ENLARGING THE PRODUCT OFFERING OF SPACE QUALIFIED RESISTORS AND NETWORKS

Ms Dominique Vignolo
Vishay Sfernice Division
199, Bd de la Madeleine
06003 Nice Cedex (France)
Dominique.vignolo@vishay.com

ABSTRACT

Because of their outstanding stability, Vishay Sfernice thin film resistors have been successfully used for decades in applications requiring high reliability, such as space equipment.

The aim of this paper is to present the work performed by Vishay Sfernice to enhance its product offering in order to fulfil the needs of space customers in terms of resistors and resistor networks.

In cooperation with the European Space Agency, Vishay Sfernice has been writing specifications and has qualified ESA "R" failure rate resistors. We will present experimental data. We will also summarize interest in the application of the 100% overload performed during screening tests at the end of the production process of ESA "R" failure rate parts.

We will also present the Vishay Sfernice product roadmap:

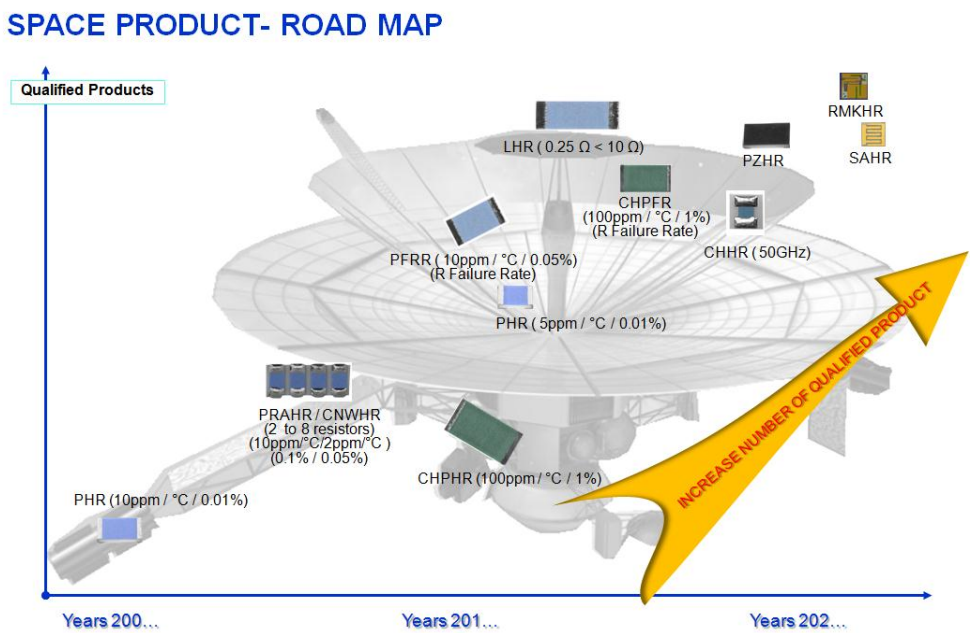
- Existing qualified product offering
- Range extensions (low values and straps)
- Hyper-frequency chip resistors and mounting process
- Work on gold pads for dies that can be used in space applications

In addition, we will present data on load-life behaviour and bonding tests.

In conclusion, we will highlight the involvement of Vishay Sfernice in the space market and the goal of working together with other Vishay divisions as a "one-stop shop" for Space customers.

VISHAY SFERNICE ROADMAP

The goal of Vishay Sfernice is to fulfil our customers' requirements by offering all types of performances needed for space applications, and to propose solutions when there are neither MIL-qualified, nor ESA-qualified products.



In the above time-frame, Vishay Sfernice has qualified its manufacturing process (ESCC/QML) and enlarged the number of qualified or suitable products for space applications with appropriate testing.

QUALIFIED PRODUCTS

Space Level

The need of the space market is to save weight and room on PCBs. So we have extended the qualified range of our PHR (thin film chip resistors) down to size 0402 (DCR has been raised) with outstanding performances: 0.01 %, 5 ppm/°C [-55°C to +155°C].
Another consideration for our customers is power rating, so we are now offering a 2512 size, which can dissipate up to 1 W.

Some space programs require operation at very low temperatures. Some of our customers' qualifications are at temperatures as low as -135 °C (data available at CNES).

