Design of a high performance single beam contact for demanding and long life time applications in Industry and Telecom markets

Jan Broeksteeg
Tyco Electronics Netherlands B.V.
Rietveldenweg 32
's-Hertogenbosch, The Netherlands
Phone: 31 73 6246 436
Fax: 31 73 6246 973
e-mail: j.broeksteeg@tycoelectronics.com

First publication at IMAPS 41st Annual International Symposium on Microelectronics, November 2008

Abstract:
For long life time (Telecom) and demanding (Industry) applications, contact systems are often designed with bi-furcated or dual beam contact springs. This gives redundancy to the connector. The market is also requesting increased density and superior signal transmission quality. In some cases this results in contradictions. A revolutionary new connector design solves this contradiction.

1. Introduction

Tyco Electronics recently introduced a new board to board connector program in the Z-PACK product family. The new product is named Z-PACK Slim UHD and is available for applications up to 20 Gbps signal speed. This paper describes the solutions in mechanical connector design concentrated around the contact interface. See Figure 1. A complete and actual description of the connector program can be found at www.zpackuhd.com or by contacting your local Tyco Electronics representative.

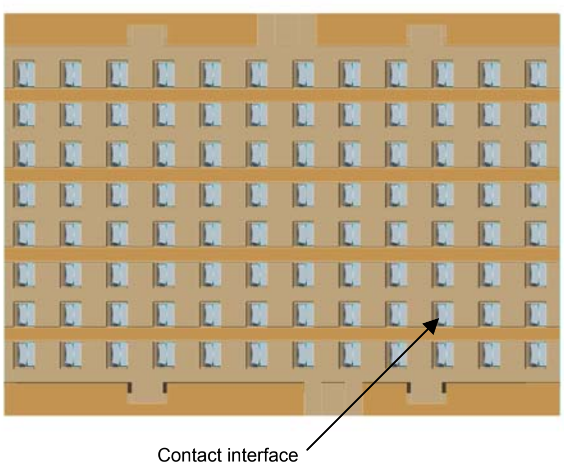


Figure 1. (Cross section)

2. The evolution of Telecom connectors.

In order to better understand the content of this paper, a brief summary of the connector evolution over the last decades is necessary.
First the definition of a two piece connector as referenced in this paper [1]:

By function, a connector provides a separable connection between two elements of an electronic system without unacceptable signal distortion or power loss.

By structure, every board to board connector includes two permanent interfaces to the boards, the contact springs in each half of the connector, the separable interface and the connector housings.

In the 1970's two piece board to board connectors were introduced, next to card edge style connectors (one piece) and became popular for board to board applications. Various industry standards are based on two piece connectors. A two piece connector typically has a male and female connector type. Either one can be placed on the back panel, were the other is placed on the daughter card. Coplanar and mezzanine applications also occur, but detailed explanation takes us outside the scope of this paper.
A typical two piece board to board connector application is shown in figure 2.

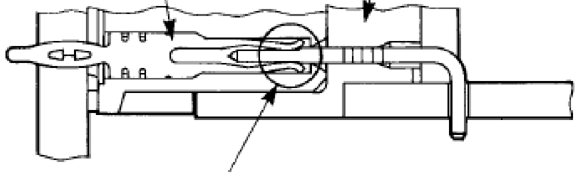


Figure 2 [1]

Contact normal force was preferred to be >100 cN for noble contact plating like Au over Nickel. Application was in so called 19 inch racks, where one or two 96 position connectors were simultaneously inserted. High insertion force, directly related to the normal force, was not considered a problem.
In the late 1980's more and more variations to the original 96 pos DIN / Eurocard connectors were created. Versions with 128 contacts (4 row), enlarged versions and shielded versions.
This increased density also made it necessary to re-consider insertion and extraction forces and with that also contact normal force, since these are directly related. New generic requirements were defined for separable electrical connectors used in Telecommunications hardware. Connectors with contact normal forces under 100cN, had to qualify according these new requirements.

