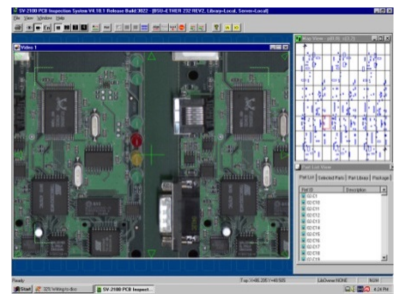
Powerful Circuit Test: ICT & Flying Probe

For complex electronics assemblies or those that target high-reliability applications, in-circuit test (ICT) is a great choice. But the type of ICT used – fixtured or flying probe – will depend on a variety of factors and trade-offs that we address in this paper.

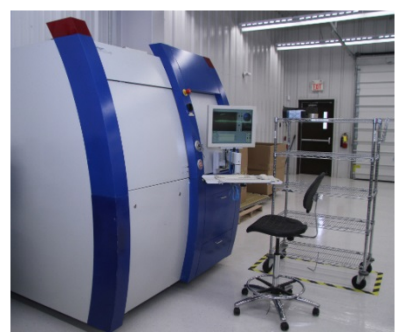
ICT 101

ICT - this type of circuit test isolates individual components in the circuit and tests the electronic characteristics of each one. Where circuit and isolating techniques allow, basic ICT tests detect component presence, orientation, shorts, opens, resistance, capacitance, and inductance. More advanced techiques may also include power-up, functional testing, device programming, automated inspection, laser height measurements, JTAG testing, capacitively coupled opens testing, and even LED colour and intensity checks.

Let's compare ICT to other tests:

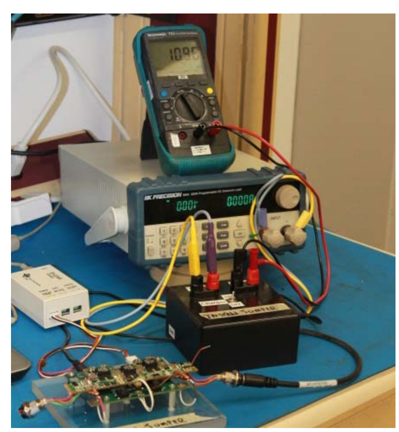


Automated optical inspection (AOI) – This visual inspection method uses a camera to scan for visibly recognizable defects – such as missing components and component placement errors. An image of the assembly is compared to an image of a good assembly using machine vision techniques. AOI cannot detect defects hidden underneath components and cannot detect defects within PCB substrates or components that are out of spec. Today's smaller parts have no markings and so validating intended values is less and less possible using this method. ICT is able to detect all of those defect types.



Manual visual inspection (MVI) – Another visual inspection test that uses the human eye aided by a magnifying tool to look for visibly recognizable defects. AOI is generally preferred to manual inspection today, but manual inspection is still important for spot-checks on solder quality and component quality. Manual inspection has the same shortcomings as AOI, in addition to lower reliability and repeatability.

X-ray inspection – An X-ray system is used to inspect underneath components, examining solder joints. This method is used on packages such as ball grid arrays (BGAs), and is typically used for only a small proportion of the joints due to time and cost. X-ray methods cannot detect components that are electrically defective or out-of-spec. ICT can detect these issues.



Functional or system testing – In functional test (FT), the test system feeds specified inputs into the assembly and measures outputs to determine if the unit functions as intended under the specified conditions. Functional tests assess only the gross function of a product within tolerances.

Functional test failures are not typically localized and so debugging is time consuming and requires an understanding of the circuit, specialized interconnects, and advanced instruments, in addition to considerable skill and time - all of which increase costs. Defects could still be present but if they do not have a measured effect on function, they will not be detected – for example, defects that are detrimental to emissions, susceptibility, performance over temperature, and lifespan. ICT can detect these defects. In addition, ICT is able to localize defects for easy, cost effective, and quick repair without the help of a specialized technical person and special tools.

Defects, Reliability, and Test Coverage

Within the electronics supply chain and manufacturing process, there are a number of reasons why defects occur. These include:

Defective PCB substrates – the processes for fabricating multilayer PCBs with small vias or other advanced features are complex and difficult. Process control is challenging. These defects are not always obvious or readily detected.

Small form factors – as the demand for smaller and smaller end products increases, component spacing, lead spacing, land sizes, and component sizes all continue to shrink. Pushing this boundary increases the likelihood that defects will occur in production.

Defective components – despite common belief to the contrary, components themselves are not always defect-free. They may be mis-packaged, mis-labelled, marginally out of spec, grossly defective, or functional for only a brief period. Some of these defects are obvious and others require electrical testing to detect.

Component markings –component markings are disappearing as parts get smaller and smaller and as cost competition mounts. This creates new opportunities for distributors to ship incorrect parts. It also makes detecting such errors later on more unlikely.

Soldering and Process issues – sometimes, component plating and lead or board finish is not as solderable as one would hope. There is variability within any brand and also between alternates. Machines age and undergo maintenance. Batches of materials and chemicals vary and age. Environmental conditions also vary. All of this variability, despite best efforts, can sometimes lead to defects.

