

Merging Technologies – Automatic Optical Inspection and Electrical Test.

As process methods used in printed circuit board manufacture advance at a high rate, the core technologies used for process control and test change accordingly. The advent of 'non-contact testing' takes the true test application a step away from the conventional 'probe and analyse' approach of traditional bed of nails or moving probe testers, and moves it into a new arena.

Without this hard contact between the probe and circuit, are these new methods conclusive and reliable, or can other processes give equivalent results ?

A look at a new way of scanning circuit images, Automatic Optical Test (AOT), could give the same or a higher level of confidence in finished bare-boards as off-contact testing; this article explains how and why.

Conventional testing

Let's take a look at the fundamental components of conventional testing and analyse the strengths and weaknesses of the process.

Conventional testing can take various forms, but if we concentrate on the following elements:

- contact with test points
- analysis of connectivity (check continuity)
- report faults

It is now possible to build up a process flow chart as illustrated in Figure 1.

The important issues to remember here are that the contact - analysis - report sequence is essential to this test process and each action is inter-dependant on the others for success of the operation.

There are many different approaches to this type of testing, with a myriad of ways to generate data, to engineer fixtures or to use roving probe machines; the exact methods used vary immensely across the manufacturing base according to equipment and cost parameters.

Some methods have positive benefits over the rest, but broadly speaking, the advantages and disadvantages of the fixture testing and moving probe testing can be summarised in the table shown in Figure 2.

We can see that the fixture methods have distinct advantages in speed but suffer with the necessity to build an expensive fixture; on the other hand the moving probe systems suffer with the cycle time for each test.

Overall, these testing processes are well understood, are well proven and offer reliable testing methods for finding open and short circuits on pcbs. The fault report contains this important information but cannot go any further than straight continuity testing.

Non-contact testing

These new methods of testing have arrived in the pcb manufacturing world in recent years and have been labeled as the 'biggest step forward for testing technology'.

The need for these types of technology has generally been brought about by miniaturization and the increasing density / decreasing spacing between test points on the contemporary pcb.

Fixture type machines are not capable of 100% testing all the test points on a pcb when many component footprints of, for example micro-BGA components, are situated close together. Even with the most up to date fixture building software using all available tools such as pin-staggering, deliberate pin-deflection and state-of-the-art test pins, it is not possible to test all test points in some cases.

So here is the need for a test process which does not have these limitations. Add to that, the high volume requirement and moving probe testing is eliminated by its low-speed restriction. The need for an alternative is clear.

What types of 'non-contact testing' are available today ?

There are several on the market, some of which are further developed than others, but all have essentially the same approach; this is made up of the following process components:

- validate test point presence
- analysis of connectivity (check continuity)
- report faults

It is now possible to build up the process flow chart as in Figure 3.

It can be seen by comparing this with Figure 1, that the flow charts are virtually identical with the exception that the 'contact test points' from the conventional testing has been replaced with 'measure between test points'. Not surprising really, but what does this actually mean to the test result ?

It means that the result is based on a machine 'predicting' what the continuity of the tested article was, rather than actually 'measuring' it. Not perhaps a great deal of difference one might think, but it is an important step away from the perfectly measured world of contact testing.

The technology that is used in these first generation non-contact testers, such as "Plasma Arcs" or "Electron migration" devices, to name but two of them, is in its infancy. It is not suggested that they are not reliable, but with such test point densities as modern micro-BGA circuits, it is conceivable that they are not fully mature at present.

The major advantages that non-contact testing offers are:

- no marking of the test board
- finer pitch capability than fixture tester
- no fixture to prepare

The results from non-contact testers should be the same as that of conventional testers that is only opens and shorts will be reported.

The boundaries between conventional contact and non-contact test are already being blurred with talk of machines using probes for part test and relying on non-contact for other parts of the board. This is in addition to existing technology that can use a test hybrid approach by using a fixture for one part of the circuit and moving probes for

another – a multitude of choices exists depending on the equipment available and the application.

So where do optical inspection or more pertinently optical test, fit into this scenario ?

Automatic Optical Inspection (AOI)

Automatic Optical Inspection (AOI) has always been regarded as a tool to inspect inner layer circuitry prior to bonding in the multi-layer process. Furthermore, it has not enjoyed a good reputation for performing a useful function on outer layer images.