There were no qualified SMD networks, neither MIL nor ESA, so Vishay Sfernice decided to qualify resistor networks (PRAHR / CNWHR) that include resistors with the same or different ohmic values. And because of the miniaturization requirement, smaller sizes are now available with an option (pending qualification): PRAHR073 and PRAHR074 (like 0302 or 0402 chips resistors beside each other).

To complete its range of qualified products, Vishay Sfernice has qualified a thick film chip resistor, the CHPHR and in order to be a complement to any MIL- or ESA-qualified part, the gold terminations have been qualified for use at high temperatures.

R Failure Rate

Many space programs only require an R failure rate level. This level existed in the MIL system, but not in the ESA system. Vishay Sfernice has worked closely with ESA to introduce an R Failure rate, but with enhanced performances, tolerance down to 0.05 % and TCR down to 10 ppm/°C so as to open new possibilities to design engineers.
Recently, the 0402 size has been qualified for miniaturization purposes.

Failure Rate Sampling Plans and Procedures
Below is a comparison between MIL specification MIL-STD-690 and ESA specification ESCC26000.

Requirements	ESA Specification	MIL Specification	Comments
Failure Rate Level P	0.1% / 1000 hours	0.1% / 1000 hours	0.1% failure per 1000 componants hours
Failure Rate Level R	0.01% / 1000hours	0.01% / 1000hours	0.01% failure per 1000 componants hours
Failure Rate Level S	0.001% / 1000 hours	0.001% / 1000 hours	0.001% failure per 1000 componants hours
Duration of life test to cumulate unit hours	8000h Min	1000h Min	
Confidence Levels	60% / 90%	60% / 90%	Probability of disqualifying a product when the true failure rate of the product is at the failure rate specified for the qualification
Sampling Plans based on 60% confidence Level	20.2M cumulative unit hours: 1 failure permitted	20.2M cumulatuve unit hours: 1 failure permitted	R Failure Rate Initial qualification
Sampling Plans based on 90% confidence Level	38.9M cumulative unit hours: 1 failure permitted	38.9M cumulatuve unit hours: 1 failure permitted	R Failure Rate
Reconduction of qualification	5.32M cumulative unit hours	5.32M cumulative unit hours	Sampling Plans 10% confidence Level
Periodicity of Failure rate Maintenance Sampling plans	15 months	9 months	R Failure Rate. Periodicity based on volume of production on USA and in Europe

The ESA specification calls for a longer load-life than the MIL specifications – 8000 hours versus 1000 hours - because 1000 hours might not be sufficient to stabilize the parts and determine the acceptable limit.

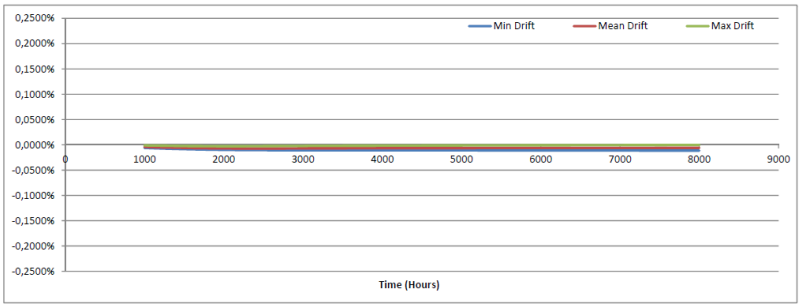
Example 1:

FINAL RESULTS OF CUMULATED DRIFT AFTER 8000 HOURS (%)

Type : PFRR 2010

Values : 698 Ω

Time	500	1000	2000	4000	8000
Min Drift	-0,0036%	-0,0061%	-0,0101%	-0,0109%	-0,0116%
Mean Drift	-0,0020%	-0,0043%	-0,0070%	-0,0065%	-0,0059%
Max Drift	0,0004%	-0,0013%	-0,0028%	-0,0016%	-0,0004%



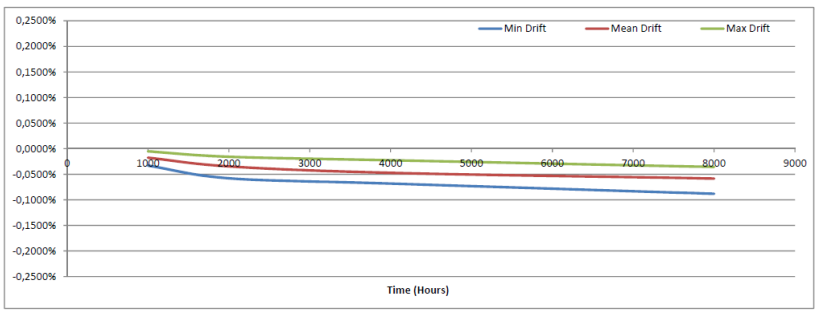
Example 2:

FINAL RESULTS OF CUMULATED DRIFT AFTER 8000 HOURS (%)

Type : PFRR 0603

Values : 46400 Ω

Time	1000	2000	4000	8000
Min Drift	-0,0330%	-0,0578%	-0,0682%	-0,0881%
Mean Drift	-0,0177%	-0,0346%	-0,0473%	-0,0585%
Max Drift	-0,0052%	-0,0158%	-0,0227%	-0,0358%



In example 1, we can see that the parts showed almost same behaviour after 1000 hours and 8000 hours. In Example 2, however, the parts had still not stabilized after 1000 hours and the load-life drift after 8000 hours is more accurate of what the customer might expect during the life of the parts in their application.

Short Time Overload:

Requirements	ESA Specification	MIL Specification	Comments
Short Time Overload	100% of delivered parts	20 samples fom Inspection Lot	MIL spec: If the manufacturer can demonstrate that these tests have been performed five consecutive times with zero failures, the frequency of these tests, with the approval of the qualifying activity can be performed on an annual basis

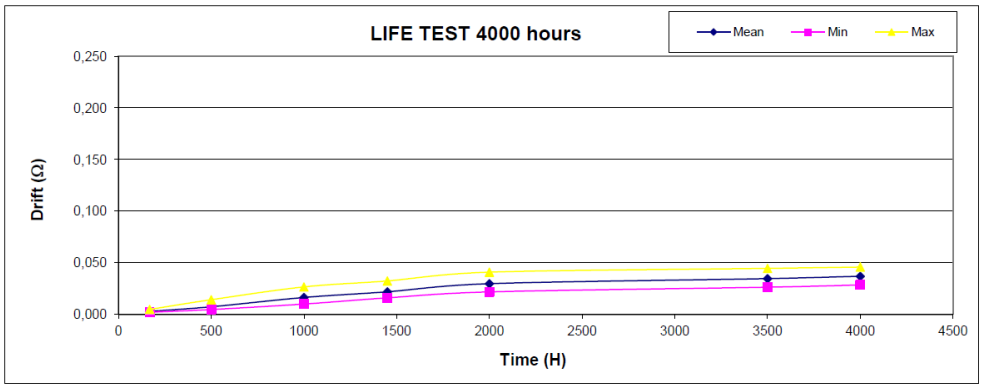
The purpose of short time overload is to check if humidity has been trapped under the protective coating during the manufacturing of the parts (human contamination). If so, parts will start drifting and will eventually "open."
By performing 100 % overload during the end-of-production screening test, the ESA specification ensures that no part will fail in the field.

ON-GOING QUALIFICATION

Space Level

Another gap to fill in both MIL-qualified and ESA-qualified products was the <1 Ω chip resistor. Vishay Sfernice decided to fill this gap by evaluating the LHR thin film chip resistor.
Evaluation has now been completed by the CNES. The ESA draft specification has been written, and full qualification is expected within Q3 2013.
This part is already available with option "46" and has been used for space application for 10 years.
The future qualified ohmic range will be 0.25 Ω to 9.99 Ω, while Vishay Sfernice can produce from 0.1 Ω.

The long-term behaviour of the LHR takes advantage of thin film technology.
Load-life testing at 70 °C of a LHR0603, 0.25 Ω resistor, at 150 mW shows a maximum drift of less than 0.05 % after 4000 hours.



