Test of the Flight Model of UG electronics for the AMS TRD Gas System

Bruno Borgia, Alessandro Bartoloni, Francesca R. Spada

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1 Introduction

We report here the results of the space qualification of the UG electronics, i.e. the electronics that controls the gas circuit for the Transition Radiation Detector of the AMS-02 experiment [1]. The UG electronics rôle in the TRD gas system is shown in figure 1.

The tests date to the period may–june 2008. Aim of the tests is to verify that the UG electronics, Flight Model (hereafter, *the FM*), i.e. the hardware that will actually fly, as it is built, is acceptable for space operation.

The FM UG electronics underwent environmental stress (ESS) and thermo-vacuum (TV) stress tests (*acceptance tests*). A second, spare, set of flight elec-

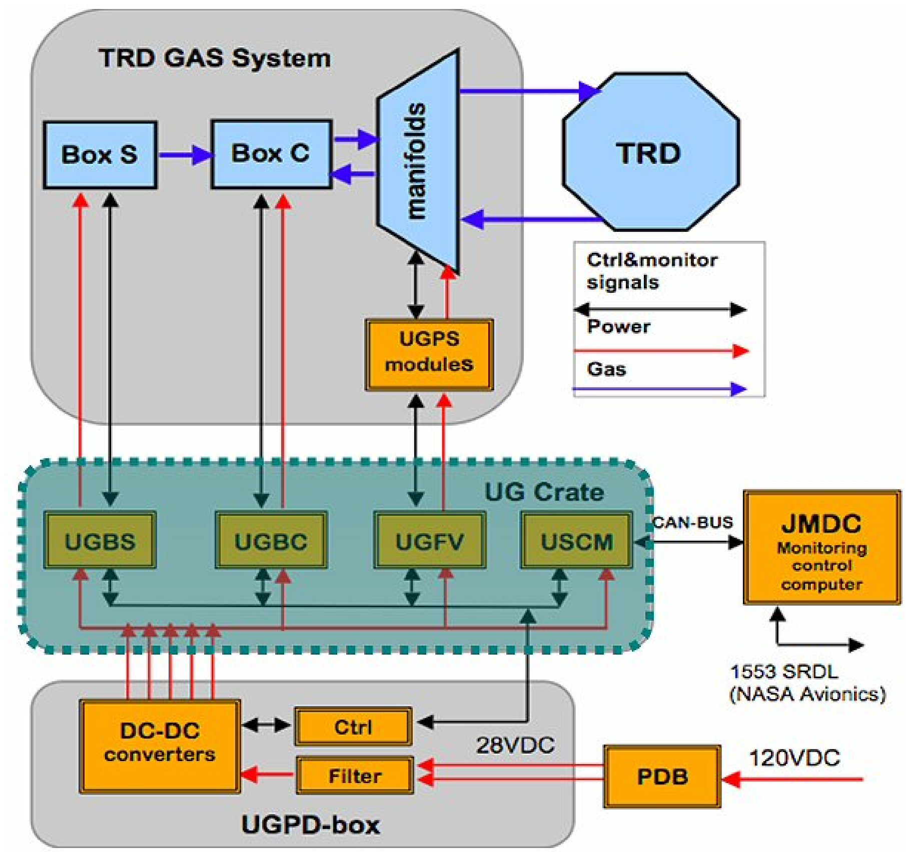

Figure 1: *The UG electronics in the Transition Radiation Detector gas circulation system.*

tronics, (hereafter, *the FM*), was built and tested like the FM one. This document describes the test procedure and results of the FM UG electronics.

The UG electronics construction and test is responsibility of INFN Roma. The space qualification and acceptance tests of the crate were performed according to the official procedures described in the experiment guidelines [2]. A preliminary discussion of the UG electronics FM acceptance tests has already been released [3].

1.1 The UG-crate

The crate is equipped with a total of eight boards of four different kinds ("A" and "B", redundant for safety reasons):

1. two UGSCM (S/N F1 and F2)
2. two UGBS (S/N 003 and 004)
3. two UGBC (S/N 003 and 004)
4. two UGFV (S/N 003 and 004)

plus a backplane (UGBP) to which the boards are connected.

Except for the UGSCM's, which are provided by the AMS electronics team, all the boards have been projected, engineered and tested by INFN Roma. The mechanics of the crate were built by G&A Engineering [4], following the drawings provided by Carlo Gavazzi Space [5]. The UG electronics is shown in figure 2.

1.2 Test setup

The qualification of the UG electronics was performed using the test facilities of the "Laboratorio per lo Studio degli Effetti delle Radiazioni sui Materiali per lo Spazio" (SERMS), Terni, Italy.

In the TV test, in addition to the UG electronics, also the UGPD crate, provided by CSIST, Taiwan [6] was included in the setup, supplying the power by DC-DC converters and powered by two external 28 V commercial power supplies. When the UGPD was not present, i.e. in the environmental stress test, external power supplies have been used also to power the UG electronics. However, in both power supply setups, part A or part B of the UG electronics have been powered one at a time, as prescripted.

