Institute of Experimental Physics, Slovak Academy of Sciences
Department of Space Physics

Watsonova 47, SK-040 01 Košice, Slovakia
Tel.: +421-55-6224554, Fax: +421-55-6336292, URL: http://space.saske.sk

ENERGETIC PARTICLE SPECTROMETER

DOK-M

FOR SPACE EXPLORATION PROJECT

RESONANCE

V 1.7

Ján Baláž, Igor Strhárský

Košice, April 2015

CONTENT

LIST OF ACRONYMS

A/D	Analog to Digital
ADC	Analog to Digital Converter
CHCKSM	Checksum
CMOS	Complementary Metal-Oxid-Silicon semiconductor technology
CDMS	Command Data Management System
CSA	Charge Sensitive Amplifier
D/A	Digital to Analog
DAC	Digital to Analog Converter
DCDC	DC (direct current) to DC converter
DSP-IEP-SAS	Department of Space Physics, Inst. of Experimental Physics SAS
DUTH	Demokritus University of Thrace, Greece
EC	Event counter
EEPROM	Electrically Eraseable Programmable Read Only Memory
EGSE	Electrical Ground Support Equipment
EMC	ElectroMagnetic Compatibility
EMI	ElectroMagnetic Interference
EPROM	Eraseable Programmable Read Only Memory (by UV)
FM	Flight Model
FS	Flight Spare
GSE	Ground Support Equipment
GSE-DOK-M	Ground Support Equipment of the DOK-M
HK	HouseKeeping information
I/F	Interface
ID	IDentifier
IEP-SAS	Institute of Experimental Physics, Slovak Academy of Sciences
IGI	Interactive Graphic Interface
IKI	Space Research Institute, Moscow
ITG	Inflight Test Generator
LPA	Linear Pulse Amplifier
MGSE	Mechanical Ground Support Equipment
MLI	Multi-Layer Insulation (thermal blanket)
PA	Pulse Amplifier
PC	Personal computer
PCB	Printed Circuit Board
PHD	Peak Hold Detecor
PIPS	Passivated Ion-implanted Planar Silicon detector
PROM	Programmable Read Only Memory
QM	Qualification Model
SPA	Shaping Pulse Amplifier
SP	Sensor Platform
STM	Structural Thermal Model
SUSPI	*Sistema Upravlenia Sbora i Podachi Informacii* (CDMS)
TEM	TEMperature
TM	TeleMetry
TR	Registration period

1 INTRODUCTION

Earth's magnetosphere, as natural resonator for many types of electromagnetic waves, is a place where electromagnetic waves efficiently interact with charged energetic particles via cyclotron resonance. The project RESONANCE is a magnetospheric space exploration mission dedicated for advanced study of the wave – particle interactions in the Earth's magnetosphere. The project is conducted by Space Research Institute of Russian Academy of Sciences (IKI-RAN).

The DOK-M is a scientific space device under development at Institute of Experimental Physics of Slovak Academy of Sciences, dedicated for charged energetic particles temporal and energy sampling on board of two of four cooperating RESONANCE spacecraft. The DOK-M is a joint international scientific space project of IEP-SAS, Democritus University of Thrace, Greece and Space Research Institute, Moscow.

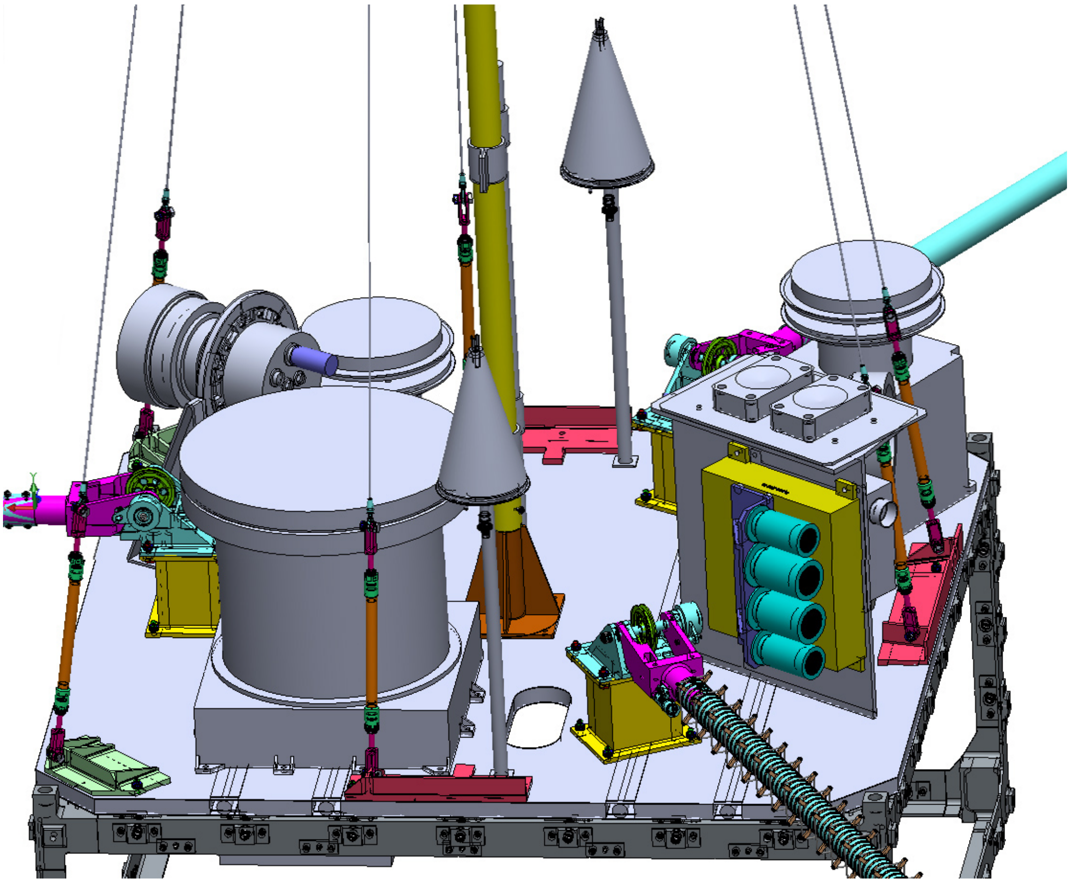

Figure 1. *RESONANCE spacecraft with DOK-M on board (virtual model).*

1.2 BASIC SPECIFICATION OF DOK-M

Weight	3.2 kg
Max. dimensions:	212 x 192 x 100 mm
Electronic box wall thickness	7 mm (aluminium alloy)
Power consumption:	3.5 W (at 27 V)
Powering voltage:	18 - 34 V
Operating temperature range (technical): ...	-30 °C ... +50 °C
Preferable temperature range (electronics):	0 °C … +20 °C
Preferable temperature range (sensors):	-50 °C ... -10 °C
Number of particle sensors:	4, silicon, ion implanted

Sensor 1P

Field of view..	conical, 10° unobscur., 5° fwhm,
Geometrical factor:.............................	0.0001 cm^2.sr
Active area:.......................................	25 mm^2
Thickness:	100 µm
Bias voltage:	50 V
Magnetic filter field intensity	tbd T
Electron cutoff energy	tbd keV

