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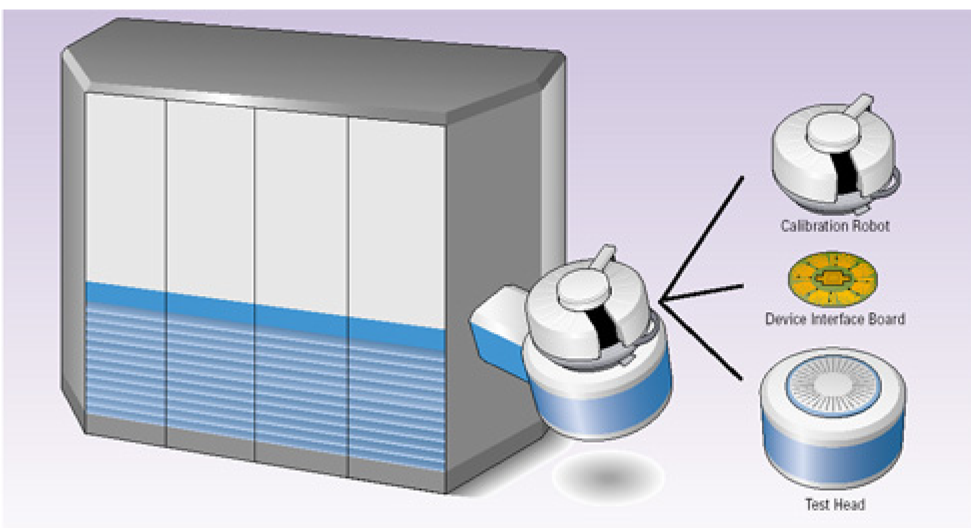
ATE Calibration Robots: Driving Down Measurement Error

The Automatic Test Equipment (ATE) industry faces an ongoing challenge: developing test equipment capable of testing ever-faster and more complex chips in a cost-effective manner.

Chip speeds have increased exponentially with the introduction of high-speed communications and more powerful microprocessors. Achieving cost-effective testing requires obtaining the best performance from today's circuitry, in order to test the next generation of even faster chips. During the tests, the accuracy of timing signals generated by the tester is a critical factor in testing the chip. Overall timing accuracies (OTA) of 50 picoseconds or less are required. (In comparison, light travels only ½ inch in 50 picoseconds!)

Given such extremely tight accuracies, even minor changes in test head position or slight variations in environmental conditions can cause significant timing error. The only cost effective way of achieving these accuracies is by using an automated calibration robot that can measure the signal timing at the test head, thereby allowing a software calibration to correct the tester's circuitry.
(Example of a calibration robot.)



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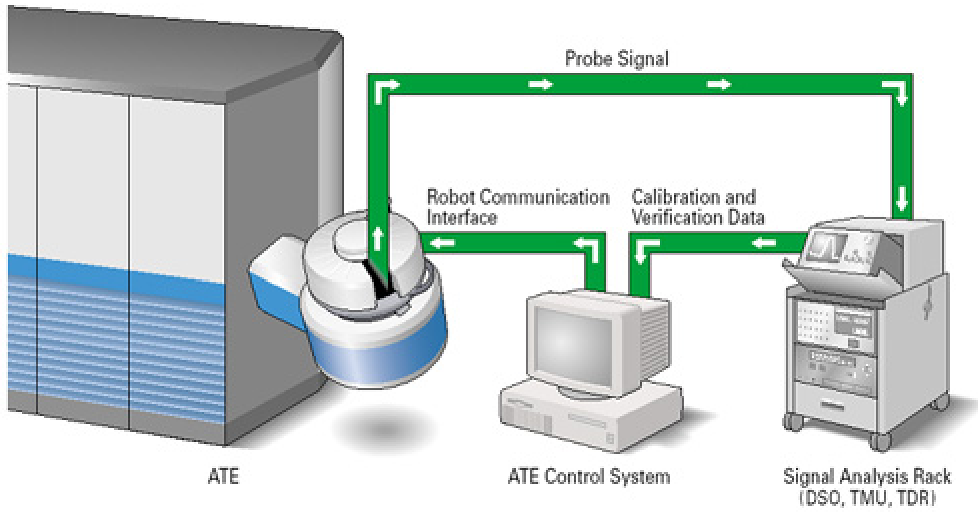


A Calibration Robot is typically a three-axis robot. Two axes provide the movement over the test head. Depending on the pin layout, an R-Theta or X-Y robot will achieve better results. The third axis, the Z axis, actuates the test probe to provide signal contact. A custom Device Under Test (DUT) Board is used to create a probe interface to the bed of nails signal pogos of the tester.

