Module 4: Ensuring Package Reliability: Testing & Performance Evaluation

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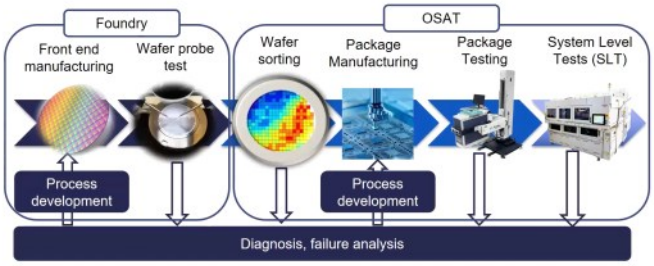
L1: Introduction to Package Testing & Electrical Functionality Checks

This is done after the package has been manufactured.
Must test package electrically after optical tests have been carried out.

Wafer Mapping: Must map out all the good dies from the wafer in order to avoid spending resources to packages faulty dies. Done by wafer probing & at foundry or at OSAT

Post package manufacturing, we move to package testing & board level testing after product assembly.

Diagnosis & failure analysis helps us understand why failure occurs & how can it be improved.
Useful in improving yield.



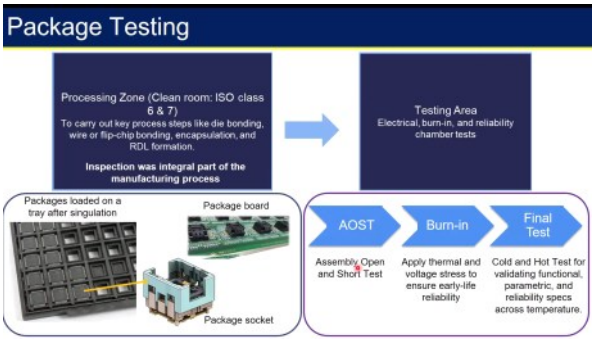
Package Testing:

Now IC has been packages in the clean rooms & inspection has been carried out.
The ICs are then moved to the testing floor, which may not have as stringent cleanliness standards like a clean room.

Testing for the packaged systems is done on a package socket on package boards.

After singulation , we carry out a variety tests:

1. AOST: Assembly Open & Short test (Detects opens & shorts)
2. Burn-In: Apply thermal & voltage stress to ensure early-life reliability (Testing on stress application)
3. Final Test: Cold & Hot test for functionality, parametric tests, reliability across temp ranges etc. (Performance analysis under temp cycling)



Assembly Open & Short Test (AOST):

Objective: Test for shorts or opens on package solder balls or leads.
Done after singulation or lead trim or form.

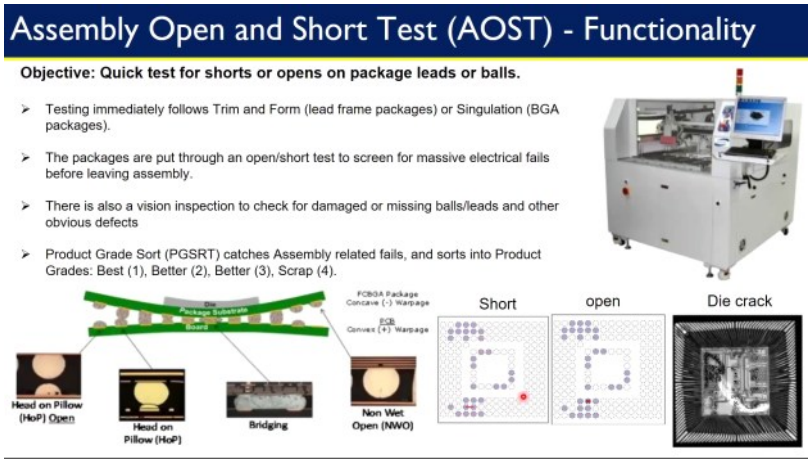
ICs are check for open/short testing.

Can have issues like:

1. Head on Pillow Open (HoP Open)
2. Head On Pillow (HoP)
3. Bridging
4. Non Wet Open
5. Die Cracks
6. Package warping

Product grouped into:

1. Best
2. Better
3. Scrap



L2: Reliability & Performance Testing of Semiconductor Packages

Burn - In Test: Tests packages under elevated conditions in terms of voltage, temperature, power & cycling.

Helps identify chips that may fail prematurely
Parts are loaded into burn-in trays & tested under elevated temps, voltage which helps catch initial failures.

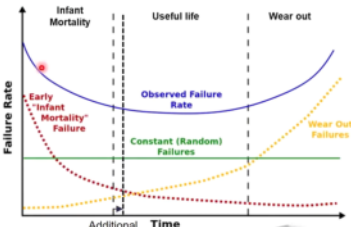
Prominent defects caught in this stage: Metallization Failure, Electromigration.
But shortens overall lifespan.

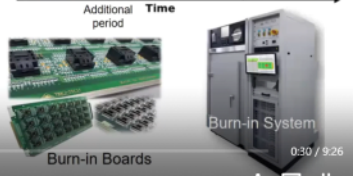
We have some finite failure rate even if a chip survives the burn-in.

Burn-in Test

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.





Final Test:
Corner tests to verify that packaged die meets specs.

Use a temp controlled environment:
1. Hot Test: Elevated temps.
2. Cold Test: Parts are subjected to low temps.

ATE: Automatic Test Equipment.
Electrical Test Units & Handler (Placing DUT).

These test equipment send out automatic test patterns generation (ATPG) to a device under test (DUT).
Check for:
1. Parametric Tests: Measure current or voltage from units to ensure function within specified range
2. Functional Test: Test functioning under expected test conditions.
3. Speed Test: If device performs at desired speed.

KPIs: Yield, Test time & Coverage

They Have 2 distinct units:
1. Handler
2. In-Circuit Tester

Final Test

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

6 Specifications — *LM741 OPAmp (TI) Datasheet*

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		–55	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	$R_S \le 10$ kΩ	$T_A = 25°C$		1	5	mV
		$T_{AMIN} \le T_A \le T_{AMAX}$			6	mV
Input offset voltage adjustment range	$T_A = 25°C$, $V_S = ±20$ 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	$T_A = 25°C$, $V_S = ±20$ V		0.3	2		MΩ
Input voltage range	$T_{AMIN} \le T_A \le T_{AMAX}$		±12	±13		V
Large signal voltage gain	$V_S = ±15$ V, $V_O = ±10$ V, $R_L \ge 2$ kΩ	$T_A = 25°C$	50	200		V/mV
		$T_{AMIN} \le T_A \le T_{AMAX}$	25			
Output voltage swing	$V_S = ±15$ V	$R_L \ge 10$ kΩ	±12	±14		V
		$R_L \ge 2$ kΩ	±10	±13		

Summary: ATE & Test categories

Automatic Test Equipment (ATE)

- Test equipment's that send automatic test pattern generation (ATPG) to the device under test (DUT).
- Major test categories:
  - ✓ Parametric Tests: measures current (or voltage) from the unit to ensure the circuits are functioning within specified parameters.
  - ✓ Functional Tests: evaluate functionality of the unit under operating conditions.
  - ✓ Speed Tests: assesses speed of units according to data sheet specifications. Sorting is done based on speed.
- **Yield, Testing Time and Test coverage** are key performance indicator during testing.