SJIT, Solder Joint Integrity Test, To Find Latent Defects in Printed Wiring Board Assembly

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Abstract
To find defects of solder joint in printed wiring board assembly, quite a few test methods have been developed so far. Capacitance method and IEEE 1149.1 or boundary scan method are often used to find opens between component leads and pads on a printed wiring board. These methods, however, can find complete opens or complete shorts only. Latent defects that can be complete defect after several years have not been found by the conversational method.

We have developed a method to find such latent defects by using 4-wire small resistance measurement technique and have built in a flying-probe in-circuit tester. It measures the resistance between component leads and pads, and checks the volume of the solder. Because the volume of the solder is inversely proportional to the resistance in-between, resistance measurement can be a way to test the solderability.

This technique is industry proven. A lot of manufacturing plants which produce printed board assembly used in automotive have adapted it. The printed wiring board assembly for automotive must endure vibration. Thus if a board assembly has a latent defect, it can bring a serious accident. In my presentation, I would like to introduce the importance of SJIT, Solder Joint Integrity Test, and a technique of SJIT.

Testing Printed Wiring Board Assembly
Printed wiring board assemblies, PWBA, are tested several times after production. The tests are categorizes as production test, board-level test and system test.[1] Usually, automatic optical inspection, AOI, is done in process of production and used to not only checks component placements but also monitor the yield of the production.

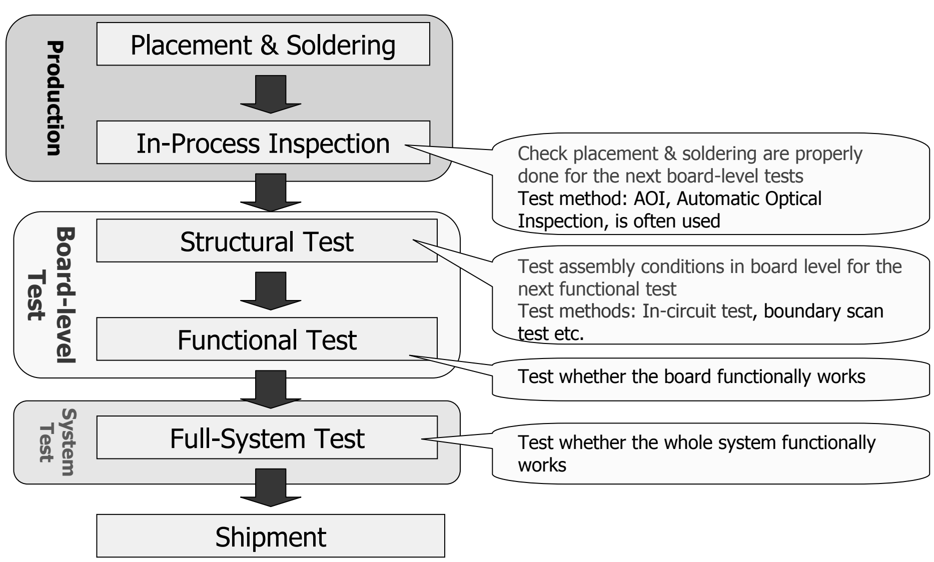


Figure 1 - Typical Way of PWBA Test

The Board-level test stage follows in-process inspection at the production stage. In this stage, board assemblies are tested structurally first. Either in-circuit test or boundary-scan method or sometimes both of them are used for structural tests. The structural test, especially in-circuit test, has another purpose. It works as a pre-check for next functional test. In the functional

test, power sources should be applied to the board assembly to be tested. Thus if the board assembly is not structurally complete, it can be damaged while the functional test.
The board-level structural test is done, functional tests of board-level and system-level follows.

Carrying out all the tests makes test cost increments. Thus in some cases, board-level tests are skipped and only system test is done. Moreover, in an extreme case, manufacturers do not test their products at all.
Omission of test items should be done as carefully as possible, however. It can be rebounded as a massive cost increment. Assume board-level tests including structural test and functional test are not done, and a defect is found afterwards.

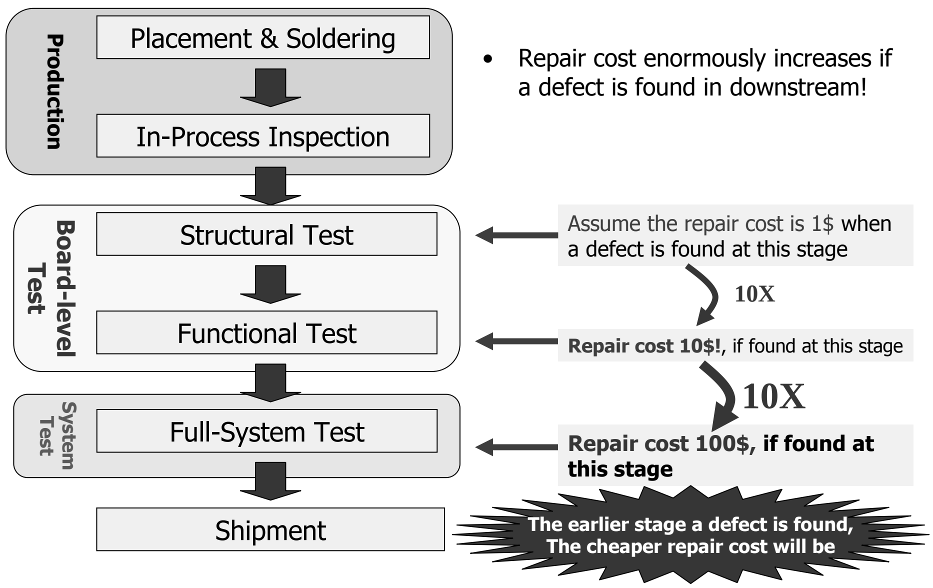


Figure 2 - The 10X Rule in PWBA Tests

Repair cost will be enormously increases as the production/test stage reaches the shipment. It is called "The 10X rule in PWBA tests."[2]

If a product including a defect comes out to the market, the problem will be much more serious. Think about the case of a car with a defective PWBA. The malfunction of the PWBA may relate to a car accident and give the driver injury. Once a defective PWBA is distributed in the market, its recall cost can be 100000X or much more.

Everyone wants to make test cost as low as possible, but as stated above, the loss will increase if test strategy is wrong. To determine test strategy, the following two factors should be considered.

1. Quality
Required degree of test quality largely depends on the quality that the products needs. A cheap complimentary toy for example does not need board-level test. If it does not work at the system level functional test, it may be thrown away.

2. Volume
How many the products is produced is another important factor to determine test strategy. For small volume production, tester may not be required, but for high volume manufacturing a dedicated tester and jigs may be required otherwise the test process can be a bottleneck.

