A Brief Survey of Kelvin *Sockets* for Fine Pitch DUTs.

Nick Langston, Liberty Research

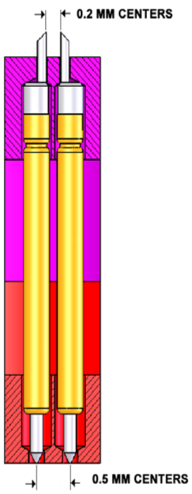
The push for miniaturization of consumer electronic products has been enabled by a variety of technologies, including LCDs, processors, multi-band RF transceivers and power management technology. Scalable Power Management Devices have been an important enabler for extended battery life in energy sensitive systems such as cell phones and personal media. The most popular packages for current generation of voltage references, LDO regulators and analog switches are the MLF(QFN), CSP, and WLCSP packages. These are packages which use a pitch typically of 0.5mm but also transferring increasing numbers of designs into 0.4mm pitch. While there is a considerable amount of Kelvin testing of WLCSPs using wafer probes, due to improved economics of test, pogo pin technology has been growing at an increasing rate.

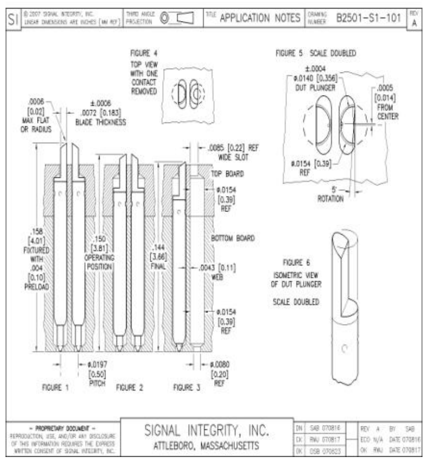
Why Kelvin Testing?

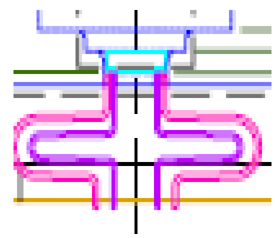
Any time that you are making DC measurements using a multi-meter or a Parametric Measurement Unit (PMU) of an ATE system, unaccounted for Resistances exist in the measurement path. These resistance values can be effected by the intrinsic properties of the copper trace dimensions of the PCB, the socket interfacial contacts to the DUT and the PCB, the socket pin's internal resistances or even the temperature of the environment. When you need to make high accuracy DC measurements, you must factor in these resistances. The Kelvin measurement approach , also generally known as the "4 wire" measurement, essentially nulls out any resistances in the path between the measurement source and the DUT and therefore makes high accuracy and very repeatable DC measurements possible. While the advantage of using the Kelvin approach is the high accuracy available, the disadvantage of the Kelvin approach is that the contacting scheme is slightly more complicated and for the device packages mentioned above, some are very difficult.

Which Contact Methods are available?

In the mid 1970's Pylon Corp introduced the "Horses Hoof" concept for pogo pins for use in a Kelvin contact application. This concept uses an ***eccentric*** plunger (elliptical shape) inside a standard barrel which allowed the offset centers to effectively reduce the pitch of the plungers. This allowed the force and sense pin contacts to make contact with the same pad on the board. These pins were developed for board and module testing and they had some pros and cons for the pin's mechanical design. A number of the major pogo pin suppliers use a variation of this concept, including *Signal Integrity Co*., www-signalin.com and Interconnect Devices Inc., and ECT. Other Asian pogo pin suppliers such as Leeno, SER, Link Micro, NHK and Yokowa, use very small diameter plungers of ~0.15mm so that they can put 2 pins on a single pad. They are standard circular (not eccentric) designed pins. For the QFN/MLF devices, these techniques work surprisingly well both electrically and mechanically. The Signal Integrity pins and the IDI pins have published lab test data that shows their Kelvin offset eccentric pins for 0.5mm pitch are good to at least 200k insertions. These ***eccentric*** pins are also scalable down to 0.4mm pitch applications, though at this level, accurate and consistent alignment of DUT pads to pin plungers becomes very difficult. The spacing between the FORCE and SENSE pins is limited to ~0.15mm so that if a ball is 0.20mm in diameter, it is intuitively difficult to align the device accurately using the sidewalls of the socket to guide. Handlers and probers that employ optical alignment however; often have accuracies down to <.001" which will be more than adequate. For Strip testing, the probes will work beautifully for 0.4mm pitch devices. The ECT pins and the IDI pins are patent protected and proprietary to their own branded sockets while the other pin vendors offer their pins to oems such as Liberty Research and the general socket market. While the ***eccentric*** design has been







