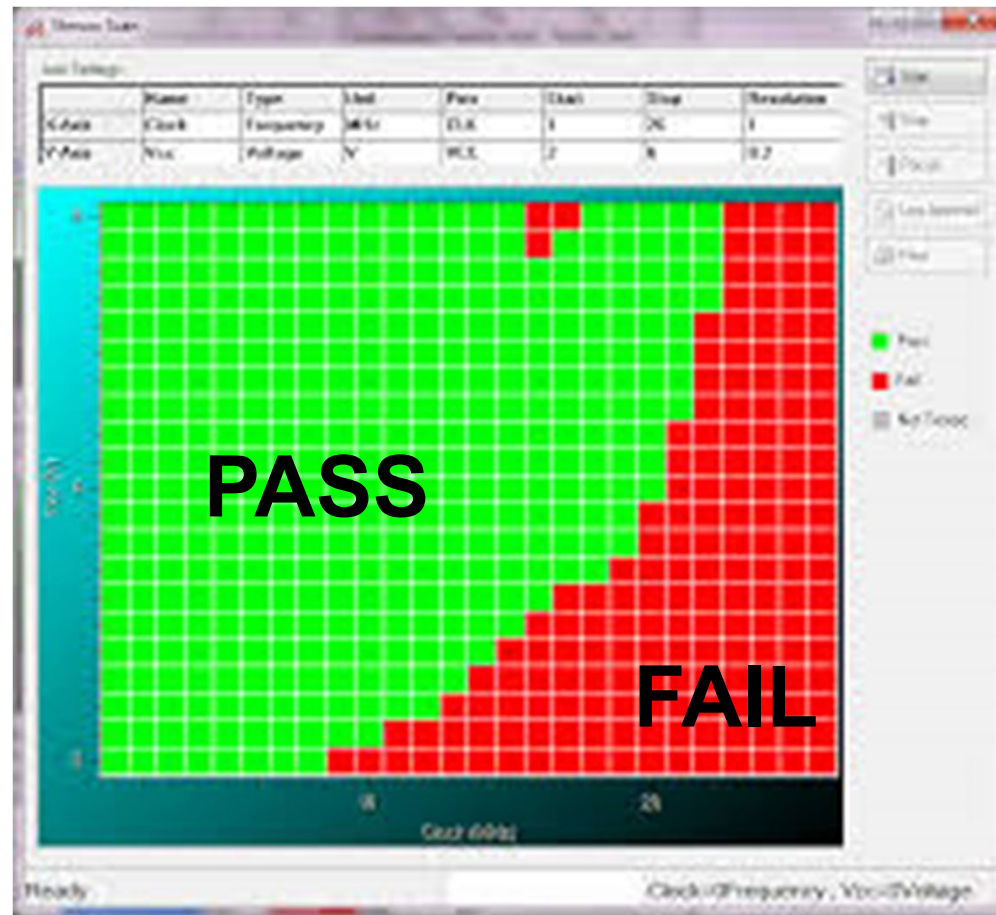


Characterization Tests

- Test a small amount of prototype IC very thoroughly
 - ◆ Test cost and test time are not big concerns
- Purpose of characterization test
 - ◆ 1. Verify IC **function** is same as design (**silicon debug**)
 - ◆ 2. Confirm IC **specifications** under different **test conditions**
 - * Specifications: speed, VOH/VOL, rise/fall time ...
 - * Conditions: VDD, Temperature ...
 - ◆ 3. Developing **test program** for production test
 - * Determine Pass/Fail limits