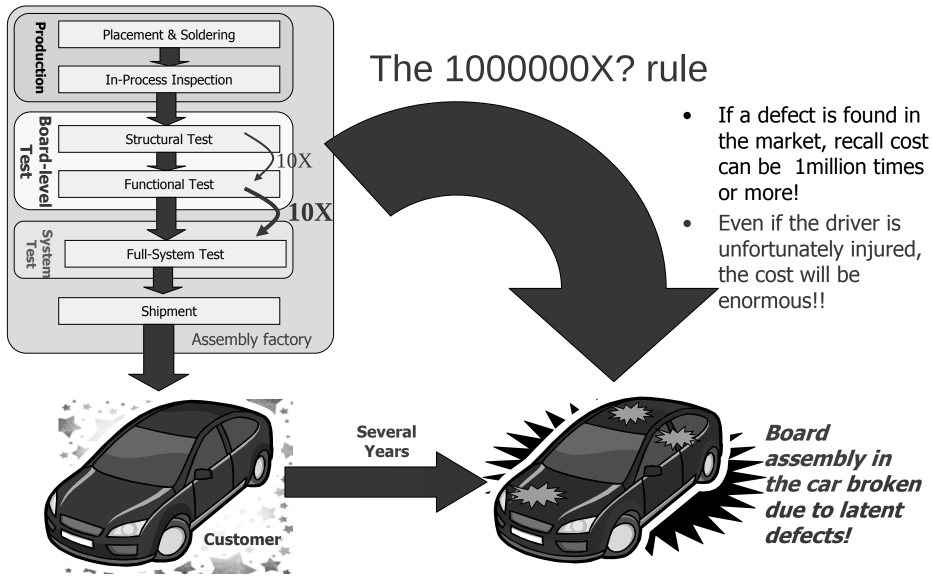


Figure 3 - The 1000000X? Rule

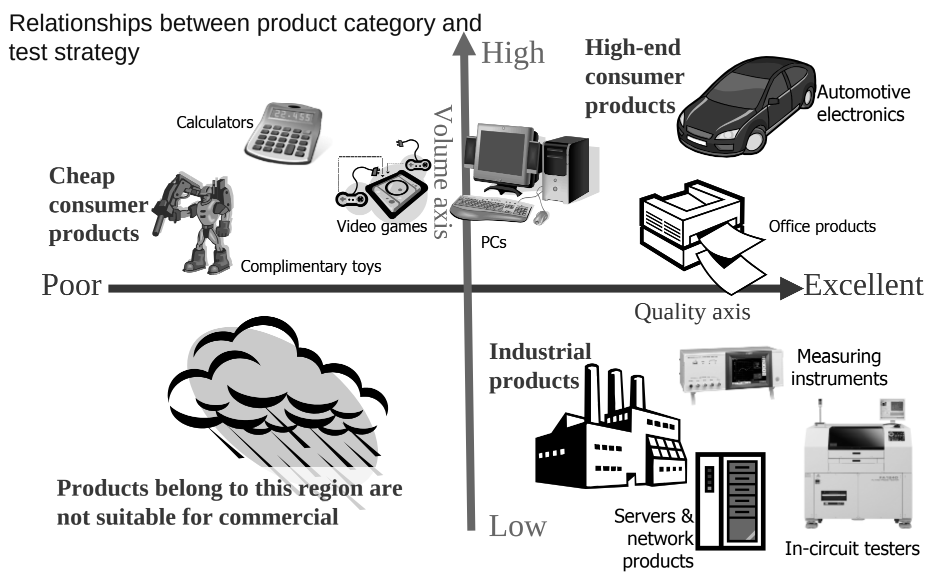


Figure 4 - Relationships between Product Category and Test Strategy

Figure 4 shows examples of the relationships between product category and test strategy. The volume of automotive manufacturing is very high, but high quality is required as well.

Latent defect test

The defects that come out after a PWBA is delivered to customers are called "Latent defect". In automotive industries for example, latent defect may happen if any solder joint is not complete. While driving a car, the PWBA inside suffers vibration and the solder joint without solder or with insufficient solder may become complete open. Thus even though there is not a failure in an initial stage, defect happens sometimes after long time due to a latent effect.

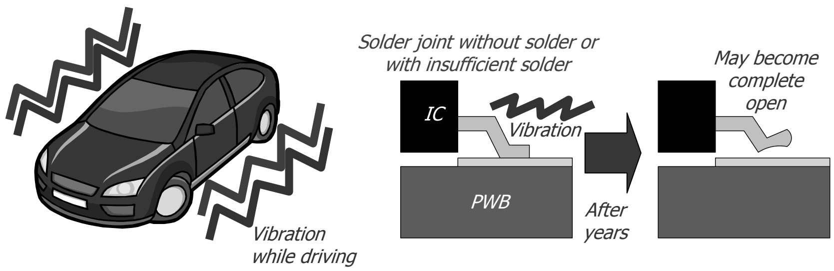


Figure 5 - Example of Latent Defect Occurance

Basics of SJIT, Solder Joint Integrity Test

The purpose of SKIT is to find latent defects. There are some way to find IC pin opens, but conventional capacitive, magnetic and diode methods cannot find latent pin opens. Also, boundary-scan test can find IC pin opens, but cannot find latent pin opens. X-ray test can find latent pin opens, but it is too slow to test a whole board assembly.

The only practical way to fine latent defects is 4-wire resistance measurement method.. The less the volume of solder is, the more resistance becomes. By measuring resistance across solder joint, therefore reliability of solder joint can be tested.

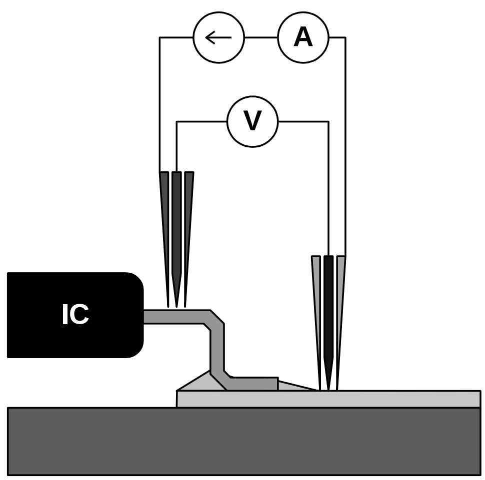


Figure 6 - SJIT, Solder Joint Integrity Test, by 4-Wire Resistance Measurement

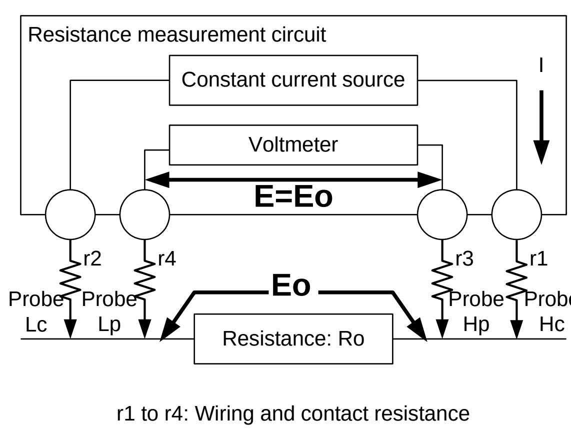


Figure 7 - 4-Wire Resistance Measurement Method

Case studies of SJIT
In the following pages, some solder conditions and measured resistance are shown.

Complete solder joint

- Resistance of solder joint: **1.364mOhms**
- **This time we define this resistance as “PASS” criterion**

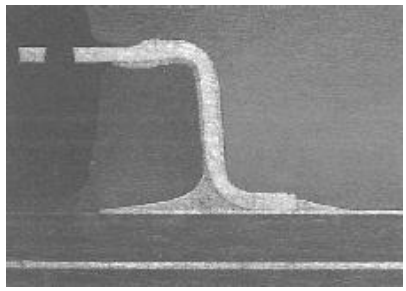
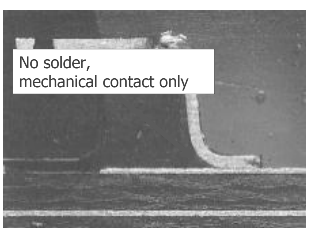


Figure 8 - Complete Solder Joint

Poor solder joint #1

- Resistance of solder joint: **201.1mOhms**
- Test result: **FAIL, over 100X higher than the criterion**



Poor solder joint #2

- Resistance of solder joint: **3.969mOhms**
- Test result: **FAIL, about 3X higher than the criterion**

