PCB Design Guidelines for In-Circuit Test

With some forethought during the design and layout process, circuit boards can be easily, economically and reliably tested in a bed-of-nails environment. This article outlines considerations and suggestions for the physical design of UUTs (units-under-test) to be efficiently tested at the loaded-board level.

There are three general areas for the board designer to be concerned about. First, it is necessary to determine what connections are needed from an electrical standpoint. Once this is determined, there are the mechanical concerns about how to provide areas for the probes to contact and how to align the board. Finally, the data needs to be available in an efficient format for the fixture fabricator and test programmers. Each of these items is discussed below.

Sometimes, all of the design goals cannot be met due to physical and/or electrical constraints of the UUT. However, by meeting as many of these goals as possible, you will minimize fixture costs and maximize fixture reliability.

Electrical Connections

To obtain full in-circuit test coverage, in-circuit/MDA test systems need electrical access to each node on the circuit board. A node (or 'net') is one electrical connection, although it can go to multiple places and components. Examples are 'GND', 'VCC', and 'DATA0'. Dedicated functional test fixtures generally use a lot less probes since they only need access to circuits on the block level.

Mechanical Considerations

Probe Spacing

Ideally, boards would be tested with industry-standard 0.100" spring probes. These low-cost and reliable probes are designed to probe circuit points that are 100-mil (0.100"/ 2.54mm) or more apart from center to center.

If it is not possible to have the luxury of 0.100" spacing, standard probes are designed for 0.075"(1.91mm) access, 0.050"(1.27mm) access, and even closer spacing is available. Note that as the probe size decreases, the cost increases and obtaining high reliability becomes more challenging.

Probe Access

All modern test fixtures are designed to accommodate, as the standard, bottom access to the UUT. Whenever possible, you should provide access at the bottom of the UUT for each network on the board.

Fixtures can be designed to also have access to the tops and sides of the UUT. However, due to the added complexity, non-bottom access increases the cost and decreases the reliability of the fixture.

Top probes locations need to be kept far enough away from tall components to allow for the pressure plate closure arc and possible clearance holes for components.

Probe Targets

For reliable probing, the probes need to have good targets. Each probe should contact a target 0.025" (.635mm) in diameter or larger. The targets should be as large as possible, ideally 0.035" to 0.045"(.89mm to 1.14mm). When top probing an assembly, targets on the top should be 0.035"(.89mm) or larger.

The target can consist of:

- A test pad, round or square
- A through-hole with a soldered lead
- An open through-hole
- A non-masked via

For probing on soldered leads, ensure that the lead trim-length is consistent within plus and minus 0.030"(.762mm).

Open through-holes should have a relatively small hole diameter so that the probe can contact the hole edge. For standard probing, the hole should be less than 0.050".

0.100”(2.54mm) < 0.050”(1.27mm) (standard)
0.075 “(1.91mm) < 0.035”(.89mm)
0.050 “(1.27mm) < 0.015”(.381mm)
0.039” (.991mm) < 0.012”(.305mm) All with annular rings (size based on chisel point tip style)

Special Rules for CheckSum/ECT Tilt style fixtures

Tilt is wireless approach to ICT fixturing that uses a “tilt” pin technology, with the probes coming in at an angle to the UUT. This approach allows for probing down to .015”(.381mm) target sizes with minimum .024” (.61mm) spacing.

Please note top probes on Tilt fixtures follow the same rules as all other fixtures.

SMT Lead Probing

Probing on leads of surface-mount-technology (SMT) devices should be avoided. Because of the variability of the placement and edge geometry, probing is not reliable on SMT leads. Also, the probe can press the SMT lead to the pad, causing a bad connection to allow the component test and connection to pass. CheckSum will allow probing on SMT

pads only on a case-by-case basis with a signed waiver from the customer releasing CheckSum from any liability related to fixture workability and circuit board damage.

Test Pad File Structure

The process of building a test fixture requires a file with the X-Y center location for each test probe. There are several methods to generate this file. We suggest that test pads are added like any other component in the design and board layout. During the layout process for the assembly, the test pads are automatically included. Then the file with the X-Y center location of each test pad should be generated and used for probe placement.

Target Plating and Solder-Resist

Solder-resist (solder-mask) or conformal coating prevents the probes from making electrical contact, so the probe contact areas must not be covered with either of these materials. Ideally the solder-resist should be at least 0.020"(.51mm) radially from the probing target. This prevents the problem of having the probe contact the solder-mask first, preventing it from contacting the target.

Target surfaces should be gold or solder-coated for best probing. Generally, harder materials are more difficult to obtain a good contact, and have a tendency to dull the probes prematurely. Organic Solderability Preservative (OSP) should be avoided since it can present a very hard, non-conductive surface for test probes.

Alignment Holes

UUTs are accurately positioned on the test fixture with the use of guide pins that mate into tooling holes in the UUT. The UUT should have at least two tooling holes for positioning. These should be as far apart as practical, with the ideal being on two opposite corners. Unplated alignment holes work better than plated holes due to solder in holes, deformed holes due to bolts tightened incorrectly, plating too thick, etc.

Tooling hole sizes that work well fall into the range of 0.125"(3.18mm) to 0.250"(6.35mm) diameter. Diameters of 0.125", 0.156", 0.187", and 0.250" are standard sizes. These sizes are easy to accommodate with off-the-shelf guide pins, and are strong enough for use without damage or premature wear.