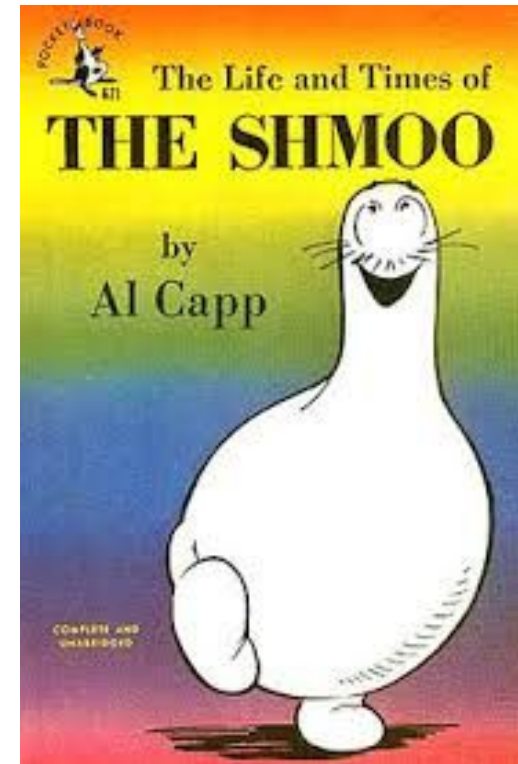
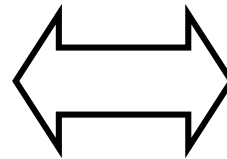
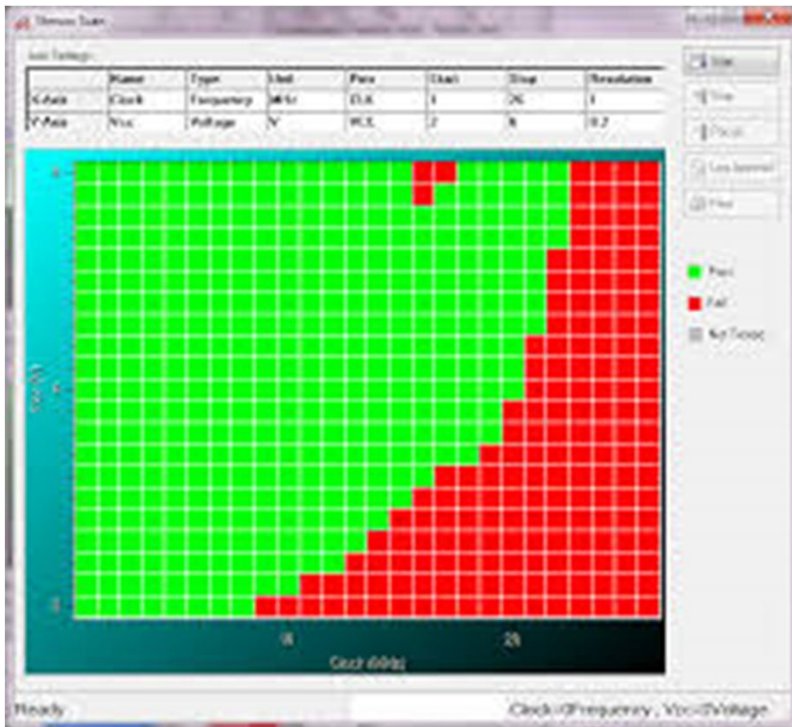
Shmoo Plot

- Graphical display of CUT test results under different **test conditions**
- Example: clock period vs. VDD
 - ♦ Green = PASS ; Red = FAIL



Why Shmoo?