In the TVT setup, the UGPD crate and the UG crate were connected to a common metallic plate. The UG mechanical ground was connected to the UG electrical ground by means of a removable wire designed for this purpose. We observed a noticeable noise increase with respect to ESS setup, possibly due to the electrical and mechanical ground connection, absent in the ESS setup.

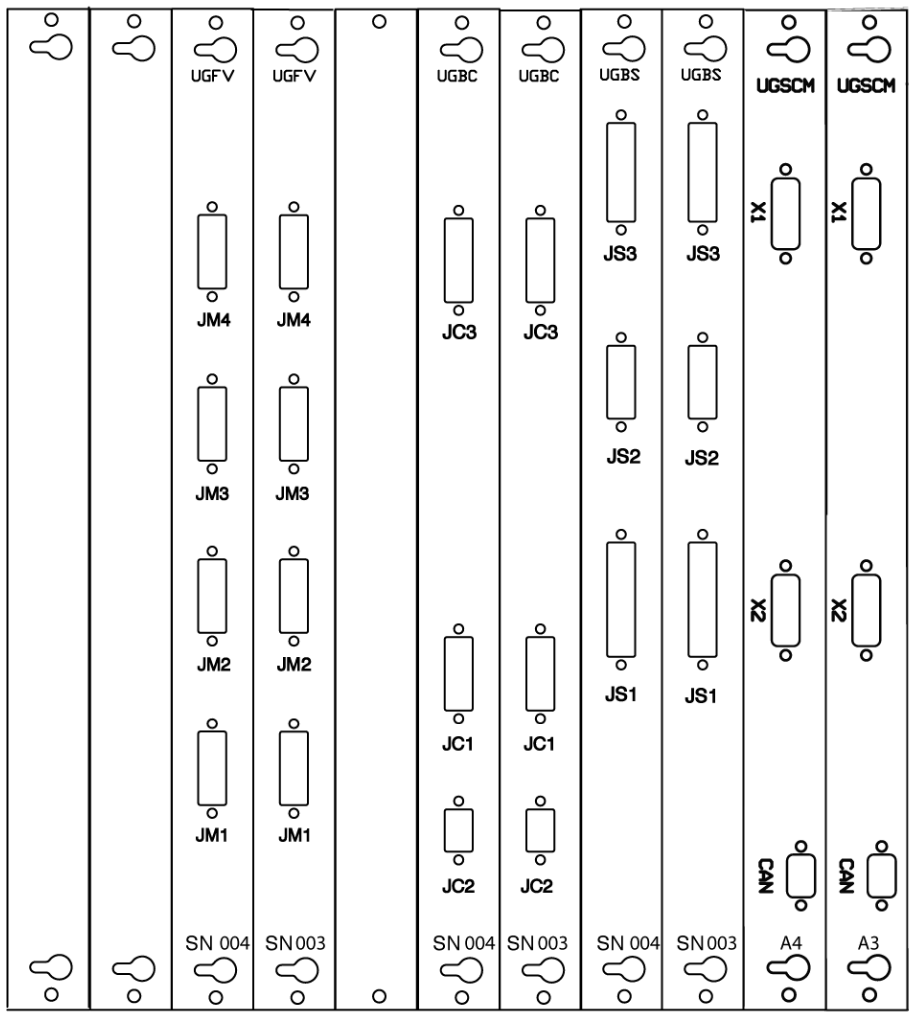

Figure 2: *The UG crate. From right to left, two UGSCM boards, two UGBS boards, two UGBC boards, one dummy metal panel and two UGFV boards.*