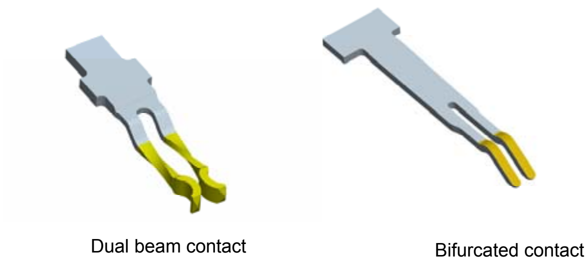


Figure 3

Today's High Speed / High Density data transmission board to board connector systems are tested and released according these test conditions.

Early examples can be found in the Tyco Electronics Z-PACK connector family, like Z-PACK 2mm HM connectors and Z-PACK FB connectors.

The commonly used contact principle as shown in Figure 2 and Figure 3 (left) is called "dual beam", since contact normal force is build up between two metal contact halves and only plastic deformation and permanent set of the metal contact beams must be taken into consideration. In the evolution to higher speed and density, this principle is still used, but at a smaller scale and with lower contact normal forces.
Since the introduction of these connector types in the 1990's, density and signal transmission speed has only gone up further, resulting in products like Z-PACK Slim UHD connectors.
Now the dual beam contact principle becomes difficult to realize, for various reasons:

a. High speed signal transmission. Electrical requirements for the contacts is no longer restricted to conductivity alone. Crosstalk, characteristic impedance, skew and attenuation become critical variables. The electrical performance of these types of connectors is determined by mechanical parameters like material properties, distances between conductors and dielectric, PCB constrains, footprint requirements and signal routing on the boards.
b. Density. A dual beam contact principle can become a limiting factor for minimizing the contact pitch at least in one axis.

As a result of this, bifurcated spring beams, as per Figure 3, become common practice for use in Telecom and Computer connector types. In order to maintain the principle of two contact point per contact, these single beams are often split lengthwise, thus creating a so called bifurcated single beam. The contact normal force is further reduced, but if the contact interface is well engineered and the contact geometry correctly defined, the reduction of contact normal force can be compensated.
Dual beam contacts and bifurcated contacts are often referred to as *redundant* contact principles, because of their two contact interfaces. Contact normal forces have to stay at an acceptable level during product life cycle.

3. Requirements for the Z-PACK Slim UHD Connector

(selected from a longer list, but related to the contact interface)

- No pre-defined differential pairs, by design. Differential pair positions are defined by footprint on the Printed Circuit Board (PCB).
- Achieve 384 contacts on <70 mm board length.
- Connector height must allow board spacing of 15 mm, but connector height measured from component side of the board should not exceed 7.85 mm.
- Operating temperature -55° C to 105° C.
- Inclination of 1° and misalignment of 1 mm in all directions must be accepted during mating and un-mating.

4. The concept.

In order to achieve the 384 contacts over less then 70 mm board space and comply with the other electrical and dimensional objectives resulted in a connector module, offering 96 positions. A connector with 384 contacts is created by end-to-end stacking of 4 modules. The overall length of this connector is 69.5 mm.

Electrical requirements limited the choice of materials for the housings. It was also necessary to limit the amount of air in the connector. The dielectric constant of glass filled Liquid Cristal Polymer (LCP) was ideal for the job. The concept limits the amount of air in the connector over the complete lengths of the electrical contacts, for both male and female connector. This gives the connector a very robust appearance. Male pins and female contacts are almost fully surrounded and protected by tough LCP material.

The mated module with overall dimensions of only 27.30 x 17.30 x 12.55 mm (depth x width x height), hosts 96 contacts. See Figure 4.

Due to electrical en density constrains, however, dual beam and/or bifurcated contact principles are not preferred for this design. Z-PACK Slim UHD connector has a non-bifurcated single beam contact spring.

5. The challenge.

Our choice for 96 contacts per module, triggered a comparison with traditional 96 position DIN 41612 / IEC 60603.2 Eurocard connectors. These connectors were created in the early seventies of last century and are still used in Telecom and Industry applications today.
Where the extreme electrical performance of Z-PACK Slim UHD connector is valued by Telecom customers, the extreme density and robustness is noticed by customers that do not specifically look for high speed interconnect. For these applications, the question is:
Is this connector as robust as it looks? How does this connector perform under stringent system conditions?
In order to answer those questions we have to critically review al aspects of the connector in relation to possible failure modes.