If the UUT is symmetrical, provisions should be made for a third non-symmetrical hole that is used to keep from installing the UUT onto the fixture in the wrong orientation.

Tolerances between the tooling holes and targets should not exceed +/-0.002"(.051mm), and probe targets should be at least 0.175"(4.45mm) from the center of the tooling hole.

Overall UUT Size

There are benefits from keeping the size of the UUT small:

1. Most fixture systems accommodate UUT sizes of up to about 12"(305mm) x 16"(406mm) with standard size fixture kits. If the overall board size is larger, use of special, more-expensive, kits become necessary.

2. The overall cost of the test system is reduced (less test points are required),
3. The cost of replacing fixtures in the event of ECOs is reduced,
4. Related large-board problems, such as board-flex during vacuum fixturing, are reduced.

Special Considerations for Vacuum Fixtures

To accommodate vacuum sealing, there are some special considerations in designing UUTs for vacuum fixtures, these include:

- Leads, targets and component bodies should be at least 0.125"(3.18mm) from the edge of the UUT for gasket sealing integrity.
- Probe loading should not exceed 25 probes per square inch (40 is the theoretical maximum for vacuum fixturing at sea level).
- Routed openings should be minimized so that less gasketing is required.
- Components on the bottom of the UUT should be less than 0.125"(3.18mm) high to prevent special fixture machining. Heights beyond 0.375"(9.53mm) require very significant fixture machining.
- There should be no open holes, such as unmasked and unsoldered vias. If it is necessary to have openings, minimize the number.
- Board outline shapes that are rectangular in nature are more economical to fixture.

Note that vacuum fixtures using seal-boxes eliminate most of the above considerations and take on the special considerations of mechanical and pneumatic fixturing shown below, however at considerably higher costs. Also tall components or access to switches and trim pots generally is not achievable with seal boxes. Over clamp fixturing is available to help solve other issues again with a higher cost associated to the initial fixture kit.

Seal box and Over-clamp issues

Pressure rods must have UUT stops directly opposite each other to prevent SMT devices from being damaged due to UUT flexing.

Special Considerations for Mechanical and Pneumatic Fixturing

Mechanical and pneumatic fixturing have some considerations during the design process:

- Bottom components should be less than 0.300" (7.62mm) high to eliminate special machining.
- Top components should be less than 1.150" (29.2mm) (mechanical or vacuum seal box) or 3.325"(84.46mm) (pneumatic) to eliminate special machining. These dimensions can vary from one type of fixture system to another.
- Except for very dense UUTs, pressure rod placement is normally accommodated without special design. There should be some open spaces on the top of the UUT for pressure rod placement preferably directly over the bottom probed areas. The number of pressure rod spaces should be approximately the number of probes divided by 25, with a minimum of 4. These spaces should be somewhat evenly distributed and at least 0.1"(2.54mm) diameter. Boards with large populations of SMT parts or high probe count need extra pressure rods to minimize board flex.

CheckSum InLine Test Systems

See the Analyst ils Fixture Manual (available from the CheckSum web site) for the test equipment requirements.

Panelized UUTs

Panelized UUTs (multiple UUTs in a single panel) can be tested using the same guidelines presented here for unpanelized UUTs. However, consider the case of testing once the individual UUT is broken away. If you will ever encounter this case, provide tooling holes for alignment in the individual UUTs, and have one fixture position with both guide pins for individual UUTs.

Vectorless Test

Vectorless test (e.g., TestJet Technology[1]) uses special sensor plates over UUT components to detect open connections and polarity of capacitors. Open connections on bussed devices are often a common problem with SMT UUTs.

These sensor plates can be mounted on the top, bottom or sides (e.g., for access to the ends of connector pins or sockets) of the UUT. If you are using this technology in your fixtures, make sure that test pads are 0.100"(2.54mm) or more from the edge of the component. This gives the fixture vendor mechanical room to accommodate both test probes and sensor plates without compromising reliability.

Generally, it is best to have all of the components to be tested with vectorless test technology on the opposite side from the standard test probes.

[1] TestJet Technology is protected under U.S. Patent Nos. 5,124,660 and 5,254,953.

Data Considerations

The fixture fabricator must be able to determine the physical location of each probe. Minimally, this can be determined with a schematic, bare-board and Excellon-type drill file for the UUT.

In the best case, the fixture fabricator is provided with direct data that specifies the electrical and physical probe locations. An optimal way of doing this during the design process is to follow the following guidelines:

1. Define a component known as a test-point. Mechanically define it as a 0.035" (.89mm)(or larger) diameter bottom-access pad with a 0.1"(2.54mm) diameter keep-away. It can be a via, through-hole, or a pad.
2. Place one of these test-point components on each network of the schematic.

If you follow this process, you will end up with a number of benefits:

- Annotated schematics that are useful for UUT trouble-shooting.
- Minimal fixture cost since the fixture fabricator can easily use the resultant pick-and-place data and net-list.
- A very reliable fixture since it will use standard probes with efficient targets. Bottom access to each net is guaranteed.

This technique works well for both SMT and through-hole UUTs.

Summary

Building test fixtures for almost anything is possible given enough time and money. However, using the guidelines presented here will help you design boards that are economical and reliable to test. In many cases you may not be able to fully follow the guidelines, but if you deviate as little as possible, you will achieve the best success.

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