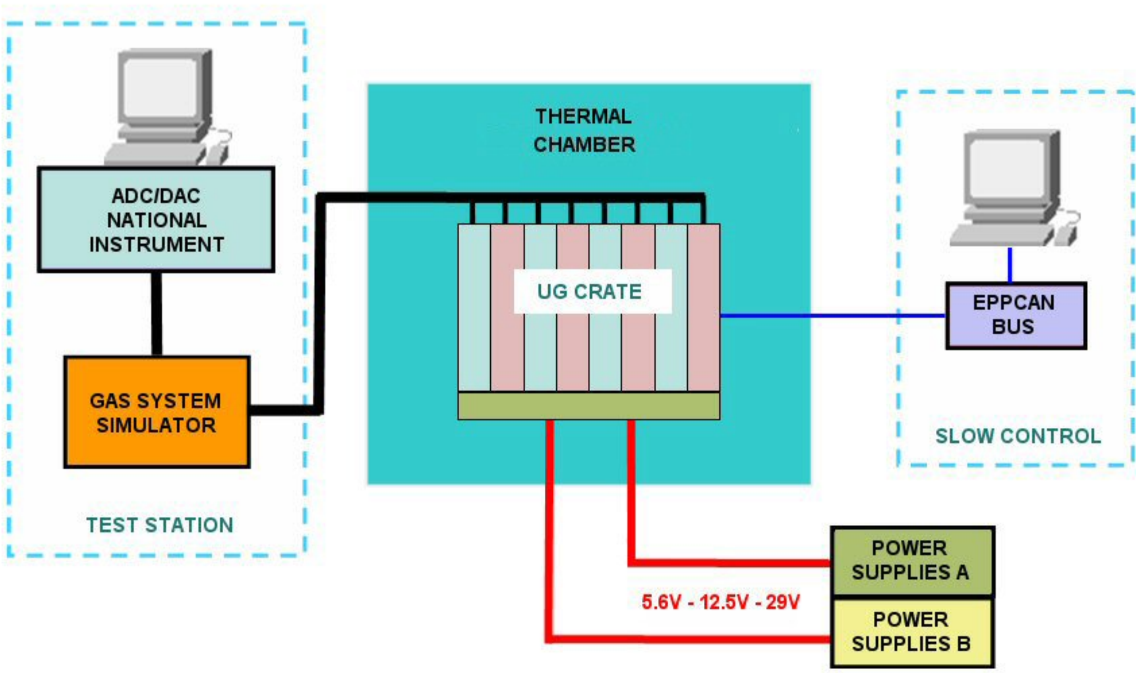

Figure 3: *Setup used in the environmental stress tests.*

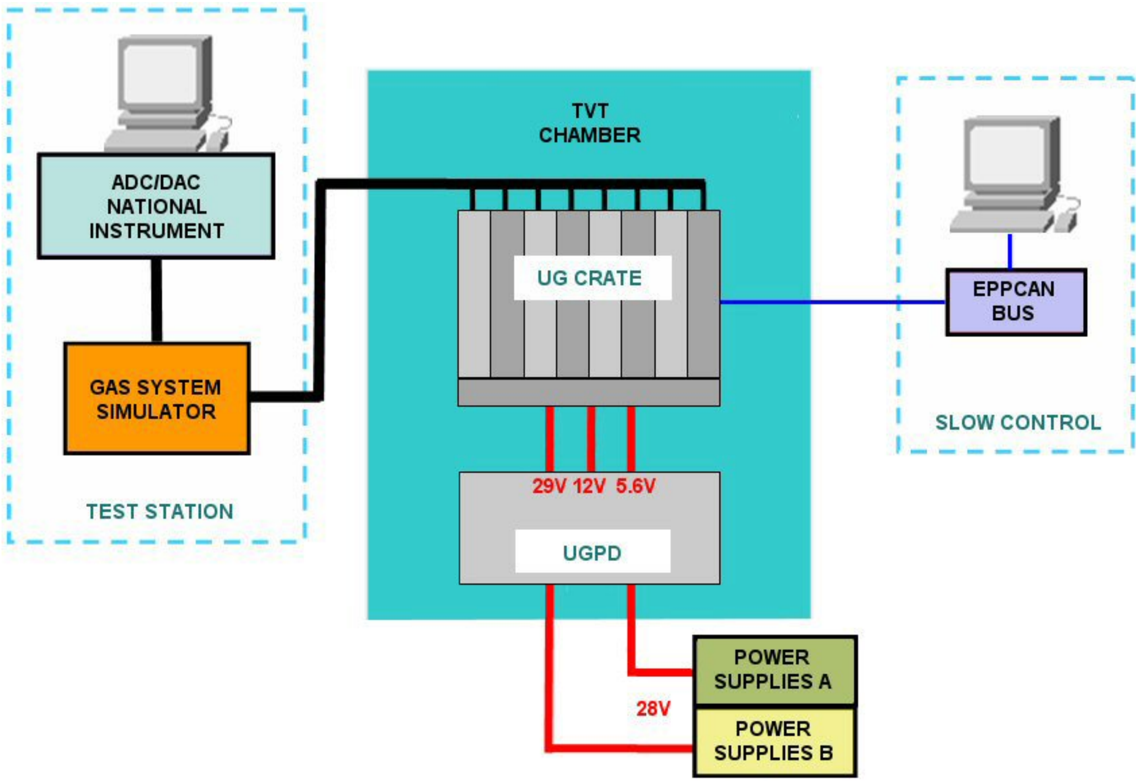

Figure 4: *Setup used in the thermo-vacuum tests.*

ESS and TV tests were performed while checking the full functionality of the electronics. For this reason, a Test Station (UGTS), with a set of six boards simulating the input/output operations of TRD gas circuit, was connected to the UG crate.

The complete setup used for the sub-tests, described in detail in the corresponding sections, are sketched in figure 3 and 4.

1.3 Functionality test sequence

At fixed stages of ESS and TV tests a functional check of the UG electronics was performed in order to ensure that the boards were behaving correctly. Commands were sent to the UG electronics from the external control computer communicating with the boards via EPPCAN bus (see again figures 3 and 4). The communication among the boards and between the UG electronics and the UGPD occurres via a LeCroy bus.

The operation sequence, together with temperatures, pressures, status flags that were read out during the test, were stored in a disk together with the output from the Test Station.

