The definitive guide to test within electronics manufacturing

JJS MANUFACTURING

Introduction

Testing is part of life. At the end of our school years, we sit exams to prove the knowledge and skills we have accumulated. Our cars undergo an MOT test each year. Businesses are assessed to see whether they meet industry safety and quality standards. And, when it comes to manufacturing, testing is just as crucial.

Testing is an integral part of the manufacturing process, which ensures defects are rooted out and resolved before a product reaches its intended customer. Testing is the only way to achieve optimal processes that result in products that have as close to a 0 per cent failure rate as possible.

However, many people believe that testing is optional - something you do after a product has been made; a postscript to the manufacturing process. In fact, testing should be carried out at various stages along the way. Finding a fault in a product before it has been manufactured to its full value, and either rectifying or scrapping it, is a lot more effective than testing the finished goods, only to discover a problem and then reject them.

Whether you are an original equipment manufacturer (OEM) or an electronics manufacturing services (EMS) provider, testing should be at the heart of everything you do.

In this eBook we will explore seven different types of test:

1. In-circuit test (ICT)
2. Flying probe
3. Boundary scan
4. Soak test
5. Stress screening
6. Functional test
7. Electrical safety testing

We will be looking at how each of these methods is intended to prevent and minimise manufacturing defects - some of the test strategies also look for design defects, but that will not be our focus. These procedures cover different elements of the manufacturing process and, depending on your product, you should implement a combination.

We will discuss each test type in detail. What is it? What is the cost to your organisation? How can you implement it? And how thorough is the test coverage? And, most importantly, what could be the cost if you don't test effectively?

Finally, we will look at four specific product case studies. For each of these, we will highlight the relevant test methods that should be applied and explain why they are a crucial element of the manufacturing process.

Testing is an integral part of the manufacturing process

A general look at test

So why is test so important? And why should both OEMs and EMS providers do it?

Testing should confirm that a product has been manufactured correctly and, therefore, provided the design is sound, will do what it is supposed to. For example, have the right components been used and do they work? Are any components missing? Having in place good testing procedures will ensure your organisation produces consistent, high-quality products to your customers' requirements.

Many people believe that if you build products right in the first place, you shouldn't need to test them. According to this viewpoint, testing is an unnecessary expense that doesn't add value. But this is simply not true.

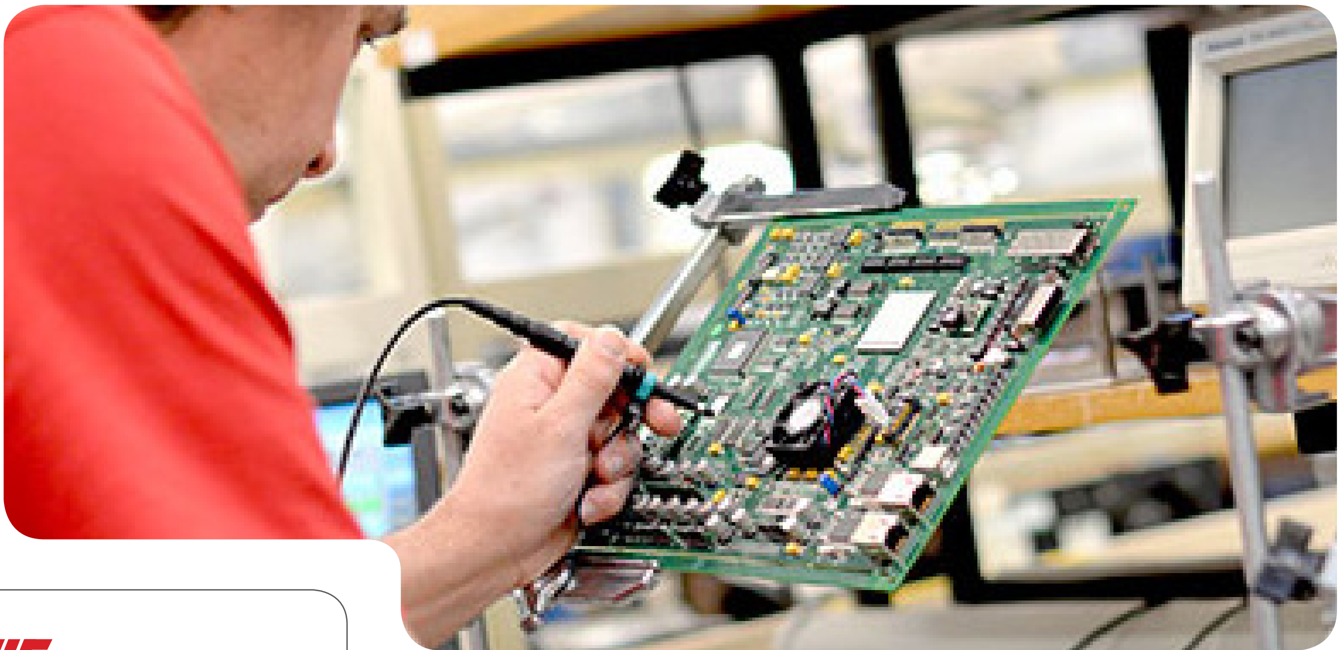
Yes, testing has a cost, but failing to test could cost your organisation a lot more in the long run. According to DfR Solutions: "Resolving product acceptance or post-deployment problems is an unwelcome item on the daily to-do list. Depending on the industry (e.g. aerospace, defence, medical, telecom, transportation), potential issues include schedule delays, cost impacts, customer complaints, mission impacts, or even loss of life."

