Extreme Temperature Characterization of Passive Components

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INTRODUCTION

This article describes the setup developments and some of the results obtained for the temperature characterization from -190ºC to more than +300ºC of passive components normally used for space missions, but with a standard operating temperature range in most of the cases. One of the setups used is based on direct contact with Kelvin probes with a multiplexed solution to allow the characterization up to 150 samples in the same thermal cycle. A second measurements setup is used for measurements at higher temperatures based in not standard soldering and the use of a ceramic custom made climatic chamber door.

SETUPS FOR PASSIVE COMPONENTS CHARACTERIZATION

ALTER TECHNOLOGY TÜV NORD S.A.U. (ATN) is checking the response of standard passive space validated components for temperatures out of their specs. The setup for doing this is based on the use of a quite small climatic chamber with an internal volume of 25cm x 30cm x 30cm from Sun Electronic Systems. This chamber, shown in Fig. 1, cools with liquid nitrogen and heats with dissipative resistances. The temperature range is from -190ºC till 315ºC with controlled temperature rates up to 50ºC/min. Two different setups are used to measure a high number of samples.

Fig. 1. Sun Systems Climatic Chamber

SETUP 1

The first measurements setup used by ATN is based in the use of a commutation matrix manufactured by Sun Electronic Systems able to handle up to five component boards. The component boards provide easy Kelvin (4-wires) contact to the component terminals allowing very precise electrical measurements. The use of different component boards allows to measure up to 160 axial or radial components and 80 4-leaded components. The matrix and the different sockets are shown in Fig. 2. ATN develops labVIEW custom control software for automation and control each type of measurement. The use of the commutation matrix with programmable climatic chambers and custom control software allows performing fully automated measurements at pre-programmed temperature steps. The temperature control is guaranteed by the use of the control thermocouples of the chamber plus several additional thermocouples available to monitor homogeneity of the temperature along the different boards inside the chamber.

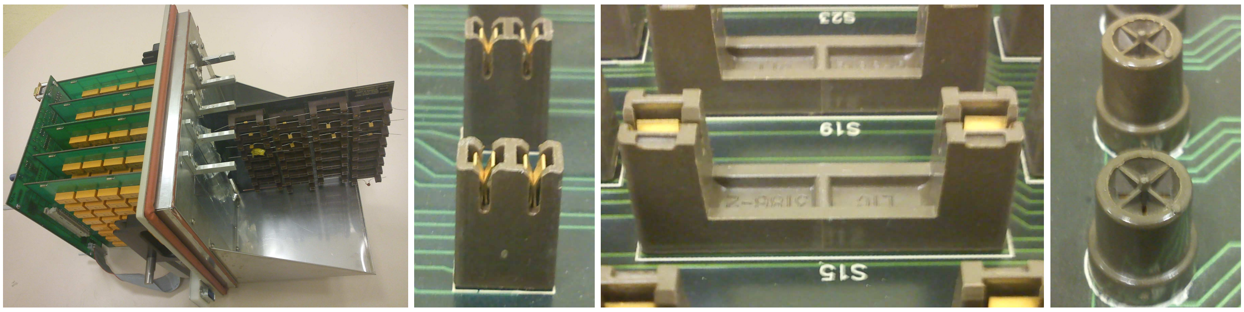

Fig. 2. Matrix door and Kelvin Sockets

The matrix door setup presents two limitations: the maximum allowed current is 4 amps due to the relays limitations and the sockets welding limits the usage of this setup to temperatures lower than 200ºC.

SETUP 2

This second measurements setup has been developed by ATN in order to overcome some of the limitations presented by the previously explained setup. In this case the contact to the terminals is made with cupper wires ended in golden receptacles. The cupper wires come out of the chamber through a Duratec drilled board. The Duratec material provides good electrical isolation (less than 1nA of leakage current at 250V between consecutive pins) and withstands all the temperature range for which the setup is intended. This system removes the 4 amps current limitation at the cost of only allowing semiautomatic measurements. The golden receptacle contacts are welded to the cupper wire using a high melting point soldering compound, allowing measurements to up to 300ºC without damaging or even staining the component terminals, like shown in Fig. 3. The measurements are performed through only two wires but the contact resistance added by the setup is lower than 5mΩ. The 4-wire measurement is performed from the other extreme of the cupper wires.

