COMMERCIAL NON-MAGNETIC METALIZED POLYPHENYLENE-SULPHIDE FILM CAPACITOR FOR SPACE APPLICATION

I. Jernej[(1)], R. Wilhelm[(2)], W. Magnes[(1)], R. Gottselig[(2)] and A. Valavanoglou[(1)]

[(1)] Space Research Institute (IWF)
Austrian Academy of Sciences
Schmiedlstrasse 6
A.8042 Graz
Austria
Email:irmgard.jernej@oeaw.ac.at

[(2)] WIMA
Besselstrasse2-4
D-68219 Mannheim
Germany
Email:roland.wilhelm@wima.de, rolf.gottselig@wima.de

INTRODUCTION

A Digital FluxGate (DFG) magnetometer has been developed for the NASA mission Magnetospheric MultiScale (MMS) which is to explore the dynamics of the Earth's magnetosphere and its underlying energy transfer processes. The launch of the four satellite mission is scheduled for October 2014. The reliable operation of the DFG requires an absolutely non-magnetic and temperature stabile capacitor in the excitation circuit of the sensor unit. A commercial metalized polyphenylene-sulfide (PPS) film capacitor from WIMA (MKI-2) was selected for this application. It features a wide operating temperature range, self-healing, low dissipation factor, low dielectric absorption, good impulse strength and very constant capacitance value versus temperature. The capacitor was manufactured with non-magnetic copper leads by request of IWF. The temperature range of the capacitor is -55°C to +140°C, whereas DFG has to operate at temperatures down to -60°C and has to survive temperatures down to -100°C. To check if the MKI-2 capacitor is capable of surviving these deep temperatures, a series of 16 capacitors has been tested with a liquid nitrogen based setup. Finally, the flight capacitors were successfully screened and qualified according to NASA's instructions for EEE parts selection, screening, qualification and derating (EEE-INST-002) [1].

DEVICE SPECIFICATION

Table 1: MKI-2 Device Specification [2]

Type:	MKI-2
Manufacturer:	WIMA (Germany)
Package:	Leaded, solvent resistant, flame retardant Polybutylenterephthalat (PBT) case with epoxy resin seal (UL 94 V-0)
Lead material:	Cu
Operating temperature:	-55°C to +140°C
Dielectric:	Metalized Polyphenylene-Sulphide (PPS) Film

LOW TEMPERATURE TESTS

For the low temperature tests, 16 MKI-2 capacitors (0.068µF, 20%, 63V, RM5 package) with copper leads were used. These capacitors were serialized and soldered to two wires (GORE Type 26195E) with an average length of 40 mm each. Capacitance was measured every 10 seconds using a Fluke PM6306 RCL Meter.

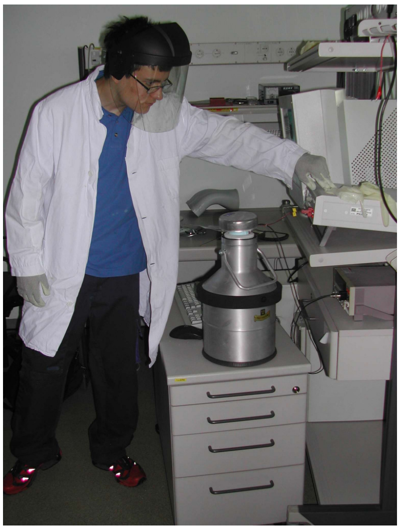

Fig. 1: Test Set-up with N_2 Dewar

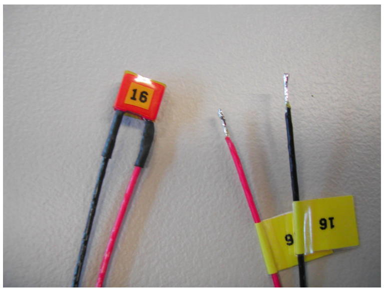

Fig. 2: Non-magnetic MKI-2 Capacitor

Low Temperature Shock Test (Immersion into Liquid Nitrogen)

Set-up

For this shock test the capacitors were immersed twice to liquid nitrogen (-196°C) for 100 seconds.
After immersion, they were released to room temperature (28°C) for 200 seconds. The temperature of the capacitors wasn't not measured as the temperature of both, the liquid nitrogen and the room, was known and as the test was meant to be a pure survival test.

