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Low-Force XL-2 Contacts for NiPdAu Packages
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Abstract

Johnstech has named the XL-2 (Extended Life) contacts Low-Force XL-2 contacts as a move to segment this contacting solution in the market. It is the *raison d'etre* of this document to advance the benefits of this unique contact to Johnstech customers, explain why this need existed and the genesis leading to its development and successful application to specific situations such as contacting NiPdAu plated packaged devices on the production floor. A few features of this contact design, which are delineated in more detail in this paper, include: longer contact life, extended MTBA, improved continuity, extended load board pad life, and reduced cost of test when testing NiPdAu packages. *In toto*, the new Johnstech Low-Force XL-2 Contacts meet the challenges of NiPdAu packages by providing lower forces and a self-cleaning wipe function to achieve longer contact life and higher performance vis-à-vis competitive socket technologies.

Overview

As stated in Johnstech's marketing brochure titled, *Contacting Solutions for Reliable, Repeatable Test Results on NiPdAu Packages*, "Johnstech has developed the new Low-Force XL-2 Series Contacts for the Pad ROL™200 and ROL™100A Contactors for NiPd and NiPdAu package applications. The new Low-Force XL-2 (extended life) Contacts work in concert with new elastomers to provide an optimized contacting system for maximum contact life. The contactors are designed to deliver the proper amount of force to both the device-under-test and the load board pads for longer contact life, exceptional continuity, longer MTBA, and longer load board pad life. The Low-Force XL-2 Contacts provide a self-cleaning wipe for excellent MTBA, even on NiPdAu surfaces that contain contaminants or debris. In addition, the contact motion is designed to avoid package burrs, resulting in less debris generation and longer contact life." The contact profiles and elastomers for the Pad ROL™100A Series and ROL™200 Series configurations are shown in Figs. 1 and 2 of this document.

History and Need

The ROHS lead-free initiative was the harbinger of things to come in the semiconductor industry, especially with respect to new plating alternatives structured to supersede traditional use of lead-based plating on the leads and pads of packaged devices. Except for certain particular circumstances (e.g., devices for use in military electronics) lead-free platings have become the mandated norm. After much deliberation, trial and testing, the Industry principally settled on NiPd, NiPdAu and matte tin as acceptable replacements to tin-lead. Matte tin has its own set of problems, namely tin-whisker growth and tin oxide issues, hence the Industry is leaning more toward NiPdAu plating, especially since its cost has decreased measurably and it is relatively oxide-free.

Along with the lead-free mandate, another issue evolved. In the drive to trim "back end" costs of device production, the industry started to singulate packaged devices by sawing the NiPdAu plated lead frames. This has the challenging effect of leaving sharp burrs in the sawn area. Since NiPdAu is quite hard, the burrs can cause excessive wear on the contact pins during the contacting process of a DUT in test. Also, the burrs can become dislodged during this operation and end up as debris thereby causing more frequent cleaning cycles. The solution to this issue is to create a contact pin whose tip can duck under the rough edges of the sawn packaged device. Low-Force XL-2 Contacts answer this need rather nicely. Subsequent success with these burr-avoiding contacts on customers' production floors have shown this to be true.

Low-Force Contacting

What is meant by the term, Low-Force Contacting? Two things must be considered in order to answer this question, namely the definitions of both "Force" and its companion, "Stress." "Force," according to a definition from physics, and the one used in this document, is any external agent that causes stress in a fixed body. As applied to the domain of contacting, whereby a semiconductor device is inserted into a test contactor for evaluation, the action of the handler pressing against the DUT (applied force) does indeed cause a stress in both the tip of the contact pin and the pad or lead of the DUT. The nature and degree of the stress induced can be evaluated using the technique of Hertz analysis.

In physics, "stress" is a measure of the average amount of force expected per unit area (Newtons/square meter) of a surface within a deformable body on which internal forces act. The level of stress developed in both the contact pin and the pad or lead of the device under test (DUT) is crucial since too much stress will cause the material to exceed its yield strength which in turn can lead to failure at the interface. Also, since maximum stress occurs a short distance below the surface when the force is applied, internal cracks can occur within the material "shelling" that can lead to "spalling" or sloughing off of contact and pad material.

As previously mentioned, the developed stress is contingent upon two major factors, namely 1) the applied force and 2) the radius of curvature of the tip to which the force is applied. If the force is large and the radius of contact is modest, then the induced stress level may be small. However, this is still a case of "high force." However, if the force is low and the radius of contact to which it is applied is modest, one has a low-force condition with low stress, but the overall operation of the contact against the DUT may be unsatisfactory because of high contact resistance (CRES). This could occur as a result of inadequate penetration of any oxides existing on the contact tip or DUT pad at the interface, even though this is a "low force" condition. Ideally, one wants a low force applied to the interface which is just strong enough to induce stress in the tip of the contact that is below the yield point, is sufficient to result in a low CRES, and provides adequate scrub penetration through any oxides present at the interface. This is a true "low force" condition.