Design for manufacturing (DFM) issues – sometimes, a product has to be designed a certain way for good reasons that may result in a manufacturing challenge. Other times, design oversights may lead to manufacturing challenges. In either case, it may not be possible or cost effective to correct those issues and defect rates may increase.

This may sound like bad news, but modern manufacturing techniques include a great variety of tools to help mitigate these factors and control defects.

Complex products (those with many components, layers, small form factors, and densely placed components) have greater opportunities for defects than simpler designs. Each part, lead, solder joint, and process adds to the potential defect count. In this case, ICT is a good choice because of the excellent test coverage that it provides and its ability to reduce or eliminate debugging.

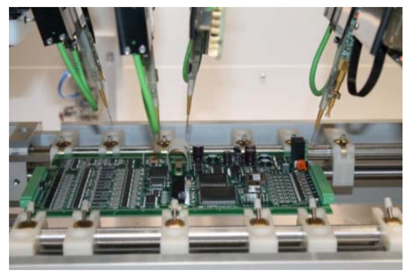
Reliability issues are related to both defects and design. Reliable products have the ability to perform in the intended target environment for longer than the intended minimum lifespan. Finding all defects, including those that would be missed by functional test, is critical to reliability. This makes high reliability products excellent candidates for ICT.

Coverage on a functional test may include all possible functions of a product, and a product may pass such a test yet still fail early in the field due to defects that were not detected during functional test or inspections. Certain defects may not interfere with the system's ability to operate to specification but may cause long-term problems that shorten its life span in the field. Unidentified defects can also cause the product to under-perform or fail at a particular temperature range, under certain exposure to emissions or vibration, or cause it to emit more than intended.

(We recommend this related article, available on our website, that examines how lead-free electronic processes increase a product's vulnerability: Establishing Long-Term Reliability for Lead-Free Electronics Products).

Fixtured vs. Flying Probe ICT

The two types of ICT are fixtured and flying probe. Both isolate individual components and test the electronic characteristics of each, and both test for similar defects.
Both types of ICT can provide:



- Testing of each component
- Manufacturing defect analysis (MDA)/shorts/opens/values
- Capacatively coupled tests
- Functional tests
- JTAG tests and parts programming
- LED tests (on/off, light characteristics)

The primary difference is that fixtured ICT uses fixed test probe fixtures (sometimes called a bed of nails) that must be designed and manufactured for each product design. They provide very fast per-unit test speed and are typically used for stable, high-volume products.

In contrast, flying probe test pins move about and are electro-mechanically controlled. They are easily programmed and re-programmed, making this method suitable for low- to mid-volume products and designs that are still in flux. Flying probe is also favoured for prototypes because there is no investment required in costly fixtures, and design changes are easily accommodated by changing the test program.

Table 1: Fixed vs Flying Probe ICT Deltas

	Fixtured	Flying Probe
Test Development Costs	High – tens of thousands of dollars and up	Low – only programming
Test Design Lead Time	> 4 weeks	< 1 week
Test Coverage/Access	• No AOI included • Requires test pads designed-in, more design restrictions • Higher costs for fixture and programming to access from both sides of board	• May include AOI • Better access to nodes through vias, lands, leads • Can test from both sides of board cost-effectively
Support for Design Changes	• Difficult and time consuming – new fixture/wiring/ programming required • Many times more costly than Flying Probe reprogramming	• Easy and inexpensive – update the program in a short period
Operating Speed & Cost	Very fast • Typically <1min per test unit • Lower test cost-per-unit	Medium to slow • Modern and higher-end machines are faster than others • Typically still several times slower than fixtured ICT • Higher test cost-per-unit

Table 1 above summarizes the key differences between fixtured and flying probe test to be taken into account when determining the best test ICT method for a product.

De-Risking Products with Test Strategy

No matter what the test method is, having a test strategy built into the design phase is the most effective means of de-risking products and manufacturing. Test is most effective when it is (a) planned for in the design, and (b) done before products are assembled into final systems. The earlier in the process we can test, the lower the cost of debugging will be.

Some tests may require specific considerations to be implemented into the design. There may also be some overlap in coverage between various test methods, and overlap should be minimized and fault isolation weighed against production and debug costs.

ICT is one type of test that brings a lot of power and specific capabilities to bear. In addition to its many benefits, ICT comes with a cost. Consideration should be given to the product's reliability needs, complexity, and costs as well as complementary test capabilities and debugging challenges, when assessing the test strategy.

We are able to provide guidance on these matters and input that ensures test costs are factored into product pricing and marketing strategy. We will work with you to understand the applicable fault spectrum and devise a test plan that covers this spectrum effectively for your production volume.

(For best practices on how to ensure the testability of your PCB design, please read our DFM Tip, Planning Your Test Strategy).

Test Services at OCM Manufacturing

At OCM, our Test Services include:

- AOI - automated optical inspection
- MVI - manual visual inspection
- X-ray inspection (automated and manual)
- ICT - flying probe
- Functional/system testing
- DFT - design for test analysis and test planning assistance
- Test development

We welcome the opportunity to learn more about your specific project and to provide a quotation.

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