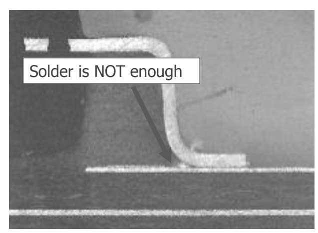


Figure 9 - Example of Poor Solder
#1: No Solder #2: Insufficient Solder

Poor solder joint #3

- Resistance of solder joint: 63.45mOhm
- Test result: FAIL, about 16X higher than the criterion

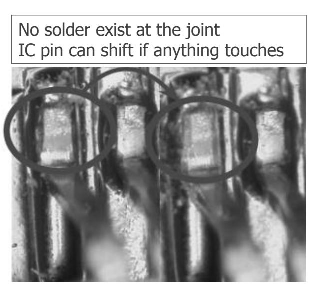


Figure 10 - Another Example of Poor Solder

Conclusion

Repair cost enormously increases if a defect is found in downstream. It is called "The 10X rule in PWBA tests". This rule means that PWBAs need to screen out defectives in an early stage by structural tests.
Even if a defect is found in the market, recall cost can be 1million times or more, so in the structural test at the assembly factory, need to screen out latent defectives as well.
SJIT, Solder Joint Integrity Test, is to find latent defects, and 4-wire resistance measurement method is the only way to find them at the moment

References

[1] Hiroshi YAMAZAKI, "Key Drivers and Challenges for Electronics Packaging Test and Inspections", The Japan Institute of Electronics Packaging, Vol. 14, No. 1, 2011, pp. 26-30

[2] Koji UCHIYAMA, "Preparation for Test/Inspection Economical Scale", The Japan Institute of Electronics Packaging, Vol. 14, No. 2, 2011, pp. 103-108

SJIT, Solder Joint Integrity Test, to find Latent Defects in Printed Wiring Board Assembly

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First of all…

- We Japanese seldom use MDA, Manufacturing Defect Analyzer
- When you find ICT, In-Circuit Tester, in this presentation, please refer to both MDA and ICT

Agenda

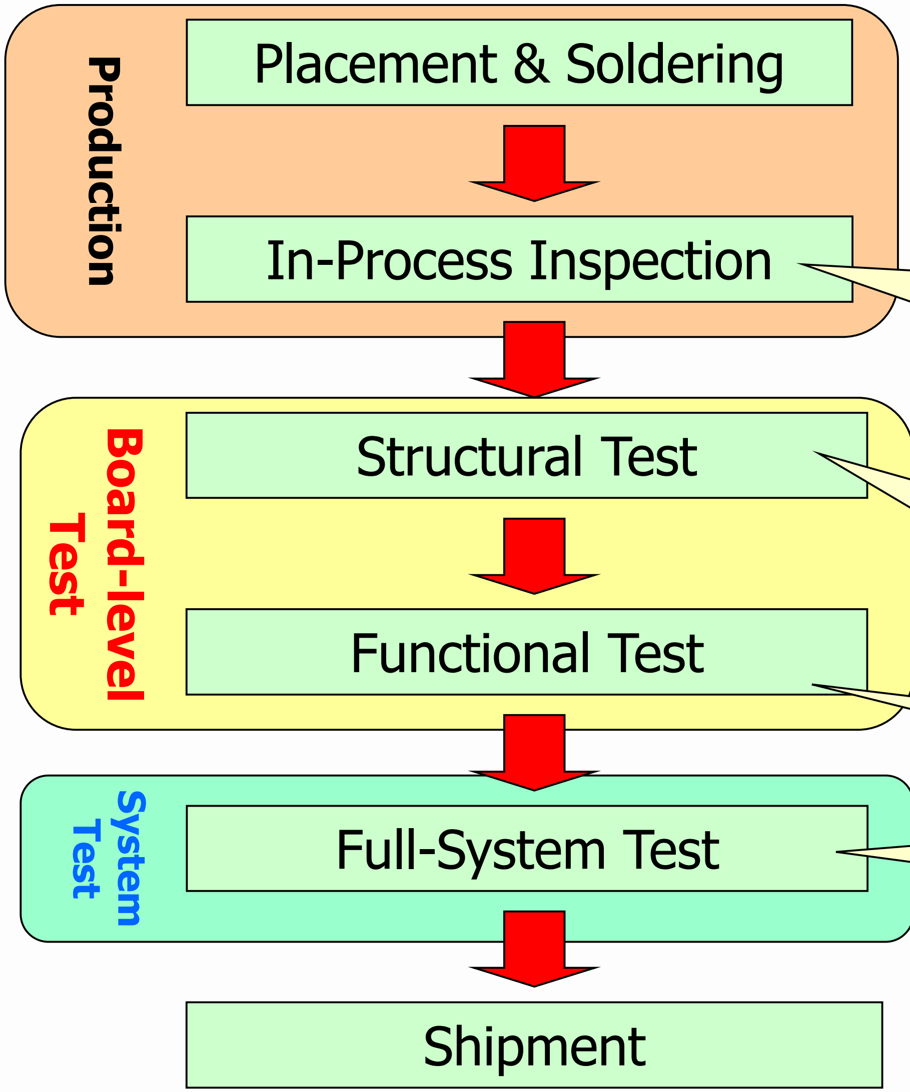
- Testing printed wring board assembly
- Basics of SJIT, solder joint integrity test, to find latent defect
- Case studies of SJIT

Testing Printed Wiring Board Assembly

SJIT, Solder Joint Integrity Test, to find latent defects in printed wiring board assembly

Typical way of PWBA test

- First of all, review how PWBA tests are done



Check placement & soldering are properly done for the next board-level tests
Test method: AOI, Automatic Optical Inspection, is often used

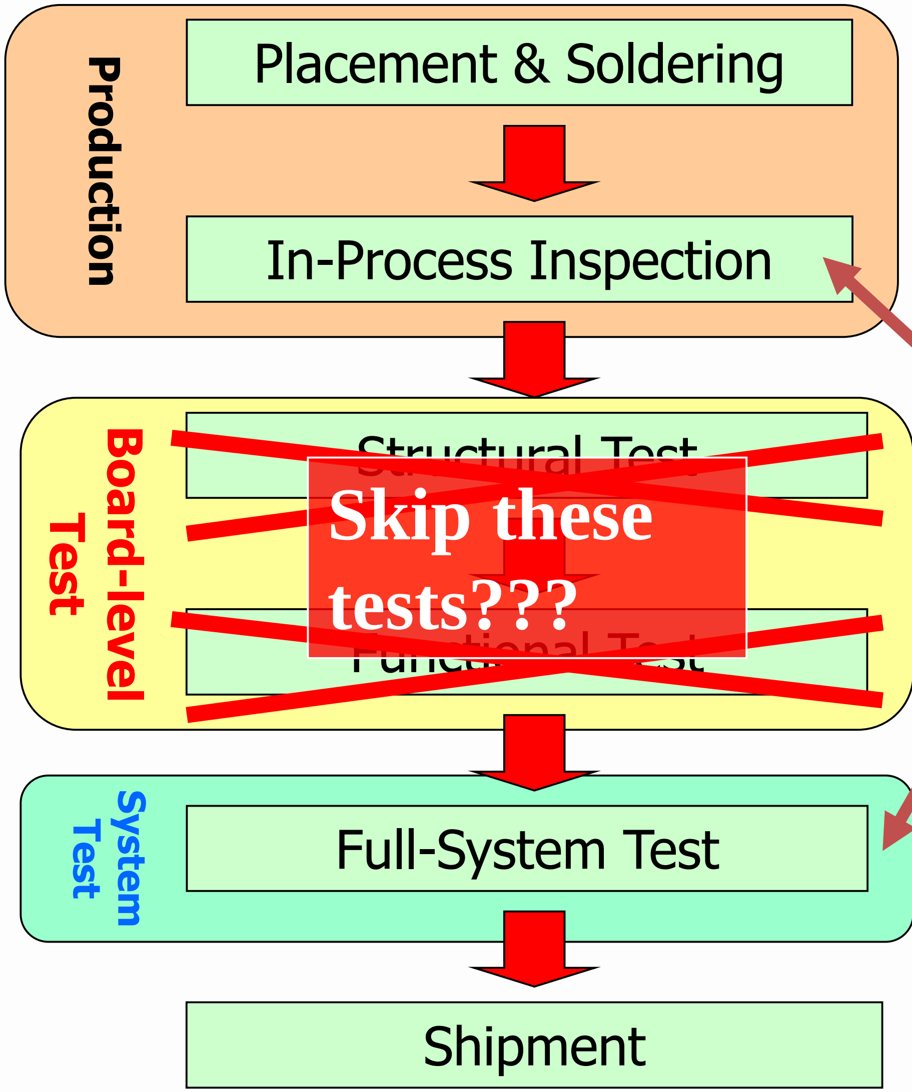
Test assembly conditions in board level for the next functional test
Test methods: In-circuit test, boundary scan test etc.