One of the best ways to analyze the stress of two bodies in contact with each other is by using the concepts of Hertz stress. In fact, the internal stress in each object will clarify whether the objects are "low force," high stress; high force, low stress; or somewhere in between. How much force should be applied? The whole premise of two bodies in surface contact with each other is that just enough force should be applied to give an adequate scrub action, wipe through any surface oxides, and maintain a solid, low resistance metal-to-metal connection at the interface. In summation, "Hertz's theory yields stresses, deformation and the shape of the interface formed at two contacting bodies. These quantities depend on elastic properties, shape and relative position of the two bodies at the point of contact and the force pushing them together."[1]

A key to this thinking is to consider the yield strength of the contact pin material. Yield strength is generally accepted to be 2/3rds of the hardness of the material. This can, in turn, dictate the radius of curvature of the contacting surface of the pin. The next factor is the type and nature of oxides that the pin must swipe through. If the surface of the pad material of the DUT is NiPd or NiPdAu, but not matte tin, than only a low activation force need be applied, say in the neighborhood of 20 grams. If these conditions are met, then we have a low-force contact condition. It is worth noting that Low-Force XL-2 contacts were developed primarily for use against NiPdAu plated pads and leads.

The advantages of Low-Force Contacting?

In any DUT-contactor-LB setup, there are several things to consider…all of them at the economics based (Cost of Test). In this vein, the following must be considered.

- MTBR
- MTBA
- CRES
- Life length of contacts and contactors
- Benignity of the test to the components involved

In all of the aforementioned cases, it would appear that Low-Force contacting would be superior. Let's examine each line item on a case basis.

MTBR means "Mean Time Between Repair" and refers to the number of insertions of a device in the contactor, before some part of the test setup fails or needs to be repaired. This generally means contact pins are worn out (tip flattened, etc.) and not functioning properly. At this point, the damaged contacts must be replaced. It could also be a situation where the contactor housing is worn or broken or the elastomers are sufficiently grooved and in need of replacing. In any event, that particular contact must be pulled out of service and rebuilt.

MTBA (Mean Time Between Assists) is not as severe as MTBR, but must be addressed when it occurs. A result of MTBA is a decrease of FPY in test and a noticeable increase in CRES, opens, or shorts. The test must be stopped and the contacts cleaned to restore a satisfactory contacting interface again. If the plating on the pads or leads of the DUT are NiPdAu, then the MTBA should be on the order of many ten's of thousands of insertions before cleaning is required, especially under low-force conditions. At the other extreme is the case of pads or leads plated with matte tin. Tin oxide is an insidious substance and clogs up the tips of contacts rapidly. MTBA is significantly shortened under these conditions and cleaning is more difficult.

CRES (Contact Resistance) is the interface resistance at the point where the contact touches the pad of the device. CRES should be low and consistent. With a properly designed contact like the Low-Force XL-2 and in the case of using these contacts against NiPdAu, CRES should remain relatively low and consistent. When contacting against matte tin, CRES will slowly vary upwards until FPY is affected, falls below acceptable levels, and the contacts must be cleaned.

Life length of contacts and the contactor is enhanced by the use of low force presentation. Firstly, stress is reduced in the tip of the contact itself. Secondly, less force is exerted on the elastomer which prolongs their life because they don't take a "set" too quickly. These two factors reduce the resilience of the elastomers. Additionally, low force is easier on the contactor housing and precludes web damage and tail grooving of the housing. Lastly, lower forces are transmitted to the load board which extends the life of said load board by reducing pad wear.

If due consideration and reflection is given to the material mentioned in the preceding paragraphs, one can arrive at a so-called "benignity of the test to the components involved."

This terminology neatly sums up the value of "low force" contacting, because in general, good results are achieved with less stress to all components of the test and its operation. Since the goal of these tests is lower cost of test and higher FPY, Low-Force XL-2 contacts are a good investment because they can achieve these goals.

Why are Low-Force XL-2 Contacts unique?

What makes the Low-Force XL-2 contacts unique? The XL-2 contacts are cut from a BeCu base material and then plated with nickel and gold per Johnstech specifications. The special characteristics of these contacts are largely defined by their tip geometry which consists of a "burr-avoiding" design with an optimized radius and thickness. The upturned narrow tip easily allows the contact to duck under the rough edges of sawn device packages, contact the pads, and still provide sufficient scrub action to ensure good contact and CRES (See Figs. 1 and 2).

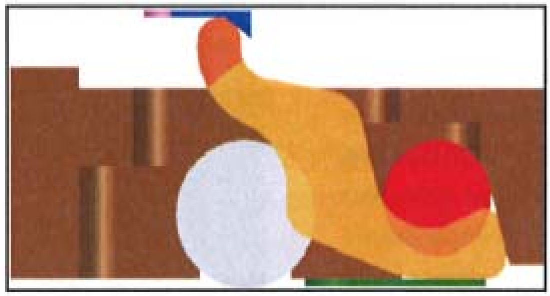

Fig. 1. Pad ROL™100A Series

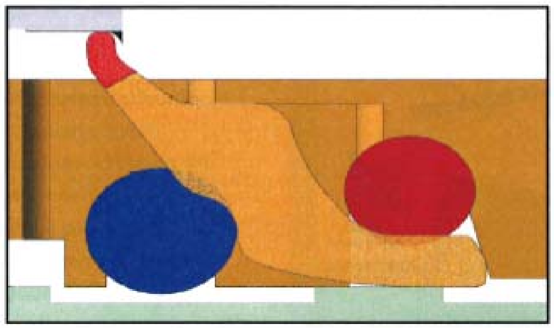

Fig. 2. Pad ROL™200 Series

Benefits

These contacts are a new solution that is being marketed by Johnstech. The benefits are:

- Longer contact life
- Extended MTBA
- Improved continuity
- Extended load board pad life
- Reduced cost-of-test against NiPdAu packages
- Provide lower forces
- Self-cleaning wipe function
- Can achieve longer contact life, and
- Provide higher performance

How Low-Force XL-2 Contacts benefit customers

Johnstech's customers can benefit by using the new Low-Force XL-2 contacts in several ways. In addition to the factors alluded to in the "benefits" section of this document, one can concentrate on two major benefits, namely cost of test and low force which can increase handler capacity.

- **Cost of Test (COT)**
  How does low force affect cost of test? There are many parameters that contribute to COT. In these times, COT is a significant contributor to the overall process of manufacturing semiconductors whereas 20 years ago, this was not so. One can surmise that factors affecting COT include those listed immediately below.
  - One factor of COT is "hardware," and test sockets fall within that category.
  - Another factor is MTBA and MTBR
  - Another factor is First Pass Yield. Is a test contactor contributing to lowering FPY?

  Generally, test contactors are directly included in the "hardware" factor of COT. However, they affect "yield" also because FPY is always the cost to test a good part hence if more parts have to be tested to meet production quotas and FPY is down because of test socket issues, hence COT is driven up. Also, test sockets enter into the category of "support" because calibration, repair, and maintenance are in the area. Superior contacts such as the Low-Force XL-2 will lower COT.

- **Low force and handler capacity:**
  Any handler ever designed and sold has an upper limit to the total force it can exert on a device in a test contactor. This means that the maximum number of pads, leads, or balls on a device under test is limited by the contribution of the total force and the maximum force per pad, etc. If a high force per pin is required, then smaller devices only can be tested. If the force per pin is low, then larger devices can be tested. This important because large test contactors are usually more expensive than smaller ones. The same holds true for large devices. Again, this is an area where economics plays a role.

Performance comparison between Pad ROL™100A and ROL™200 contacts[2]

The choice between Pad ROL™100A and ROL™200 Low-Force XL-2 Contacts usually depends upon the electrical performance required for the DUT. The table shown immediately below summarizes key performance differences between these two types of contacts. These parameters are based on contactors configured for NiPdAu packages.

Electrical Specifications (NiPdAu Configuration)	**Pad ROL™200 Series**	**Pad ROL™100A Series**
Inductance	Self: 0.55nH Mutual: 0.24nH	Self: 0.37nH Mutual: 0.15nH
Capacitance	Ground: 0.35pF Mutual: 0.12pF	Ground: 0.08pF Mutual: 0.03pF
S_{21} Insertion Loss	-1dB @ 18.5 GHz	-1dB @ 40 GHz
S_{11} Return Loss	-20dB @ 5.8 GHz	-20dB @ 18.3 GHz
S_{41} Crosstalk	-20dB @ 29.5 GHz	-20dB @ 33.5 GHz
Current Carrying Capability	2.8 A	2.6 A
Compliance	0.20mm	0.175-0.20mm

Customer Production Performance Improvements

Customer production testing with the new Low-Force XL-2 Contacts has yielded solid performance results. Johnstech's customers whom are utilizing these new Low-Force XL-2 contacts have experienced higher yields, improved continuity, longer load board pad life, and extended MTBA. Customers have seen significant improvements in contact life, often beyond 500,000 cycles, even with the most challenging NiPdAu package platings.

Applications

The Pad ROL™100A and ROL™200 Contactors are used extensively for RF/wireless, precision analog, and high speed digital devices that require the highest electrical and mechanical performance for engineering and production applications. Offering the highest electrical performance, the ROL™ series lowers your engineering risk and allows you to set tighter guard bands. With the consistent results it provides, ROL™ series provides the robust mechanical performance and site-to-site repeatability in production applications to increase your yields and maximize your OEE.

Summary

The new Johnstech Low-Force XL-2 Contacts for the Pad ROL™100A and ROL™200 Contactors stand up to the challenges of NiPdAu and NiPd packages. Furthermore, the price of the XL-2 Contacts has been significantly reduced compared to the previous Eco™ -1 Contacts. The extended contact life and lower spares costs will lower your overall cost of test. Refer to www.johnstech.com for technical product information, or contact your local Johnstech Representative.

References:

[1] Deeg, Emil W., *Computing Hertzian Stresses in Fiberoptic Connector Modeling*

[2] Johnstech Corp., *Contacting Solutions for Reliable, Repeatable Test Results on NiPdAu Packages*

NOTE:

The Low-Force XL-2 Contacts are also available on the Leaded ROL™200 and Pad ROL™200K Kelvin Contactors.