Example R-Theta robot

Example X-Y robot

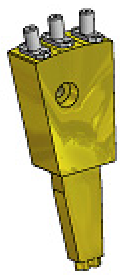
As shown in the schematic, the calibration robot is mounted to the DUT board, which is then mounted to the test head. The tester commands the robot to move the high frequency probe tip to the desired DUT Board pad locations. The tester then generates a timing signal, which is passed through the test head and the high frequency test probe in the Calibration Robot and analyzed by a Time Domain Reflectometer (TDR) or similar instrument. The TDR results are communicated back to the tester and used to validate the tester's signal performance and create calibration algorithms to achieve the necessary timing accuracies.

Increasing test speeds have been fueling the need for ATE Calibration Robots for over a decade. Faster test speeds continue to drive developments in robot design and measurement techniques, including test probes, device interface boards and probe targets.

Two alternative measurement methods, manual probing and relay tree, are no longer accurate enough to support the timing accuracy requirements of high-speed testers.

Traditionally, an oscilloscope and a manual test probe have been used to gather data on signal timing and accuracy. Increased pin counts, now in the thousands, have made manual collection impractical. The potential for human error and the ergonomic implications of taking thousands of measurements call for an automated method of collecting the data.

A Relay Tree solves the problems of manual collection by tying together all the signals electronically and using relay combinations to select the signal of interest. The construction of the tree means that the measurement path length varies, depending on the measurement location in the tree. For measurements requiring 200 picoseconds accuracy or less, these varying path lengths cause unacceptable measurement errors. The Calibration Robot eliminates the problem of varying path lengths by using a single probe and constant cable length.



As tester speeds move into the GHz range, the measurement accuracy requirements are driven to 50 picoseconds and less. Given these extremely tight accuracies, errors introduced by path length variations in the probe and DUT boards must be considered. Direct (i.e. fixed length) probes have replaced compliant spring-loaded pogo style probes, as the path length changes as the pogo pin is compressed affecting accuracy. The impact of using a direct probe is that the Z compliance must now be moved to the calibration robot's Z axis.

Eliminating the DUT board error is a more challenging problem. One solution is to calibrate the DUT board separately. In this technique, the tester is calibrated independently by probing the test head's signal pogo pins directly with the Calibration Robot. The DUT board is then separately calibrated and it's calibration data stored with the board. In this way, the DUT board's calibration moves with the DUT board allowing different DUT boards to be used on a tester without influencing the test results.

A second solution that is currently under development involves adapting the Calibration Robot with special test probes to test the pads directly under the chip. This would include all sources of error from the tester to the chip in the calibration. Mechanical, grounding,
and socket configuration issues must be resolved before this method is practical in production.

In addition to increasing chip speeds, the number of I/O has also increased. Tester pin counts of 4000+ are not uncommon today. ATE manufacturers have designed much higher density test pin arrays to minimize test head size and weight, and pin pitch has reduced from .120 inches to .050 inches or less.

The increasing density of test pins requires much greater positional accuracy from the Calibration Robots. High-speed applications and new probe designs also require improved positional accuracy for the best signal quality and repeatability. Positional accuracy requirements for robots have tightened from +/-.020 inches to +/-.003 inches. Rigid construction, precision bearing and lead screw mapping have enabled the robots to achieve higher positional accuracy.

Example High Accuracy robot

Evolving chip package designs, increasing chips speeds and greater I/O density will continue to drive the need for Calibration Robots. Achieving the necessary overall timing accuracies for thousands of test pins require an automated solution. It is much more cost- effective to provide an efficient means to calibrate the required accuracies than to use costly electronics in the ATE designs. The family of Calibration Robots developed by Owens Design provides such a solution.