Test whether the board functionally works

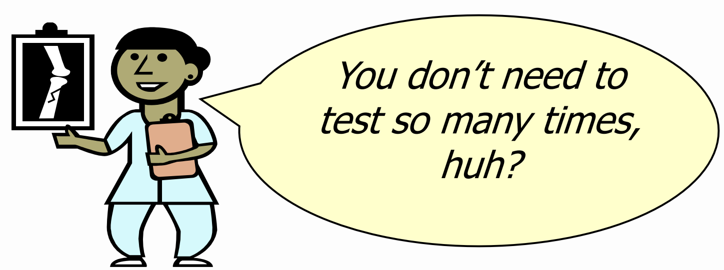
Test whether the whole system functionally works

However, all the tests are needed?

- Can some of the tests be skipped?

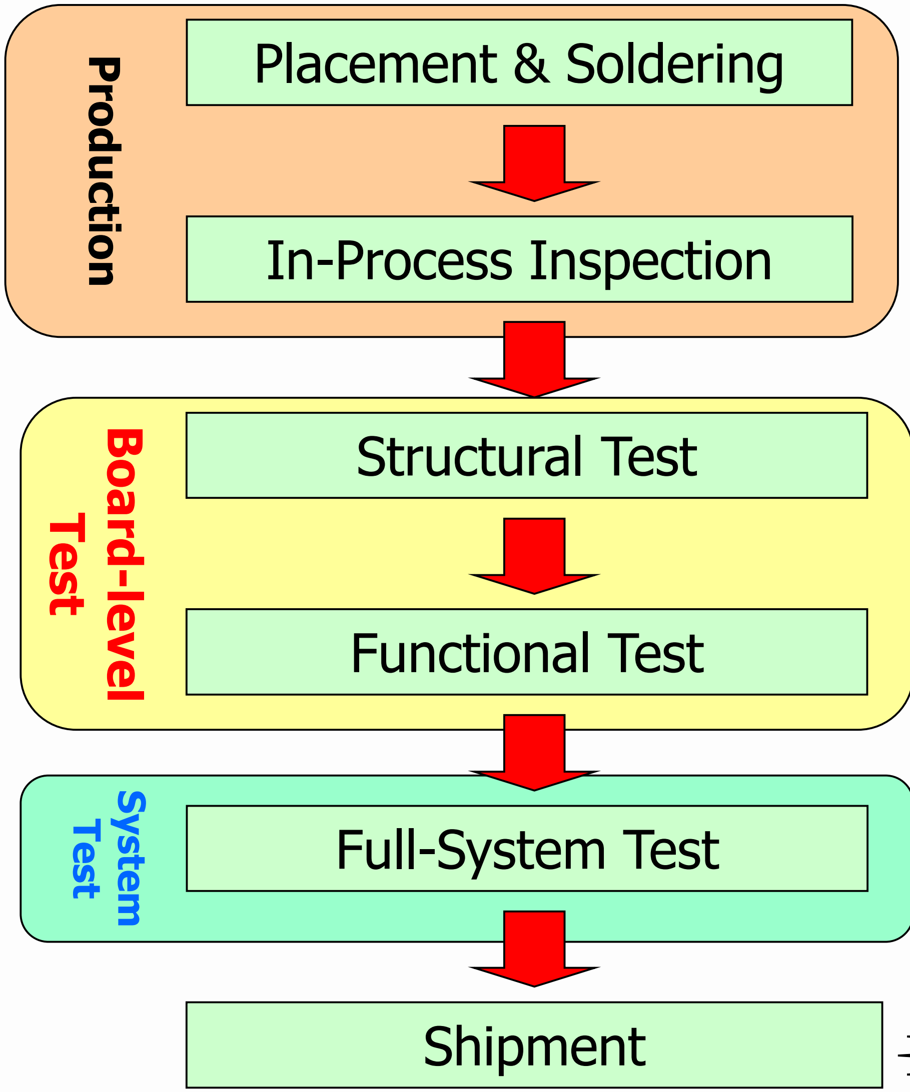


To reduce test costs, skip board-level test and carry out in-process inspection & full-system functional test only?



The 10X rule in PWBA tests

- Repair cost enormously increases if a defect is found in downstream!