Sensor 2P

Field of view..	conical, 20° unobscur., 8° fwhm,
Geometrical factor:.............................	0.003 cm^2.sr
Active area:.......................................	25 mm^2
Thickness:	100 µm
Bias voltage:	50 V
Magnetic filter field intensity	tbd T
Electron cutoff energy	tbd keV

Sensor 1E

Field of view..	conical, 10° unobscur., 5° fwhm,
Geometrical factor:.............................	0.0001 cm^2.sr
Active area:.......................................	25 mm^2
Thickness:	500 µm
Bias voltage:	140 V
Mylar/Aluminum foil thickness	tbd µm / tbd nm
Hydrogen ion (proton) cutoff energy....	tbd MeV
Helium ion (α-particle) cutoff energy....	tbd MeV
Oxygen ion cutoff energy	tbd MeV

Sensor 2E

Field of view..	conical, 20° unobscur., 8° fwhm,
Geometrical factor:.............................	0.003 cm^2.sr
Active area:.......................................	25 mm^2
Thickness:	500 µm
Bias voltage:	140 V
Mylar/Aluminum foil thickness	tbd µm / tbd nm

Hydrogen ion (proton) cutoff energy....	tbd MeV
Helium ion (α-particle) cutoff energy....	tbd MeV
Oxygen ion cutoff energy	tbd MeV
Energy range - ions	20keV - 4 MeV
Energy range - electrons	20keV - 350 keV
Number of energy channels:	16, 32, 64, 128 (set by command)
Time resolution:	100 ms, 200ms, 500ms, 1s, 2s, 5s, 10s
Registration dead time:	4 μs
Minimal telemetry rate	48 bps
Average telemetry rate	1000 bps
Telemetry rate (max, burst mode):	26000 bps
Standard date packet size:	2032 bytes
Command-Data interface (main):….............	RS422, 125000 bps, 8E1, insulated
Command-Data interface (redundant):.........	RS422, 125000 bps, 8E1, insulated
Command & Data connector (X32H)	RS-10, (Rx/Tx-main, Rx/Tx-redu., 0TM)
Insulation resistance against instrument box:	> 20 MΩ (at 25°C, 50% rel. humidity)
Insulation common mode voltage:	> 200 V (at 25°C, 50% rel. humidity)
Housekeeping information:	temperatures (-55°C...+80°C), internal voltages, digital status byte
Debugging-monitoring interface ....…	RS232, 115200 bps, 8N1, not insulated
Power interface (X31H connector)	RS-7, (+27V, 27V_ret)
Insulation resistance against instrument box:	> 20 MΩ (at 25°C, 50% rel. humidity)
Insulation common mode voltage:	> 200 V (at 25°C, 50% rel. humidity)
Grounding stud	M4 x 12mm, stainless steel
Technological connector (XT)	RS-4, (Rx, Tx, Reset, Sig. ground = Chassis)
Surface treatment of the electronic box	IRIDITE 14-2 (conductive chromat)
Electronic box α/ε	tbd /tbd
Surface treatment of the sensors	ELECTRODAG 502 (black conductive)
Sensor and sensor platform α/ε	0.92 / 0.90

2 MECHANICAL DESIGN

An overall mechanical design of the DOK-M is illustrated in Fig.2. The DOK-M consists of 5083-aluminium alloy rectangular box dimensions of 180 x 180 x 45mm, with four external cylindrical sensors fixed on a thermally insulated platform on the top of the box.

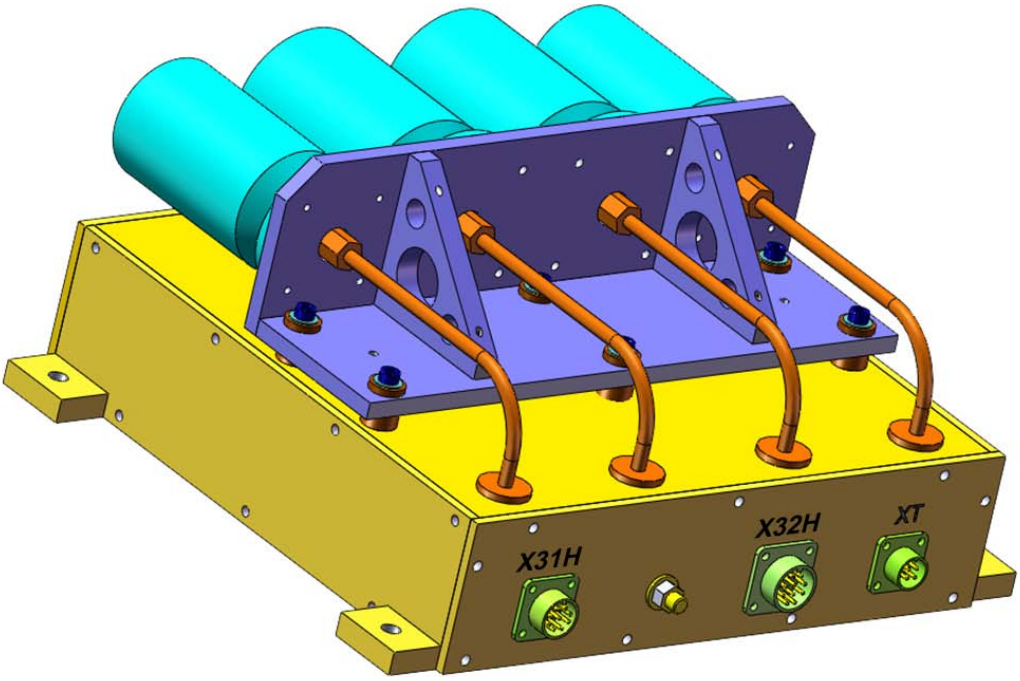

***Figure 2**. Mechanical design (virtual 3D model).*

2.1 ELECTRONIC BOX

The electronic box (EB) is made from 7 mm-thick 5083-aluminium alloy plates, the surface finishing is performed by IRIDITE 14-2 process (yellow, electrically conductive chromating). All the mechanical components are fixed each other by stainless steel screws (DIN912/A4 specification). The box is fixed to dedicated spacecraft platform by the four lugs with M5 screws. The box is supposed to be in good thermal contact with the temperature controlled spacecraft platform and fully covered by a multilayer thermal insulation (MLI).

2.2 SENSOR PLATFORM

The sensor platform (SP) is made from 5083-aluminium alloy and provides mechanical, electrical-grounding and thermal interface between the sensors and the electronic box. The SP is mechanically fixed to the EB by six cylindrical insulators made from high-performance plastic material PEEK 450G and stainless steel screws M3/DIN912/A4. The SP is thermally insulated against the electronic box with MLI pillow that covers entire EB, but the SP and sensors are above the MLI and so that radiating the heat into the space background. The surface treatment of the SP is provided by space qualified conductive black paint ELECTRODAG-502.

2.3 SENSORS

The sensors have cylindrical bodies fixed by dedicated flanges to the SP. Each sensor contains a solid state semiconductor detector that is connected by double-shielded coaxial cable to the EB.

The ion sensors 1P and 2P are equipped with a permanent magnet deflection filter that prevents the electrons from entering the detector. The filter is consists from a neodymium magnets and iron yoke and provides magnetic field intensity of 0,3 T in the middle of the collimator. The cutoff energy for electrons is tbd keV. The geometry factor is 0,0001 cm^2sr for 1P and 0,003 cm^2sr for 2P.