Results

All capacitors survived immersion to liquid nitrogen without any failures. Capacitance values decreased with immersion to liquid nitrogen, but came back to nominal values after warming up.
The maximum change in capacitance was found at capacitor C09 with a capacity change of 1.62 nF over the complete test temperature range ($\Delta T > 210°C$) [3]

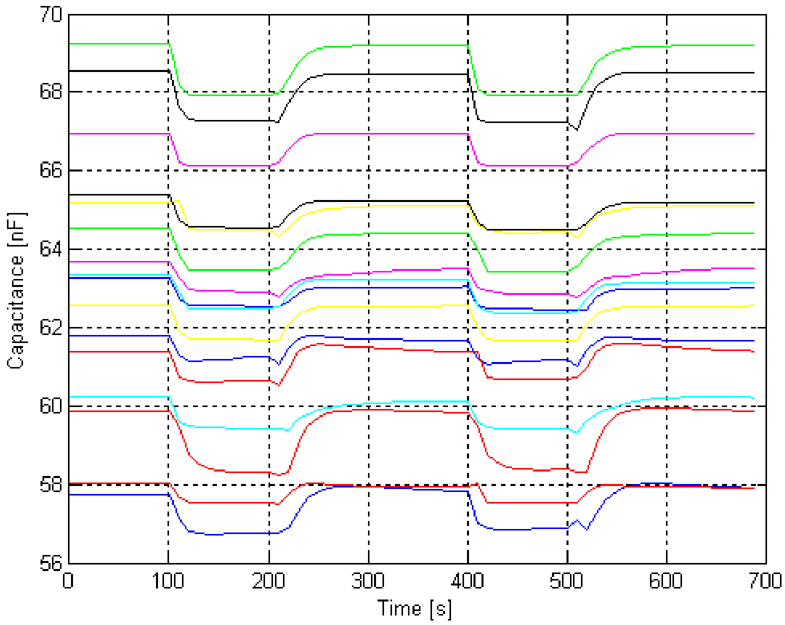

Fig. 3: Capacitance versus Time of all 16 DUTs during Low Temperature Shock Test

Low Temperature Survival Test (Indirect Cooling with Liquid Nitrogen)

Set-up

Liquid nitrogen was put into a container. For temperature measurement, a type of PT100 was used. Both, capacitor and PT100, were fixed to a small PCB with the help of screws and a cord.
For the test, the capacitors were put into the N_2 container without touching the liquid nitrogen. Each capacitor was tested to 5 temperature cycles. One test-cycle comprised at least10 minutes within the container and at least 10 minutes at room temperature (see MIL-STD-883, TM 1010).

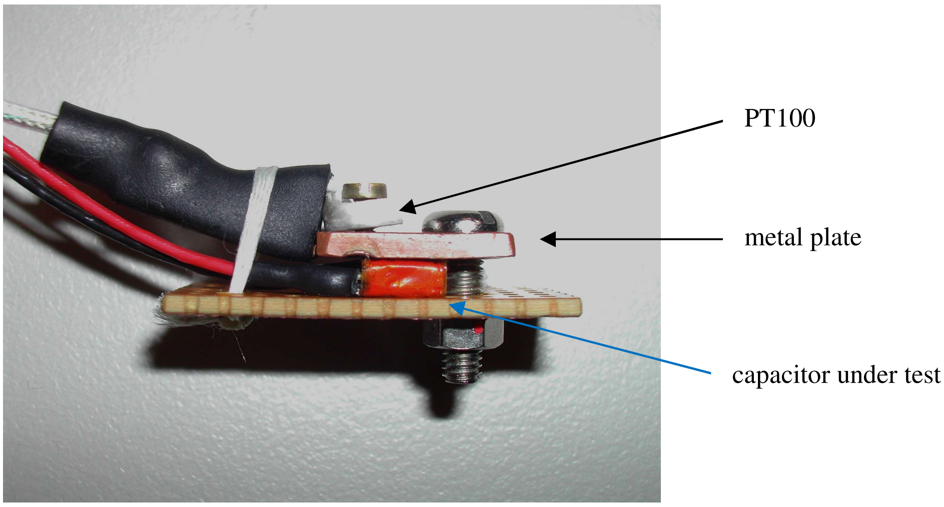

Fig. 4: Test Fixture for Low Temperature Survival Test

Results

All capacitors showed good temperature stability. The maximum change of capacitance over temperature was -1.6% ΔC/C at a temperature of -143°C (capacitor C15). The variation of the graphs may be explained with the difference in the temperature gradients as the temperature wasn't controlled by a temperature chamber. The capacitance values between the two temperature extremes might not reflect the precise capacitor temperature as the temperature gradient was rather high there, but the readings at the beginning and at the end of the curve should be ok. The capacitance reference value for the temperature coefficient of each capacitor was taken at the beginning of the temperature test, before the capacitor was being cooled. [3]