As with any human endeavour, there will always be a margin of error within manufacturing so, unless your product is exceptionally simple and of very little value, reassurance is required. It is much easier and cheaper to remedy faults along the way than to try and identify what's gone wrong after you've finished making a product.

It's worth reiterating that the types of test we will be considering in this eBook are focused on detecting manufacturing defects - and not problems with the original design. So, for example, a product could be flawlessly manufactured but still not work as it was intended to - because there are errors in the design.

If you are an OEM outsourcing to an EMS provider, genuine manufacturing faults should, of course, be rectified free of charge - but costs associated with design-related test failures are likely to head back your way. Test, therefore, provides a feedback loop, not only to the production department but also to your design team. Less rework and a higher first-time pass rate correlate to longer term reliability.

Let's look in detail at seven different types of test.



The different types of test techniques

Whatever strategy you choose for your product, testing must not be an afterthought. It can certainly adapt according to where you are in the product lifecycle, but right from the start you need to be thinking about designing your product for test, as well as the short and longer term development costs, and the price per unit.

1. In-circuit test (ICT)

In-circuit test (ICT) is a type of automated test equipment (ATE) that is used to test printed circuit board assemblies (PCBAs).

ICT carries out what is called “manufacturing defects analysis” (MDA), which covers the majority of the most common process faults that can occur. These include: open circuits (e.g. something not soldered), short circuits, passive component measurements (resistors and capacitors), diode and transistor orientation, and usually, basic supply voltage measurements.

Integrated circuits (ICs) can have some powered, even basic functional testing, as well as “vectorless” test to check the soldering of pins to the PCB through a non-contact, usually capacitive, probe or plate. And ICT can also provide limited analogue and digital measurements.

In order to carry out ICT, you will need to invest in a dedicated test program and a “bed of nails” test fixture. Both of these will be unique to the PCB design you are testing and usually cost in the region of £10,000. Because of this high non-recurring engineering charge (NRE), this method is most suited to high volumes and stable designs. If you change your PCB design, you will need to purchase new equipment.

