Merifix Guide to Test Fixtures

Introduction

Testing of electronic assemblies involves three elements: the device under test (DUT), test equipment, and a fixture to make the connections between them.

DUT

The DUT is usually a single printed circuit assembly, i.e. a printed circuit board (PCB) with components mounted on it.

The DUT could also be just a bare board, a partially assembled board, a number of boards assembled together, or even a completed product in its enclosure.

Test Equipment

Test equipment runs the gamut from something as simple as a power supply and digital multi-meter to racks full of signal generators, analysers and controllers.

Test equipment is either manually controlled by an operator, or is under computer control with a complete suite of tests being automatically performed on demand. In this case the test equipment will be connected to the controller by a control bus. A common bus for discrete test equipment is GPIB. Common bus standards for modular card-rack test equipment are VXI (VME based cards) and PXI (PCI based cards).

Fixtures

Test fixtures provide mechanical support for the DUT and make connections to it. Connections are typically made by spring probes that contact test points on the DUT.

In the simplest case the fixture may just act as a connection interface, with the spring probes being wired to a rear panel connector that is used for connecting the test equipment.

Often the fixture includes some simple electronics to help with testing. For example, it may include a power supply to power the DUT, or some filtering or level-shifting interface circuits between the DUT and test equipment.

If the tests are simple enough sometimes fixtures are entirely self-contained. For example, a small microcontroller board and some simple interface circuits mounted in the fixture might be all that is required to test a simple board and provide a go/no-go indication.

Types of Test

Bare-board test

Printed circuit boards are often tested before any components are mounted. This type of testing is known as bare-board test (BBT) and its purpose is to find manufacturing faults - opens or shorts - in the copper traces of the board itself.

For high-volume production this testing is sometimes performed using a fixture with many hundreds or even thousands of probes. These fixtures are expensive to construct.

More usually, bare-board testing is performed using "flying probe" testers. These machines have a small number of probes that move around the board at high speed, measuring continuity one trace at a time.

In-Circuit Test

The most straightforward type of electrical test on an assembled board is to check that all components are present, of the correct type and value, and connected together as expected with no shorts or opens.

This type of testing is commonly known as in-circuit test or bed-of-nails test due to the large number of test probes that are needed.

Because this type of test requires at least one test probe per net, a large number are needed for even a modest sized board. All the probes exert a high force, so the test fixture must be substantial and robust. Many wired connections are required from the probes to specialised automatic test equipment (ATE), which is programmed with the expected connections and component values. The ATE program runs through many tests per second to check a board in a short time.

Because of the labour needed to construct and wire up such a fixture, and the cost of the fixture and the ATE, this type of testing is usually only performed in high-volume production.

With the trend away from designs incorporating many discrete components and towards designs based on a small number of high-complexity ICs, this type of testing is becoming less common.

Functional Test

The most common form of electrical test is functional testing. The board is powered up and the circuit is exercised while operating.

The most straightforward approach is to have the board under test just operate normally. External test equipment provides stimulus signals and measures the response. For example, a filter might be tested by measuring its frequency response.

When the board being tested includes a microprocessor it can play a part in the testing, to reduce the amount of test equipment required. For example, a microprocessor might test its RAM chips by writing and reading patterns, then just report the result. This sort of functionality is often known as BIST (built-in self-test) or BITE (built-in test equipment).

When a board includes a microprocessor, a CPLD, FPGA or similar device, often programming will be needed. This is not strictly a test function but it is often performed at the same time, on the same fixture as functional testing.

Whatever the details of the functional testing, this type of testing typically requires many fewer connections than in-circuit test. Connections are made either by test probes, through the board's ordinary connectors, or a combination of both.

The remainder of this paper concentrates on functional testing.

Types of Users

There are two main users of functional testing: Engineering, during design; and Production, during manufacturing.

Engineering

Engineering departments must perform functional testing during product design to verify correct operation of prototypes.

Often basic functional testing can be performed using the board's ordinary connectors, but complete design verification normally requires access to internal signals. Usually these are made available on test points. Connection can be ad hoc, by means of test clips or soldered wires, or can be made by a simple test fixture. Using a fixture has the advantage of making it easy to test multiple boards.

Engineering users also often need to program devices such as microcontrollers. During firmware development in particular programming may need to be done hundreds of times.

If there is sufficient free space on the board often a programming connector is provided. This can be a proprietary arrangement or something standard such as a JTAG header. Often there is not room for a connector and test points are used. Again, connections may be ad hoc or by means of a simple fixture.

Engineering departments are also often required to "check out" samples from an initial pre-production run. Production test procedures and fixtures may not be finalised at this stage, so engineering fixtures can be helpful.

Production

Production is traditionally the point at which functional testing is performed.

A product typically goes through several testing stages. Each board may be tested several times, for example after automated assembly and then again after manual secondary operations, or before and after programming. Boards may be combined to produce sub-assemblies which are tested, and there is usually one final test after the product has been completely assembled before it goes to the finished goods store.

The production manager will typically prepare a work-flow plan showing the various assembly and test stages. Each of the test stages may require a fixture.

Types of Fixture Construction

There are various basic forms of construction for fixtures for functional testing of printed circuit assemblies.

Connections

Connection to the DUT may be made either using the connectors that are ordinarily present on the board, or using test probes that make contact with test points.