The reasoning behind this is that the majority of AOI has been developed for inner layer inspection only. Inner layers differ from outer layers not only in the fact that they have holes drilled in them, but that the circuit patterns present on many outer layers have conductors whose shape and appearance confuse the fault detection logic of many AOI systems.

AOI machines can be broken down into three elements, those being:

- Optical scanning
- Application of fault detection algorithms
- Fault reporting

Whilst the optical scanning is a tried and tested part of all the AOI systems, it is the application of the fault detection algorithms used by any particular system that largely determines its efficiency and bottom line performance.

Many AOI systems use a picture comparison technique, or a design rule technique to determine faults present on panels, whilst others prefer to use morphological reference, that is one that depends on the shape of conductors or rather the mis-shape to detect faults.

It is these very same algorithms that set the machines apart, that actually restrict their outer layer usage. Picture comparison machines become limited because they work by detecting differences between a 'perfect image' and the scanned image; but in real life, there are so

many differences from panel to panel that are part of the process, that real defects become hard to determine. As far as morphological systems are concerned, contemporary outer layer circuits contain the most diverse range of conductor shapes and either confuse the fault detection algorithm or require extensive 'workarounds' that their use is severely restricted. You only have to look at the long set-up and high use of 'don't inspect areas' to see how limited some systems are on outer layers.

However, to highlight the point and to compare process steps, the process flow chart for AOI can be summarised as in Figure 4.

It can be seen that the flow steps are different to those used in either of the test approaches by several steps. Whereas a continuity check is performed at some stage during the process in both conventional testing and non-contact testing, at no stage in the AOI process is continuity referred to for fault detection.

Where does this lead ?

Automatic Optical Test (AOT)

There is the process of Automatic Optical Test (AOT) which is available for scanning any type of layer produced in a pcb. It has been used for many years for inner and outer layers, but its true potential is only recently being realised as more and more pcbs are not able to be tested 100%.

It is imperative to state that this process is not put forward to replace any form of electrical test, but it can certainly complement test at many stages where it becomes difficult or impossible.

The full AOT process would involve the optical test of all layers including the outer layers at their relevant stages of production.

So how does AOT differ from AOI ?

The three key stages are still present, namely:

- Optical scanning
- Application of fault detection algorithms (connectivity based)

- Fault reporting

The process flow chart for AOT is shown in Figure 5.

The key difference between AOI and AOT is that the fault detection algorithms for AOT are based on the connectivity of the pcb and not any other graphical or shape related property of the pcb. Furthermore, close comparison of Figures 3 and 5 reveals many similarities; indeed the only different step is that the AOT principle works with an image rather than some form of 'off-contact' measurement – otherwise the two processes are identical.

The AOT systems can optically scan using either white light and advanced line-scan CCD electronic cameras or alternatively using laser and CCD cameras. Developments in recent times in the image quality gained by CCD camera systems has meant that the images gained from pcbs under optical test tend very much towards a 100% representation of that pcb. It is of paramount importance to this approach of fault finding on pcbs that a good working image is obtained.

After obtaining the image of the pcb for fault analysis, a simple, but powerful set of detection algorithms based on the pcb connectivity are employed to find critical faults on the pcb. The AOT method uses test points, netlists and continuity just like any other test process, but it has powerful benefits.

Whereas test machines find opens and short circuits only, AOT system can analyse the circuit further and find image quality defects such as conductor width and spacing faults; this will identify any latent faults present at the bare board stage.

Furthermore, the AOT approach does not require large amounts of time or resources in terms of data preparation, it does not require a test fixture and it is possible to scan the most dense, complex circuit image in only a few seconds; there are no limitations on circuit density to restrict performance.

It can be seen that there are many benefits of using AOT when compared to any other test method. If the manufacturer accepts that the 'testing' part of the AOT is performed on an image of the pcb rather than with physical contact, then the results from AOT should be at least as good as for non-contact testing.

A comparison of the benefits of AOT when compared to other test methods is shown in Figure 6.

Conclusions

The electrical test process for bare boards is going through a huge technology change at the high end. Conventional fixture testers and moving probe testers are no longer capable of providing the results that the end-user requires. Several hybrid test methods are coming to the forefront as providing partial answers to some of the problems, but overall the picture is, at best, cloudy.