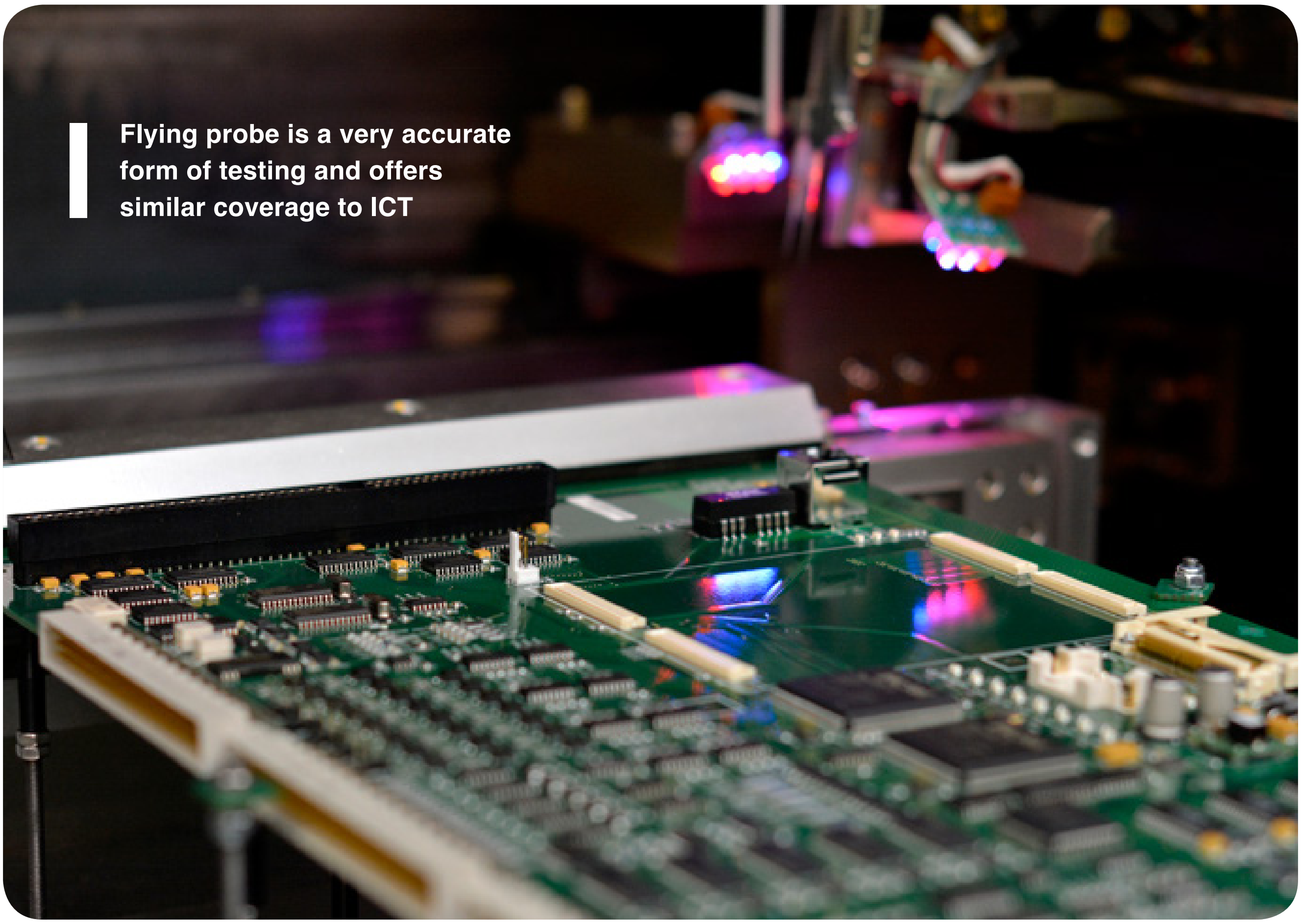
To achieve good coverage, a bill of materials (BOM), computer-aided design (CAD) data and schematics are required. The CAD data is used to generate the basic test program, ensuring information is taken from the original design rather than a manual interpretation of other data.

Populated and unpopulated sample PCBs are then necessary for fine-tuning the test programs -“debugging” - and making the fixture, to ensure the assemblies will physically fit as they should.

It is very important to take into account design for test (DfT) when using this method. ICT requires at least a 50thou wide test pad per net, designed into the PCB up front, which is used as a target for the fixed test probe. Ideally, these should be on one side of the PCB as double-sided fixtures are expensive.

ICT is a highly accurate form of testing and, despite the initial investment required, the cost per unit is low. Typically, it takes around 30 seconds to test a medium-sized board, at a cost of less than £1.