The electron sensors 1E and 2E are equipped with aluminium-metalized polyester foil filter that prevents the ions from entering the detector. The cutoff energies are tbd keV for Hydrogen (proton), tbd keV for Helium (α-particle) and tbd MeV for Oxygen ions. The geometry factor is 0,0001 cm^2sr for 1E and 0,003 cm^2sr for 2E.

The surface treatment of the sensors is provided by conductive black paint ELECTRODAG-502. The sensors are equipped with red-color dust covers that must be removed before the flight.

2.4 MECHANICAL CONTROL DRAWINGS

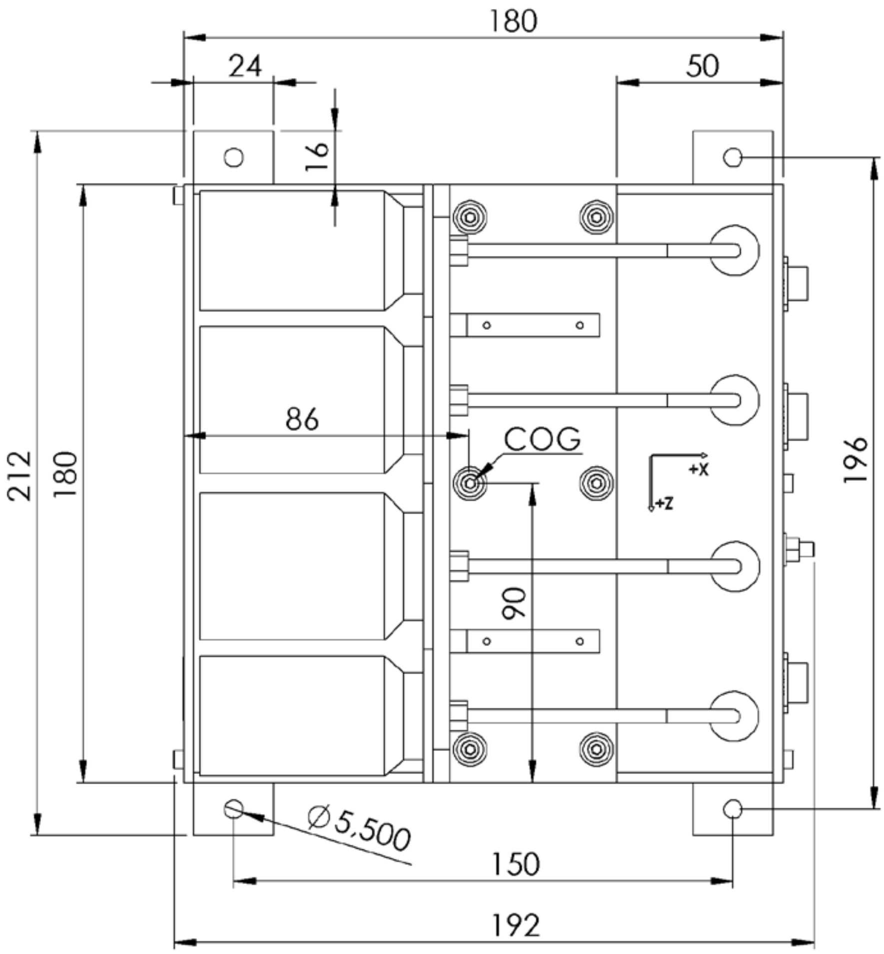

***Figure 3**. Mechanical control drawing – top view.*

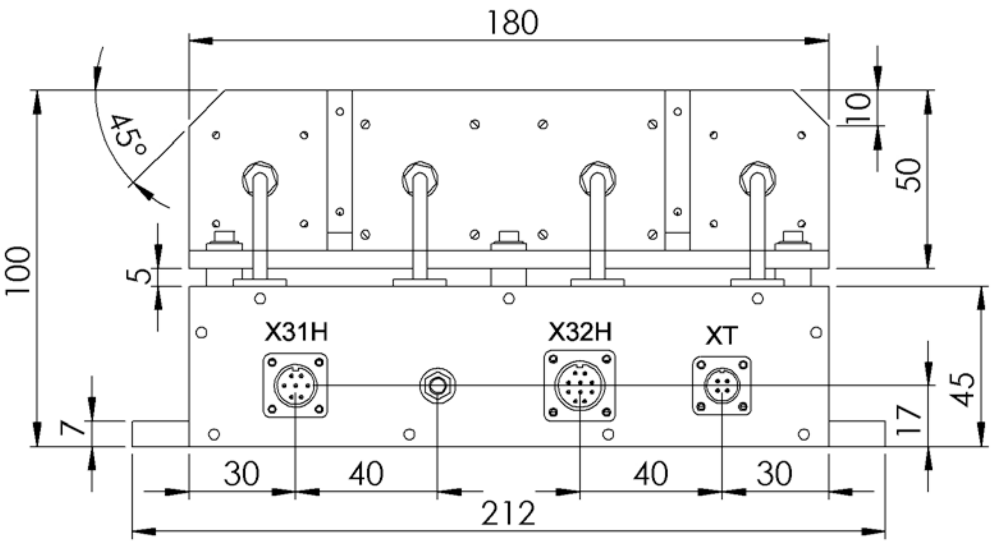

Figure 4. Mechanical control drawing – back view.

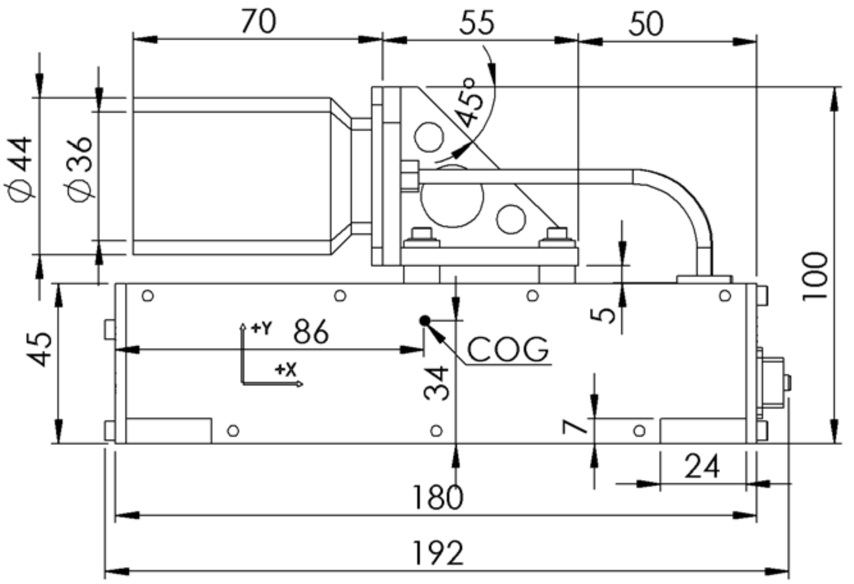

Figure 5. Mechanical control drawing – side view.