Assume the repair cost is 1$ when a defect is found at this stage

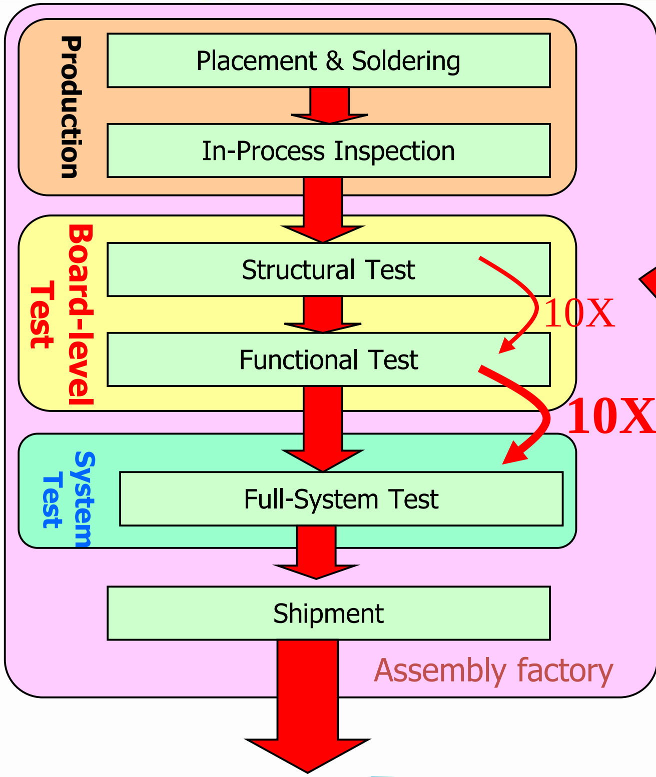
10X

Repair cost 10$!, if found at this stage

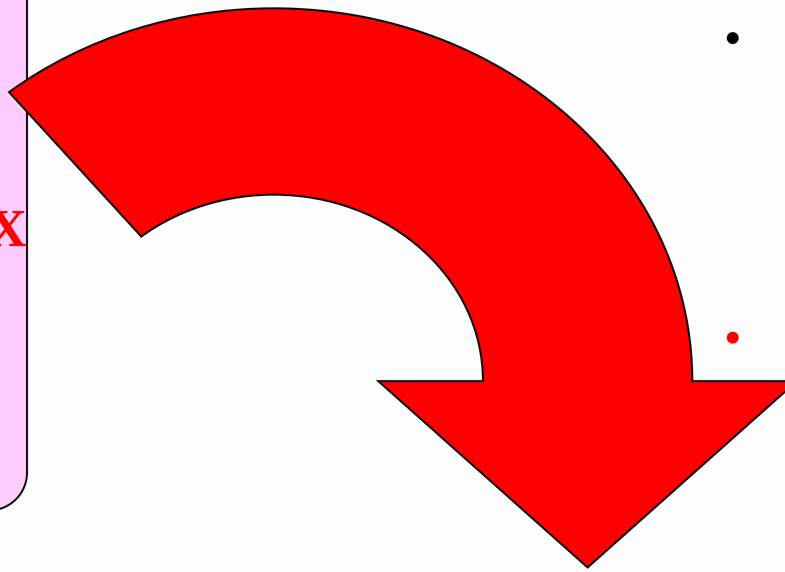
10X

Repair cost 100$, if found at this stage

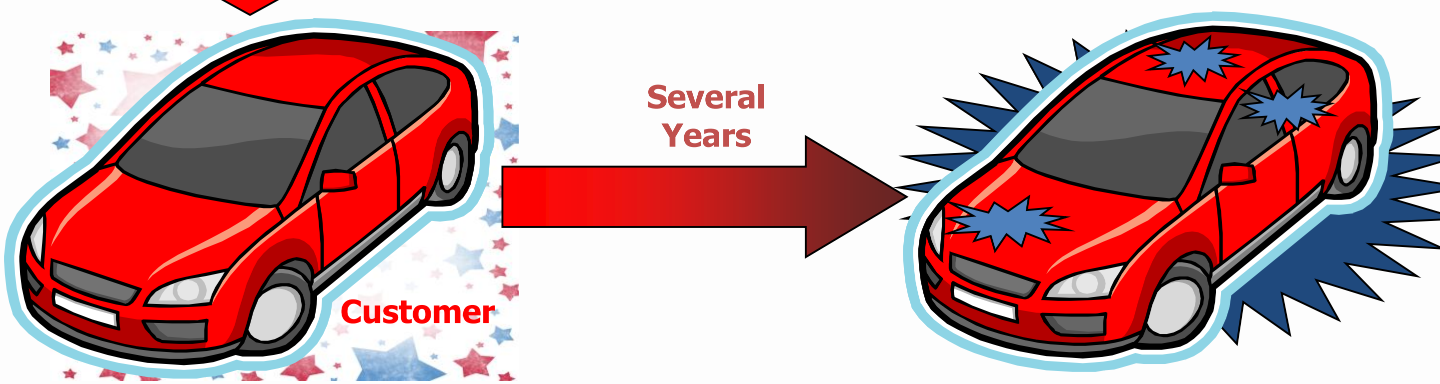
The earlier stage a defect is found, The cheaper repair cost will be



The 1000000X? rule



- If a defect is found in the market, recall cost can be 1million times or more!
- Even if the driver is unfortunately injured, the cost will be enormous!!



Board assembly in the car broken due to latent defects!

To determine test strategy

- Everyone wants to make test cost should be as low as possible
- If you failed to design test process, however, your loss will increase as the volume of the production rises
- The following 2 factors have to be considered to determine test strategy

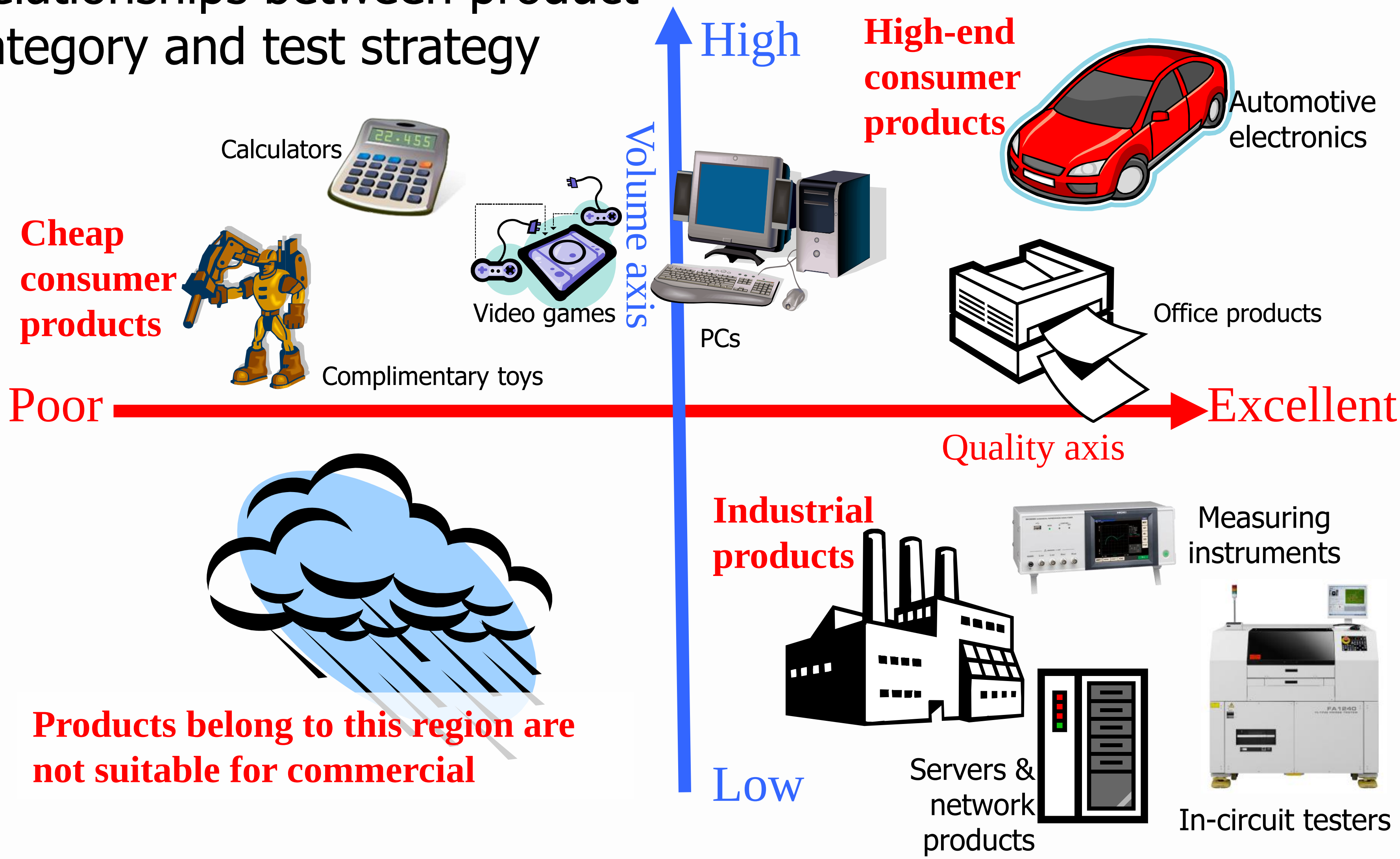
Quality

What quality level is the target?

Volume

How many is the product manufactured?

Relationships between product category and test strategy



Production
- Placement & Soldering
- In-Process Inspection

Board-level Test
- **Structural Test**
- Functional Test

System Test
- Full-System Test

Shipment

To stop 10X rule

- Need to screen out defectives in an early stage
- Structural test is indispensable

In-circuit test, boundary scan test etc.