Whatever strategy you choose for your product, testing must not be an afterthought



2. Flying probe

Flying probe is another type of ATE used in electronic PCB assembly. And, like ICT, it carries out MDA. However, unlike ICT, most flying probe systems also offer limited optical inspection, which can add coverage for those components that can't be accessed electrically.

This test method typically uses four probes, which can be programmed and reprogrammed for each board design. The flying probe machine itself can cost more than £150,000. However, if you are an OEM outsourcing to an EMS provider, you will only need to pay for each program you require, at a cost ranging from around £1,000 to £2,000. Therefore, flying probe is best suited to lower volumes where the design may change a number of times throughout the lifetime of the product, or for boards where test pads have not been designed in.

As with ICT, a BOM, CAD data and schematics are required, as well as populated and unpopulated sample PCBs.

DfT is less of an issue when using this method. Unlike with ICT, flying probe machines can probe the ends of component pads and uncovered vias (as long as they are not "tented") to get access to the electrical networks. Nevertheless, it's a good idea to maximise test access on one side of the assembly if possible - i.e. have at least one probable point for each network. Unless you're using a double-sided machine, it costs more to turn the board over and test from both sides.

Flying probe is a very accurate form of testing and offers similar coverage to ICT – but it is a much slower method. Therefore, despite the low initial cost, the cost per unit varies a lot and can be up to approximately £50 for complex boards.

3. Boundary scan

Boundary scan testing is used for checking that digital devices on a PCB are connected. It uses test logic that has already been built into the digital integrated circuits (ICs) on the board, thereby removing the need for physical test probes and equipping manufacturers to debug and program complex digital circuits.

The standardised specification for this method was devised by the Joint Test Action Group (JTAG), and it is ideal for testing a single PCB, or multiple PCBs. Boundary scan can be used in tandem with ICT or flying probe, but on a board with multiple ICs, it is more likely to be used as a standalone test method.

Implementing this method requires a tailored software program. The licence required to write the software program usually costs a few thousand pounds - and can be over £10,000 in some instances. A test access port (TAP) is then designed into the board. The TAP consists of four pins:

1. Test data-in (TDI)
2. Test mode select (TMS)
3. Test clock (TCK)
4. Test data-out (TDO)

Some TAPs also have an additional fifth pin: test reset (TRST).

A signal is sent around the board like a chain. This signal is injected into the first digital device on the board, travelling around its perimeter, before passing on to the next device and repeating this process. If any pins are missing, these will be detected and reported.

It's important to take test into account during PCB design. As mentioned above, all digital ICs need to be boundary scan-enabled. However, no test pads are required, as this test method gains access purely from the board edge (TAP), making it an extremely useful and non-intrusive test technology. Most often, the hardware designer develops the test routines as a debug tool, and this is later transferred to production as a test for mainly digital devices. Device programming can be included as well.

Boundary scan is a reliable and extremely rapid test method that takes just a few seconds and delivers in-circuit levels of test coverage and diagnostics for digital circuits. It is the perfect way to identify structural fault locations, even beneath ball grid arrays (BGAs), without requiring mechanical access to the circuit.

4. Soak test

Soak testing is used to find out how a product "survives" in the wild. This test method involves simulating the real-life conditions under which a product will be placed, to identify any manufacturing defects that will effectively "kill" the product.

For example, an OEM or EMS provider making traffic lights might replicate the conditions at the junction they will be placed in over a defined period, to validate their performance and stability.

During a product's lifecycle, many problems tend to strike either very early on, or towards the end of the product's life. Therefore, soak testing helps to ward off the first potential batch of problems. It also identifies faulty components that may have passed an earlier test - ICT, for example - but falter under continuous testing.

A soak test is bespoke to the product being tested and so cost and set up time are variable, dependent on the product and the equipment being used. If you are an OEM outsourcing to an EMS provider, you will need to specify to your partner exactly what you are hoping to achieve via the soak test. What are you looking for? What might go wrong? Where are the potential fail points?