The operation sequence is the following:

1. UGSCM A and B are initialized;
2. all valves controlled by UGBS (V1a, V2a, V3a, V4a, V10a, V20a, V1b, V2b, V3b, V4b, V10b, V20b, Sp1, Sp2) are enabled and opened for 5 s one at a time, and status is read, then disabled;
3. all pressure sensors controlled by UGBS (P1a, P2a, P1b, P2b, Pk1c, Pk2c, Pk1d) are read out;
4. all heaters controlled by UGBS (H1, H2, H3, H4, H5) are enabled and started for 1 minute, then disabled, one at a time;
5. operations 2 to 4 are repeated four times: [UGSCM-A + UGBS-A], [UGSCM-A + UGBS-B], [UGSCM-B + UGBS-A], [UGSCM-B + UGBS-B];
6. all power supplies (29V, 12V, 5V, 8.5V) controlled by UGBC are enabled, and the status is read out;
7. all valves controlled by UGBC (V6a, V18a, V6b, V18b, V6a&V18a, V6b&V18b) are enabled and opened for 5 s one at a time, and status is read, then disabled;
8. all pressure sensors controlled by UGBC (P3, P4) are read out;
9. all circulation pumps controlled by UGBC (CP1, CP2) are enabled at H speed, started and stopped after 5 s, then enabled at F speed, started and stopped after 5 s then disabled, one at a time;

10. all UGBC serial ports (RS232_1, RS232_2, RS232_3, RS232_4) are enabled and the status is read, read/write operations are checked, then the ports are disabled;

11. all power supplies (29V, 12V, 5V, 8.5V) controlled by UGBC are disabled;

12. operations 7 to 11 are repeated four times: [UGSCM-A + UGBC-A], [UGSCM-A + UGBC-B], [UGSCM-B + UGBC-A], [UGSCM-B + UGBC-B];

13. all power supplies controlled by UGFV (12VPS, 12VFV, 21V, MUX) are enabled;

14. modules 1 to 4 are selected one at a time, and for each module, valves V1 to V5 are opened then closed after 5 s;

15. multiplexers 1 to 4 are selected one at a time, and for each multiplexer all pressure sensors (P1, P2, P3, P4, P5) are read out;

16. all power supplies controlled by UGFV (12VPS, 12VFV, 21V, MUX) are disabled;

17. operations 13 to 16 are repeated four times: [UGSCM-A + UGFV-A], [UGSCM-A + UGFV-B], [UGSCM-B + UGFV-A], [UGSCM-B + UGFV-B].

The time needed to perform these tests is of the order of 40 minutes.

At each run, after the computer controlled procedure, we read out the Dallas temperature sensor, i.e. the one present on the UGSCM, and the one(s) connected to bus 8 through the UGBS, namely one located on the gas system simulator and one located on the UGPD when present. The readout was repeated for A and B modules.

2 FM qualification test

In this section the qualification tests performed on the FM version of the UG electronics are described.

2.1 Environmental stress test

The ESS test consist in a cycle of thermal stress followed by a vibration cycle, again followed by a thermal stress cycle, all in air.

The thermal profile is shown in figure 5. During the phases called *cold storage* and *hot storage*, the crate was not powered. During *cold operating* and *hot operating* phases, after a stabilizing period of one hour, the crate was powered and the functional test was executed. Table 1 shows the temperatures corresponding to the test

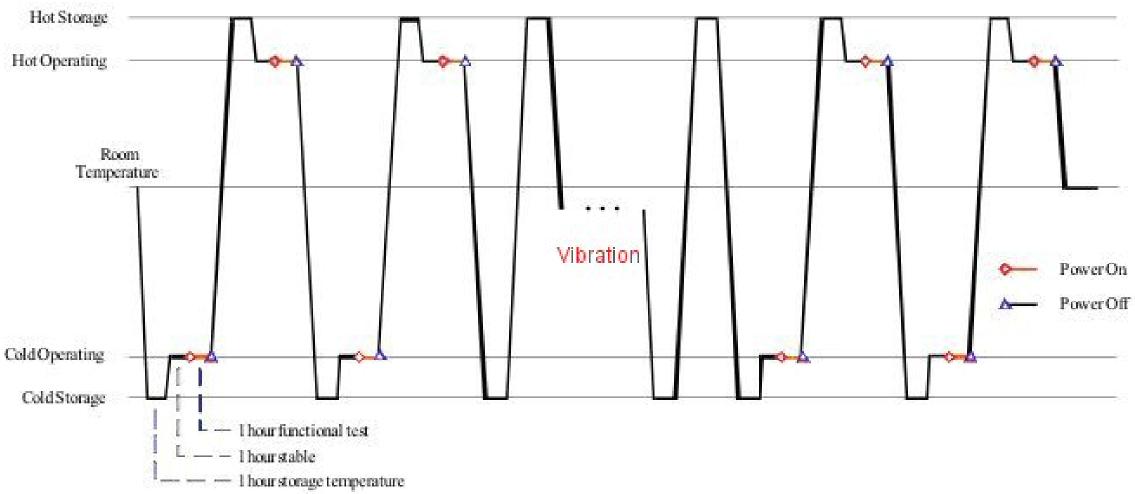

Figure 5: *Nominal temperature profile for UG electronics thermal stress test. The red dots correspond to crate power up and execution of the functional tests, while the blue triangles correspond to power off. Between the first and the second thermal cycle, the vibration test was executed.*

Thermal stress test phase	Temperature
Cold storage	-40 °C
Cold operating	-20 °C
Hot operating	$+50$ °C
Hot storage	$+80$ °C

Table 1: *Temperature levels for the thermal stress test.*

phases. Between the first (10 cold–hot cycles) and the second (5 cold–hot cycles) thermal stress, the vibration test was executed.