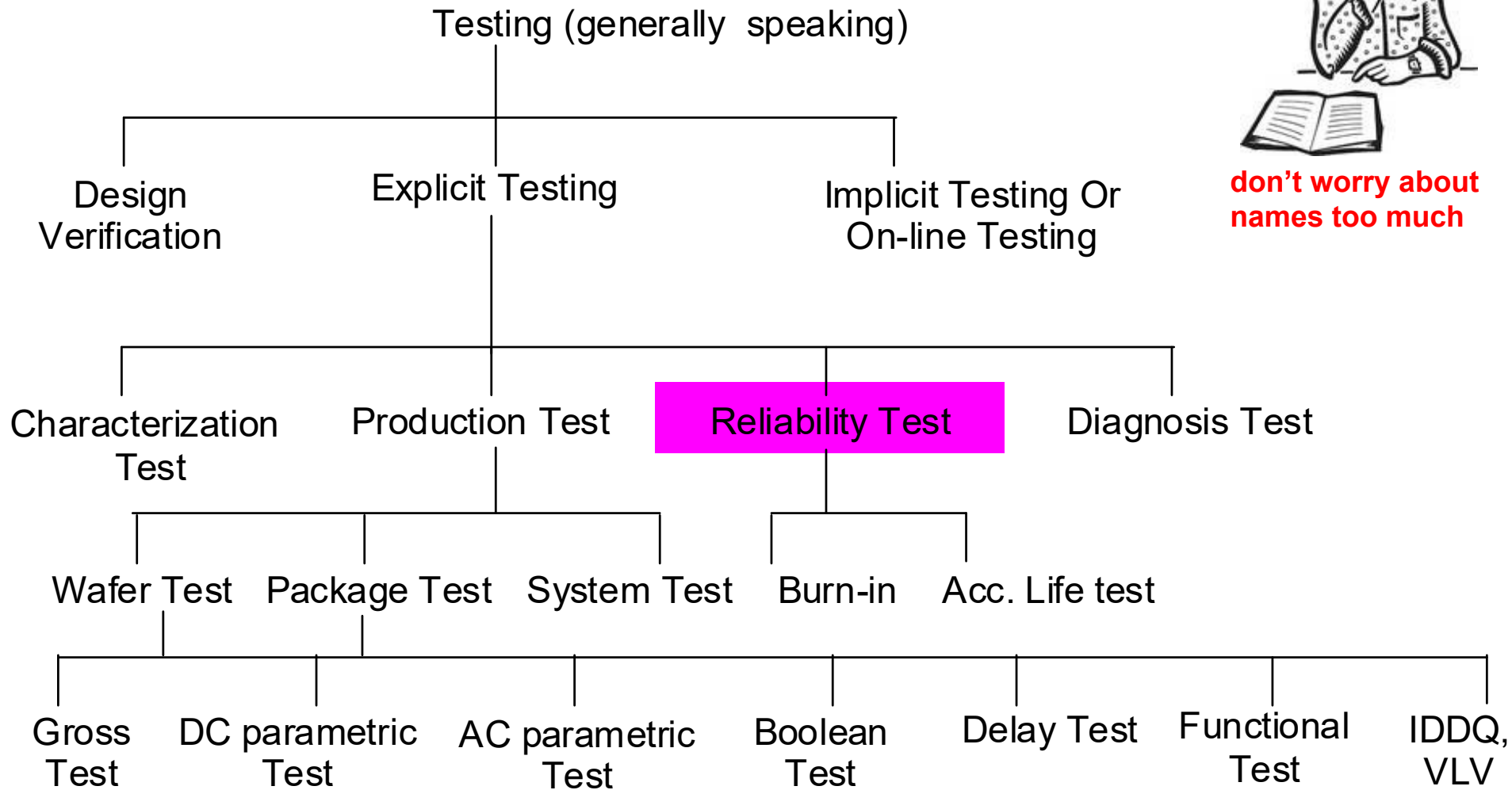
- Funny shape resembles a cartoon character: shmoo
 - ♦ Youtube Video: 1979 NBC Cartoon



Types of Testing

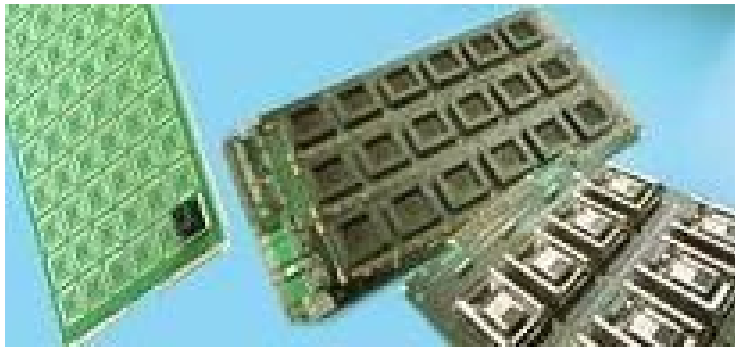


don't worry about names too much



Reliability Tests

- **Burn-in**
 - ◆ Goal: screen out *infant mortality* (aka. *Early-life failure*)
 - ◆ Method: raised temperature and voltage for hours or days
 - * **cook IC in oven!**
 - ◆ Very costly. Only applied to expensive IC
- **Accelerated life test**
 - ◆ Goal: estimate life time of IC
 - ◆ Method: burn-in until IC are dead
 - ◆ Only applied to sampled IC