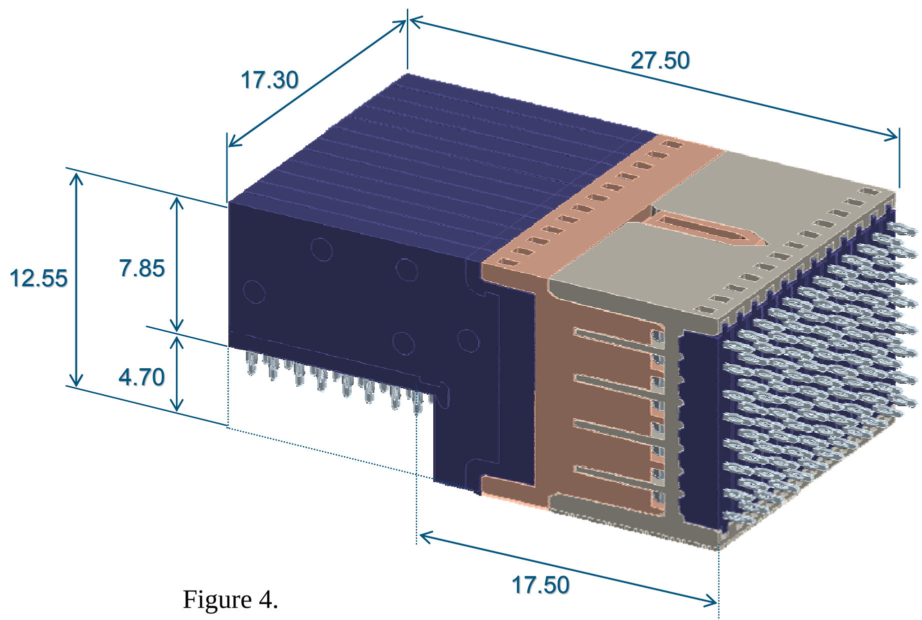


Figure 4.

6. Failure modes.

Failures mode are often divided in *intrinsic* and *extrinsic* failure modes. [1]

Intrinsic failure modes: Determined by material, geometry, and design decisions.

For the contact interface, loss of contact normal force is a typical failure mode.

a. Permanent set in the contacts:

b. Stress Relaxation of the contact material:

c. Degradation of polymer housing material.

d. Misalignment of the contacts.

Precautions were taken during the development of the Z-PACK Slim UHD connector to avoid intrinsic failure modes and assure contact interface stability.
See Figure 1 and 5.

- Spring deflection is limited by design to avoid deflection beyond design deflection level.
- Effective lead-in angels and positive alignment features are present.
- Chamfering of mating parts, both in housing as in contacts.
- Contacts are well protected by polymer material, both in un-mated as in mated position.
- Male and female contacts are fully captured in polymer, except the functional areas.
- Female contact is pre-loaded and accurately fixed in position.
- Production steps and process tolerances are minimized.

Extrinsic failure modes: Exist due to environmental conditions in which the part is used and are of great concern.

Although corrosion and wear are important degradation mechanisms, these are addressed successfully in the Z-PACK Slim UHD product, by contact finish and surface treatment. Extensive product testing has been executed to support this statement. It is somewhat besides the scope of this paper to address this in detail.

Particulate contamination has been mentioned as an other important failure mechanism for noble metal contacts operated at normal forces below 100 cN value.

Signal distortion or power loss is directly related to loss of contact normal force and is unacceptable for high signal speed transmissions, since data can be lost. Traditionally vibration and mechanical shock tests are performed, in combination with dust, to check the performance of the connector.
This is were dual beam and bifurcated contacts have been successfully implemented to reduce sensitivity to dust and provide redundant contact interfaces.

Due do extreme density and signal speed requirements, a single –non bifurcated- beam construction was selected for the Z-PACK Slim UHD connector.
The precautions taken during the development of the Z-PACK Slim UHD connector to avoid intrinsic failure modes, also assure contact interface stability during dust, vibration and mechanical shock testing.