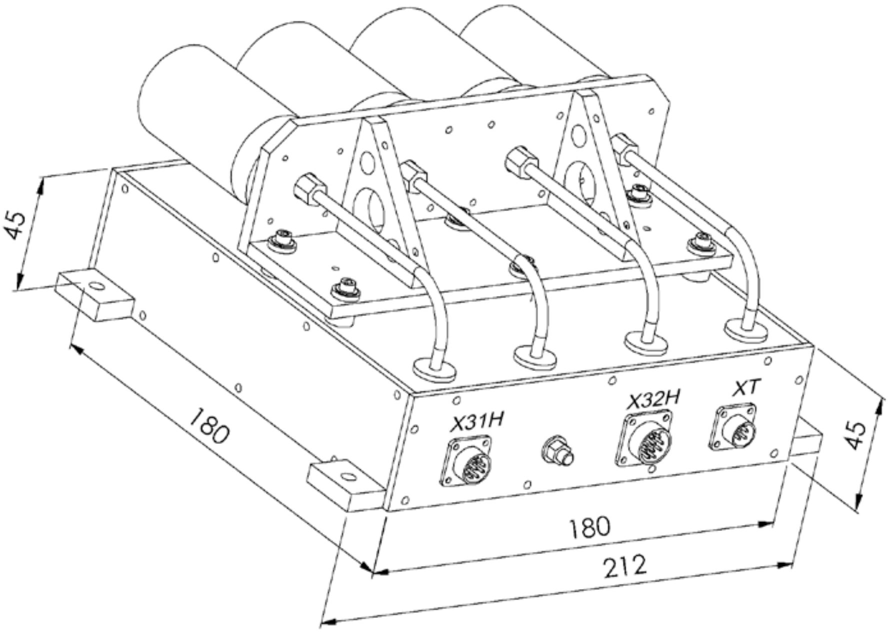

Figure 6. *Mechanical control drawing – isometric view.*

3 STRUCTURAL THERMAL MODEL DOK-M / STM

The STM provides the same mechanical a thermal properties as the flight model.

Figure 7. *The Structural Thermal Model of DOK-M.*

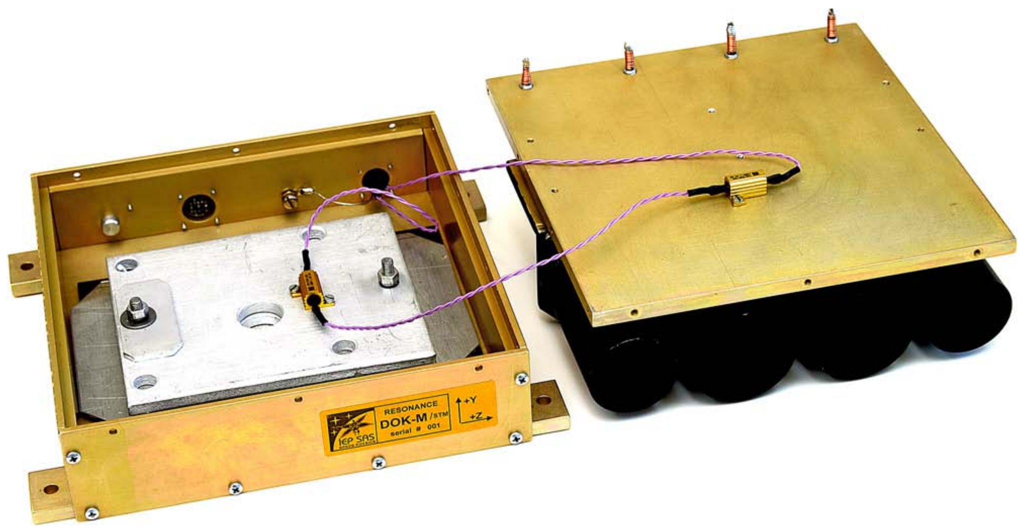

Figure 8. *Internal structure with Dummy mass and Dummy power dissipation elements.*

The STM electronic box is built from the same aluminium-alloy parts as the flight model, however, the internal details are not provided and the electronic boards are simulated. The mass of the electronic boards is simulated by aluminium dummy-mass plates fixed to the bottom plate. The power dissipation is simulated by two power resistors in serial that are thermally coupled to the bottom plate (100 Ohm, 1,5 W dissipation) and to top plate of the box (120 Ohm, 1,8 W dissipation). The internal structure of the STM is shown by a photograph in Figure 8. The STM sensor platform (SP) is thermally insulated against the electronic box (EB) the same way as designed for FM, i.e. with 6 thermal insulators made of PEEK 450G high performance plastic and M3 x 20 stainless steel screws.

The sensors and platform are painted by ELECTRODAG 502 electrically conductive black paint.

4 ELECTRICAL DESIGN

4.1 FUNCTIONAL BLOCK DIAGRAM

Functional diagram of the DOK-M is illustrated in Fig. 9. DOK-M incorporates 4 sensors and four identical analog preprocessing channels. The charged particle that penetrates to the detector, produces charge amount (electron-hole pairs) proportional to the energy deposited in detector active (depleted) volume. The free charge is drained and converted to voltage pulse in the Charge Sensitive Amplifier (CSA) type of Cremat CR110. Its sensitivity is 1,4V/pC, providing 62 mV/ MeV energy-to-voltage conversion ratio for silicon detector. The CSA output voltage pulse is then amplified by a wideband Pulse Amplifier (PA) with gain approx. G = 4. The signal is then shaped and amplified with Gaussian type shaping amplifier type of Cremat CR200-250 with shaping time constant of 250ns and gain G = 10. The total conversion gain of the complete analog preprocessing channel is 2,5 V/MeV. This value is subject of an exact physical calibration with real energetic particles from radioisotope source or from particle accelerator.

The output of the analog preprocessing channel is supplied to the Peak Hold Detector (PHD) that provides time extension of the peak amplitude until it is sampled by the Analog to Digital Converter (ADC) of DPU. The PHD is reset immediately after the sampling and is ready to record another pulse. The registration dead time 4 μs is derived from the DAC sampling frequency. The particle events are sorted by the energy to dedicated bins in the DPU memory, the basic accumulation time is 100ms and raw amplitude resolution is 128 levels (in linear distribution) and is identical with 128-channel amplitude analysis operational mode. The lower number of energy channels in telemetry saving modes is provided by summation of respective adjacent energy channels. This can be done individually for each sensor. The longer accumulation times in slower operational modes of individual sensors are always a multiple of the 100ms basic interval (i.e. 100ms, 200ms, 500ms, 1s, 2s, 5s, 10s).

The accumulated data are transferred to the telemetry system according to spacecraft standard communication protocol (2032 bytes of data per packet).