Assume the repair cost is 1$ when a defect is found at this stage

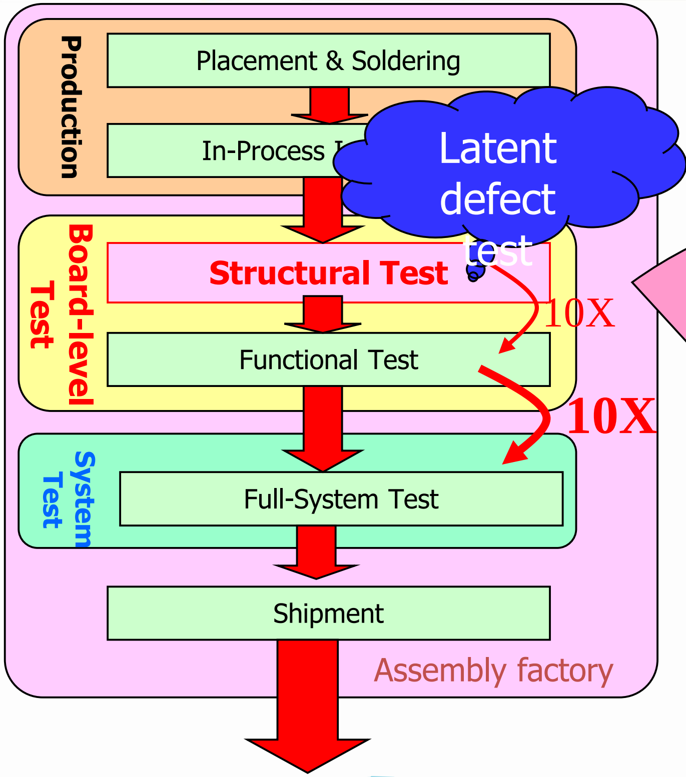
No! ~~10X~~

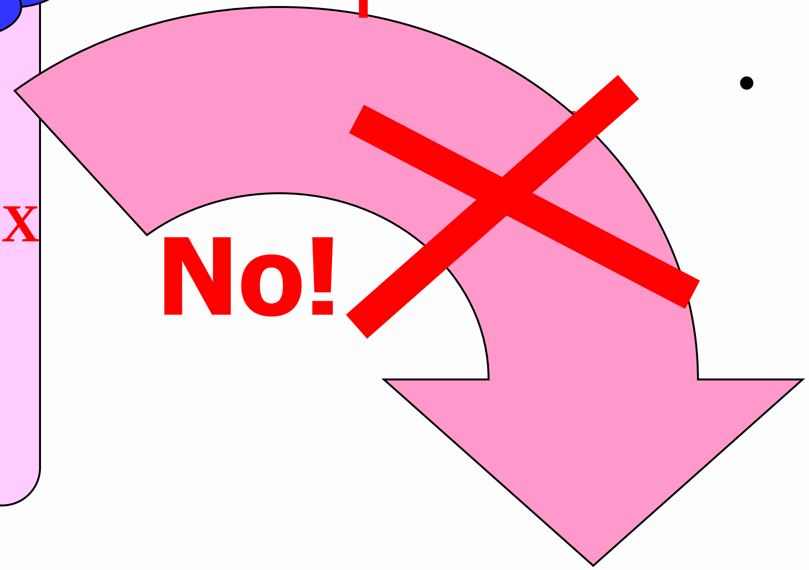
Repair cost 10$!, if found at this stage

No! ~~10X~~

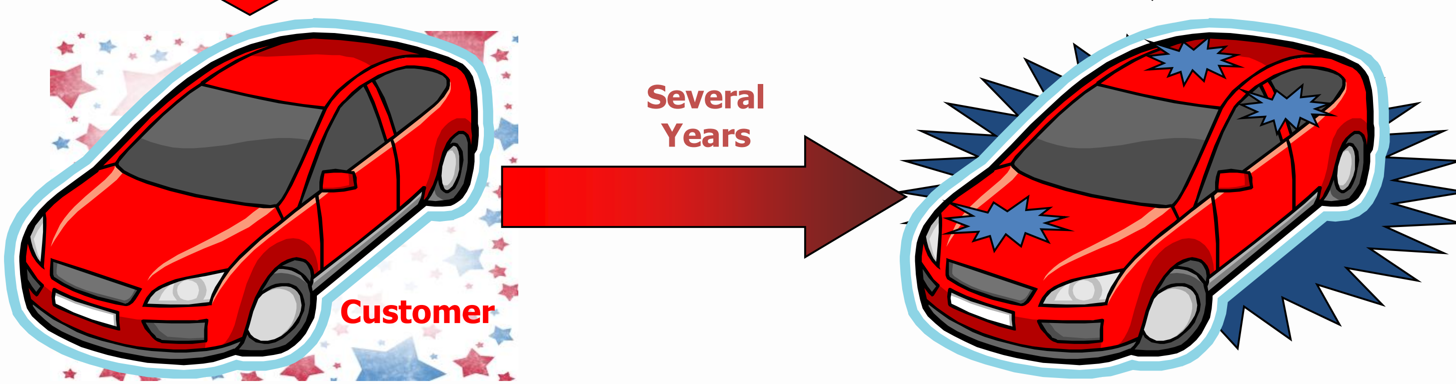
Repair cost 100$, if found at this stage

Moreover, to stop 1000000X? rule





- In the structural test at the assembly factory, need to screen out latent defectives



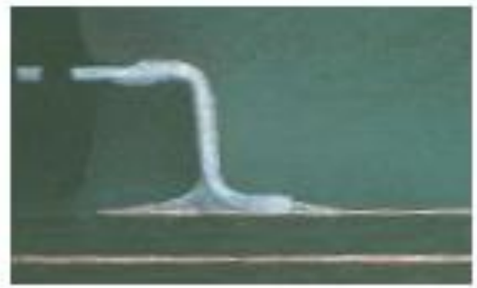
Board assembly in the car broken due to latent defects!

Basics of SJIT

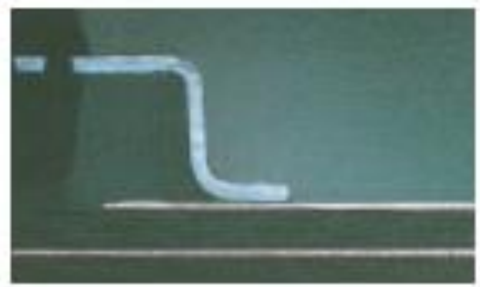
SJIT, Solder Joint Integrity Test, to find latent defects in printed wiring board assembly

What is SJIT?

- SJIT, Solder-Joint Integrity Test, is a technique to find latent open defects
- The solder joints shown right have electrical contact, but Case B & C have completely or not enough solder



