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Dog-Bones and Daisy Chain for Test Labs

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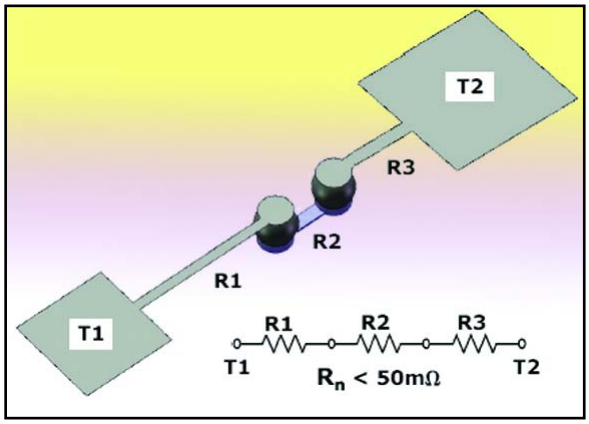
Engineers routinely use dummy IC packages with internal daisy chain circuitry — fondly known as "Dog-Bones" within the PC board design community. Daisy chain provides engineers with a simple and cost-effective testing mechanism to glean valuable data about process failures. Such failure analysis provides scientists and engineers with a pathway to improve SMT assembly processes and raw materials sets.

Research starts by mounting daisy chain devices onto a test vehicle board with complementary dog-bone daisy chain circuitry. This combination creates a short circuit with near zero ohms resistance measured at test points on the test vehicle board. Under controlled conditions, the test vehicle board is subjected to harsh environmental conditions, such as dropping, vibrating, freezing, and heating with humidity up to the point of failure when a connection gradually deteriorates, and ultimately breaks.



Simplified two-port daisy chain circuit.

Easy Measurements

Failures are easily measured when the daisy chain becomes an open circuit (infinite ohms). The failure is usually observed, measured and recorded with a simple ohmmeter.

Daisy chain components are better than using "live" devices when performing SMT assembly and process improvements. Daisy chain allows a simple Pass/Fail test with easy to detected "Go", "No Go" conditions. On the other hand, "live" components inherently offer too many variables that may obfuscate and complicate the end result. Using forensic analysis and experimentation, researchers can make improvements in the assembly process. After the assembly line, the machine or material set is optimized using dummy components, then the assembly line can move forward using live components.

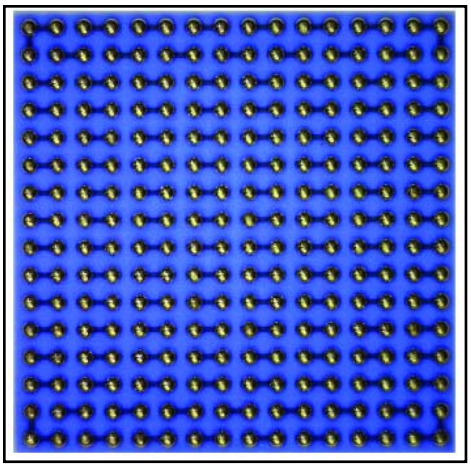
Daisy chain is available in a wide variety of components such as BGA, CS-WLP (wafer level package), bumped die, bare die, flip chip, QFP, TQFP, LQFP, QFN, DFN, TSOP, SOIC, SSOP, SOD, TSSOP, QSOP, MSOP, SOT, PLCC, Flat Pack, CERQUAD, LCC, CLCC, DPAK and virtually every other alphabet soup acronym possible. In addition, customized daisy chain configurations are routinely available.

Leadframe type daisy chain test components — QFP, QFN, TSOP, SOIC — are manufactured by wire bonding gold wire directly to pairs of pins on the component's copper lead frame. Daisy chain array products, such as BGA, are typically made with copper dog bone patterns placed on the ball side of the substrate. WLP wafer level die and flip chips have RDL (redistribution layers) running between the I/O pads. Adding a dummy silicon die inside a daisy chain component is highly recommended to give thermal mass to the package, and to make the daisy chain test IC mechanically identical to its live IC counterpart. The topside of the daisy chain component is iden-

tified with a symbol to indicate that the device is a test vehicle, rather than a live component.