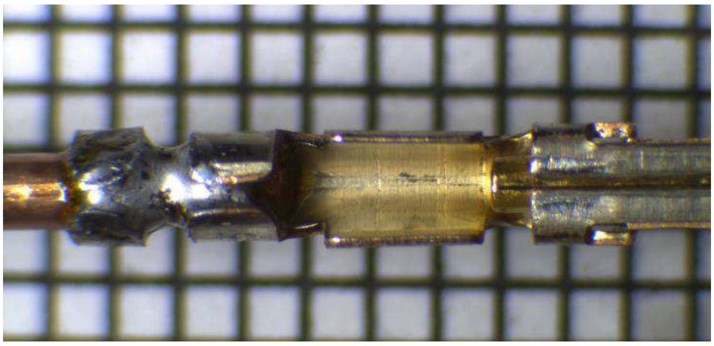

Fig. 3. Gold receptacle contact

The samples are placed on aluminium boards inside the chamber. The high mass of the aluminium boards allows to drain out the heat dissipated by the samples (if any) and the temperature of each one of the samples can be monitored and registered in steps of less than a minute. Up to 150 washer thermocouples can be screwed on the sample packages in order to monitor component case temperatures using a high density data logger. The overview of the custom door is shown in Fig. 4.

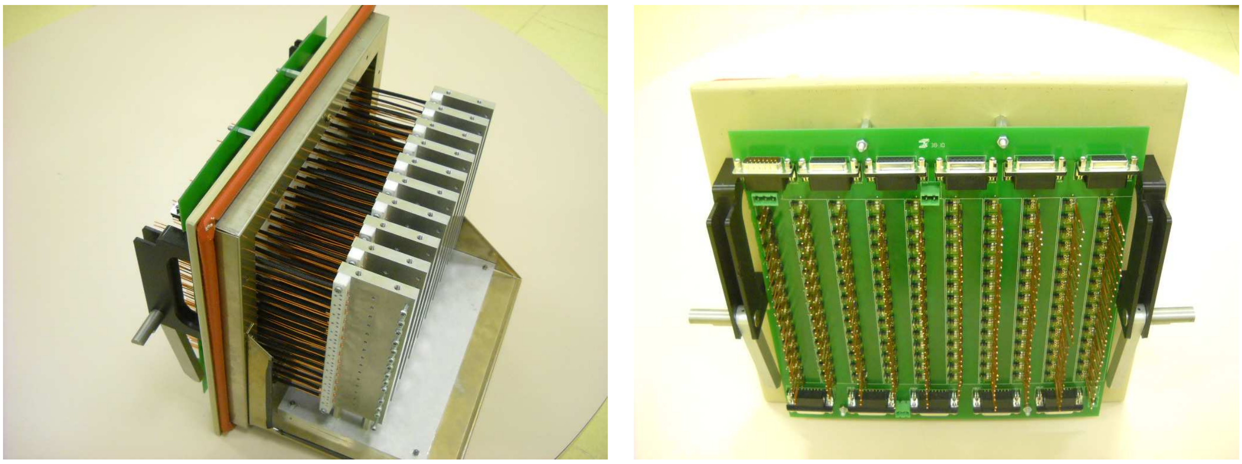

Fig. 4. Custom climatic chamber door

The full setup includes a N2 bottle to fill the chamber in order to avoid corrosion of the samples at very high temperature measurements. The complete setup is shown in Fig. 5.

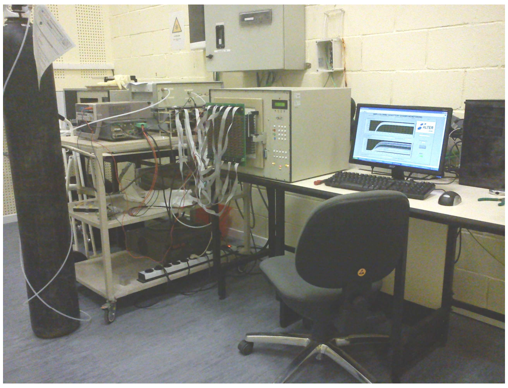

Fig. 5. Full measurements setup

The measurements are performed from the outside with special 4-wire connector and the custom control software developed by ATN keeps track of the measured samples, checking the result of each measurement and indicating the operator any problem during measurements. If the electrical value and temperature are in range, the system automatically jumps to the following sample for the next measurement.