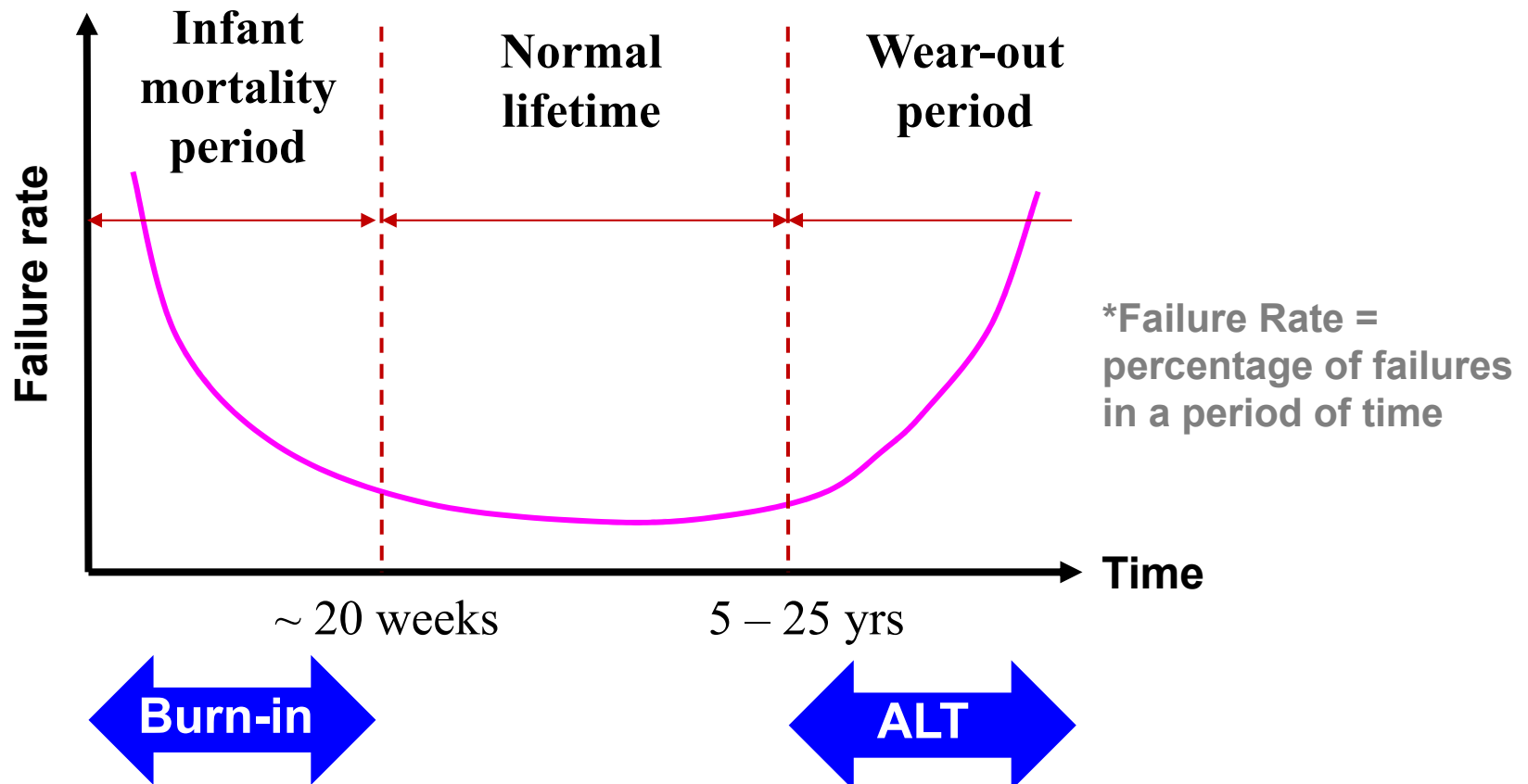
Burn-in board



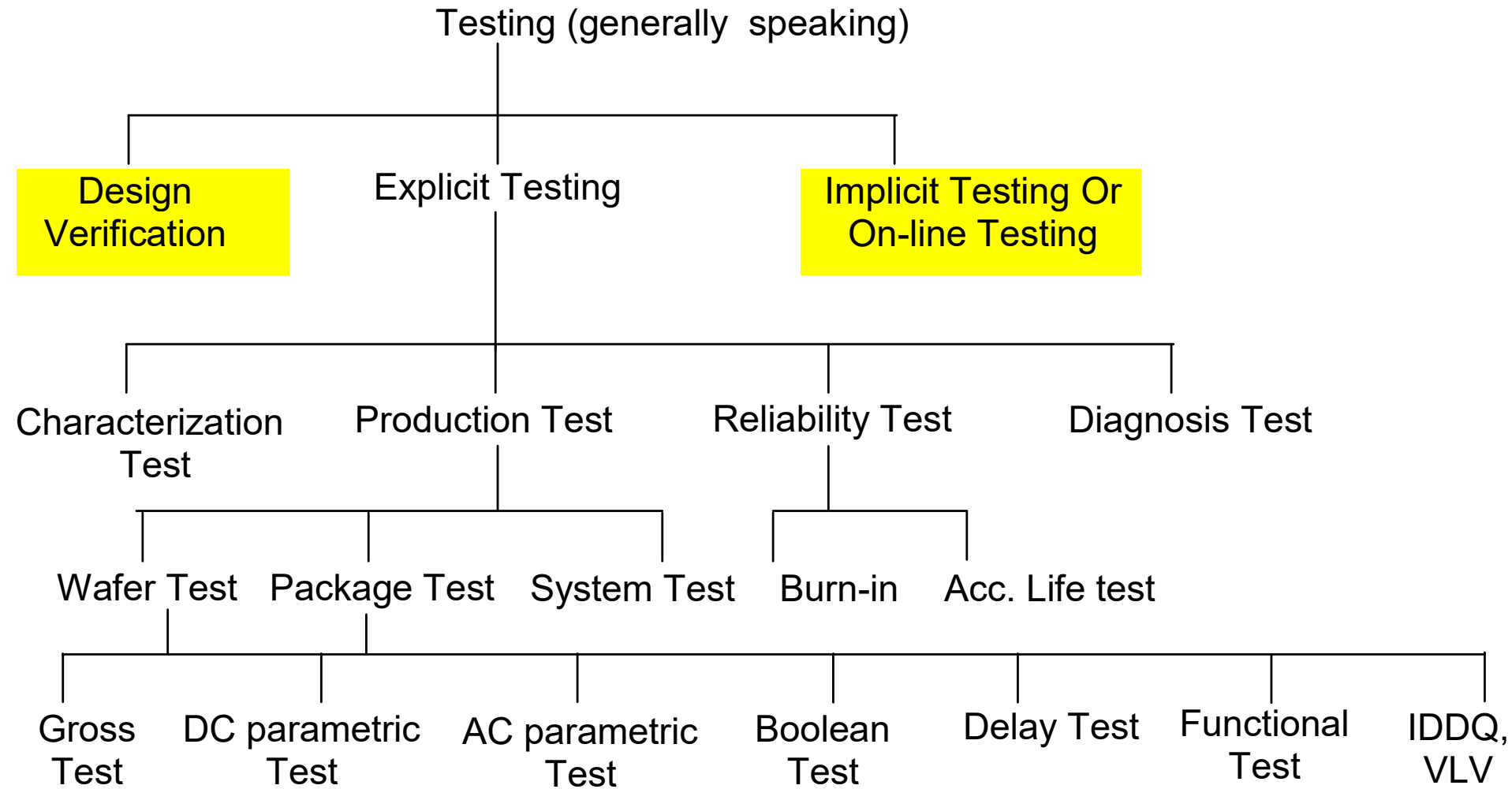
Burn-in oven siliconfareast.com

Bathtub Curve

- IC's **failure rate*** resembles a bathtub
 - ◆ **Infant mortality**: fail early in life, due to **reliability defects**
 - ◆ **Wear out**: normal life time, due to **aging**