The UG electronics showed no malfunctioning at any temperature during the tests, either before or after the vibration.

The random vibration along the three orthogonal axes was executed according to the profile shown in figure 6. The crate was mounted on a fixture matching the crate axis with the slip table axis. Accelerometers were fixed on the crate by cyanoacrilic glue. The actual vibration profile measured for the three axes is shown in figure 7.

For all subtest (each single axis) performed, no damage has been reported, and all the subtests were normally completed. The full operation sequence 1–17 described in paragraph 1.3 was executed without errors.

2.2 Thermo-vacuum test

After passing the environmental stress test, the UG electronics together with the UGPD crate was fixed to the lower cold plate of the the thermo-vacuum chamber

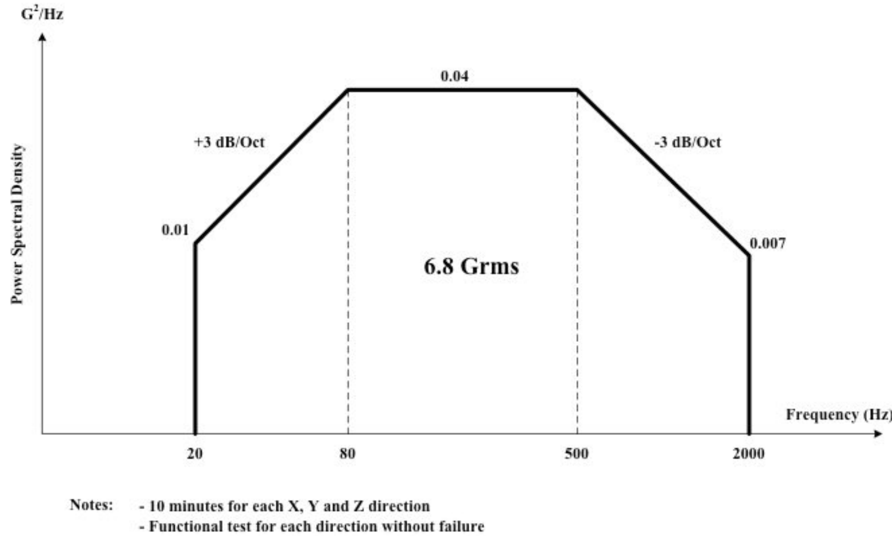

Figure 6: *Nominal vibration profile for UG electronics, to be repeated for each of the three axes.*

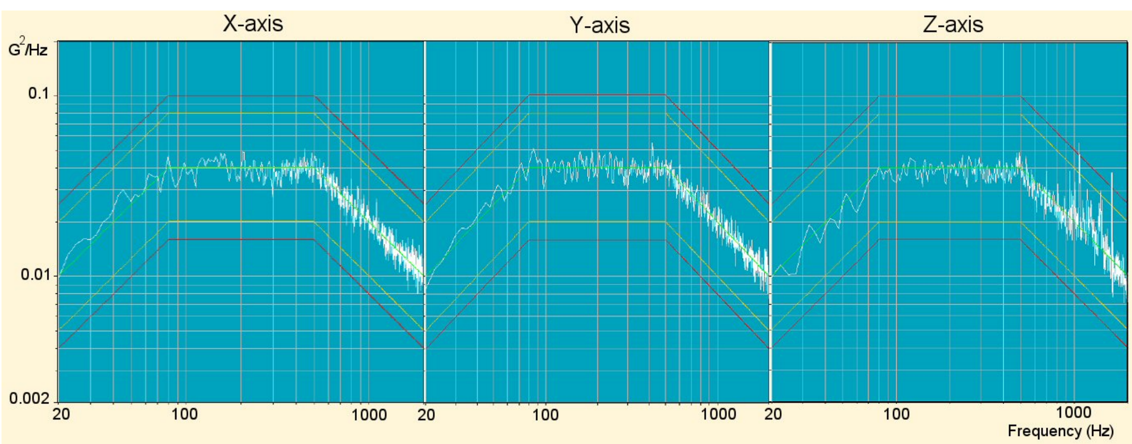

Figure 7: *Measured vibration profile for FM UG electronics: left to right, X-axis, Y-axis and Z-axis profiles.*