PASSIVE COMPONENTS CHARACTERIZATION RESULTS: RESISTANCE MEASUREMENTS

The resistance measurements can be performed in a very precise way using the Kelvin sockets. The resistors show a slight increase in the resistance for temperatures below the minimum rated temperature. In some cases the resistance value obtained falls out of the specification limits for the standard temperature range like shown in Fig. 6. Most of the tested resistors show a very stable behaviour even out of their rated temperature range, an example is shown in Fig. 7.

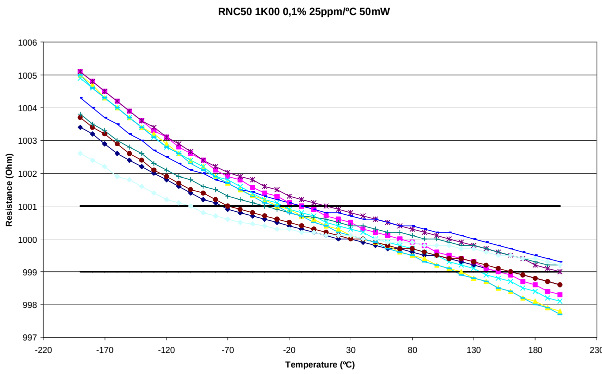

Fig. 6. 1K00 Resistor

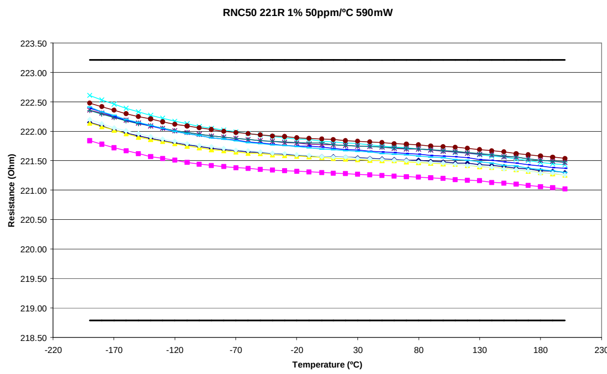

Fig. 7. 221R Resistor

Several measurements have been carried out on thermistors using the same system. The following picture shows the evolution of the resistance of thermistors that are being used to monitor the internal temperature of thermopiles for the REMS (Rover Environmental Monitoring Station) currently aboard the MSL (Mars Science Laboratory) on Mars surface. The resistance evolution and the actual thermocouple can be seen in Fig. 8 and Fig. 9 respectively.

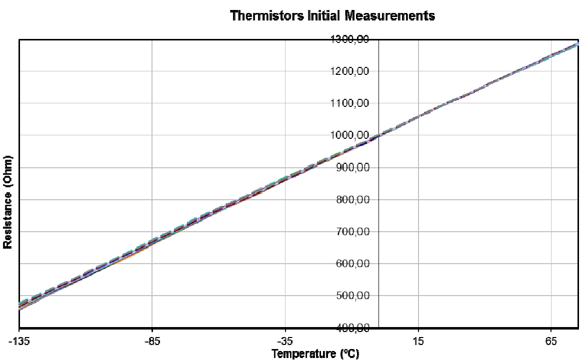

Fig. 8. Resistance evolution

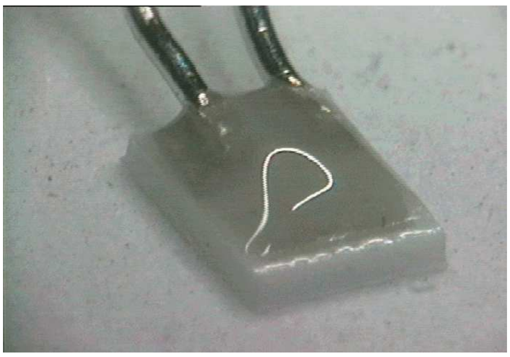

Fig. 9. Tested REMS thermistor

PASSIVE COMPONENTS CHARACTERIZATION RESULTS: CAPACITANCE MEASUREMENTS

Several capacitance measurements have been performed using the relay matrix in order to characterize a high number of capacitors at the same time. Measuring capacitances implies a high number of calibrations that directly affect to the measurements precision. The capacitance added by the relay matrix shows some temperature dependence even if the relays are outside the thermal chamber and an external heating system is used in order to stabilize the external relay matrix temperature and reduce this effect. A calibration cycle is performed using empty component boards resulting in absolute errors of up to 2pF at high temperature and around 10pF at low temperature. This error is the main limitation while characterizing low capacitance samples with this setup. Fig. 10 shows the high variation of the capacitance with temperature in regular ceramic capacitors. Ceramic capacitors with temperature compensating dielectric were tested resulting in very stable capacitances for all the tested temperature range. The low variation for this type of devices is shown in Fig. 11.