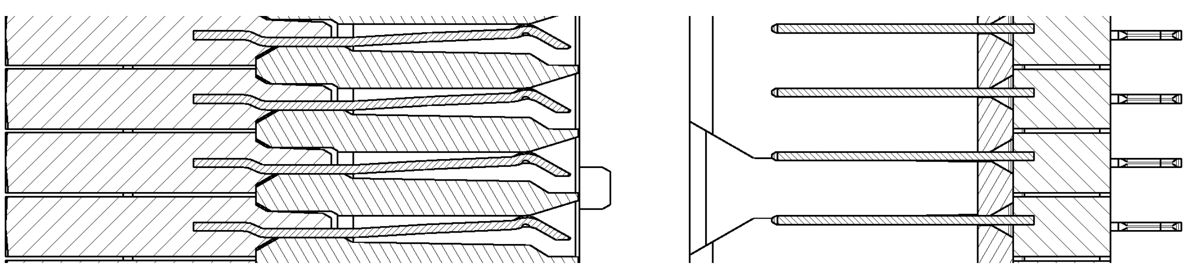


Figure 5.

Since racks and sub-racks, where these type of connectors are typically used in, require special vibration tables, this test is more often performed on connector level, using a test frame, limiting the movement to the connector components only. Vibration and shock tests are performed in thee axes.
One of the potential applications for the Z-PACK Slim UHD connector however was a new mini computer, with overall dimensions of 107 x 94 x 94 mm, with one back panel and two daughter boards. Two Z-PACK Slim UHD connectors were used, one build up out of 4 modules (384 contacts) and one build up from one module (96 contacts).

The daughter boards were supported by card guides, perpendicular to the back panel, giving limited freedom to the boards. The side of the daughter board parallel to the back panel was not supported. A test frame was build, copying the dimensions of the real application. No additional support was added.
For the test we decided to equip one daughter board with a 30 pos DIN 41612 / IEC 60603-2 connector, with contact normal force >100 cN and dual beam contacts, for reference, and the other daughter board with a 2 module Z-PACK Slim UHD connector (192 contacts). Both connectors are similar in size.
See Figure 7.

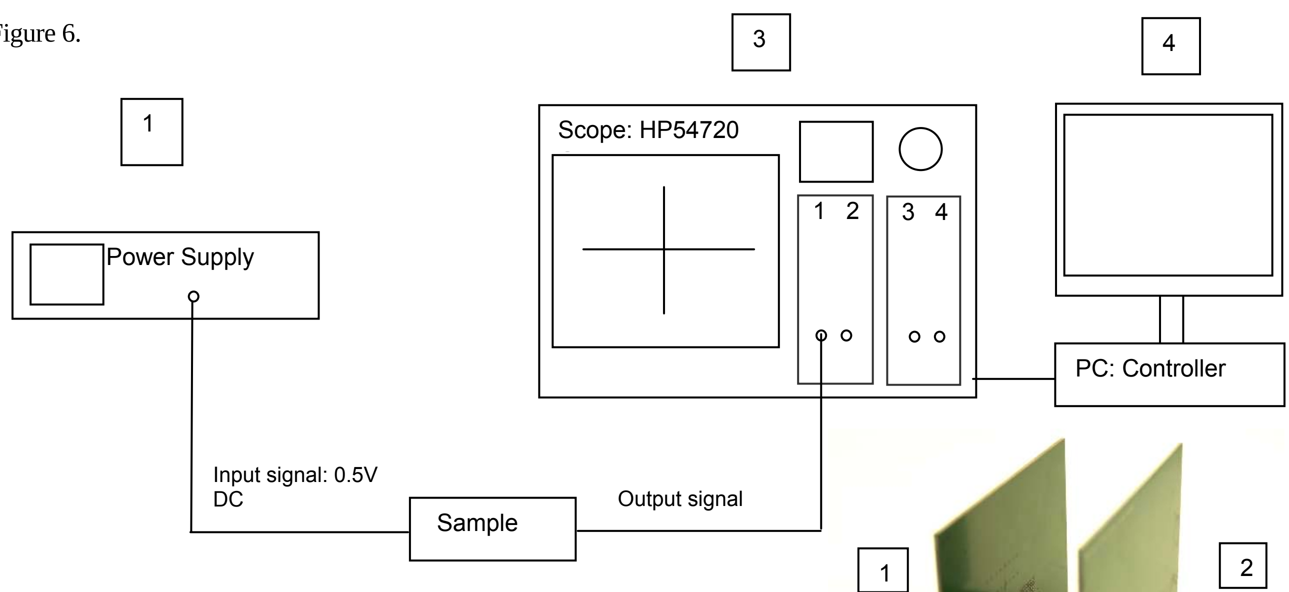
The DIN connector was also mechanically mounted to the board by either soldered board locks (Back panel) or bolts and nuts (Daughter board). Since this test was set up to test the contact interface, all contacts were soldered to the boards.
Traditionally these connectors are tested for interruptions > 1µsec, but this is not realistic today. We therefore decided to check for interruptions > 10 nsec.