Case A:
Good solder joint contact with appropriate solder volume

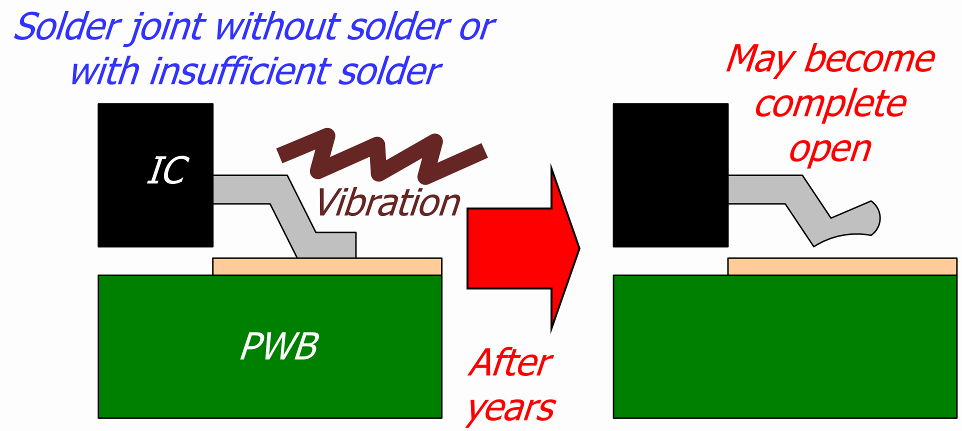


Case B:
Poor solder joint contact without solder

Case C:
Poor solder joint contact without sufficient solder

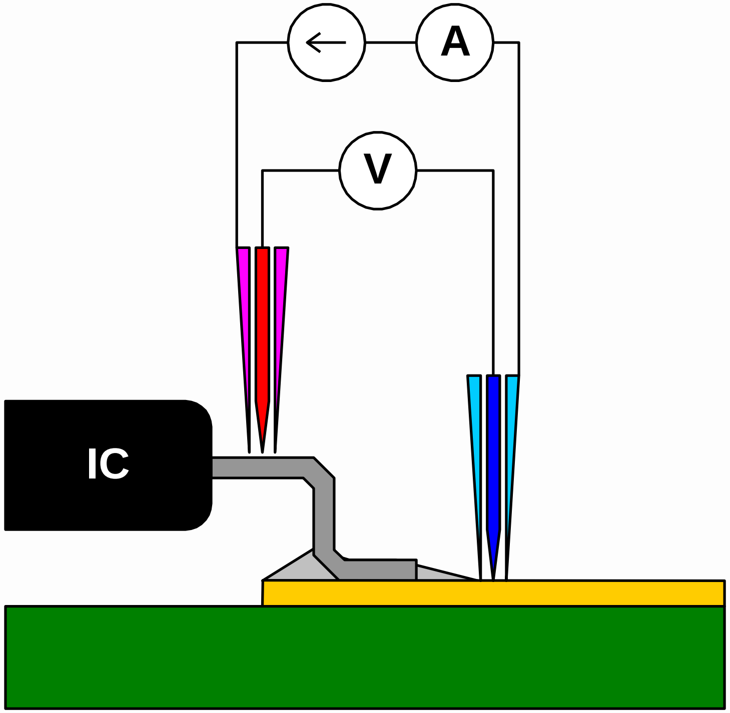
What is latent defect?

- If there is completely no solder or not enough solder, the strength of the joint is not enough
- Even if conventional open test passes in board-level structure test, the joint may become complete open due to:
  - Vibration, e.g. board assembly inside a car
  - Corrosion of oxidation
- Defects come out after the board assembly is delivered to customers are called "Latent defects"



Practical way of SJIT to find latent defects

- SJIT is done by measuring resistance between pad and IC-pin sholder

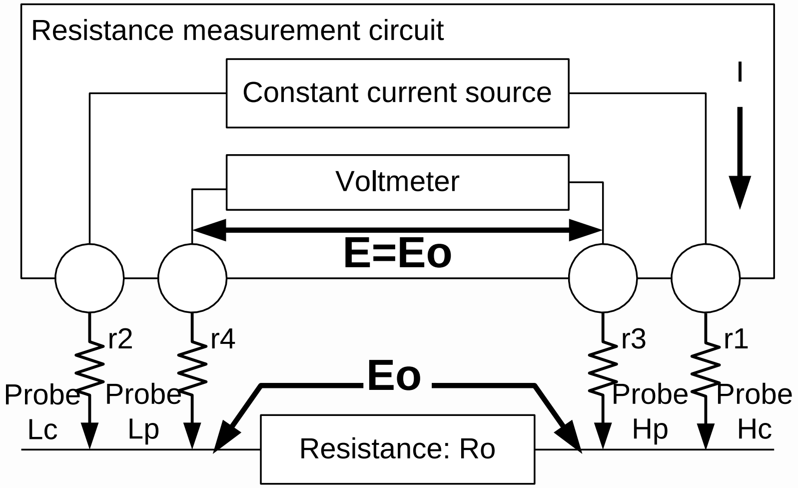


With 4-terminal resistance measurement method, the tester measures very small changes in resistance

If solderability is not good, measured resistance will be high because the volume of the solder is insufficient

4-wire resistance measurement method

- The 4-terminal resistance method
  - Cancels wiring and contact resistance
    - By providing sense (voltage) probes separately, actual voltage applied to via/trace is measured
  - Measures TRUE solder joint resistance



r1 to r4: Wiring and contact resistance

Comparison

- 4-wire resistance measurement method is only a practical SJIT method at the moment
  - There are several ways for pin-open tests in board-level structure test, but the other ways are not capable

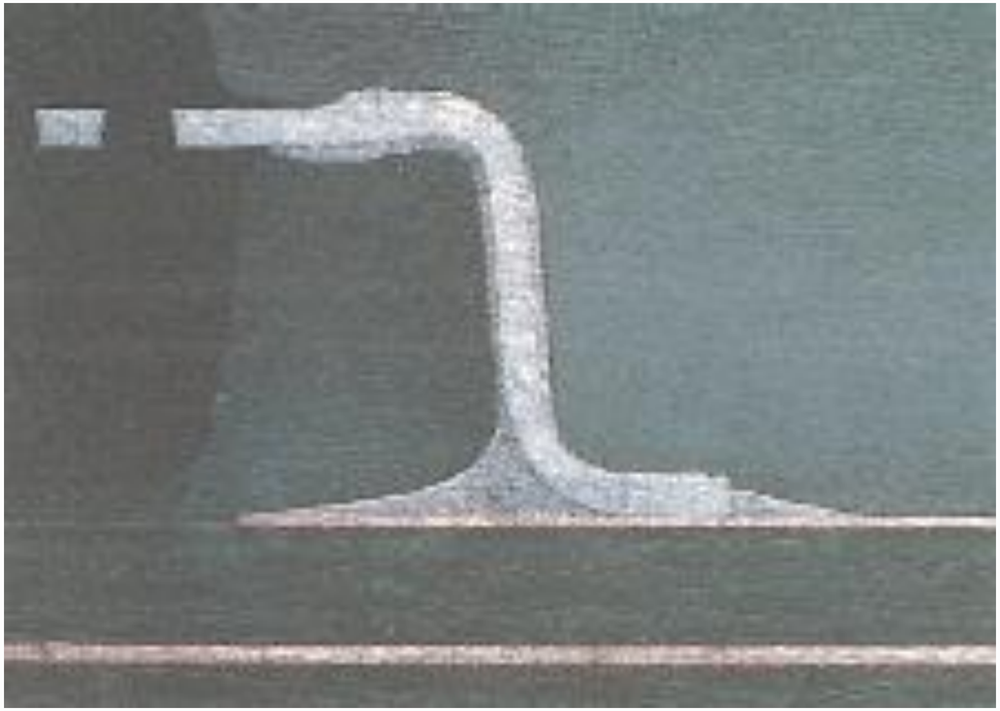
Method	Pin open test	**SJIT** **Latent pin-open test**	Test speed
Capacitive	Yes	No	Fast
Magnetic	Yes	No	Fast
Diode	Yes	No	Fast
4-wire resistance	Yes	Yes	Fast
X-ray	Yes	Yes	Slow

Case Studies of SJIT

SJIT, Solder Joint Integrity Test, to find latent defects in printed wiring board assembly

