Printed Circuit Board (PCB) Design for Automated Testability

A Bloomy Tutorial

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1 Purpose

This document suggests various circuit configurations and design items to aid the design and production of PCB assemblies (PCBA) that will be testable by typical automated test equipment (In-Circuit, Functional and JTAG). In-circuit Automated Test Equipment (ATE) checks each node of a circuit with the goal of verifying that the PCB was fabricated properly per its schematic. A bed of nails tester connects a spring-loaded pogo pin to each test pad (or through-hole /component lead) for testing. The first test is a shorts test where the resistance of each node is checked to ground and to each other node. A solder short can be detected this way. Likewise, a missing or wrong value passive component is easily detected without using a technician's time. Active components can be tested with the PCBA powered up. A "truth table" check is performed for discrete digital components and simple analog tests are implemented for analog circuits. The key is that the testing is fast, and faults don't require highly skilled labor to locate. Functional testing goes beyond verifying that components were installed and connected correctly, it provides the ability to check that circuits work properly to accomplish their intended functionality. Functional tests typically stimulate circuits and measure responses for things like power supply voltages, analog and digital inputs and outputs, communications interfaces, LED operation, calibration settings, etc. Functional testers often also contain hardware that can program FPGAs, microcontrollers and such.

2 Layout Suggestions

2.1 Locate tooling holes for unambiguous orientation

- Provide tooling holes (mounting holes) that allow the PCB to be placed in the fixture in only one orientation
- Use tight tolerances on tooling holes so that mounting pin engagement enforces probe pin alignment to test pads

2.2 Place test pads on one side of the PCB, one pad per electrical node.

- Most layout tools provide some sort of design for test preparation utility that will check/add test points to all nets.
- Placing all test pads on one side of the PCB greatly reduces the cost of fixtures. This is generally the 'bottom' of the board.
- Avoid tall components on the test pad side of the PCBA so that the fixture stripper plate will not require clearance holes.

2.3 Utilize test pads that can be accessed with a 100 mil test probe.

Test pads that are sufficiently large and spaced to utilize 100 mil test probes will be inexpensive to implement and highly reliable.

- For a 100 mil probe, provide a minimum 0.025" pad diameter, though 0.050" or greater is preferred.

- Alternatives are 75 mil probes and 50 mil probes. As the probes get smaller, they are more difficult to wire and are more fragile.
- Place test points on a grid if possible.
- Plate the target pads with solder to provide a “soft” landing spot for probes, thereby enhancing probe life.
- Keep the soldermask at least 0.020" away from the edge of holes or pads which are to be probed. Otherwise, the test probe will contact the soldermask first and may not contact the conductor at all

2.4 Include many test points

- Provide test points before and after all filters/regulators/power supplies/optocouplers. This helps with debug/fault isolation.
- Identify test conditions that could cause damage to tester or device under test (DUT) . Provide and identify test points for “Safe-to-turn-on Tests”

2.5 Use Component enables wisely

It is always preferable to tie any IC enable/control signal high or low through a pullup/pulldown resistor instead of directly connecting to the power rail or ground.

- Place a test pad between the enable pin and the 1kOhm resistor that is connected to Vdd or ground.so that the tester can override the designed in logic state. This provides much more flexibility for the test engineer creating a test program.

2.6 Allow control of oscillator signals.

An oscillator that is hard wired into a circuit can cause false failures during an in-circuit truth table test.

- Connect the Enable pin in your circuit to a control line for oscillators with a built-in enable.
- Add an "AND" gate to the output of an oscillator with one input tied high via a 1k Ohm resistor. A test pad on this node will allow the test system to pull this line low, thus turning off the oscillator signal.

2.7 Allow control of bussed components.

Components on a bus that cannot be disabled will control the bus during test. However, if the test system can control the bus, each component on that bus can be tested individually. Defects can be quickly detected.

- If an enable to ground is used, pass the enable through a 1k Ohm resistor to ground. A test pad before the resistor will allow the test system to pull the enable high, thus disconnecting this device from the bus.

