Packaging Evolution: From Basics to 3D Integration

Module 4: Ensuring Package Reliability – Testing and Performance Evaluation

This module addresses the critical testing and quality assurance processes that ensure semiconductor packages function correctly and reliably under real-world and accelerated conditions.

4.1 Functional and Electrical Testing Overview

Testing is performed at various points along the semiconductor manufacturing pipeline to detect defects, verify performance, and classify components.

A. Foundry-Side Testing

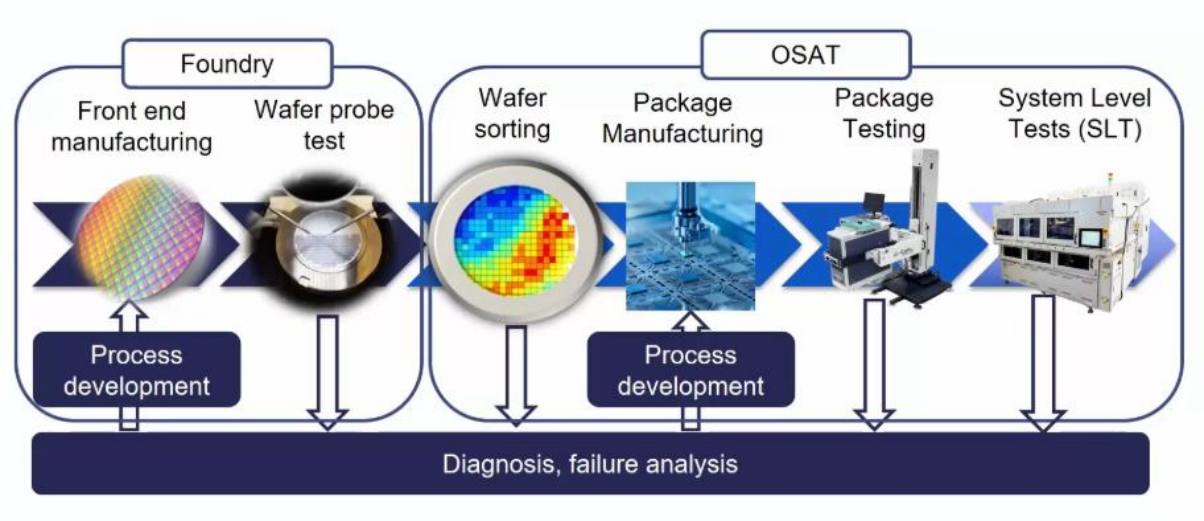
- **Wafer Probing:**
    - Conducted on each die using a **probe station**.
    - Electrical parameters such as I-V characteristics and leakage currents are measured.
    - Dies are **binned** based on performance and functionality before packaging.

B. OSAT-Side (Assembly & Test) Testing

- **Assembly Open/Short Test (AOST):**
    - Checks for electrical **shorts and opens** in the package interconnects (wires, balls, leads).
    - Includes **vision inspection** and **product grading** (e.g., PGSRT).
- **Burn-In Test:**
    - Devices operate at **elevated temperature and voltage** (e.g., 125°C, 1.2x nominal VDD).
    - Used to detect **infant mortality** (early-life failures).
- **Final Electrical Test:**
    - Performed on completed packages.
    - Includes:
        - **Voltage margin testing**
        - **Functional and timing verification**
        - **Parametric measurements** (e.g., drive strength, leakage)

C. System-Level Test (SLT)

- Mimics **end-user environment** by running actual **firmware or software** on the device.
- Captures **integration-level failures** and hard-to-detect bugs.
- Particularly important for complex SoCs or memory systems.

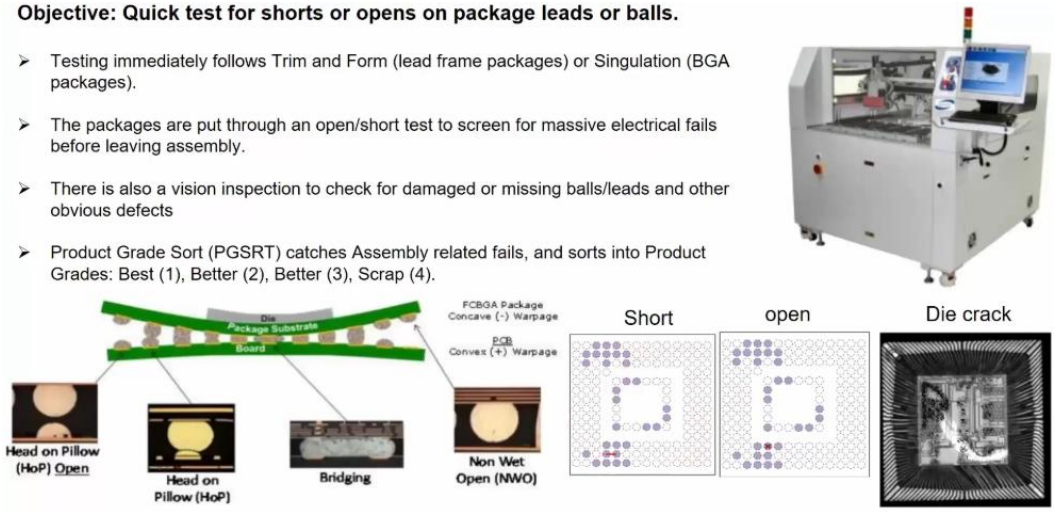


4.2 Reliability and Stress Testing

These tests simulate long-term operating and environmental stress to ensure robust field performance.