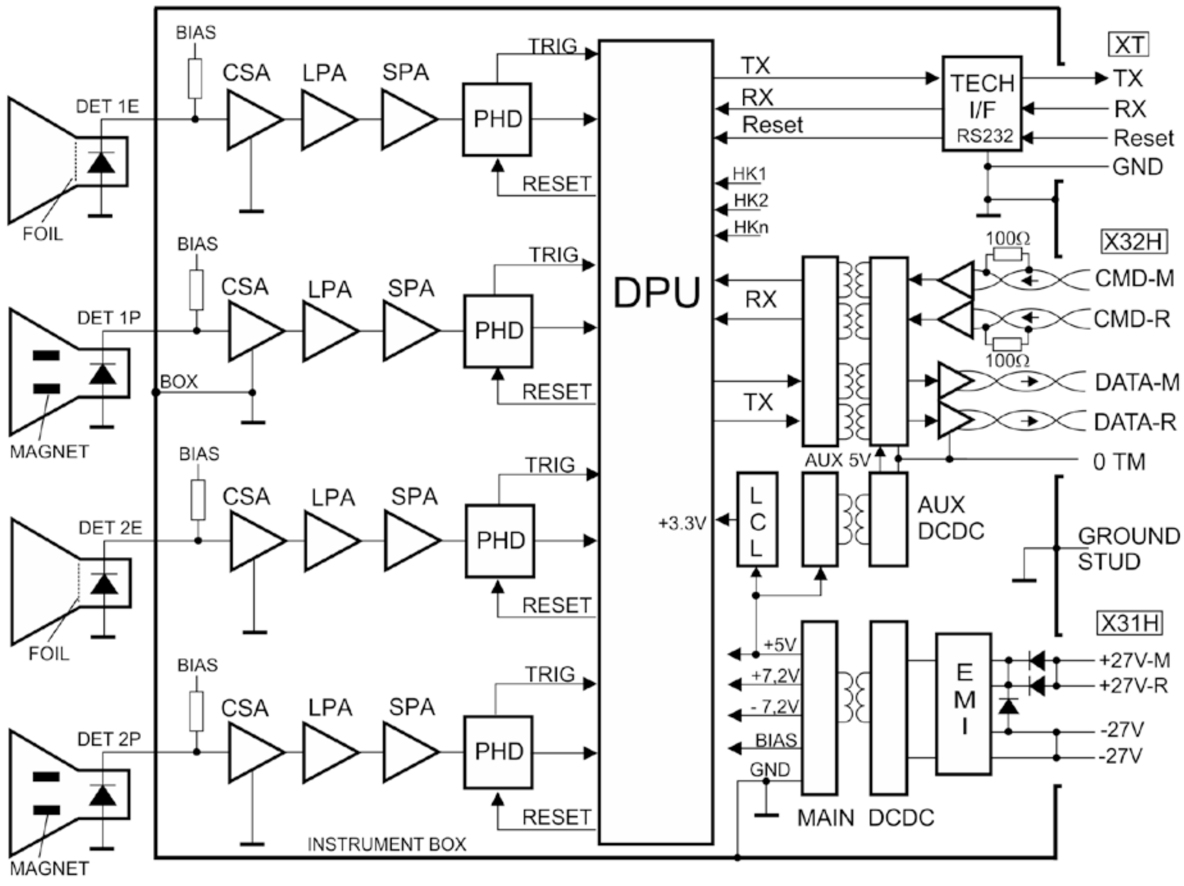

***Figure 9**. Functional block diagram.*

4.2 POWER INTERFACE AND POWER DISTRIBUTION

The power interface to the spacecraft power system is located on X31H connector (RS-7 type). The interface consists of multi-stage EMI filter, an active inrush current control and insulated DCDC converters. The converters are running at frequency 200kHz in flyback operation mode with current mode pulse-width modulation. Acceptable input voltage is in the range 18-34V, total efficiency is about 80%. The power distribution (PD) voltages are as follows:

- +5V for the digital electronics powering
- +7V for the analog electronics powering
- -7V for the analog electronics powering
- +2.50 V a precision bandgap reference voltage
- +140V detectors bias voltage

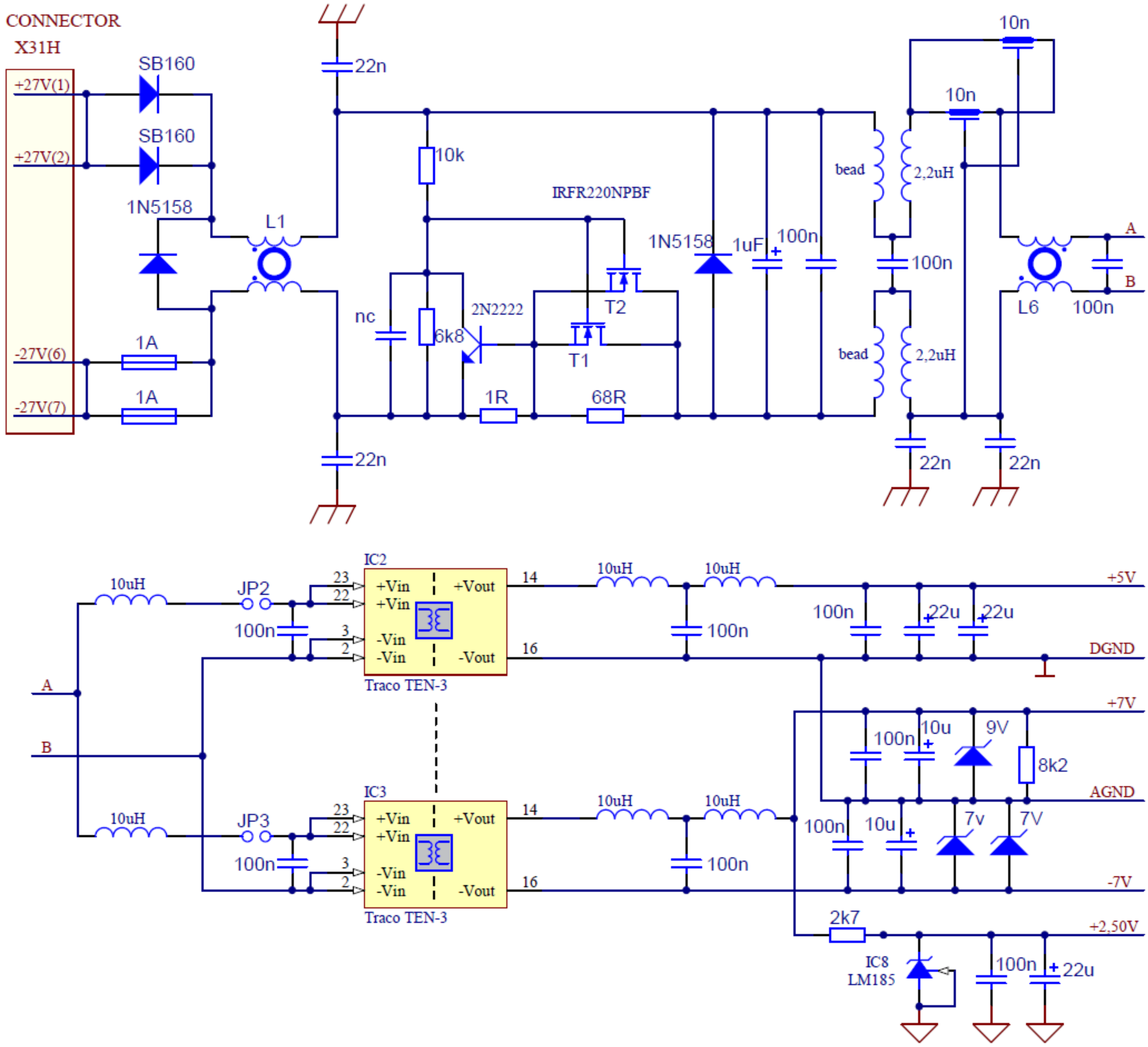

Figure 10. *Power interface and power distribution.*

A detailed electrical scheme of the PD is illustrated in Fig.10. A common-mode EMI filter is placed immediately by input (PWR) connector. The polarity protection is performed by Schottky diodes. The inrush current is limited by FET transistors with 1Ohm sensing resistor. The converter primary side is galvanically fully insulated from the rest of DOK-M electronics.

4.3 COMMAND & DATA INTERFACE

The command and data interface to the SUSPI telemetry system is provided in compliance with RS422 standard running at 125 kbps bitrate. The interface is located on X32H connector (RS-10 type) and is dual redundant.