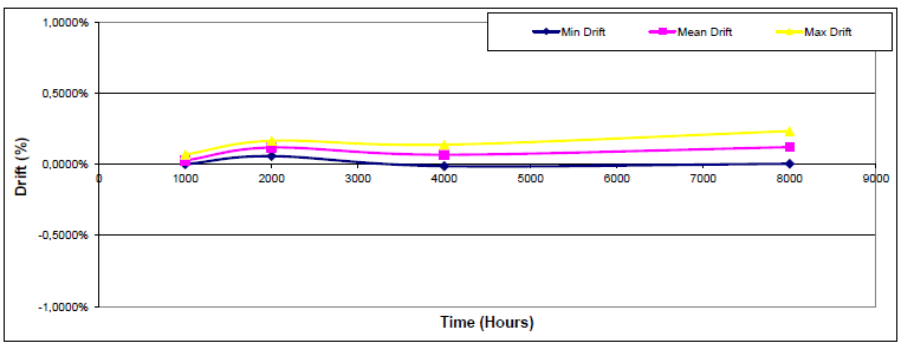
R Failure Rate

Vishay Sfernice, taking into account the goal of European projects to be more price competitive, has developed and is qualifying a thick film chip resistor to an R failure rate (CHPFR). There was no such existing ESA-qualified part.
Some components/hours have already been reached and Vishay Sfernice foresees full qualification within the year's end.
The following load-life curves show the outstanding behavior of this thick film chip resistor with drift after 8000 hours much better than 0.5 %.

Example 1:

Type : CHP0603
Value : 10Ω

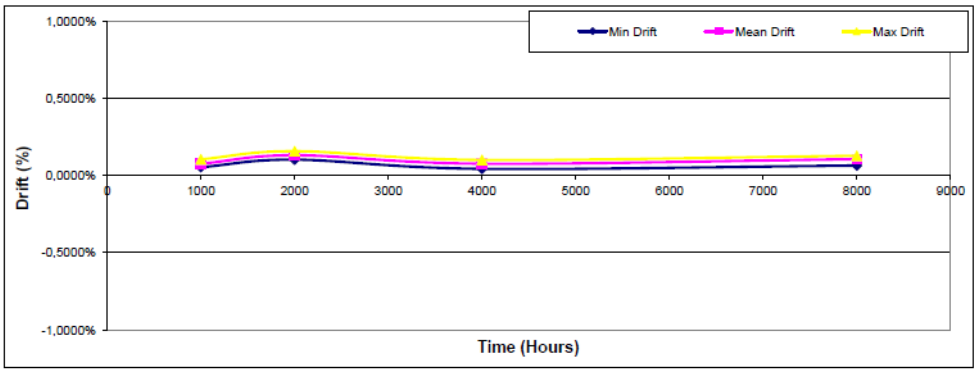
Time	1000	2000	4000	8000
Min Drift	0,0026%	0,0600%	-0,0113%	0,0057%
Mean Drift	0,0287%	0,1196%	0,0693%	0,1227%
Max Drift	0,0707%	0,1675%	0,1401%	0,2358%



Example 2:

Type : CHP0603
Value : 1KΩ

Time	1000	2000	4000	8000
Min Drift	0,0557%	0,1042%	0,0450%	0,0664%
Mean Drift	0,0775%	0,1329%	0,0780%	0,1076%
Max Drift	0,1067%	0,1596%	0,1026%	0,1297%



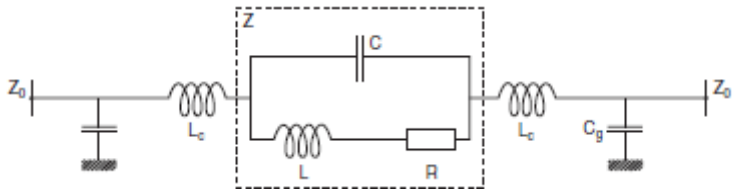
CUSTOMER EVALUATION

Hyper-Frequency Chip Resistor

With higher speed communications being used in space applications, a new demand is growing for hyper-frequency chip resistors.
No existing qualified products could be found on the market. To meet this need Vishay Sfernice is producing this type of product for commercial applications (CH series). The production of a space part will be within the perimeter of the ESCC/QML, and by this means the qualification could be easier.

The important performances in such applications are the behavior of the resistor, which should act as a "pure" resistor, even at frequencies up to 50 GHz. To achieve these performances, Vishay Sfernice limits the ohmic range from 10 Ω to 500 Ω and recommends the use of the smallest possible part (0402 or 0603). The commercial product is also available in the 02016 size, but the space market cannot handle such small chips. The termination type is also highly important for getting the best performance from hyper-frequency chip resistors.

Electrical Model



C	Internal shunt capacitance
L	Internal inductance
R	Resistance
Z	Internal impedance (R, L, C)
Lc	External connection inductance
Cg	External capacitance to ground

R, L and C are relevant to the chip resistor
Lc and Cg also depends on the way the chip resistor is mounted.

After assembly, Lc and Cg will be combined to L and C. This combination can upgrade or downgrade the hyper-frequency behavior of the component.