The AOT process could provide an alternative way of ensuring that only good product reaches the assembly stage and by employing AOT, it can heighten the quality of bare boards by giving latent defect information. AOT provides at least an alternative to electrical test and at best a complementary process to improve pcb performance in use.

Figure 1. Flow chart for conventional electrical testing

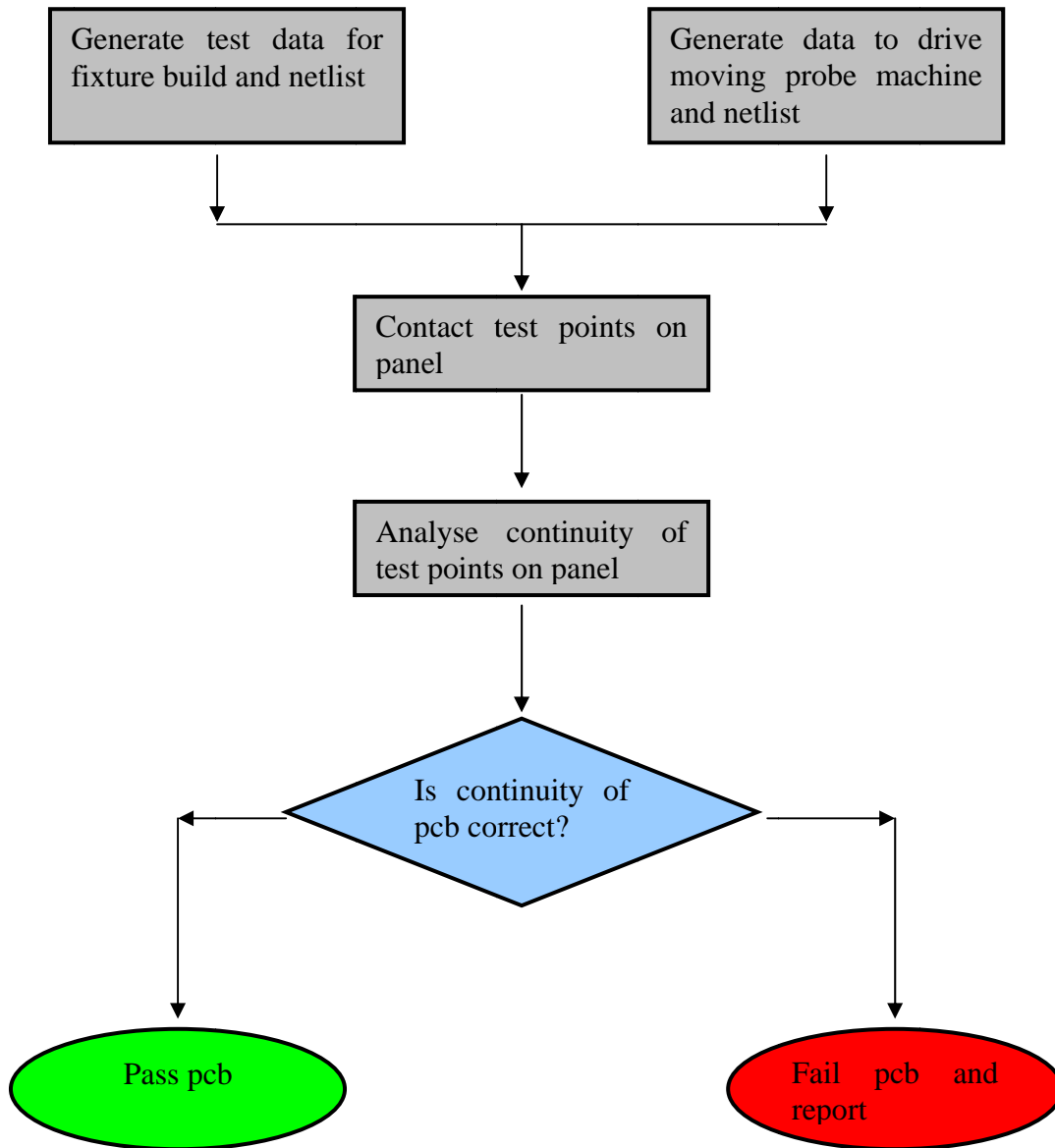


Figure 2. Comparison of fixture and roving probe testing

Parameter	Fixture testing	<u>Moving probe testing</u>
Data generation	Good	Good
Fixture build	Time/money consuming	Not applicable
Machine set up	Good	Time consuming
Test time	Fast	Slow
Fault location and repair	Mediocre	Mediocre
Accuracy of process	Good	Good
Fault types detected	Opens/shorts	Opens/shorts