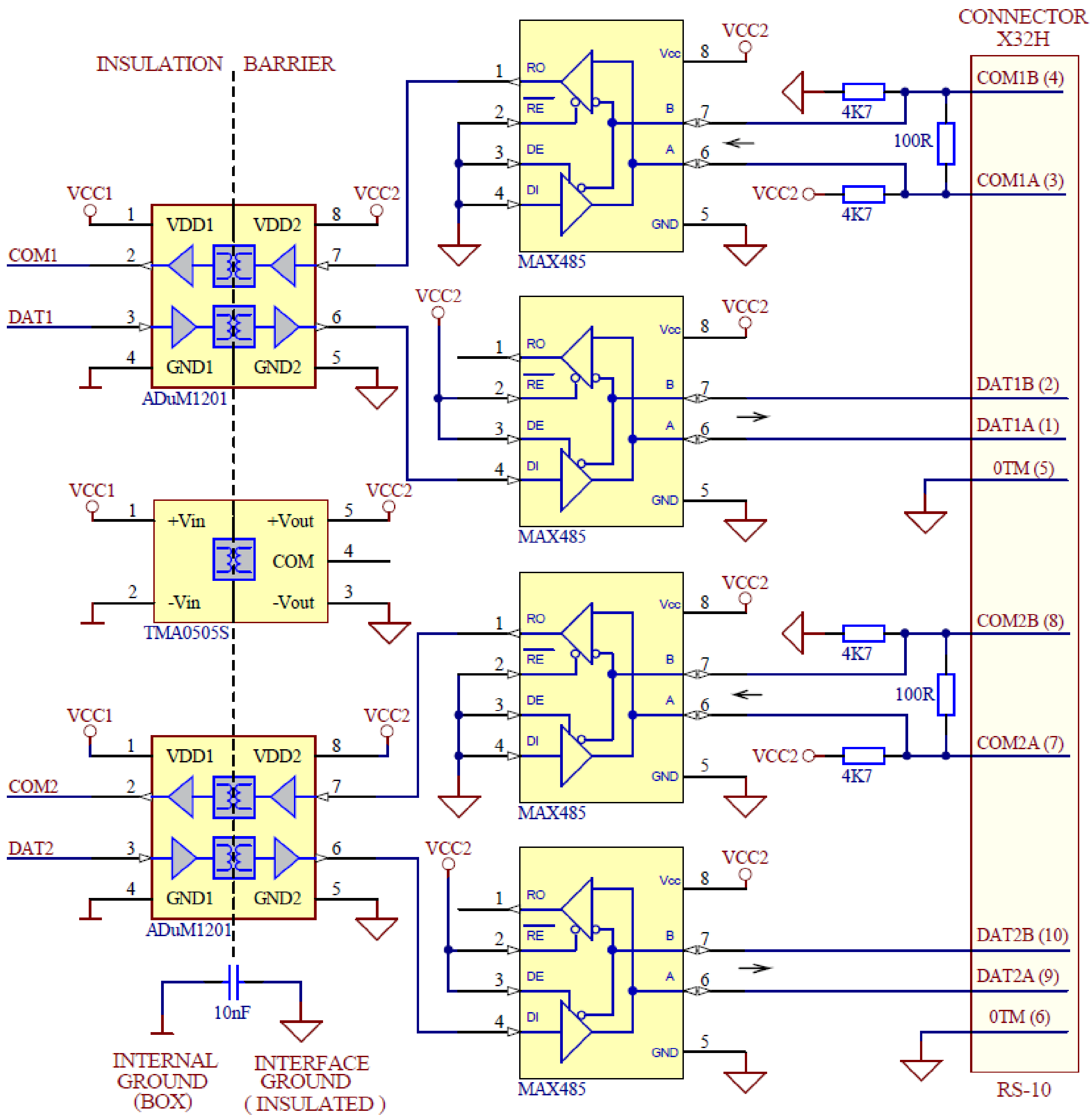

Figure 11. *Command and data interface.*

4.4 TECHNOLOGICAL INTERFACE

The technological interface is provided in compliance with RS232 standard running at 115,2 kbps bit rate. The interface is galvanically connected to instrument internal electronics (ground GND is connected to instrument box - chassis). The technological interface is available on XT connector (RS-4 type) and is devoted for connection to Ground Support Equipment (GSE-DOK-M) for software development and monitoring activities. In this configuration, pin 3 of the XT connector serves for DPU reset. The technological interface can also be directly connected to serial port RS232 of standard personal computer (at 115200 bps). The XT connector is blinded for flight with a metallic cover.

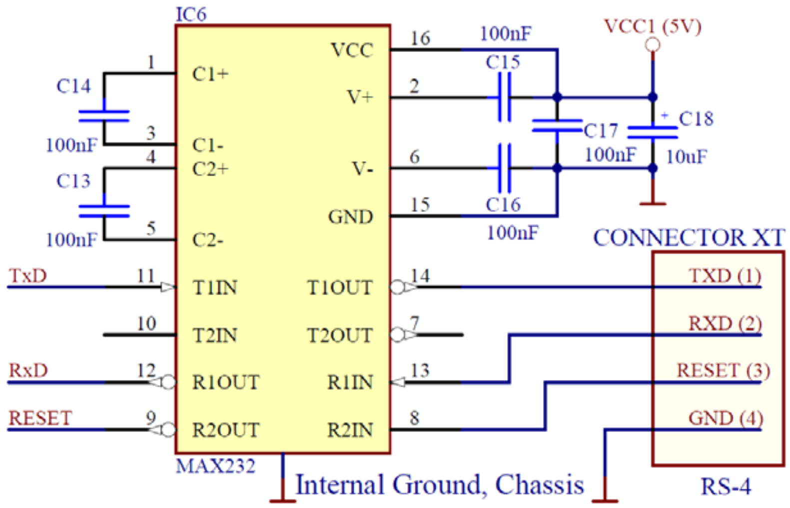

Figure 12. *Technological interface.*

4.5 INTERFACE CONNECTORS

X31H (RS-7)	
1	+27V
2	+27V
3	-
4	-
5	-
6	-27V
7	-27V

X32H (RS-10)	
1	DAT1A
2	DAT1B
3	COM1A
4	COM1B
5	0TM
6	0TM
7	COM2A
8	COM2B
9	DAT2A
10	DAT2B

XT (RS-4)	
1	TxD
2	RxD
3	Reset
4	GND

The instrument has also grounding stud for reliable low-impedance connection of the electronic box to the spacecraft platform and for grounding of outer shielding of the interface cables. The stud is provided by stainless steel screw M4 x 12mm.

4.6 FRONT-END ELECTRONICS

The detector is biased from the bias source by high-resistance (10 MΩ) resistor and connected to the input of charge sensitive amplifier CSA (CREMAT CR110) by a coupling capacitor. To the same point also electrical testing pulses can be injected by a small (2pF) capacitor. The output signal of the CSA is then amplified by a wideband pulse amplifier PA type of EL5163. The signal is then shaped-amplified by a Gaussian shaping amplifier SA (CREMAT CR200-250ns) with shaping constant τ = 250ns, providing peaking time 500 ns.

Total conversion gain of the front end electronics is calibrated to value 2,5 V / MeV (calibration performed on 60keV gamma-ray peak of Am241 radioisotope).