2.8 Through-hole connections can be used as test ‘pads’.

All through hole connections can double as test pads. There is no need for adding test pads to through-hole connections if all test pads and through-hole connections can be made on the same side of the PCBA.

- Ensure that through-hole leads used as test points are all trimmed to the same length.

2.9 Beware the probing of SMT leads

- Don't probe the leads of SMT components. The location of the small leads will vary from PCBA to PCBA. Worse, if the lead is flying (i.e., unsoldered), then pushing the lead with a test probe may make contact between the lead and solder pad, masking a true manufacturing defect.

2.10 Use connectors if necessary

Board-level testing does have its merits. For example, it can allow for verification that connectors are installed with the correct orientation, a difficult test to perform without making a physical connection to the board. But, the very act of testing a connector may influence the results of the test; for example, a poorly soldered connector may only function when the mating connector and wire bundle produces strain in a particular direction.

- Connector technologies such as card-edge connectors, where no connector is required to be mounted to the PCB, are ideal for some situations and can eliminate connector-on-PCBA problems.

2.11 Make Room for a Barcode Label

- Allow an area for a decent sized barcode, preferably on the 'top' of the PCBA. It is easier to scan large barcodes. Barcode scanning reduces operator errors and handling time (vs. typing serial and part numbers, etc.)

3 Functionality Considerations

3.1 For JTAG enabled components put in a JTAG chain with termination and connectors.

JTAG's initial application was for testing Ball Grid Array (BGA) devices because there were too many connections and no room for test pads. The test industry's response to this problem was "Joint Test Action Group" boundary scan testing. Essentially, each I/O pin of a BGA (or other) device has a buffer. This buffer can allow the input/output of the core signals of the IC - or - it can drive or read a signal at the I/O pin. By sequentially clocking in/out digital patterns, testing can be accomplished by either driving the I/O pin or recording its state. This is very effective for catching open and short circuits on JTAG enabled devices.

Industry also found JTAG interfaces useful for programming components. Many engineers only see JTAG as a means for programming parts, so they don't complete the JTAG test chain. JTAG test hardware is expensive and may not be able to be cost justified in low volumes, but don't close the door on future JTAG testing. There are many rules to correctly implementing JTAG, see JTAG Technologies' website for a free tutorial.

- Implement a JTAG chain for all enabled components, terminate it and provide a connector

- If the JTAG chain will not be used for testing, just don't populate the connector.

3.2 Employ serial communications if needed

Modern PCBAs often have on-board microcontrollers that implement key functionality. The extent to which the test system can determine the proper operations of these functions is driven by the designer's anticipation of relevant queries and responses that indicate/control states and parameters.

- Provide a simple communications interface and command set that allows individual control/acquisition of PCB hardware actions. Serial is easiest and cheapest; simple commands for each hardware I/O operation ease test step development.
- Avoid the requirement of external communications simulation or emulation to achieve a specific hardware state.

3.3 Provide for programming firmware

Many PCBAs have programmable components. Often it is assumed that PCBs will be populated with pre-programmed devices. In practice, PCBAs end up being (re)programmed after they are assembled, because of revisions to the firmware and/or the need to execute special code during test only.

- Be aware that programming a microchip could consume a significant portion of the test time.
- If manufacturing test firmware is required to achieve easier testing, the tradeoff with programming time is often acceptable.
- In some cases a 'golden interface PCBA' (or another PCBA from the higher level system) may speed up test development time by reducing the need for emulation.

3.4 Keep in mind

- Avoid the requirement for complex hardware emulation to achieve a specific functional state
- Avoid the requirement for emulating busses (address/data lines)
- High current is difficult to achieve through probe pins

4 Details

For the test system and test fixture implementer, the following design files and information are required.

- DXF of PCB layout (showing test points, through holes, etc)
- Schematic of circuit (PDF)
- Testpoint report (describes net name for each test point and includes x-y PCB coordinates)
- Netlist and BSDL Files (if JTAG is present)
- An I/O list or Interface Control Document (ICD), and Theory of Operation are very helpful.

5 Contact

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