The complex impedance of the chip resistor is given by the following equation:

$$Z = \frac{R + j\omega(L - R^2C - L^2C\omega^2)}{1 + C[(R^2C - 2L)\omega^2 + L^2C\omega^4]}$$

$$\frac{[Z]}{R} = \frac{1}{1 + C[(R^2C - 2L)\omega^2 + L^2C\omega^4]} \times \sqrt{1 + \left[\frac{\omega(L - R^2C - L^2C\omega^2)}{R}\right]^2}$$

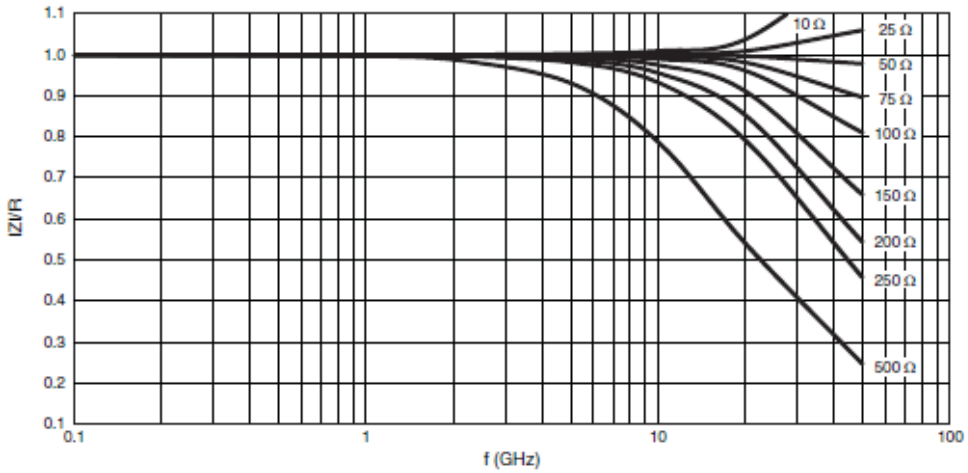
$$\theta = \tan^{-1}\frac{\omega(L - R^2C - L^2C\omega^2)}{R}$$

$\omega = 2 \times \pi \times f$
f= frequency

The chip resistor itself is purely resistive when $R = \sqrt{L/C}$.
The smaller the LxC product, the greater the frequency range over which the resistor looks approximately resistive.

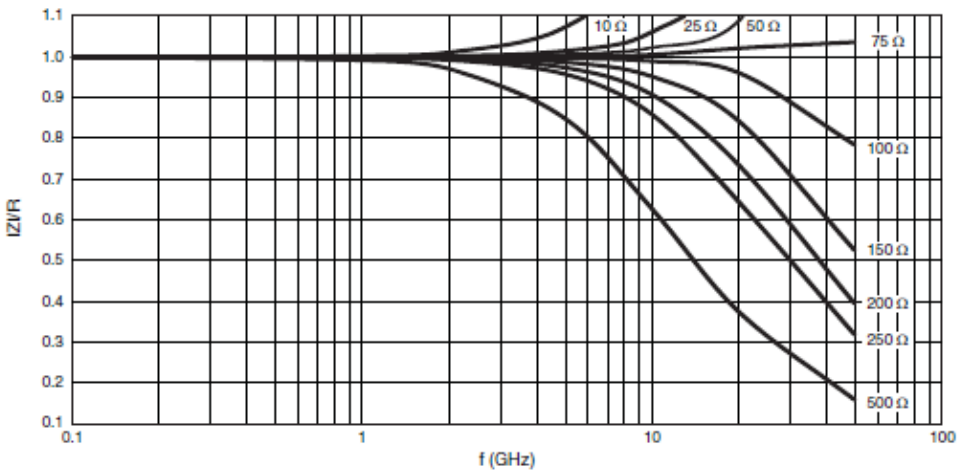
This can be seen in the following graphs, which highlight the influence of termination type and mounting in hyper-frequency behavior.

Impedance of CH0402 With Flip Chip terminals



With flip chip terminations, a 50 Ω chip resistor will act almost like a pure resistor at frequencies up to 30 GHz

Impedance of CH0402 With Wraparound Terminals



With wraparound terminals, at 10 GHz there will already be a parasitic inductance and capacitance on a 50 Ω chip resistor.

A flip chip mounting process, upside down, is not yet qualified in the ESA system. Vishay Sfernice suggests that this mounting process could be evaluated by a component working group, so as to take the best of chip resistors in hyper-frequency applications.