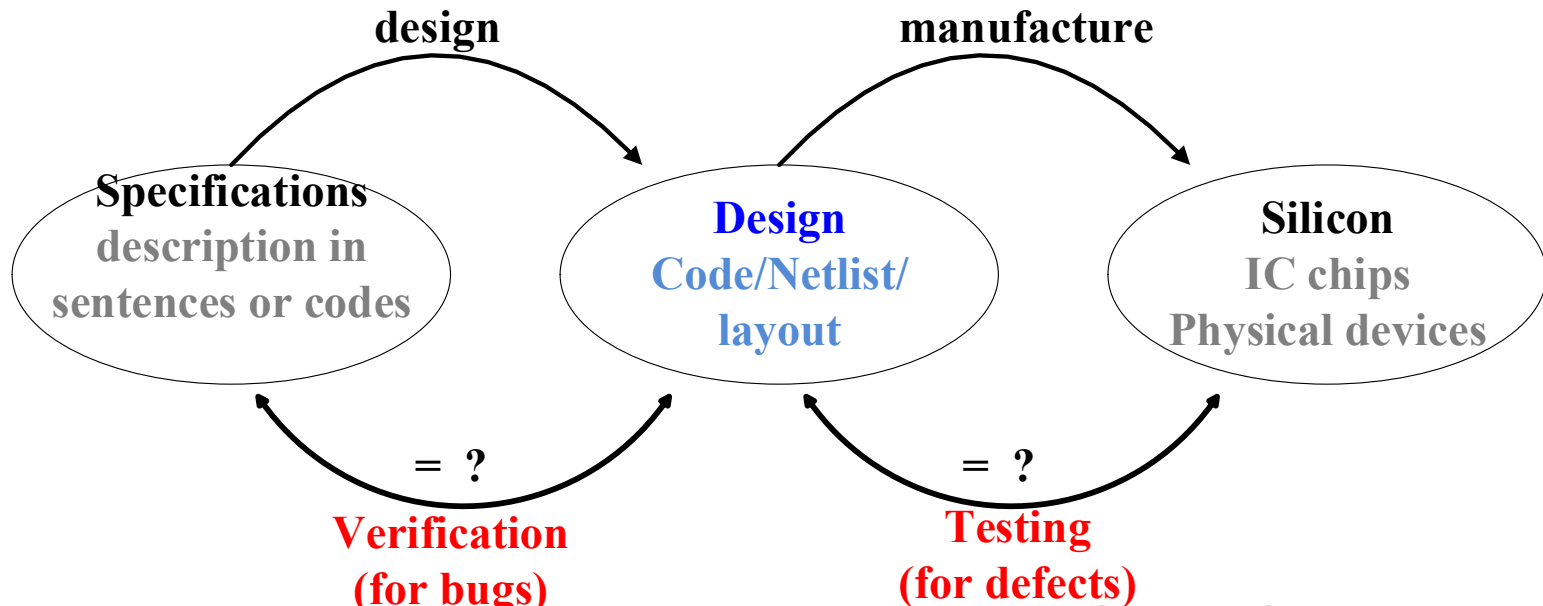
Types of Testing



These Topics Are NOT in This Course

Explicit Testing \neq Verification

- **Verification**
 - ♦ Purpose : check if design correctly implements specified behavior
 - ♦ Done **before** manufacture to catch design errors (**bugs**)
 - ♦ Approaches: simulation, formal verification, ...
- **Explicit testing**
 - ♦ Purpose: check if IC is functioning correct or defective
 - ♦ Done **after** manufacture to catch **defects**
 - ♦ Approaches: apply test patterns by tester, ...



Implicit Testing

- Purpose
 - ◆ Check IC output correctness during **normal operation**
- Also known As (aka):
 - ◆ *Concurrent Error Detection (CED)*
 - ◆ *On-line testing*
- Important for mission critical systems
 - ◆ Airplanes, satellites, mainframe computers
- Techniques
 - ◆ Circuit level techniques
 - * *Error Correction Code* (ECC) protection of memory
 - ◆ System level techniques
 - * *Watch dog timer*

Summary

- Focus of this course: explicit testing
 - ◆ Off-line IC testing on a specialized tester
 - ◆ Explicit testing \neq verification \neq on-line testing
- Many different type of tests for different
 - ◆ Purposes
 - ◆ Stages
 - ◆ Techniques