Figure 8: *The UG electronics in the thermo-vacuum chamber.*

Figure 9: *The UG electronics and the UGPD in the thermo-vacuum chamber.*

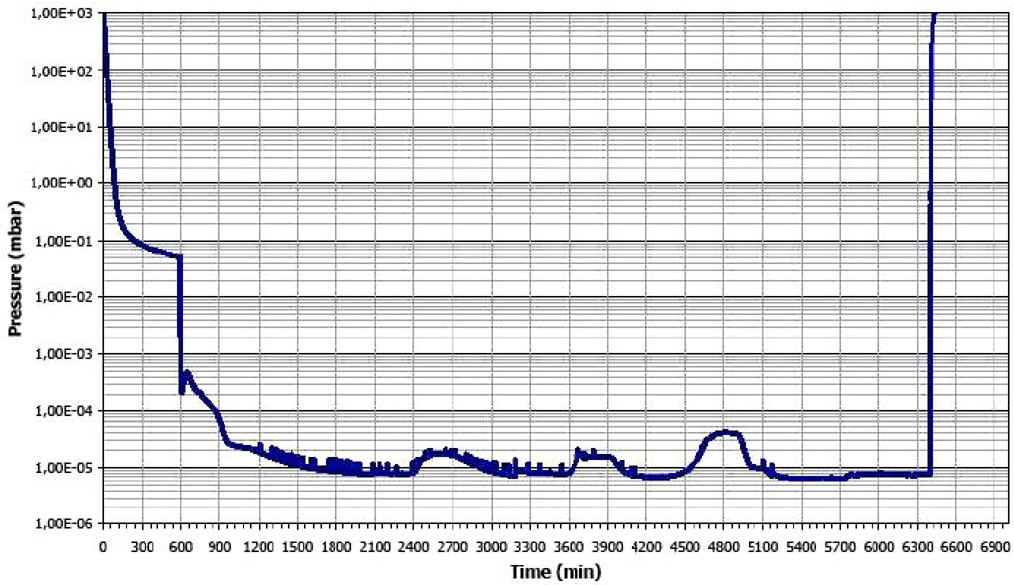

Figure 10: *Measured pressure profile in UG electronics TV test.*

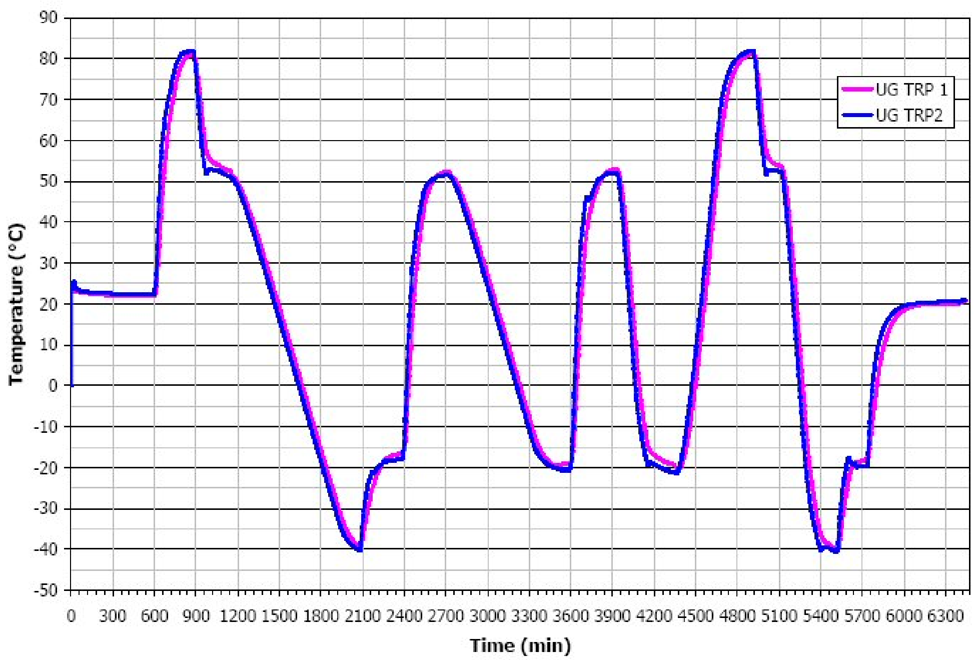

Figure 11: *Measured temperature profile in UG electronics TV test.*

through an aluminium alloy fixture with black surface treatment. Figure 8 shows the UG electronics positioned on the thermo-vacuum chamber's plate. Figure 9 shows the UG electronics and the UGPD in the chamber.

To optimize the thermal exchange, a layer of thermal conductive material (Cho-Term) was placed both between the crate and the fixture, and between the fixture and the cold plate. The crate was covered with MLI, to avoid thermal dispersion and to reproduce the flight conditions. Several PT100 thermal sensors were positioned in the chamber and on the electronics under test, to monitor the temperature variation in the chamber and at each board's location.

In order to start the first hot-storage phase, the pressure measured inside the chamber had to be below 10^{-4} hPa. The first switch-on operation could not start before the pressure had reached 10^{-5} hPa. The stabilization time was defined by the condition that the measured temperature T remained stable and within 1°C from the nominal temperature t for at least 1 hour, i.e. $|\Delta T|/\Delta t < 1°C/\text{hour}$ for at least 1 hour.

Figure 10 shows the pressure profile measured in the chamber during the test. The temperature profile, as measured at three of the UG boards in the crate, is shown in figure 11.

The analysis of the recorded data showed that all the components responded as expected. The experienced response of the LeCroy commands issued to the internal modules of the UG crates is described below.