A. Assembly Open and Short Test (AOST)

- Identifies **interconnect issues** (missing, bridged, or damaged leads).
- Often automated with **vision inspection systems**.
- Provides **product grading** for classification.

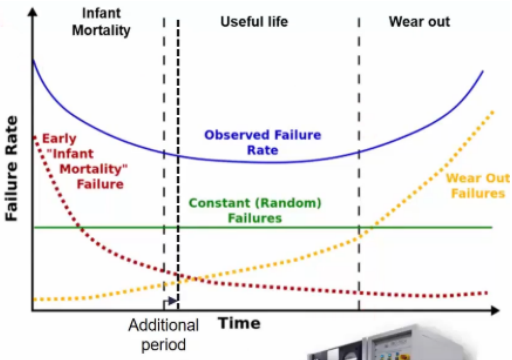


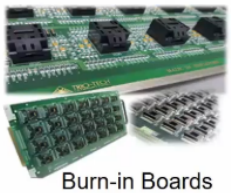
B. Burn-In Test

- Operates device under **high stress** to accelerate potential failures.
- Typical conditions: 125–150°C, high voltage, extended hours.
- Removes **weak or marginal devices** before customer delivery.

Objective: Testing of package components under elevated (stressful) conditions. temperature, voltage, and power cycling

- The goal of Burn-in is to identify "Infant Mortality" failures before it reaches the customer.
- Parts are loaded from trays onto Burn-in boards and then, into ovens (Burn-in system) during testing.
- Burn-in accelerates the failures by applying high voltage and high temperature stress.
- The test is carried out long enough to catch the initial rate of failures and then to test slightly over the point where the curve flattens out.
- Defects like dielectric & metallization failures, electromigration can be detected during burn-in.
- Although it removes the unreliable components with a high probability of early failure, the total life span of components is shortened with a burn-in test.





Burn-in Boards

C. Final Test (FT)

- Ensures **conformance to datasheet specifications**.
- Conducted **post-packaging**, includes:
  - **Voltage and current margin tests**
  - **Timing and frequency sweep tests**
  - **Functional and I/O tests**
- Usually executed with **Automated Test Equipment (ATE)**.

Objective: A temperature corner test to verify that the packaged product meets the specifications

- Parts are loaded into handler with temperature controlled test fixtures (not ovens) during testing.
- Hot Test: Elevated temperatures according to product specifications. Parts are electrically tested at high temperatures to verify if the specifications are met.
- Cold Test: Parts are subjected to low temperatures according to product specifications and electrically tested.

ATE (Electrical Testing Unit) with Handler (Placing DUT)

video

LM741 OPAmp (TI) Datasheet

6 Specifications

6.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)[1][2][3]

		MIN	MAX	UNIT
Supply voltage	LM741, LM741A		±22	V
	LM741C		±18	
Power dissipation [4]			500	mW
Differential input voltage			±30	V
Input voltage [5]			±15	V
Output short circuit duration			Continuous	
Operating temperature	LM741, LM741A	−50	125	°C
	LM741C	0	70	
Junction temperature	LM741, LM741A		150	°C
	LM741C		100	
Soldering information	PDIP package (10 seconds)		260	°C
	CDIP or TO-99 package (10 seconds)		300	°C
Storage temperature, T_{stg}		−65	150	°C

6.5 Electrical Characteristics, LM741[1]

PARAMETER	TEST CONDITIONS		MIN	TYP	MAX	UNIT
Input offset voltage	$R_S \le 10\ k\Omega$	$T_A = 25°C$		1	5	mV
		$T_{AMIN} \le T_A \le T_{AMAX}$			6	mV
Input offset voltage adjustment range	$T_A = 25°C$, $V_S = \pm 20\ V$			±15		mV
Input offset current	$T_A = 25°C$			20	200	nA
	$T_{AMIN} \le T_A \le T_{AMAX}$			85	500	
Input bias current	$T_A = 25°C$			80	500	nA
	$T_{AMIN} \le T_A \le T_{AMAX}$				1.5	µA
Input resistance	$T_A = 25°C$, $V_S = \pm 20\ V$		0.3	2		MΩ
Input voltage range	$T_{AMIN} \le T_A \le T_{AMAX}$		±12	±13		V
Large signal voltage gain	$V_S = \pm 15\ V$, $V_O = \pm 10\ V$, $R_L \ge 2\ k\Omega$	$T_A = 25°C$	50	200		V/mV
		$T_{AMIN} \le T_A \le T_{AMAX}$	25			
Output voltage swing	$V_S = \pm 15\ V$	$R_L \ge 10\ k\Omega$	±12	±14		V
		$R_L \ge 2\ k\Omega$	±10	±13		

Summary Table: Test Methods Across Manufacturing Stages

Test Phase	Tool Used	Purpose
Wafer Probing	Probe Station (ATE)	Die-level electrical validation
Assembly Open/Short Test	Vision + ATE	Interconnect integrity, defect detection
Burn-In	Thermal Chambers	Early failure screening
Final Test (FT)	Automated Testers	Full electrical verification
System-Level Test (SLT)	Target Boards/Loaders	End-use simulation & validation

Testing and reliability validation are essential for ensuring **functionality, robustness, and longevity** of semiconductor packages. These processes significantly reduce the risk of failure in the field and help maintain product quality standards across high-volume manufacturing.