Daisy Chain Simplified

The sum total resistance of a 2-port daisy chain dog-bone is typically less than 50mΩ as measured between test points T1 and T2. The actual amount of



Example of a 256-pin CBGA with daisy chain dog-bone pattern between solder balls.

resistance depends on the length of the circuitry as well as the resistivity of materials such as Cu (copper), Au (gold), Ag (silver), Al (aluminum), solder (SAC or SnPb), and so forth. Typically, ohmic testing is performed using direct current. This is because continuity testing, measurements of inductance and capacitance are not of prime consideration here, and they would otherwise complicate testing if the daisy chain circuit is powered by alternating current. Testing is often performed at low voltage and current, however, in some cases, high voltage and high current are preferred. In complex PC board (PWB) designs with multiple daisy chain data lines, the I/O is run to a connector at one edge of the board.

The list of applications for using daisy chain is expansive. Daisy chain test ICs are suitable in a wide variety of process-related applications, such as life cycle testing, drop testing, verifying the effects of CTE (Coefficient of Thermal Expansion), selecting the correct amount of solder paste, evaluation of solder paste stencils, checking for voids caused during reflow, and underfill experiments.

Side by Side

Occasionally, engineers perform parallel tests using daisy chain components with standard tin-lead (SnPb) plating alongside Pb-Free products in order to achieve a benchmark and derive comparative data.

Standard dummy components (without daisy chain) might be adequate when demonstrating mounting machines (pick-and-place machines). Rudimentary applications such as machine maintenance and machine acceptance testing don't necessarily require test components with daisy chain. However, for true research and for optimizing the assembly process, daisy chain devices with dummy die are required to obtain the most meaningful results.

Critical applications involving environmental life cycle testing require daisy chain packages with dummy silicon die. The daisy chain provides electrical continuity testing, while the dummy silicon die replicates the thermal mass of a "live" device.

Daisy chain is created inside the IC package by stitching gold bonding wire between pairs of bonding pads on the lead frame. BGA daisy chain is often made with copper traces between pairs of ball pads on the bottom side of the substrate.

Inside Connections

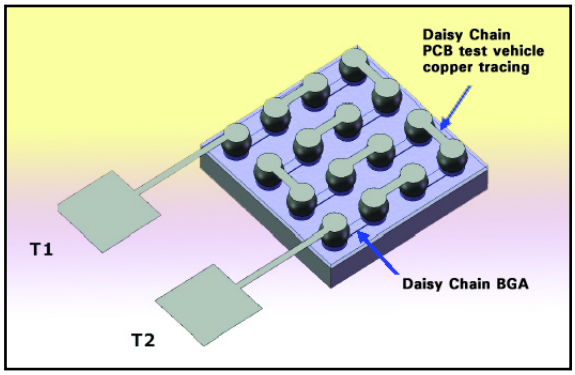
In the schematic of a daisy chain circuit, pin 1 is connected to pin 2 within the device. Pin 3 is connected to pin 4. Pin 5 is connected to pin 6, and so forth until the last pin "N". On the PCB test vehicle board, copper traces connect landing pads pin 2 to pin 3, pin 4 to pin 5, and pin 6 until the last pad.

Electrical continuity (using DC current) is made between the PC board and the DUT (Device Under Test) after soldering. A short circuit is measured using an ohmmeter from test point "T1" to test point "T2" on the PC Board. Alternately, the test points can be run to a connector located on the PC Board.

"Pass" condition occurs when short circuit (approx. 0Ω) is measured between T1 and T2. "Failure" occurs when an open circuit is measured (infinite Ω) between T1 and T2.

Solder joint reliability is verified by vibrating, drop testing and temperature cycling the assembly using JEDEC, IPC and Mil specifications (–55 to +125°C in a humidity chamber) until a failure occurs. A "failure" means the daisy chain circuit goes from a "short" (0Ω) to an "open" circuit (infinite Ω). The assembly and solder joint is forensically analyzed to determine the cause of failure. Dummy test devices with daisy chain and silicon die are an economical way to study why failures occur and how to improve the assembly process.

BGA, CSP and flip chip test die with daisy chain are used in underfill experiments. Daisy chain devices are mounted on a test vehicle board, underfilled and then temperature cycled to a point of failure. The results are observed using an ohmmeter to record short circuits (Pass) and open circuits (Failures). Dispensing and encapsulation evaluations also use daisy chain components. Scrap components or live components do not have daisy chain. It



Schematic of daisy chain BGA mounted onto a PC board with complementary daisy chain circuitry.

is impossible to make simple Pass/Fail tests with live components. It is best to use daisy chain components for such evaluations. Major companies such as Intel, IBM, Honeywell, Hewlett Packard, Cisco, Flextronics, Celestica, Sanmina-SCI, Jabil, Boeing, Northrop Grumman, Lockheed and others understand the benefits of using daisy chain components for defining and refining assembly processes. Daisy chain test die offers significant benefits for learning and improving assembly processes.

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