

Optimization Problem

Two Dimensional Linear Motor based Flying Probes Testers with Articulating Probe Modules

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Background

The Flying Probe Tester is a system of moving shuttles and probe modules that is used to test electronic circuit boards (UUTs or units under test) with electronic components assembled on them. The prime objective of testing with a Flying Probe test system is to electrically measure the values of various components and establish that the particular board is assembled correctly.

In order to perform electrical measurements to conduct these tests, points designated as test points are contacted by probe modules. A minimum of 2 probe modules are involved in each test but the number can increase to five, six or more depending on the test being performed. Probe modules are connected to an elaborate system of relays that act as multiplexers to a central measurement system that acts almost like a multimeter. Two wire, three wire, four wire tests are typically performed to measure the value of such components as resistors, capacitors, inductors, or to establish that discrete semi-conductor components such as diodes, transistors, and semi-conductors have been installed on a board and are making good contact with a board. Also tests are performed to verify that there are no shorts or opens on the UUT.

Therefore in general, Flying Probe Testers rely on a robotic component to place their probe modules at the correct location or Test Point (TP) on the UUT, and on an electrical measurement component to perform tests to verify the value and tolerance of as many components on the UUT as is possible.

To program a tester to perform these tasks, usually, there is an automated process that relies on CAD and Bill of Material (BOM) data to generate the test program automatically. The test program is subsequently debugged, and optimized to minimize motion between tests. Often electrical tests involve switching high speed relays which take a small time compared with the motion of probe modules from one combined set of positions to another. Therefore, optimization of a test program mainly involves optimizing the motion between test steps.

The Optimization Problem

A modest UUT can have a thousand components and a few thousand nets that connect the components to each other. On a complicated UUT, we could have tens of thousands of nets, and many thousands of components. On each net there can be multiple test points. Components can have different heights, and some may be so tall that the probe modules must be guided around them at all times because even at their most retracted z position, they may collide with these tall components. While the data related to each UUT is fully presented to the FLS tester, and while users will perform electrical tests at the debug phase to create stable tests for each component, at some point, it becomes necessary to perform all debugged tests in a sequence. Optimizing a sequence means finding the

sequence of tests covering all tests in the original set, that if placed in a new order, will minimize the required time to perform the tests. Since the time required to perform electrical tests is very small compared with the time required to move from one set of configuration of probe modules and shuttles to the next, it becomes sufficient to find a sequence of motions in placing shuttles and probe modules that will minimize the time for the sequence. Furthermore, the motion characteristics of shuttles and probe modules does not change during the execution of a test and it can be assumed that all motion steps benefit from the same acceleration and maximum velocity parameters for all components of the system. Therefore, the problem of finding the minimum time becomes closely linked with the problem of minimum distance travelled to complete the total sequence of steps.

Constraints and Concepts for solving the Optimization Problem

Firstly, the difference between motion steps and test steps is worth noting; In moving from one configuration of shuttles and probe modules on a stator to a new configuration, we go through motion steps but it is important to recognize that it is possible to perform multiple electrical tests during a single configuration of shuttles and probe modules contacting a given set of test points (TP). For example, while testing a resistor, i.e. measuring its value, it is usually possible to perform a shorts tests between the two nets connected to the opposite leads of the same resistor and power and ground rails of the UUT. Therefore, through performing one motion step, we are able to perform three test steps.

It is equally worthwhile noting that reducing the time required to perform z motions will have a large impact in reducing the overall test times for a given sequence of tests, however, it is not the duty of the Optimizer to reduce the time required for z motion. There are two ways to reduce the time associated with z motion;

1. Assigning a “base profile” for each UUT is based on the height of various components present on that UUT. Many surface mount components have a low profile of a few millimetres and probes have to retract a short distance before they are free to move across to the top of the next component. The larger the z distance travelled by the probe tip to retract and extend to make contact, the longer the test execution time. Inevitably, when a probe tip has to travel over a tall component, it will have to retract by a larger distance to clear the tall component and then extend again to reach the next test point.
2. Designing better servo systems that will offer better dynamic performance to make probe motions faster. However, this is not a task for the Optimizer. It is up to hardware engineers to design better servo systems to meet this challenge.

Finding the “ideal” sequence of tests that a) minimize the number of motion steps by putting as many tests into each motion step as possible, and b) minimize the overall distance travelled from motion step to motion step until all motion steps are completed becomes the duty of the optimizer, and hence, the optimization problem.

Given

- a) The multitude of solutions available for positioning shuttles and probe modules to contact a set of test points due to availability of multiple test points on the same net, on top side and bottom side of a UUT,
- b) The random nature of test point distribution on a given UUT,
- c) Component profiles (height) and the complexity of assigning test points on the UUT to a particular probe module for a given test in the sequence,
- d) The height restrictions due to very tall components imposing “ no fly zone “ restrictions
- e) The assignment restrictions arising from operators assigning a particular test point to a particular probe module by operators or restricting the probing angle for a particular test point
- f) The relationship of a test step in the sequence of tests to its predecessor and successor,
- g) The limitations related to placing 4 shuttles next to each other so they will not collide,
- h) The limitations related to probe modules crossing each other and not hitting one another,

developing an effective method for optimization of test programs is quite challenging. A method deploying exhaustive search methodologies will impose computational requirements that grow exponentially and become unfeasible for even a modest UUT.