7. Description of the test.

Interruption detection setup Figure 6:

a. Power supply: generate continue 0.5V dc. Input signal for test sample.
b. The test sample consists of a Back panel and 2 daughter cards Version 1 with the Z-PACK Slim UHD connector, Version 2 with DIN connector.. See Figure 7.
   The connectors were provided with a series circuit to detect the interruptions.
c. Oscilloscope HP54720: Port 1 is adjusted in trigger mode (glitch >10ns) and triggered on negative slope signals >10nseconds. The trigger level was 150mV.
d. PC Controller: Program in Agilent VEE to control the Oscilloscope and to detect/count interruptions.

Figure 6.



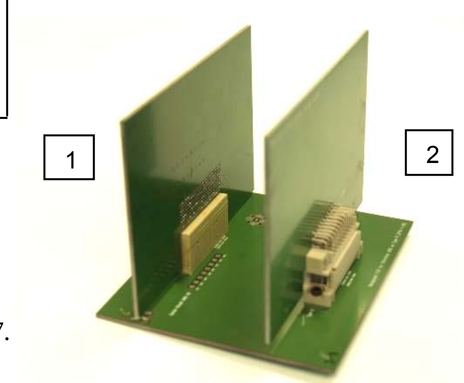


Figure_7.

8. Testprocedures

Test sequence Mechanical Shock and Vibration		
	Required value	Remark
Visual examination	As per spec 108-19320	
Initial Low Level Contact Resistance	20 mΩ max	
100 cycles pre-wear	No Damage	
Change in LLCR	10 mΩ max	
Dust exposure	1 hr unmated	See notes 2 and 3
Change in LLCR	10 mΩ max	
Monitor during vibration	no events > 10 nsec	See note 1
Change in LLCR (X,Y,Z-axes)	10 mΩ max	
Mechanical shock	no events > 10 nsec	3x30g/axis
Change in LLCR (X,Y,Z-axes)	10 mΩ max	
100 cycles post-wear	No Damage	
Change in LLCR	10 mΩ max	
Visual examination	As per spec 108-19320	

Note 1	Subject the system to be tested to a single sweep sine-wave test at a level of 5g (see note 5) from 5 to 100 Hz a logarithmic sweep rate of 0.1 octave/minute, and monitoring the system function during the vibration). The repeated sweep sine-wave test shall be maintained for 2 hours on each axis (see also note 5). Repeat the test as descibed above at the appropriate acceleration level on each of the three axes.

Note 2	Dust Composition		Minimum 0.5 milligram/cm2	
	Particulate	Weight %		See note 4
	"Arizona Road Dust"	97		
	Cotton fibres	3		