The UG FM electronics passed the ESS test without any failure at high temperature (+50 °C) and at low temperature (-20 °C). All LeCroy commands acted correctly on the UGBS, UGBC and UGFV modules, A and B. Nevertheless, in the TV chamber, with UG electronics powered by UGPD, at ambient temperature (+20 °C), the UGBS and UGBC modules, A and B, did not always reply to the LeCroy commands. The message on the screen command panel was *Command executed OK, but...*, i.e. the CAN communication had succeeded, but the LeCroy command failed for whatsoever reason. The failure was intermittent with a rate of 1/10 of failures, slightly larger in B modules. At +50 °C the failure rate was lower, while at -20 °C it was almost 1/3.

Further investigation was conducted in the Rome lab.

2.3 Test results in Rome

After the end of the TV test, we brought all the equipment to our lab in Rome and we performed the usual functionality tests in a simpler setup, supplying only the 5.6 V from the UGPD, and with a LeCroy cable connecting the UGPD and the UG crate. We observed the same failure behavior.

We thus found out that the LeCroy failures depend crucially on the actual 5.6 V power supply value. In fact, commercial power supplies feed power to the UG electronics through 3 m cables, so that nominal 5.6 V at the power supply source drop to 5.4 V at the UG backplane. Raising the external power supply to 5.8 V, so

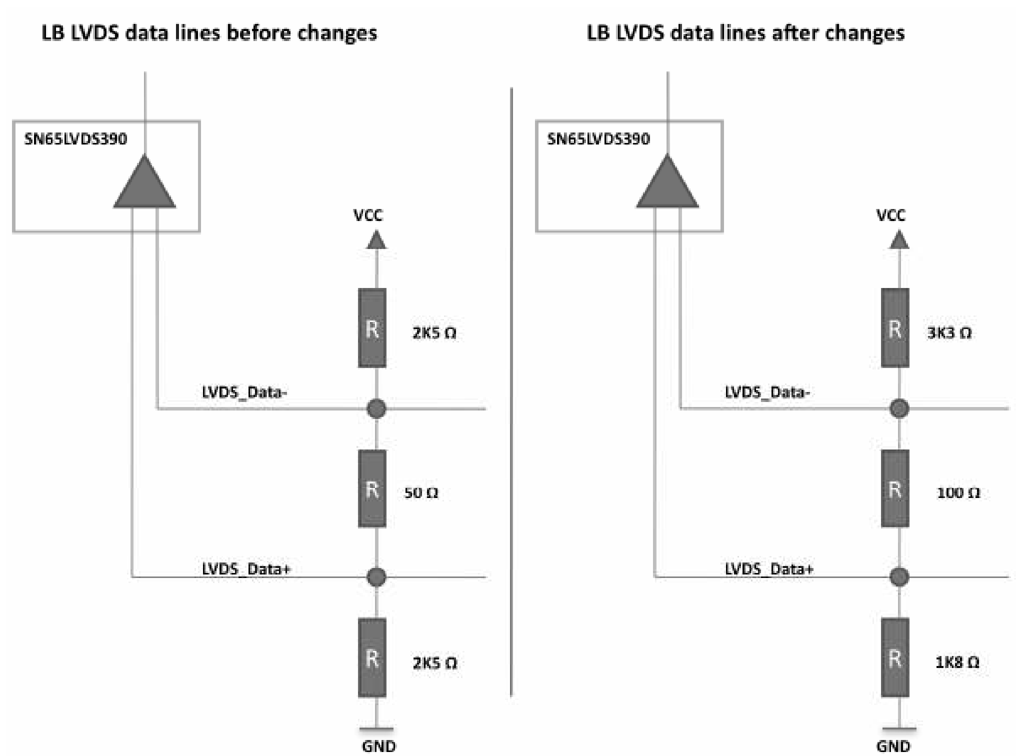

Figure 12: *Modifications implemented on the pull-down resistors on the UGBP.*

that at the backplane the measured voltage is actually 5.6 V, the failure behaviour is reproduced and is totally consistent with UGPD supplying power to the UG electronics.

Observations and measurements of the bus lines routing the LeCroy commands showed an instability of the receiver's outputs when no card is driving the bus. Such buses are implemented using LVDS technology and bus signals are routed from one card to another by controlled impedance strip lines etched on the backplane card (UGBP). The LeCroy bus data lines pull-down resistors, soldered on the backplane, produce a bias voltage value at the input of the LVDS receivers (SN65LVDS390PW) that exceeds specifications.

We verified on the QM2 UG electronics that changing the pull-down resistors at the backplane, the correct bias is restored (see figure 12). After this modification we did not observed any error at any condition and temperature. Systematic test were conducted later on the FS electronics with full compliance to the specifications (see the corresponding report on FS UG electronics [7]).

3 Conclusions

In the period may-june 2008, the FM version of the UG electronics was space-qualified, undergoing environmental stress test consisting in thermal stress and vibration (ESS) and thermo-vacuum test (TVT). In the ESS, external power supplies distributed the nominal tensions to the UG electronics, while in the TVT test the UGPD crate was used.