Eccentric **Pin design Courtesy of IDI**

Eccentric **Kelvin Contacts for QFN Courtesy of Signal Integrity, Inc**

Coaxial Kelvin 0.4mm pitch

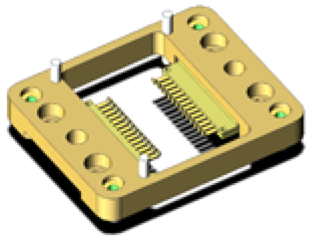
Buckling Beam Kelvin

shown to be reliable to more than 200K and even 500k insertions for QFN type packages, for bumped die however; they don't seem to survive quite as long. The failure of the pins is caused by the side load on the top plungers. The top plungers are hitting on the outside edge of the bump and after a few hundred thousand or even less, the pins show high resistance.

In addition to the offset eccentric type of pogo pin for Kelvin contacting, another approach to fine pitch Kelvin socket design is the elastomer contacting scheme. In the Elastomer approach, the interface between the DUTs ball or pad is a Kapton flex circuit. The flex circuit has pads at each of the contact points of the package. The pads are split to allow them to be wired as a Force or Sense contact point to the contact in the package. One of the advantages of the elastomer contact is the very low inductance. If the contact point is Vdd and there is any need to pull current at a high rate through these pins during normal operation of the device, you won't have any noticeable ground bounce or voltage rail droop caused by the inductance.

Another contact approach is the Buckling Beam approach. This approach has a long history of reliable operation as wafer probe contacts, but in certain sockets and contactors there are some mechanical weak spots that prevent it's broad acceptance. Companies like Buckling Beam Technology have done a lot of work to improve the reliability of the technology.

Another approach to Kelvin is the finger technology, which uses formed PC traces, positioned one on top of the other, that when compressed by the device, form a Kelvin contact. These type of contacts are useful for



Courtesy of Precision Contacts Inc.

peripheral leaded packages , such as TSOP, QFP etc and also QFN.   This technology has been available for many years from California Contacts and Precision Contacts and is particularly suited to very high current applications. This approach, obviously can't be used with BGA or array packages.

Another technology is based on the solid copper contacts from companies like Sanju, MJC, Johnstech and others. They have the ability to insert a "Kelvin" contact in their socket, subject to their design limitations, which are several.

The final contact technology that is in production, is the ***coaxial*** Kelvin Pin. These are essentially one pin which is insulated from and surrounded by a spring loaded sleeve(Coaxial). This is the best approach for testing WLCSP (BUMPED) devices at 0.4mm pitch. The advantage of this pin is the increased accuracy and the ability to use flat tipped probes which in some applications might be a more stable tip contact. The published data indicates they are in the same reliability numbers, ie >100k insertions while maintaining very stable resistance.

One of the considerations for designing Sockets/Boards using Kelvin, is the pitch of the socket contacts on the DUT/ATE board. The eccentric pogo pin designs allows you to design to 0.5mm pitch, which while painful, is fairly standard ATE board practice. The 0.4mm pitch socket will probably be easier to use, if an interposer/fan-out board is used. That will allow a much lower cost ATE board to be designed.

Liberty Research has experience with these different technologies and uses primarily pins from Signal Integrity in our sockets and probe fixtures to test devices at 0.5mm pitch QFN/LGA/SOP devices and larger and we use our Coaxial Kelvin for 0.5mm pitch WLCSP and smaller pitches. If you would like to discuss any application or need any help in selecting an approach, don't hesitate to talk to one of our engineers.

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