> **Soak testing is used to find out how a product "survives" in the wild**

5. Stress screening

Unlike soak testing, which places a product under "normal" conditions, stress screening imposes more extreme conditions that are designed to test a product to its limits - or beyond.

A product might be subject to vibration tests, thermal shock or mechanical shock. For example, a military product that will be used in the desert might be subjected to extremes of temperature by being placed alternatively in an industrial oven and freezer. And a product intended for use in a commercial airliner might undergo intense vibration tests.

There are two types of stress screening:

1. HALT (highly accelerated life testing)
2. HASS (highly accelerated stress screening)

HALT testing is designed to literally test a product to its breaking point. In industries such as defence and aerospace engineering, where high reliability is absolutely crucial, it's important to know exactly what conditions a product can stand. HALT allows you to identify the weakest points of a product and then work out how you can improve them. A product may go through several rounds of HALT, depending on how robust it needs to be.

HASS testing is comparable to an intensive soak test. For example, a product might be subject to the stresses endured during years of normal conditions in just a few minutes. However, a product should survive HASS testing without any damage

Like soak testing, stress screening is highly bespoke. So if you are an OEM outsourcing to an EMS provider, it is important to specify your requirements.

6. Functional test

A functional test essentially proves that a product does what it is supposed to do. Unlike the test methods we have covered so far, this one is predominantly focused on the design of a product - rather than the manufacturing quality.

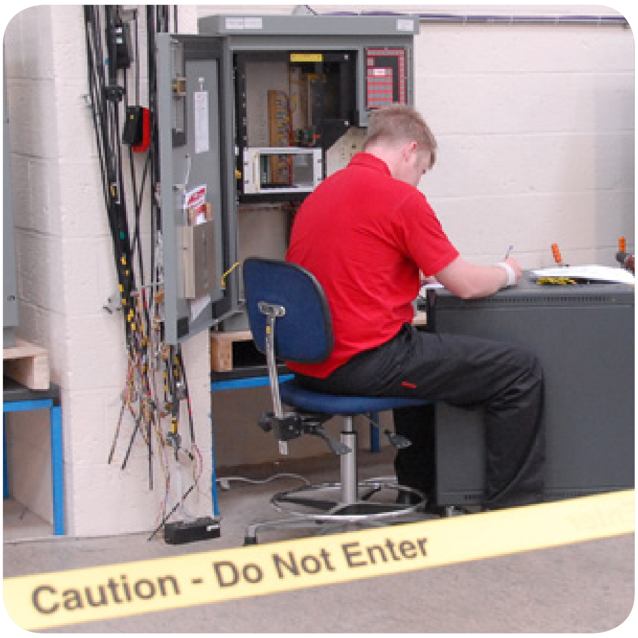
Some OEMs see functional test as the only test they need to implement. However, this is a misguided viewpoint. As this test often comes at the very end of the manufacturing and test process, the next person to power the product up is the customer. It is surprising how much can be wrong at a component level and still pass a functional test: floating pins on ICs, missing and wrong value components, etc. can all go undetected. As a result, a functional test can provide false confidence unless those potential errors have been covered elsewhere.

A functional test is usually developed by the product designer. It can be a steep learning curve - and expensive - for an independent developer to learn the product functionality before designing the test equipment. Kit suitable for the development lab is very rarely robust enough for a contract electronic manufacturing environment, but designing production fixtures probably isn't good use of your product developer's time.

A functional test is often quite slow as well, and debug can be difficult, requiring more time and a higher skill level to determine the cause if the product malfunctions. All of this adds cost.

Functional test, therefore, is generally best reserved for a quick "final assembly" check once the thoroughly tested subassemblies are put together. If the pass rate is not virtually 100 per cent, then the test strategy (or perhaps the product design) needs to be reviewed.

A functional test can provide false confidence unless potential errors have been covered elsewhere



7. Electrical safety testing

Electrical safety testing is essential for any product that uses electricity.

The simplest form of electrical safety testing is portable appliance testing (PAT). A product is connected to PAT equipment, which checks whether it is safe to use and that the relevant electrical components are insulated.