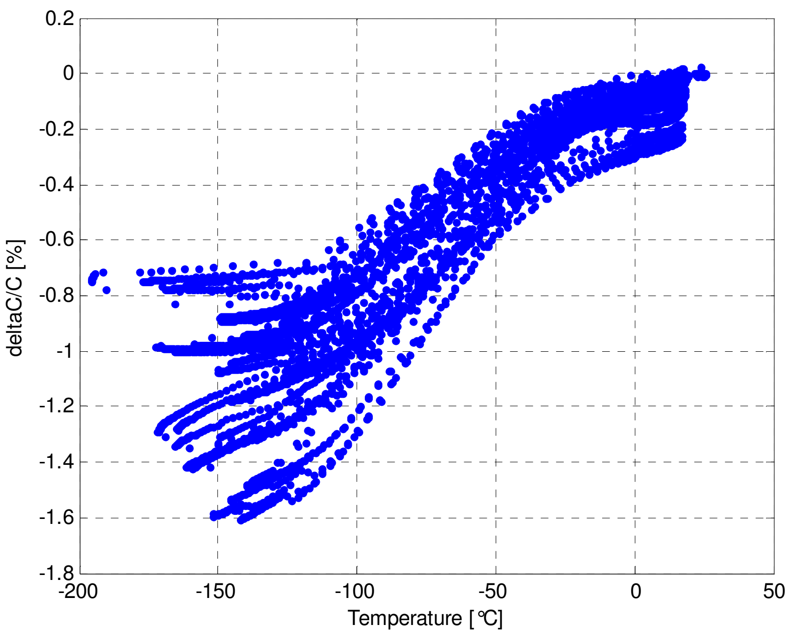

Fig. 5: Overall Temperature Coefficient of Capacitance for Low Temperature Survival Test

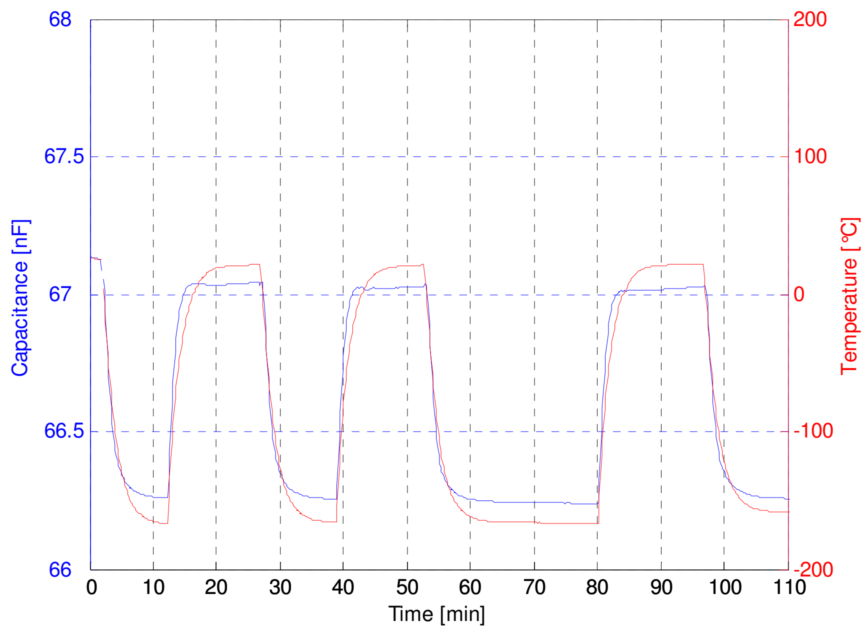

Fig. 6, Capacitance and Temperature versus Time for Capacitor C13

Table 2: Pre- and Post-Test Measurement of Capacitance Values (measurement at 23.9-24.8°C)

Capacitor #	Pre-test capacitance [nF]	Post-test capacitance [nF]	ΔC [nF]	Remarks
01	57.935	57.229	-0.706	cabling changed during test
02	57.976	57.949	-0.027	
03	64.642	64.480	-0.162	
04	63.180	63.197	+0.017	
05	60.421	60.125	-0.296	
06	63.739	63.439	-0.300	
07	65.155	65.203	+0.048	
08	65.296	64.938	-0.642	
09	59.448	59.261	-0.187	
10	69.064	69.179	+0.115	
11	61.844	60.572	-1.272	cabling changed during test
12	62.774	62.993	+0.219	
13	66.870	67.030	+0.160	
14	62.692	62.680	-0.012	
15	68.432	68.466	+0.034	
16	61.354	61.303	-0.051	

Conclusion for Low Temperature Tests

The MKI-2 capacitors showed good thermal stability and did not get damaged by temperature shocks as deep as -196°C. The capacitors didn't show much degradation of the capacitance values compared to pre-test measurements. They are suitable to be used under low temperature conditions and survive temperatures down to -150°C and less.

