KEITHLEY A GREATER MEASURE OF CONFIDENCE

Speed Up Testing with Simultaneous Sourcing

Pete Hulbert and Paul Meyer, Keithley Instruments, Inc.

TESTING is a vital step in electronic production, but it takes time and money. Anything that can speed up the process is welcome, and one of the most obvious methods is to use simultaneous sourcing—driving several devices under test (DUTs) at the same time and with the same voltage or current and reading the results for all. Simultaneous sourcing is used when the test application requires independent source control and/or continuous monitoring of multiple DUTs. It becomes more important for throughput when the test is lengthy, as is the case for accelerated life test and burn-in.

Simultaneous sourcing finds use in a wide range of applications—from high-speed parallel test to electromigration, highly accelerated life test (HALT), and highly accelerated stress test (HAST). It is particularly powerful when the test strategy requires acquisition of large measurement sets and/or individual electrical control of each DUT. In these cases, individual instrumentation is required to support independent control and monitoring.

Potential Applications

Two areas in which simultaneous sourcing methods find extensive use are life testing of printed circuit boards made with the latest lead-free solder techniques and analysis of wear-out mechanisms in modern electronic packaging, particularly in structures like fine-pitch ball grid arrays (BGAs). We'll look at both.

By statute, lead is being phased out of electronic equipment of all types. While this may reduce the amount of toxic lead in the waste stream from discarded electronic equipment, it presents manufacturers with significant problems. The characteristics of Sn-Pb solders are well understood, but the various alternatives—including high-temperature (250°C–300°C) compositions such as Sn, Sn-Ag, Sn-Ag-Cu, and Sn-Ag-Cu-Sb; mid-temperature (180°C–205ºC) compositions such as Sn-Ag-Bi and Sn-Zn; and low-melting (<180ºC) alloys such as Sn-Bi—can present difficulties. Some problems, like poor wetting and flux incompatibilities, show up right away, and others, like MSL (moisture susceptibility level) ratings, intermetallic growth during aging, and electromigration, show up later. To gain an understanding of how products using these different alloys and processes will perform, manufacturers must do extensive testing, especially accelerated life testing. This testing requires that each test structure continuously experience a specific electrical and thermal condition for an extended period of time. Variables observed include heat-stress re-crystallization, thermal stress, and voltage drops under conditions of constant electrical power input (Joule heating effects).

Another area that requires much testing grows out of new electronics packaging technologies. Ever-advancing electronics packaging technology drives a need to perform testing of higher and higher density interconnects. With hundreds of test points in a large ball grid array (BGA), it has become impractical to test each point sequentially, yet accelerated life testing requires independent testing of each ball. A concern for BGAs is electromigration due to current crowding, which requires individual electrical control to maintain constant Joule heating as well as measure interconnect resistance. The challenge is to do all this testing in a reasonable (affordable) length of time, and the solutions tend to involve simultaneous sourcing.

Simultaneous Testing Strategies

Simultaneous source testing of a large number of DUTs requires consideration of the trade-offs among practical parameters, such as cost, rack space, throughput, and precision. Current test equipment offers a wide range of simultaneous testing strategies, including:

Source-Measure channel per DUT—This strategy provides independent source control and measurement for each DUT (***Figure 1***). As a result, it is possible to use measurement feedback to maintain constant source adjustments (for constant Joule heating applications) and high sampling rates to meet challenging sample plans with large measurement sets. At the heart of this method is a source measure unit (SMU), which

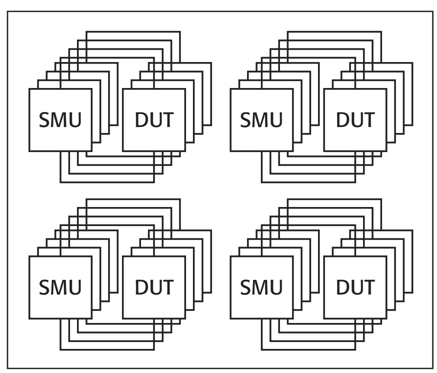

Figure 1: The SMU-per-DUT architecture provides per-DUT electrical stress control and measurement.