Connectors

When the fixture includes connectors that mate with connectors on the DUT, the portion of the connector on the fixture is usually modified to remove clips, friction bumps, locking features, etc., and perhaps to chamfer leading edges. This allows the connectors to mate and de-mate easily as the fixture is operated.

Connectors on the fixture are also usually made easily replaceable, since they will wear out quickly. This is not a concern for the connectors on the DUT, since each board will only be tested a small number of times.

If the connectors do not mate in the same direction as the fixture operates (usually perpendicular to the board) then secondary slides are needed to mate the connectors after the fixture is closed. This sort of mechanical arrangement can be complex and costly.

Single-Sided Probes

The most straightforward probing arrangement is to place all the test points on one side of the board, usually the bottom. The fixture presents probes to this side of the board.

Typically the probes are fixed and the fixture applies hold-down force to the top of the board to lower it on to the probes. Alternatively, the DUT is fixed and the probes rise to meet the board when the fixture is operated,

Double-Sided Probes

If the DUT has test points on both sides of the board then double-sided probing is required. This is mechanically much more difficult. Two probe plates are required, which must be precision aligned to each other and the DUT, yet one of them (usually the top) must move completely out of the way when the fixture is opened to allow the DUT to be extracted.

With double-sided probing the DUT is typically fixed and the probes move in from both sides when the fixture is operated.

Because of the mechanical complexity and cost, double-sided probing is usually avoided if possible.

Hold-Down

There are several common approaches to applying force to the DUT to hold it against spring test probes, including mechanical arrangements and vacuum systems.

Vacuum Systems

In a vacuum system the area between the probe plate and the DUT is a sealed cavity. A vacuum applied to this cavity pulls the two together. When the vacuum is released springs open the fixture again.

This type of system is very fast, typically capable of operating the fixture in a fraction of a second. Also, since there are few moving parts it is robust and reliable.

A secondary advantage, for a single-sided fixture at least, is that nothing is needed above the DUT. With completely clear space above the DUT operators are able to load and unload the fixture quickly.

For these reasons vacuum systems are often used on high-volume, high throughput production lines. Their cost, and the need for air lines, typically precludes their use in more modest production facilities.

One concern with vacuum systems is that the DUT must not leak air, or the vacuum will be ineffective. This means that the board must not contain large holes or cut-outs, or that these must be blocked somehow during testing. For large boards the total area of drilled holes (e.g. vias) can cause significant leakage. The board may need to be fabricated with via holes tented or plugged.

Mechanical Systems

In a mechanical system the probe plate and the DUT are brought together by a mechanical arrangement of cams, levers, linkages, etc. There are a wide variety of schemes in use, differing in complexity and cost.

One key distinction is whether the DUT or probes move. Either the DUT is fixed and the probes rise to meet the board when the fixture is operated, or the probes are fixed and the board is lowered on to them.

In either case, the DUT is either gripped around its edge or, more usually, hold-down posts press on the top surface.

In more sophisticated systems much of the mechanical complexity is involved in ensuring that the planes of the DUT and the probe plate remain parallel as the fixture operates, and there is no tilting or lateral movement. These so-called parallel motion systems typically require cams and linkages to translate the operator's movement of a handle into a linear motion.

In simpler systems the pressure plate supporting the hold-down posts simply hinges down over the DUT. If the DUT is far enough away from the pivot point the small amount of tilting that results is not a problem.

Manual

The most trivial arrangement for holding the DUT down against the probes is a manual one - the DUT is simply placed in position above the probes and held down by hand. This arrangement can work well if the board is small and the testing operation is quick.

Location

The DUT must be positioned correctly above the test probes, so that when the fixture operates they land correctly on the test points. There are two basic approaches to locating the DUT: using tooling holes or using the board edge.

Tooling Holes

Typically PCB layouts will include several tooling holes. These are un-plated holes, typically 1.5mm to 2.5mm diameter, typically located near the corners of the board. Tooling holes are used by PCB fabricators for aligning the board during drilling and routing; by assemblers during solder paste printing and on pick-and-place machines; and for alignment on test fixtures.

If a board does not have explicit tooling holes, often mounting holes can be used instead.

On a test fixture the tooling holes are located on tooling pins. The board may slide down the pins as the fixture operates. Alternatively, the pin tip may be very short, just locating the board, and the whole pin may move as the fixture operates.

Board Edge

Boards are sometimes located on fixtures using the board edges rather than tooling holes. This is less preferred because board edges are typically less accurate than drilled holes, particularly if the board edge is scored rather than routed.

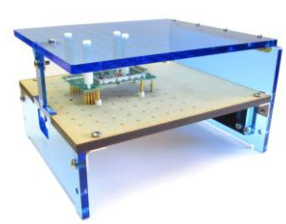
In this case the board typically sits in a well machined in a supporting plate. The size and shape of the well is the same as the board outline.

Merifix Fixtures

Merifix test fixtures are designed for functional test or programming of small printed circuit assemblies.

They are aimed at Engineering users and low-volume production.

They feature a single sided probe plate and a simple, hinged mechanical action. Locating pins mate with tooling holes in the DUT to align it. The locating pins move as the fixture operates, ensuring the DUT and probe plate remain aligned.



Merifix test fixtures are deliberately simple. Their low cost enables their use for tasks where it would be too expensive to deploy a conventional fixture. Engineering test and programming tasks that would traditionally need to be performed with temporary, flimsy, ad hoc arrangements can enjoy the convenience of proper fixtures.