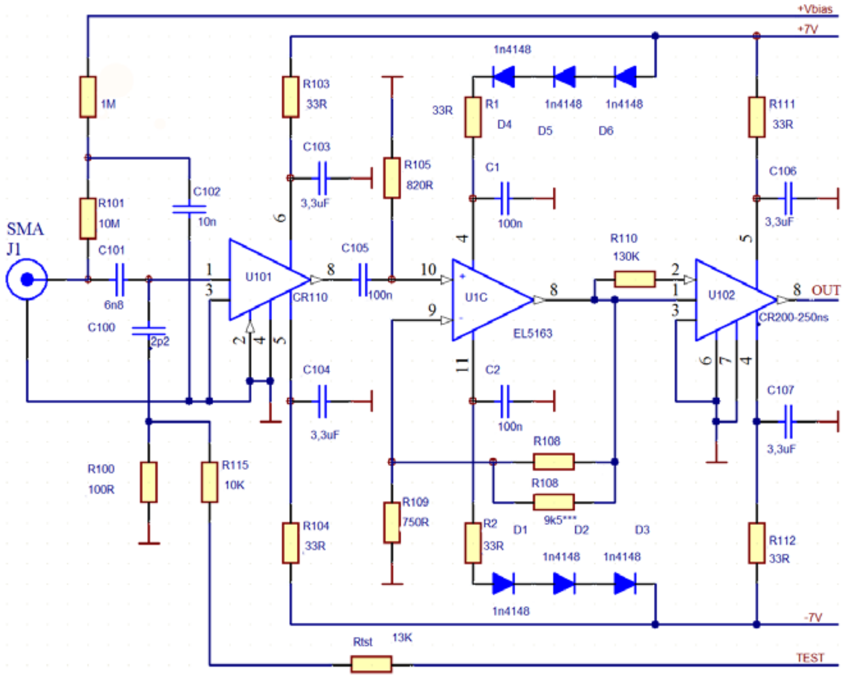

Figure 13. *Front-end electronics (one of four channels).*

4.7 PEAK HOLD DETECTOR

The amplitude of the pulse is detected by a Peak Hold Detector (PHD) based on AD8065 wideband operational amplifier (Fig. 14).

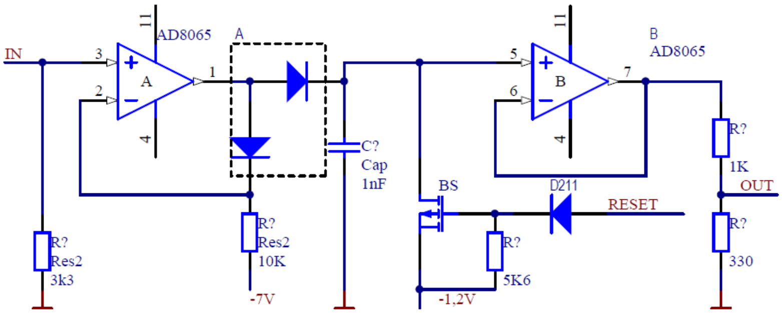

Figure 14. *Peak Hold Detector.*

The detector works in dynamically stable non-feedback operation mode with thermally compensated pair of Schottky diodes. The pulse amplitude is stored in the 1nF capacitor until DPU readout. The storage capacitor charge is restored to zero (small negative value) by the DPU immediately after readout.

4.8 DATA PROCESSING UNIT (DPU)

Detailed electrical scheme of the DPU unit is illustrated in Fig. 15.

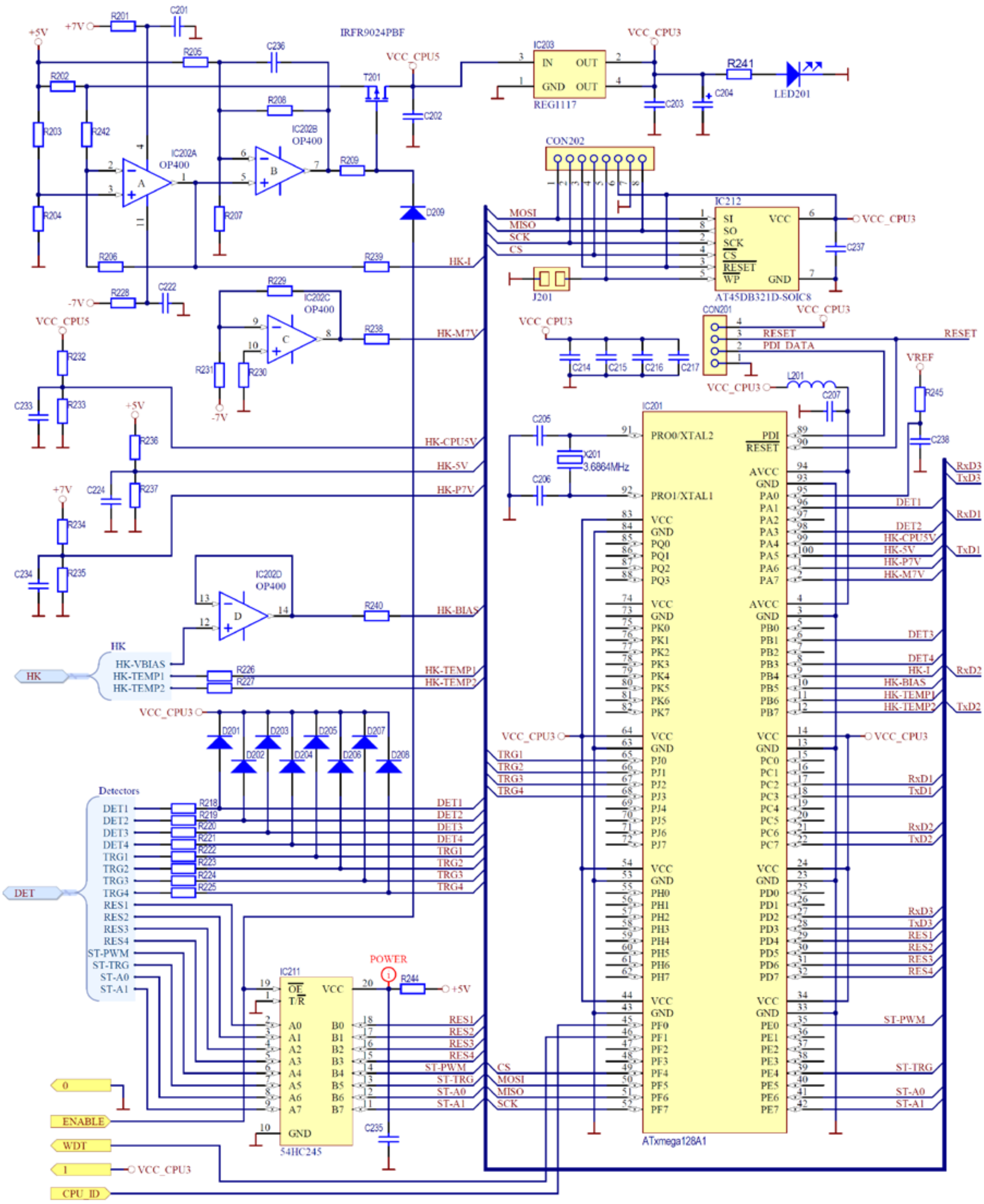

Figure 15. Data Processing Unit.