For higher voltage products, a flash test should be implemented. This test method checks whether the electrical insulators in the product have enough dielectric strength for the working voltage. A higher than normal voltage is applied to the product and, to pass, it should be able to withstand this stress.

Earth bond testing measures the resistance between the ground and any metal components on the product. A high current of around 25amps is passed through, to ensure there is sufficient electrical insulation.

A good EMS provider will carry out electrical safety testing as a matter of course. Nevertheless, you should at least specify basic electrical safety testing - e.g. earth bond and flash tests - when briefing your EMS provider.

The right test strategy for your product

Having covered seven different types of test, we will now look in detail at four particular product case studies and explain the test methods you would employ in each instance - and why.

As you will see, best practice is to test a product at various stages in its manufacturing lifecycle, in order to root out defects as early as possible. Every product is unique, and there is no set approach when it comes to testing yours, but these examples should give you a good idea of how to determine your test strategy.

1. Product A

- Complex control cabinet for a coordinate measurement machine (CMM).
- Produced in low to medium volumes, for the test and measurement market.

The control cabinet consists of two different PCBAs housed in a 19" rack enclosure, which is then fitted into a custom cabinet with a servo rack, cable assemblies and power supply.

1. The main PCBA is tested using flying probe, as it is a complex assembly produced in relatively low volumes. The back panel PCBA is considered low risk in terms of possible manufacturing defects and is, therefore, not tested at this stage.

2. The two PCBAs are fitted into a 19" enclosure and then functionally tested to check the main board, and its pairing to the back panel board, works with signals received from the back panel.

3. Once this subassembly has been tested, the enclosure is then fitted into the custom cabinet with a servo rack, cable assemblies and another power supply. Note the cable assemblies are continuity tested before being fitted into the custom cabinet.

4. The cabinet is then PAT tested to ensure it is safe to operate before mains power is applied.

5. A further functional test is carried out afterwards to ensure the sub-assemblies are connected to the servo rack and power supply correctly, and everything is working as expected.

6. The unit is then shipped with a range of interface cables, which have also been previously continuity tested to ensure their integrity.

Test methods used:

- Flying Probe
- Functional test
- Continuity test
- PAT

2. Product B

- High-reliability box build product used to control and measure safety systems.
- Produced in medium to high volumes, supplied into the automotive market.

Consists of two PCBAs housed in a plastic enclosure and connected to a cable assembly.

1. Both PCBAs are tested using ICT, to provide optimal component level test coverage and fast test times for large batches.

2. One of the boards is then functionally tested, and software is loaded into the board at the same time, providing a high degree of confidence that the assembly is correct.

3. Both boards are then assembled into the plastic enclosure and connected to the cable assembly. This particular cable assembly has not been continuity tested beforehand as it is relatively simple and will be tested later, and is easy to replace if faulty.

4. Functional test is then carried out on the product, checking interconnections between both boards and the cable assembly.

Test methods used:

- ICT
- Functional test

Every product is unique, and there is no set approach when it comes to testing yours

3. Product C

- High-reliability box build product used for communication purposes.
- Produced in medium volumes, supplied into the aerospace and defence markets.

Consists of a single PCBA housed within a plastic enclosure with a touchscreen display and user interface.

1. 10 per cent of the PCBAs built in a batch are flying probe tested. This helps to verify the build and provide feedback for process control while minimising the overall test costs at this stage.

2. 100 per cent are then boundary scan tested, as it is mainly a digital circuit with boundary scan compliant devices.

3. The PCBA then has a basic functional test, while being environmentally stress screened at elevated temperatures, which helps provide confidence in the longer term reliability of the product.

4. The PCBA is then fitted into a plastic enclosure and connected to the touchscreen display and user interface.

5. The unit is then functionally tested and programmed to ensure the assembly is correct, and then left to soak for 48 hours again to help remove the possibility of early field failures.

Test methods used:

- Flying Probe
- Boundary scan
- Functional test
- Stress screening
- Soak test

4. Product D

- Complex cabinet used to control traffic signals.
- Produced in low to medium volumes, supplied into the transportation market.