SMD Straps

The commercial part PZR has already been used with option 57 in space applications for the past 10 years. Vishay Sfernice intends to qualify it under the name of PZHR. It will be available in sizes from 0402 to 1206, with a resistance value of <30 mΩ, and maximum admissible current from 0.5 A to 6.3 A.
Today's product fully conforms to MIL-PRF-32159.
An ESA specification will be issued to describe the performances and ordering procedure.

Wirebondable Chip Resistors and Networks

For more than a decade, the various wirebondable products manufactured by Vishay Sfernice have been mounted in space applications by different customers using their own specification with the appropriate option.
Since these wirebondable products, are not qualified, customers have been ordering additional Lot Validation Testing.

In order to build a "standard" specification and to allow customers to save testing costs, Vishay Sfernice intends to write, in collaboration with the CNES and ESA, a specification to cover all wirebondable products - resistors, resistor networks and shunts - and to qualify each family of product to this specification.

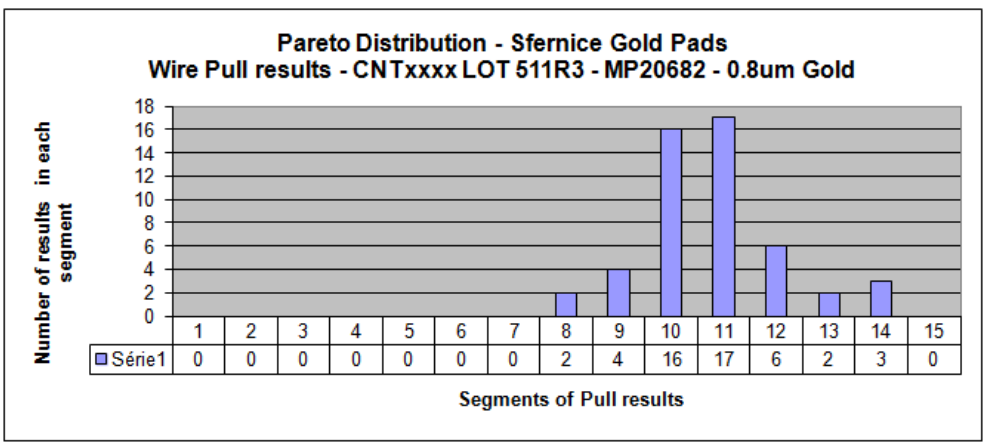
Furthermore, Vishay Sfernice has been working on gold terminations (as only aluminum terminations were offered until now), as they have been requested by customers who primarily use gold wires to perform bonding.

Wirebondable Chip Resistors
Different sizes (from 20 mils by 20 mils to 150 mils by 50 mils) on silicon substrates and different types of resistive elements (nickel chromium, chromium silicon) have been used with tolerances as tight as 0.01%, temperature coefficient down to 10 ppm/°C [-55°C to +155°C] and a huge ohmic range from 10 Ω to 2M Ω.

Wirebondable Resistor Networks
Like chip resistors, networks have been utilized in space applications under source control drawings including standard networks, on alumina or silicon substrates with additional screening, or networks customized to customer specifications. Various sizes and configuration are available (from 30 mils by 30 mils to almost no limit), with two to eight resistors (or even more), TCR tracking down to 2 ppm/°C [-55 °C to +155 °C] and a huge ohmic range from 10 Ω to 2M Ω.

Wirebondable Shunts
Available in three sizes (60 mils by 60 mils, 120 mils by 120 mils and 200 mils by 200 mils), on alumina substrates, these shunts can dissipate from 0.5 W to 6 W with an ohmic range from 50 mΩ to 1 Ω.

Gold terminations experimental data
As mentioned above, there have been requests from Vishay Sfernice customers to procure wirebondable chip resistors and networks with gold terminations to more easily bond with gold wires.
Pull tests performed on parts with gold terminations show consistent behavior and Vishay Sfernice is now ready to offer its customers this option.



CONCLUSION

Vishay Sfernice's strategy is to be one-stop shop for Space Customers.
It is the first passive manufacturer to be qualified ESCC/QML.

Vishay Sfernice has also introduced the R failure rate for ESA-qualified devices in order to offer price-competitive products for space projects where an R failure rate could be sufficient versus a space level rating.
Vishay Sfernice wants to offer a whole line of ESA-qualified products, from 0 Ω to 10M Ω, to save its customers additional testing costs.