CAPACITOR SCREENING AND QUALIFICATION PER EEE-INST-002

Seven lots of non-magnetic MKI-2 capacitors have been produced by WIMA for IWF (10nF/400V, 47nF/250V, 56nF/250V, 68nF/250V, 82nF/63V, 100nF/63V, 150nF/63V).
Two lots (47nF and 56 nF) have undergone screening and qualification according to NASA specification EEE-INST-002 (Instructions for EEE Parts Selection, Screening, Qualification And Derating) at ATC (Assurance Technology Corporation), Chelmsford, Massachusetts. [4], [5], [6], [7], [8], [9]

Screening

Table 2: Screening per EEE-INST-002

Inspection/Test	MIL-STD-202		Remarks
	Methods	Cond	
1. External Visual & Mechanical Inspection			
2. Electrical Test @ 25°C Capacitance Dissipation factor DWV Insulation Resistance	 305 305 301 302		 Dielectr. Withstanding Voltage
3. Thermal Shock, 5 cycles @ -100°C to +125°C	107	B	1 cycle: -100°C (15 minutes min.) + 25°C (5 minutes max.) +125°C (15 minutes min.) +25°C (5 minutes max.)
4. In-Process Inspection			
5. Burn-in, 48 hours @ +125°C			at 140% rated voltage
6. Electrical Test @ +25°C Capacitance Dissipation factor DWV Insulation Resistance	 305 305 301 302		 Dielectr. Withstanding Voltage
7. Calculate PDA			PDA = 10% (max)
8. Final Visual and Mechanical Inspection			Dimensions, Marking, Workmanship

Qualification

Table 3: Qualification per EEE-INST-002

Inspection/Test	MIL-STD-202		Quantity (Accept Number) Remarks
	Method	Conditions	
DPA			5 (0) DPA according to MIL-STD-1580B (section 10.7)
Group 1 Screening to table 2			 100%
Group 2 Vibration, high frequency	 204	 E (50 Gs)	6 (0) N/A (cavity devices only)
Group 3 Shock Resistance to Solder Heat Moisture Resistance Humidity	 213 210 106 103	 I G B, no bias	6 (0) N/A (cavity devices only) IR, ΔC and DF to specification V_{test}= V_{rated} (≤100VDC) for 50% of parts DWV, IR, ΔC and DF to specification DWV, IR and ΔC to specification 96 hours @ 40°C/95%RH
Group 4 Solderability Terminal Strength Resistance to solvents	 208 211 215	 A and C	3(0) Generic data ok
Group 5 Life test, 1000h @ +125°C	 108		22(1) (or 11 of highest value and 11 of lowest value) V_{test}= 1.4 x V_{rated} IR, ΔC and DF to specification

Results of Screening and Qualification

The two capacitor lots successfully passed screening and qualification and were accepted as flight components for the NASA MMS mission.

CONCLUSION

The special non-magnetic metalized polyphenylene-sulphide MKI-2 capacitors by WIMA successfully passed low temperature, screening and qualification tests for the NASA MMS mission. They are absolutely non-magnetic and can be used over a wide temperature range (-100°C and less to +140°C) with a good capacitance stability versus temperature. They show a high resistance to thermal shock. Another advantage of these foil capacitors compared to ceramic SMD (MLCC) is that their resistance to mechanical stress is higher (no internal cracks or delamination). Due to their self-healing capability they have got a high withstanding voltage and high reliability.

ACKNOWLEDGEMENTS

The author specially wants to thank the people at WIMA for their tremendous support and help. Their effort and technical knowledge made it possible to provide this important part of the MMS DFG sensor. I would also like to thank the University of New Hampshire as the lead institute for the FIELDS instrument package aboard MMS for funding the screening and qualification tests.

REFERENCES

[1] K. Sahu, "EEE-INST-002: Instructions for EEE Parts Selection, Screening, Qualification and Derating", NASA/TP-2003-212242, May 2003

[2] WIMA, "WIMA MKI 2 Metalized Polyphenylene-Sulphide (PPS) Capacitors in PCM 5mm", data sheet, WIMA, 09.06

[3] M. Luttenberger, "DFG Sensor Capacitor Temperature Test", MMS-DFG-TR-001_SensorCapThermal_I1R0, IWF, September 2008

[4] I.Jernej, "Specification Control Drawing IWF-SCD-MKI2", IWF, July 2009

[5] D. Hilbert, " Screening of 0.047µF Capacitor", Report No. 7191-800-03, Assurance Technology Corporation (ATC), July 2010

[6] D. Hilbert, " Screening of 0.056µF Capacitor", Report No. 7191-800-02, Assurance Technology Corporation (ATC), July 2010

[7] D. Hilbert, " Qualification Testing of 0.047µF/0.056µF Capacitor", Report No. 7191-800-02B-02D, 03B & 03C, Assurance Technology Corporation (ATC), July 2010

[8] B. Morrison, "Destructive Physical Analysis Report 0.047µF", Report No. DPA 7191-800-03, Assurance Technology Corporation (ATC), March 2010

[9] B. Morrison, "Destructive Physical Analysis Report 0.056µF", Report No. DPA 7191-800-02, Assurance Technology Corporation (ATC), March 2010