Consists of ten different PCBAs that are fitted into modules with front panels and then built into a custom cabinet with wiring looms and power supplies.

1. Six PCBAs are flying probe tested, as these are produced in lower volumes as optional fits.

2. Three PCBAs are tested using ICT, as these are produced in higher volumes, common to all cabinets.

3. One PCBA is not tested at all as it is simple, low risk and tested indirectly later.

4 All 10 PCBAs are then built into modules with front panels attached and then functionally tested and programmed. This provides confidence that the sub-assembly works correctly, and may be used as a "spare" for field repairs if necessary.

5. Wiring looms, which have previously been continuity tested, are then fitted into the custom cabinet.

6. Each tested module is then fitted into a 19" rack, built into the custom cabinet and connected to the wiring looms.

7. Each cabinet is then PAT tested and earth bond tested for safety.

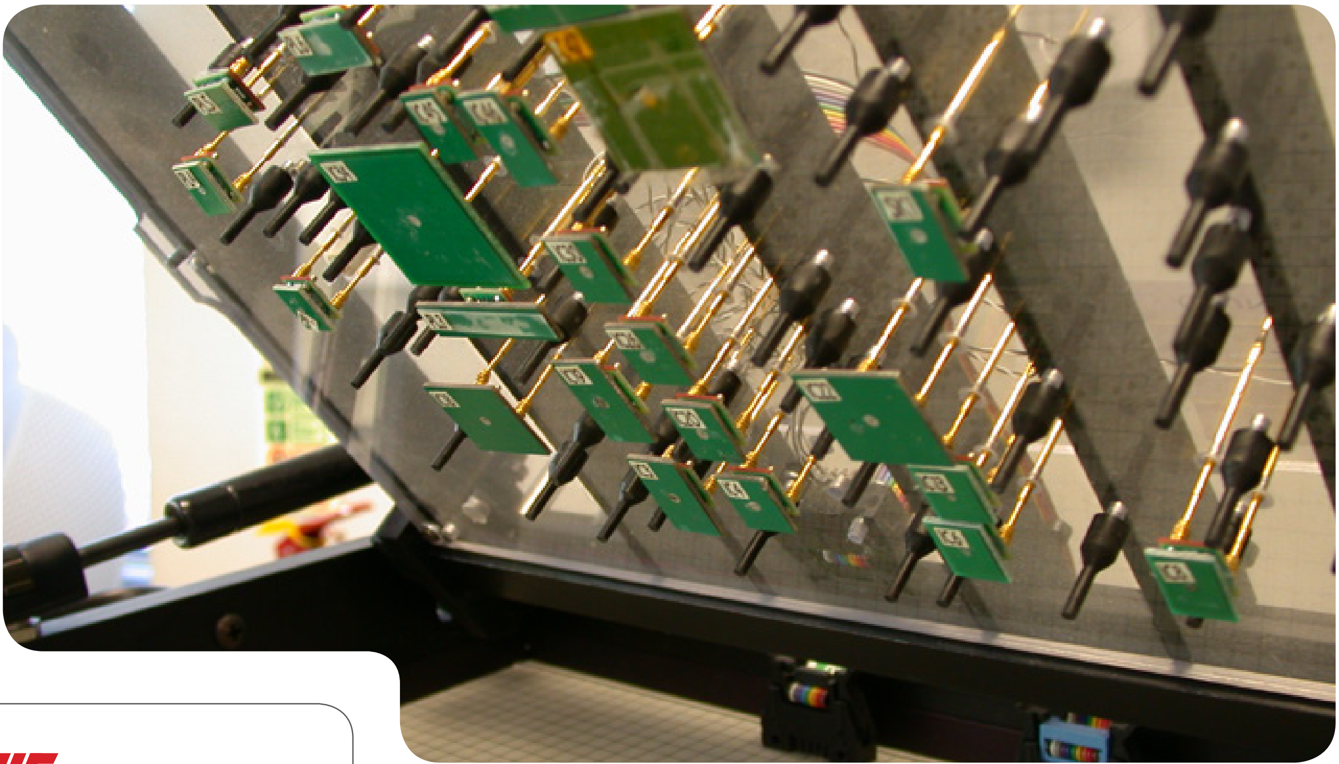
8. The cabinets are then functionally tested to ensure correct assembly of all the sub-assemblies, and to provide confidence that the unit functions correctly.