Figure 3. Flow chart for non-contact electrical testing

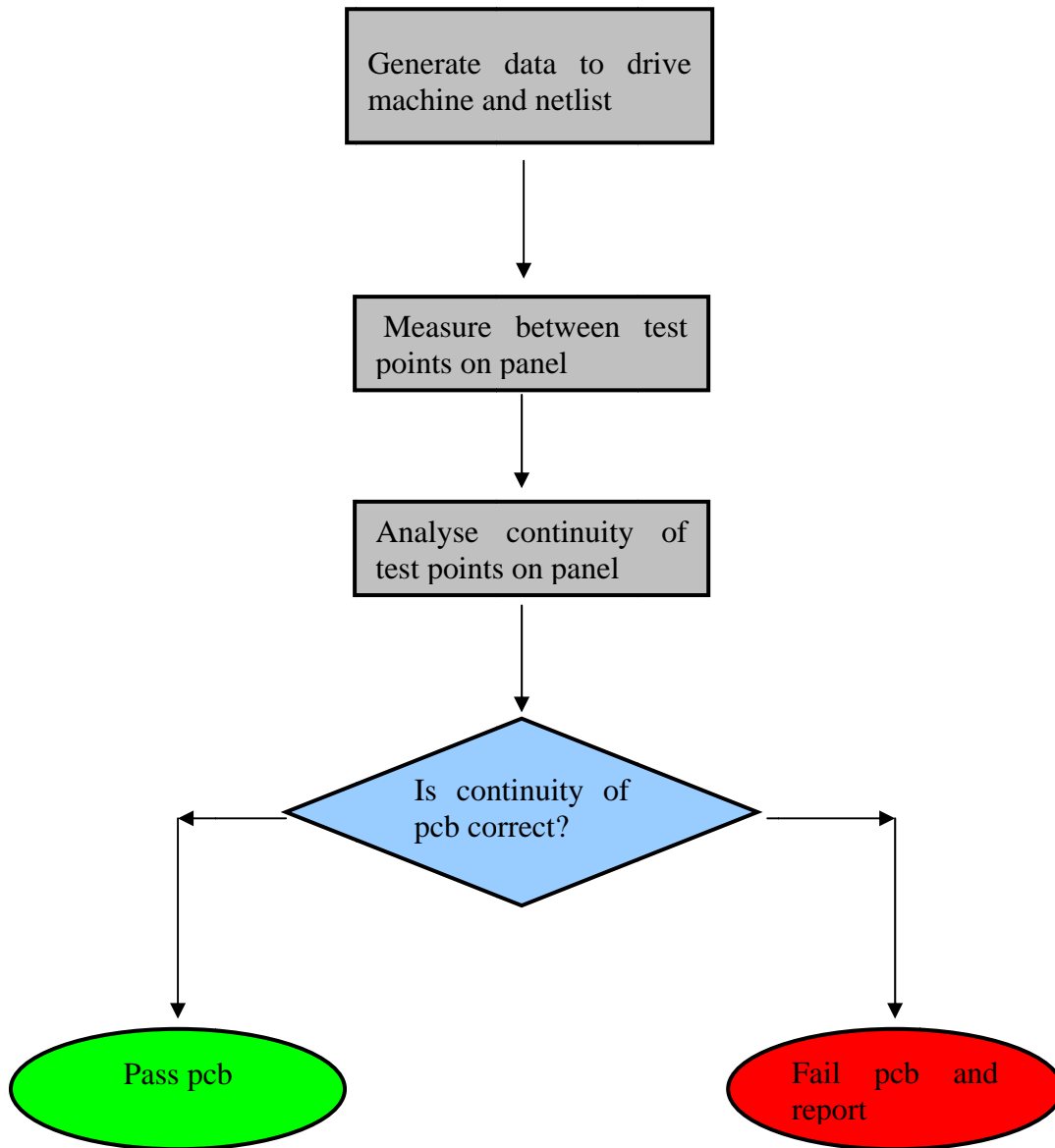


Figure 4. Flow chart for Automatic Optical Inspection

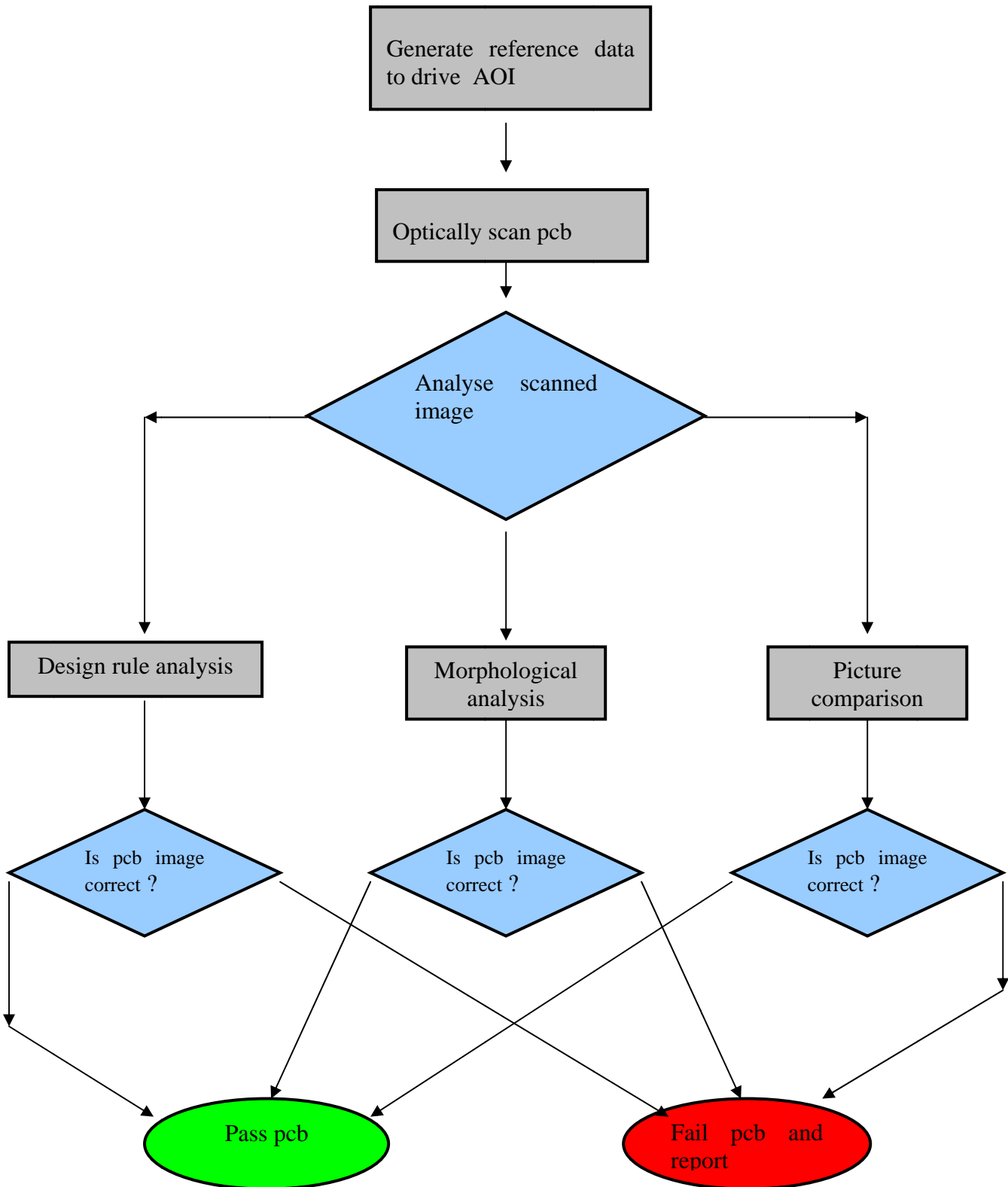


Figure 5. Flow chart for Automatic Optical Test

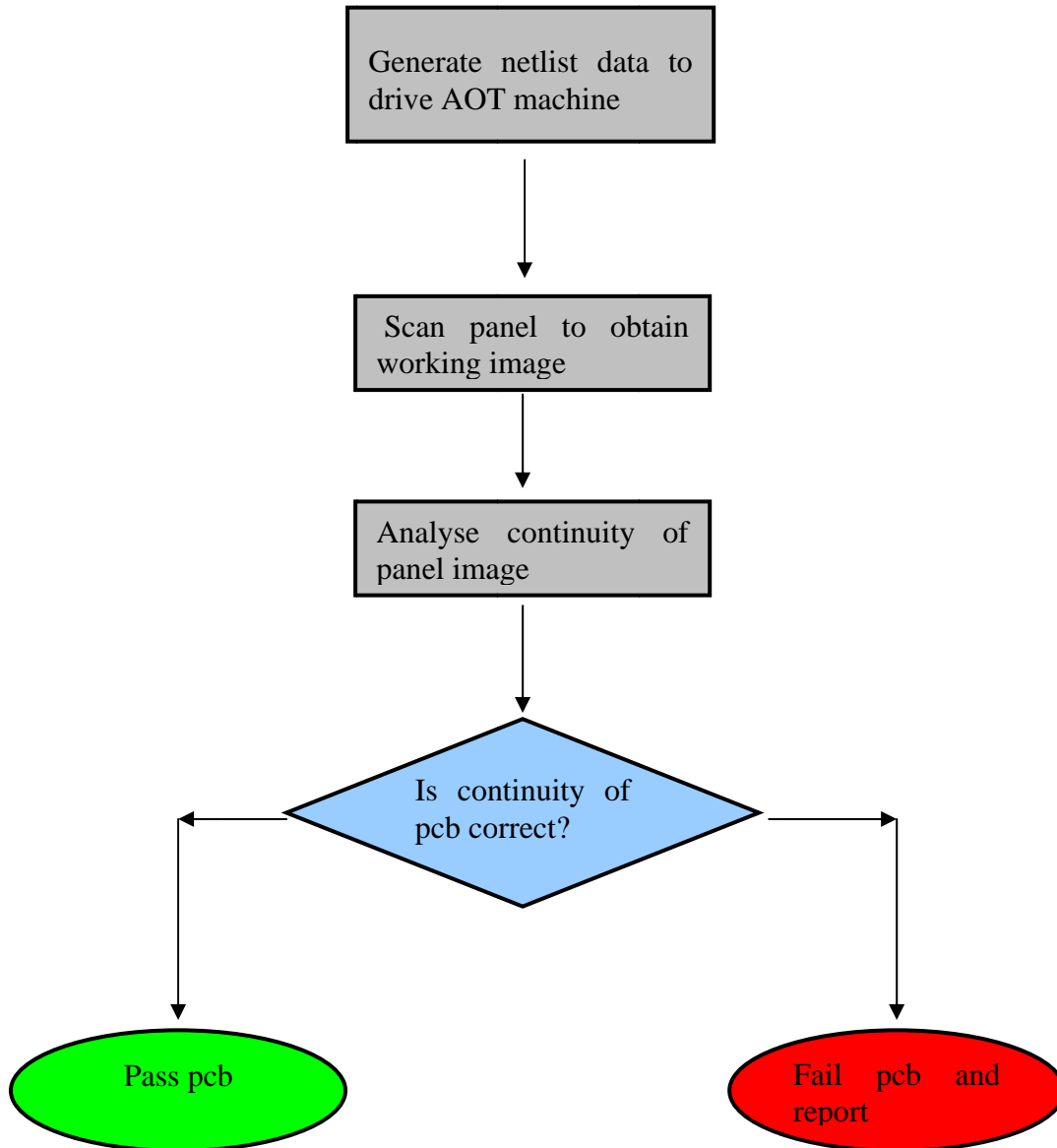


Figure 6. Comparison of AOT with all forms of testing

Parameter	Fixture testing	Moving probe testing	Non-contact testing	AOT
Data generation	Good	Good	Good	Excellent
Fixture build	Time/money consuming	Not applicable	Not applicable	Not applicable
Machine set up	Good	Time consuming	Time consuming	Excellent
Test time	Fast	Slow	Slow	Very fast
Fault location and repair	Mediocre	Mediocre	Mediocre	Excellent
Accuracy of process	Good	Good	Good	Good
Fault types detected	Opens/shorts	Opens/shorts	Opens/shorts	Opens/shorts Conductor width and spacing