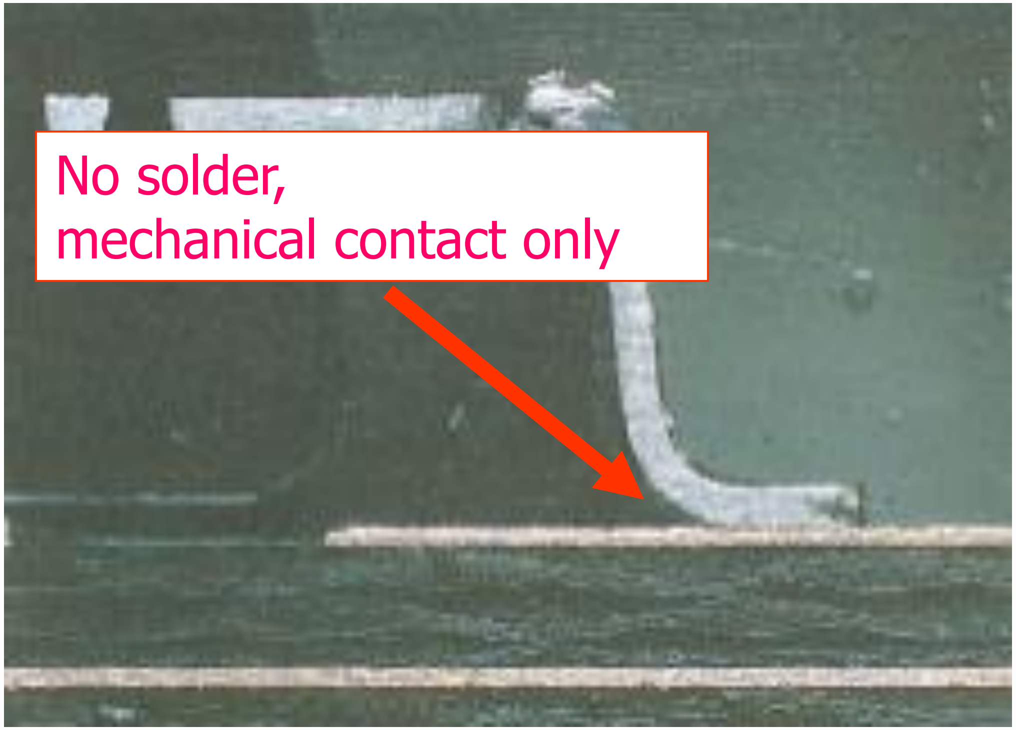
Complete solder joint

- Resistance of solder joint: **1.364mOhms**
- **This time we define this resistance as "PASS" criterion**



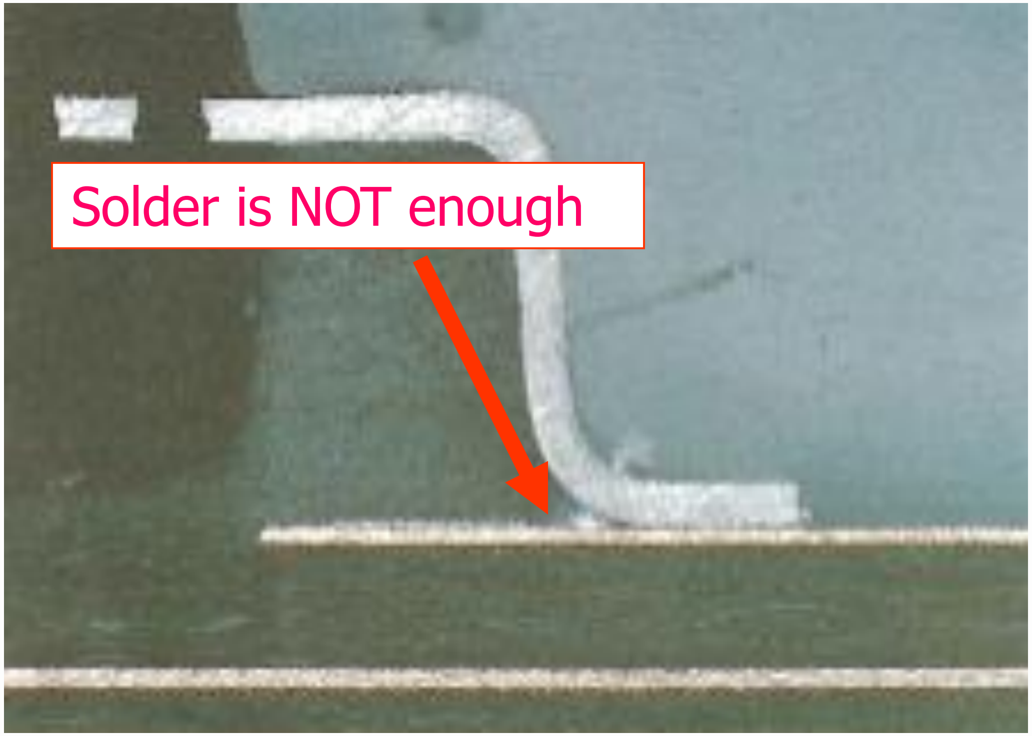
Poor solder joint #1

- Resistance of solder joint: **201.1mOhms**
- Test result: **FAIL, over 100X higher than the criterion**



Poor solder joint #2

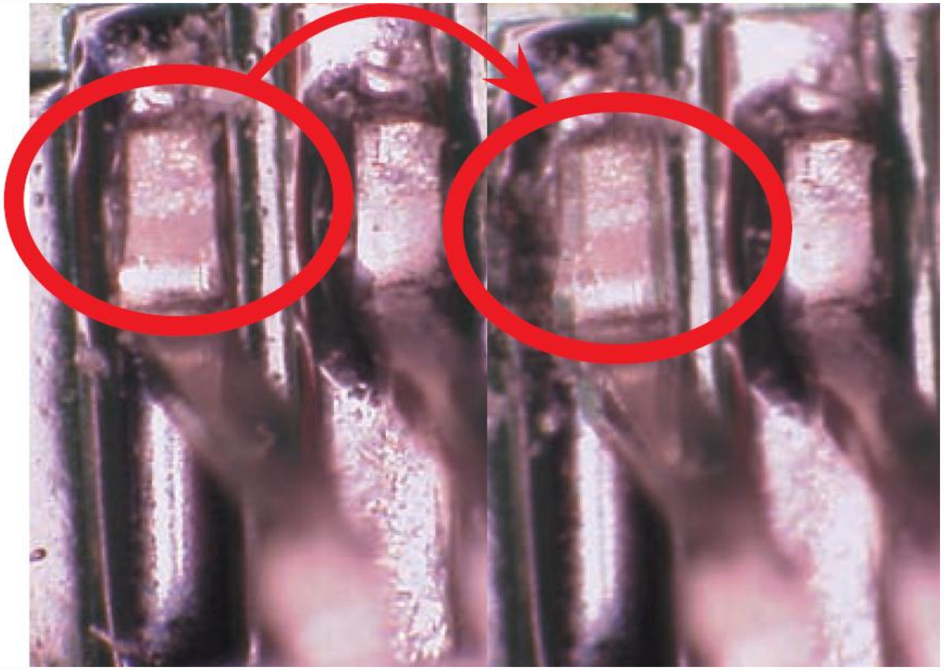
- Resistance of solder joint: **3.969mOhms**
- Test result: **FAIL, about 3X higher than the criterion**



Poor solder joint #3

- Resistance of solder joint: 63.45mOhm
- Test result: FAIL, about 16X higher than the criterion

No solder exist at the joint
IC pin can shift if anything touches



Conclusion

- The 10X rule in PWBA tests
  - Repair cost enormously increases if a defect is found in downstream!
  - Need to screen out defectives in an early stage by structural tests
- The 1000000X? rule
  - If a defect is found in the market, recall cost can be 1million times or more!
  - In the structural test at the assembly factory, need to screen out latent defectives
- The following 2 factors have to be considered to determine test strategy
  - Quality
  - Volume
- SJIT, Solder Joint Integrity Test, to find latent defects
  - Latent defects come out after the board assembly is delivered to customers
  - 4-wire resistance measurement method is only a practical SJIT method at the moment