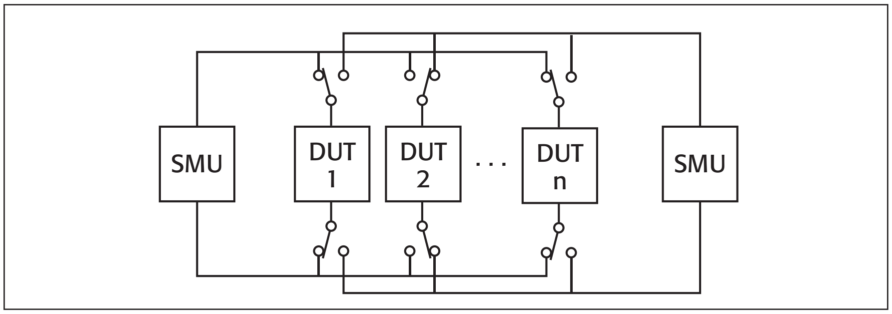

Figure 2: The shared-SMU architecture stresses all DUTs with a common SMU. DUTs must be individually isolated to enable measurement by a separate SMU.

is actually three instruments in one: a precision voltage source, a precision current source, and a DMM. An SMU can source a precise value of current and measure the resulting voltage drop across the DUT or apply a precise voltage across the DUT and measure the resulting current. SMUs are used in a wide range of applications, including semiconductor device testing, optoelectronic test, materials research, and even as general lab instruments.

Shared Source/Shared Measurement—It is possible, in some applications, to simultaneously source (in parallel or serial) an array of DUTs. In this configuration, measurement or characterization of the DUTs may be done either "on-line" or "off-line."

On-line characterization requires a multiplexer to switch the measurement instrument between several devices (***Figure 2***). Each device is characterized serially, resulting in a lower sampling rate. Off-line characterization requires a more complex switching system that can isolate each DUT to allow the off-line characterization, while the remaining DUTs continue to be sourced in parallel or series.

Conclusion

Simultaneous sourcing can make it possible to do the large-scale testing required to produce today's high-reliability electronic components or to study the behavior of new materials. As such it is a valuable technique, but it is important to work out the test plan carefully to obtain the full benefit of the technology..

About the Authors

Pete Hulbert is a senior applications engineer at Keithley Instruments, Inc., 28775 Aurora Rd., Cleveland, OH 44139. He can be reached at (440) 498-2798 or at phulbert@keithley.com.

Paul Meyer is a product marketer in the Small Systems Group at Keithley Instruments, Inc. in Cleveland. Previous experience includes production management, equipment development, and application engineering in the semiconductor industry. He earned his BSE degree from Missouri Institute of Technology. Mr. Meyer can be reached at 440-498-2773 or at pmeyer@keithley.com.

Definitions:

Sampling Plan—A sampling plan describes the rate or frequency at which a component, assembly, or process is sampled or tested. For instance, in a wafer fab, a sampling plan for a diffusion process often requires that every fifth wafer in a boat (of 25 wafers) be measured for sheet resistivity in the center, left, right, top, and bottom. When setting up a new process, the sampling plan may require all wafers to be characterized, while a mature process may require only three wafers to be sampled in five locations. Sampling plans must be balanced to optimize overall process yield—excessive sampling is costly and under-sampling results in uncontrolled process variation.

Measurement Set—The set of measurements made on a DUT during a test. A diode undergoing a sort may require only three measurements or a measurement set of three while the same diode undergoing a life test may require a leakage measurement every minute for 1000 hours of operation for a total measurement set of 60,000.

HALT/HAST—Highly accelerated lift test/highly accelerated stress test. By subjecting the DUT to elevated temperature and electrical drive currents, it is possible to estimate that the actual life expectancy under normal conditions is a much shorter time. For instance, actual device failure due to electromigration may take 15,000 hours when operated at typical ambient temperatures. When the device is operated at 300°C and three times nominal drive currents, the failure will occur in just a few hours. A reasonable correlation between accelerated life test and real life test failure is made using Weibull analysis.

Weibull Analysis—The Weibull analysis is a powerful tool that provides a means to quantify the effect caused by various design options. Weibull distribution can be used in analysis to predict failure rates and to provide a description of the failure of parts and equipment. Weibull distribution is quite versatile, including bounded, unbounded, and log normal distribution. It is frequently used in reliability analysis.

Weibull distributions are a classification of statistical data that does not fall within a Normal distribution function. The distributions are usually a skewed bell-shaped curve. Data that fits into a Weibull distribution cannot be characterized in the same way as normal distributions; instead they are usually characterized by "alpha" and "beta", which are the shape and scale parameters respectively.

Weibull distributions are often used to model the breaking strengths of composite materials. The distributions support the "weak-link" theory in composite failure, in which a dominant crack is responsible for failure. To better visualize and analyze fracture strength data, the probability of failure is plotted against the log of the fracture strength.

Electromigration—Mass transport due to momentum exchange between conducting electrons and diffusing metal atoms. Electromigration causes progressive damage to the metal conductors in an integrated circuit. It is characteristic of metals at very high current density and temperatures of 100°C or more.

Joule Heating—Joule's law gives the amount of heat Q liberated by current I flowing through a resistor with resistance R for a time t, such that:

$Q = Pt = I^2Rt.$

Keithley Instruments, Inc. 28775 Aurora Road • Cleveland, Ohio 44139 • 440-248-0400 • Fax: 440-248-6168
1-888-KEITHLEY (534-8453) • www.keithley.com

No. 2538
0804