9. Each cabinet is left on soak test for 24 hours to help remove the possibility of early field failures.

10. Following the soak test, each cabinet is then run through a series of functional tests to verify that no issues were caused during soak testing and the cabinet still functions as it should.

Test methods used:

- Flying Probe
- ICT
- Continuity test
- PAT
- Earth bond test
- Functional test
- Soak test



Conclusion

Whether you are an OEM or an EMS provider, test is fundamental to everything you do. Ensuring that a product has been manufactured correctly should not be an afterthought - it ought to be something you confirm as you go along. It is far easier to identify and resolve problems before a product has been completely assembled.

In this eBook, we have discussed in-depth seven test methods, which are implemented at different stages of the manufacturing process, to show what defects they pinpoint and why they are so important. From ICT for PCBAs to electrical safety testing, there is alot to take into consideration - and the more complex your product, the broader the range of test methods required.

It is simply not true to say that if you have built your products right in the first place you shouldn't have to test them. As with any human endeavour, there is always a margin of error in manufacturing and the consequences of failing to spot mistakes could cost you time, money and even customers - with irreparable damage to your reputation.

Testing gives you the peace of mind that your products have been manufactured to the highest possible standard and that your customers won't be in for any unpleasant surprises.

Testing really is one of the most invaluable tools at your disposal.

About Us

JJS Manufacturing is an Electronics Manufacturing Services partner, offering low risk, end-to-end procurement, manufacture and supply chain solutions.

Call us on **+44 (0)1455 55 55 00** to discuss any points raised in the eBook or to talk through your own outsourcing requirements. We would be delighted to hear from you.

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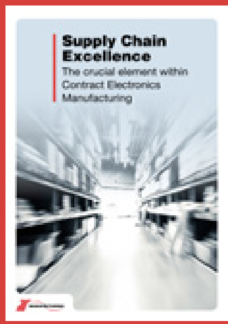

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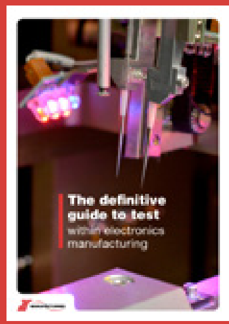

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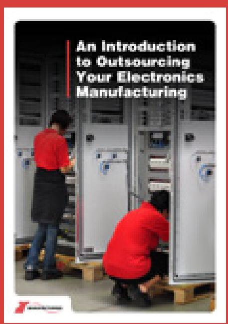

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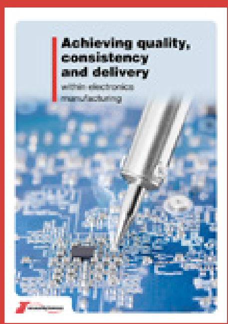

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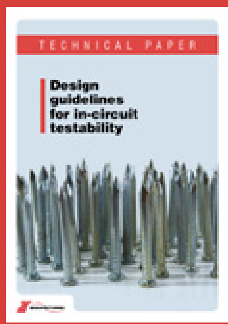

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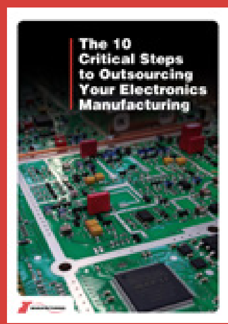

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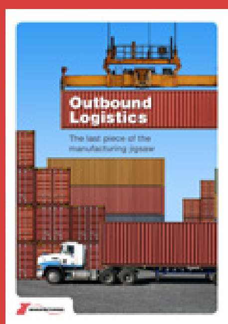

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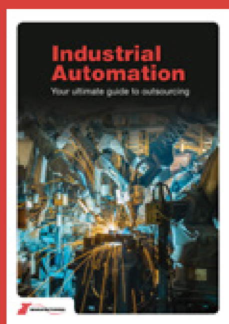

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