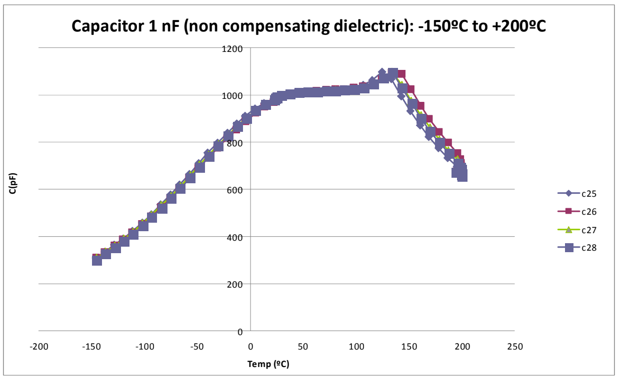

Fig. 10. 1nF standard capacitor

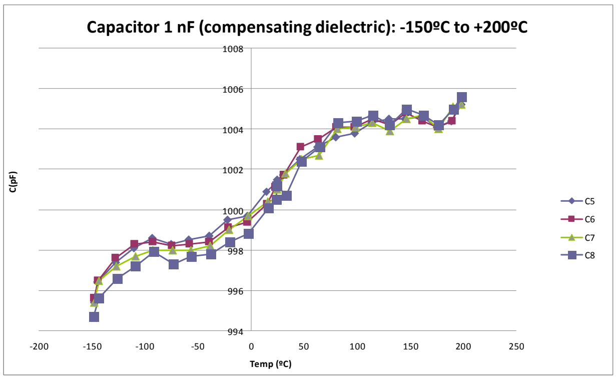

Fig. 11. 1nF temperature compensating capacitor

PASSIVE COMPONENTS CHARACTERIZATION RESULTS: HEATERS IN VACUUM

Fig. 12 shows an example of the characterization of heaters in vacuum. The particular use of the heaters and the inherent bad dissipation of the samples in vacuum lead to a difficult test. The heating by means of radiation has a big impact on the temperature of each heater, depending on the relative position of the samples. The temperature of several points inside the vacuum chamber was registered showing very high variations too.

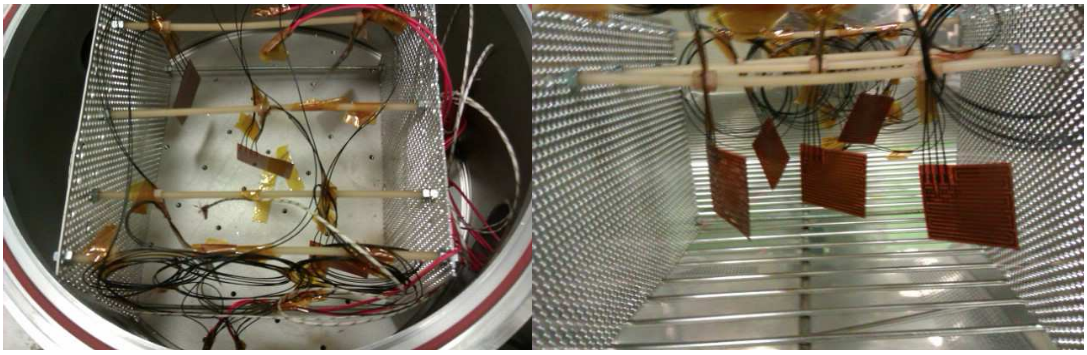

Fig. 12. Heaters in vacuum setup

CONCLUSIONS

ALTER TECHNOLOGY TÜV NORD S.A.U. is prepared for testing passive components at extreme temperatures. ATN has started the characterization of passive components at extreme temperatures. However, the electrical characterization is only a part of the tests to be done to validated these components for a wider than the standard temperature rate and for space applications. Additional tests such as the capability of surviving to thermal shocks and power and thermal step stress tests will also be performed to get a complete view of the possibilities for validation of some of these components in these extreme environmental conditions.

References

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