Figure 13 shows a typical GP50 pressure sensor readout during the test, as a function of the temperature in the chamber. At each temperature a resolution of less than 1‰ is achieved, while the sensor readout shows a temperature dependence of about 8 mV for a ΔT of 70 °C, and a readout channel dependance of about 1%.

The UG electronics fulfilled all the requirements specified in the experiment official guidelines, also showing full functionality at every stage of the space qualification test. Malfunctioning of LeCroy commands was observed when UGPD supplied power, but the cause was identified and fully eliminated.

References

[1] http://ams.cern.ch/AMS/

[2] http://ams.cern.ch/AMS/electronics/SubD/qa/

[3] http://www.roma1.infn.it/exp/ams/RomaNotes/UG_FM_tests_report01.pdf

[4] http://www.gaengineering.com/

[5] http://www.cgspace.it/

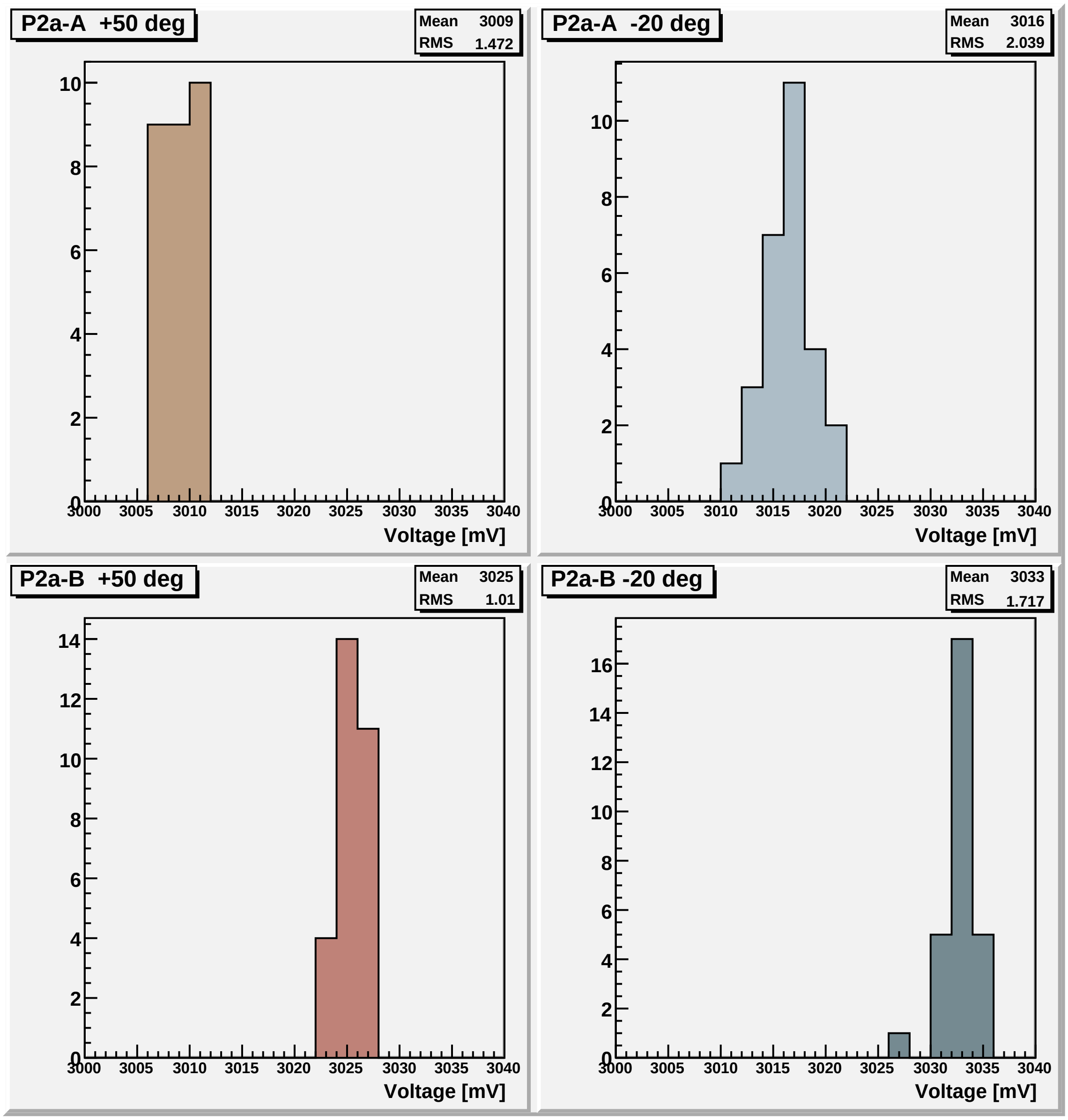

Figure 13: *Response of a GP50 pressure sensor to an applied voltage of 3 V. Top left: A-channel, +50 °C; top right: A-channel, -20 °C; bottom left: B-channel, +50 °C; bottom right: B-channel, -20 °C.*

[6] http://www.csist.org.cn/english/index.htm

[7] http://www.roma1.infn.it/exp/ams/InternalNotes.html