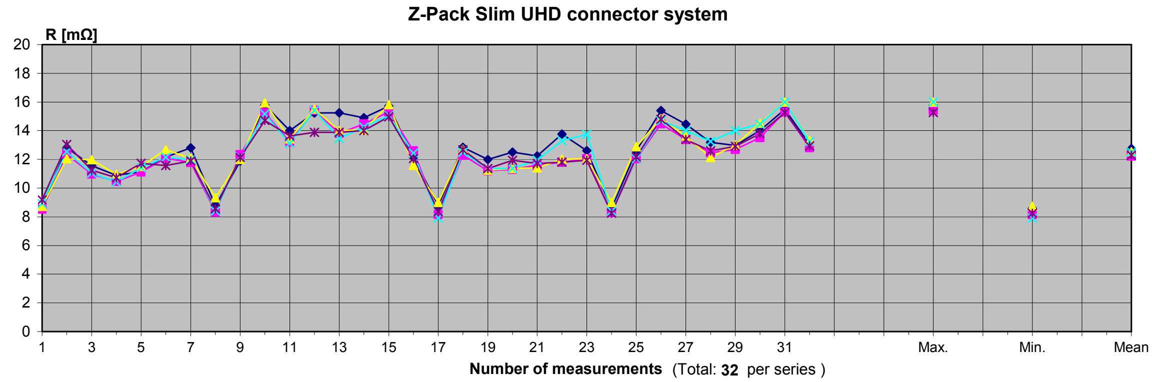
Note 3	The dust shall be introduced on the contact surfaces of the unmated test parts by means of a recirculating The prescribed quantity and formulation of dust shall be placed in a tray or holding container, distributed as a thin layer. It shall be dried for 1 hour prior to use by placing the container in an oven held at 50 (±3) °C. The container of dust shall then be placed in the dust blower system, and the air blower shall operate for the prescribed period and flow rate. On completion of the air flow, test samples shall be left undisturbed in the chamber for 1 hour prior to being removed and tested.
Note 4	1. The quantity of dust shall be 9 (±1) grams per cubic foot of volume of the recirculating dust chamber. 2. Weight gain measurements demonstrated that approximately 0.6 milligram/sq.cm. was applied by this

Note 5	Test groups (2 board assemblies each)	
Group 1	5g	2 hrs

Figure 8.

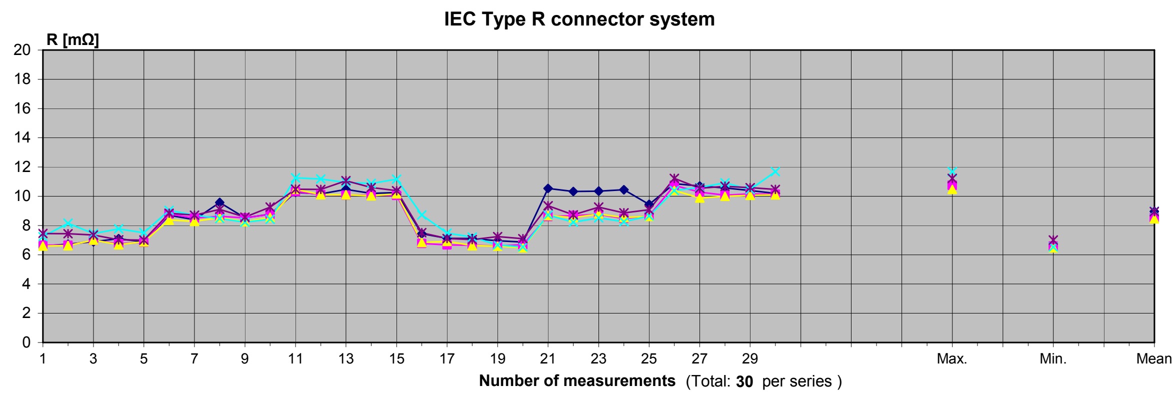
9. Results:

Contact resistance:



Series	Group	Lot	Test	ΔRmax.	ΔRmin.	ΔRmean	Max.	Min.	Mean
◆	2	1-2	Initial				15.79	8.58	12.75
■	2	1-2	After Mech. operation (100x)	0.47	-1.96	-0.52	15.41	8.15	12.23
▲	2	1-2	After Dust	0.57	-1.77	-0.23	15.99	8.73	12.52
×	2	1-2	After Vibration and Shock	1.13	-1.79	-0.25	16.00	7.90	12.50
✱	2	1-2	After Mech. operation (100x), final	0.60	-1.97	-0.47	15.27	8.25	12.29

Vibration and Shock:



Series	Group	Lot	Test	ΔRmax.	ΔRmin.	ΔRmean	Max.	Min.	Mean
◆	2	1-2	Initial				10.86	6.60	8.96
■	2	1-2	After Mech. operation (100x)	0.11	-1.97	-0.44	10.75	6.60	8.53
▲	2	1-2	After Dust	0.20	-1.90	-0.50	10.47	6.49	8.46
×	2	1-2	After Vibration and Shock	1.49	-2.19	0.02	11.69	6.53	8.99
✱	2	1-2	After Mech. operation (100x), final	0.86	-1.60	-0.01	11.23	7.01	8.95

During the two tests no discontinuities >10 nanoseconds were observed.

10. Vibration and Shock Set-up

See figure 9.

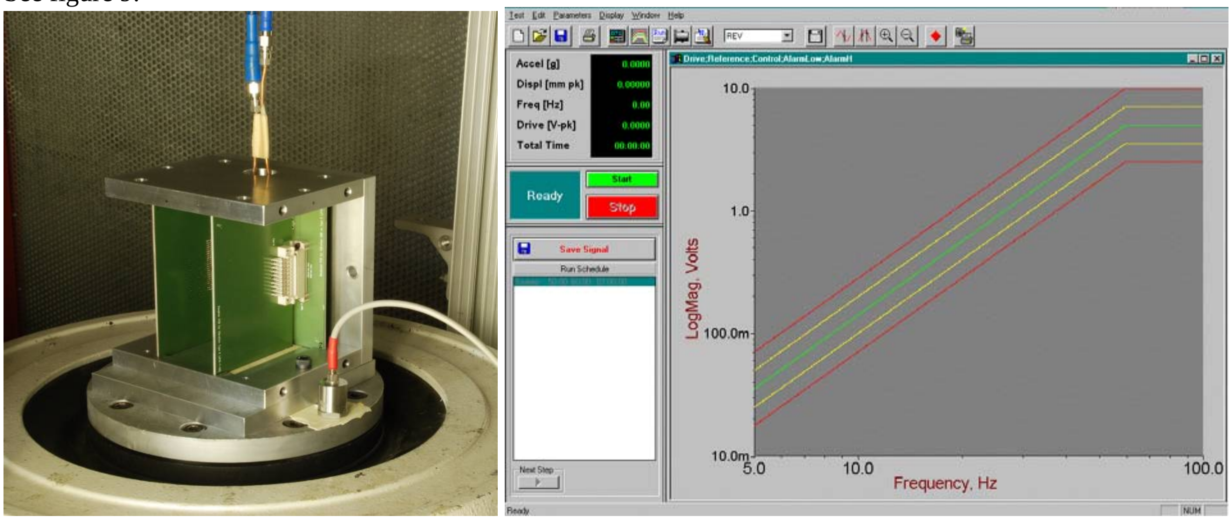


Figure 9.

11. Conclusion.

When tested under <u>extreme system conditions</u> for dust, vibration and mechanical shock, according Fig 8, the Z-PACK Slim UHD connector performs equally good as a DIN 41612 / IEC 60603-2 connector. This proves the high quality of the Z-PACK Slim UHD contact interface construction.

Sources.

[1] Robert S. Mroczkowski, “Connector Design / Materials and Connector Reliability” P351-93, AMP Inc. Harrisburg 1993.

<u>Communications, Computer & Consumer Business Unit</u>

TE Logo, Tyco Electronics, Z-PACK and Z-PACK Slim UHD are trademarks. Other products, logos and company names mentioned herein may be trademarks of their respective owners. All information, including illustrations, is believed to be reliable. Users, however, should independently evaluate the suitability of each product for their application. Tyco Electronics makes no warranties as to the accuracy or completeness of the information, and disclaims any liability regarding its use. Tyco Electronics’ only obligations are those in the Company’s Standard Terms and Conditions of Sale for this product, and in no case will Tyco Electronics be liable for any incidental, indirect, or consequential damages arising from the sale, resale, use or misuse of the product. Specifications are subject to change without notice. In addition, Tyco Electronics reserves the right to make changes—without notification to Buyer—to materials or processing that do not affect compliance with any applicable specification.