4.9 HOUSEKEEPING ANALOG CIRCUITRY

The housekeeping analog circuitry provides accommodation of monitored technical parameters of the DOK-M to the voltage range, suitable for the A/D converter. Voltage range of the ADC is limited by the reference 2500 mV, so that input voltage range 0 – 2500 mV is converted to the 0 - FF_{hex} output code. The housekeeping analog data include following parameters:

- VB ... made by resistor divider (attenuation coef. = 0,01) from the bias voltage

- V+ ... made by resistor divider (attenuation = 0,25) from +7 V power. voltage
- V5 ... made by resistor divider (attenuation = 0,25) from +5 V powering voltage
- V- ... made by active inverter (gain = - 0,25) from -7 V powering voltage
- TEMP-E (temperature of electronics)... made by AD590 integrated absolute temperature sensor with sensing resistor 6800 ohm
- TEMP-D (temperature of detectors) ... made by AD590 integrated absolute temperature sensor with sensing resistor 6800 ohm.

5 OPERATIONAL DESCRIPTION

The operation of the instrument assumes significant level of flexibility allowing relatively independent operation of individual sensors with regard to sampling rate, number of energy channels including complete disable of the sensor. In the interest of this flexibility each sensor has dedicated its own data frames that may have different occurrence in the instrument data stream (including no occurrence if respective sensor is disabled). This allows optimal use of the instrument telemetry quota.

5.1 SAMPLING RATE (Time resolution)

The fastest sampling rate is 10 s^{-1} (100ms accumulation time) and all the slower modes are created as multiple of this time period. Thus eight sampling rates are introduced:

10 Hz (T = 100 ms)

5 Hz (T =200 ms)

2 Hz (T =500 ms)

1Hz (T =1s)

0,5 Hz (T =2 s)

0,2 Hz (T =5 s)

0,1 Hz (T =10 s)

0 Hz (T = ∞, sensor disabled)

5.2 ENERGY RESOLUTION

The number of energy channels is selectable by command as follows:
16 channels (non-linear threshold distribution)
32 channels (non-linear threshold distribution)
64 channels (non-linear threshold distribution)
128 channels (linear threshold distribution)

5.3 TELEMETRY RATE

Pure data telemetry rate for one individual sensor:

Ch \ fs[bps]	10 Hz	5 Hz	2 Hz	1 Hz	0,5 Hz	0,2 Hz	0,1 Hz	0 Hz
16 ch	1280	640	256	128	64	25,6	12,8	0

32 ch	2560	1280	512	256	128	51,2	25,6	0
64 ch	5120	2560	1024	512	256	102,4	51,2	0
128 ch	10240	5120	2048	1024	512	204,8	102,4	0

5.4 STANDARD DATA FRAME

Mk1, Mk2, Mk3, Mk4	Marker 'DOKM' in ascii code
FI	Frame Identifier - sensor index or housekeeping
OBT1, OBT2, OBT3, OBT4, OBT5	Onboard time - related to beginning of measurement
FM	Frame Mode - number of energy channels and sampling frequency
Ch1, Ch2, Ch3,…, ChM	channel counts - compressed by semilog. algorithm
CHCKSM	checksum

FI (Frame Identifier)

Sensor 1P	Sensor 2P	Sensor 1E	Sensor 2E	Housekeeping
31h ('1')	32h ('2')	33h ('3')	34h ('4')	48h ('H')

FM (XY) - one byte, X= four most significant bits, Y= four least sig. bits

X	1h	2h	3h	4h
Number of Channels	16	32	64	128

Y	1h	2h	3h	4h	5h	6h	7h
Frequency	0,1 Hz	0,2 Hz	0,5 Hz	1 Hz	2 Hz	5 Hz	10 Hz

5.5 CHANNEL COUNT DECODING

Channel count is compressed by standard quasi-logarithmic compression with 4 bits for mantissa and 4 bits for the exponent. Decompression of the data can be performed by the following formula:

$$N = M \qquad \text{(if } E = 0\text{)}$$

$$N = (M + 16) \cdot 2^{(E-1)} \qquad \text{(if } E > 0\text{)}$$

Where E is represented by four most significant bits and M is represented by four less significant bits of respective data byte.

5.6 HOUSEKEEPING DATA FRAME

Mk1	Marker 1		44h ('D')	Constant

Mk2	Marker 2		4Fh ('O')	Constant
Mk3	Marker 3		4Bh ('K')	Constant
Mk4	Marker 4		4Dh ('M')	Constant
FI	Frame Identifier		48h ('H')	Constant
OBT1	Onboard time		TBD	TBD
OBT2	Onboard time		TBD	TBD
OBT3	Onboard time		TBD	TBD
OBT4	Onboard time		TBD	TBD
OBT5	Onboard time		TBD	TBD
HK1	Voltage	V5	0.0229 * val (HK1)	V
Hk2	Voltage	V5cpu	0.0229 * val (HK2)	V
HK3	Voltage	V3cpu	0.0715 * val (HK3)	V
HK4	Voltage	Vbias	0.283 * val (HK4)	V
HK5	Voltage	V+	0.034 * val (HK5)	V
HK6	Voltage	V-	-0.034 * val (HK6)	V
HK7	Currrent of CPU	Icpu	1.481 * val (HK7)	mA
HK8	Temperature electr.	Te	1.37 * val (HK8) – 275	°C
HK9	Temperature sensors	Ts	TBD	°C
HK10	Temperature	Tcpu	val (HK10) – 128	°C
HK11	Threshold 1P	Th1P	TBD * val (HK8)	keV
HK12	Threshold 2P	Th2P	TBD * val (HK9)	keV
HK13	Threshold 1E	Th1E	TBD * val (HK10)	keV
HK14	Threshold 2E	Th2E	TBD * val (HK11)	keV
HK15	FM1P		operation mode of 1P	
HK16	FM2P		operation mode of 2P	
HK17	FM1E		operation mode of 1E	
HK18	FM2E		operation mode of 2E	
HK19	FMHK		operation mode of HK	
HK20	Status		Tbd (after reset bit)	
HK21	STG		Selftest generator ststus	
HK22	Res			
HK23	CHCKSM			

5.7 TELECOMMANDS

Two-byte telecommands (CMD1, CMD2) are used.

CMD1-asc	CMD1hex	CMD2	Action
1	31	FM	Set operational mode for 1P
2	32	FM	Set operational mode for 2P
3	33	FM	Set operational mode for 1E
4	34	FM	Set operational mode for 2E
H	48	SEC	Set period of HK issue in seconds
A	41	Thr1P	Set energy threshold for sensor 1P
B	42	Thr2P	Set energy threshold for sensor 2P
C	43	Thr1E	Set energy threshold for sensor 1E
D	44	Thr2E	Set energy threshold for sensor 2E
S	53	NN	Start Automated Selftest nr. NN (TBD)
G	47	SAF	Set test generator (Bit7-Bit6 =sensor, Bit5-Bit3=ampl., Bit2-Bit0=freq.)
F	46	00	Save configuration to EEPROM
L	4C	00	Load default configuration
T	54	00	Start Time mode
h	68	00	Send forced HK
R	52	00	Reboot

6 GROUND SUPPORT EQUIPMENT GSE-DOK-M

Ground support equipment GSE-DOK-M provides simulation of the spacecraft power distribution system and the SUSPI command-data telemetry system. The GSE requires external power supply (27 V power adapter or laboratory regulated source), and control PC computer with the USB port and the DOKM.EXE control software installed.

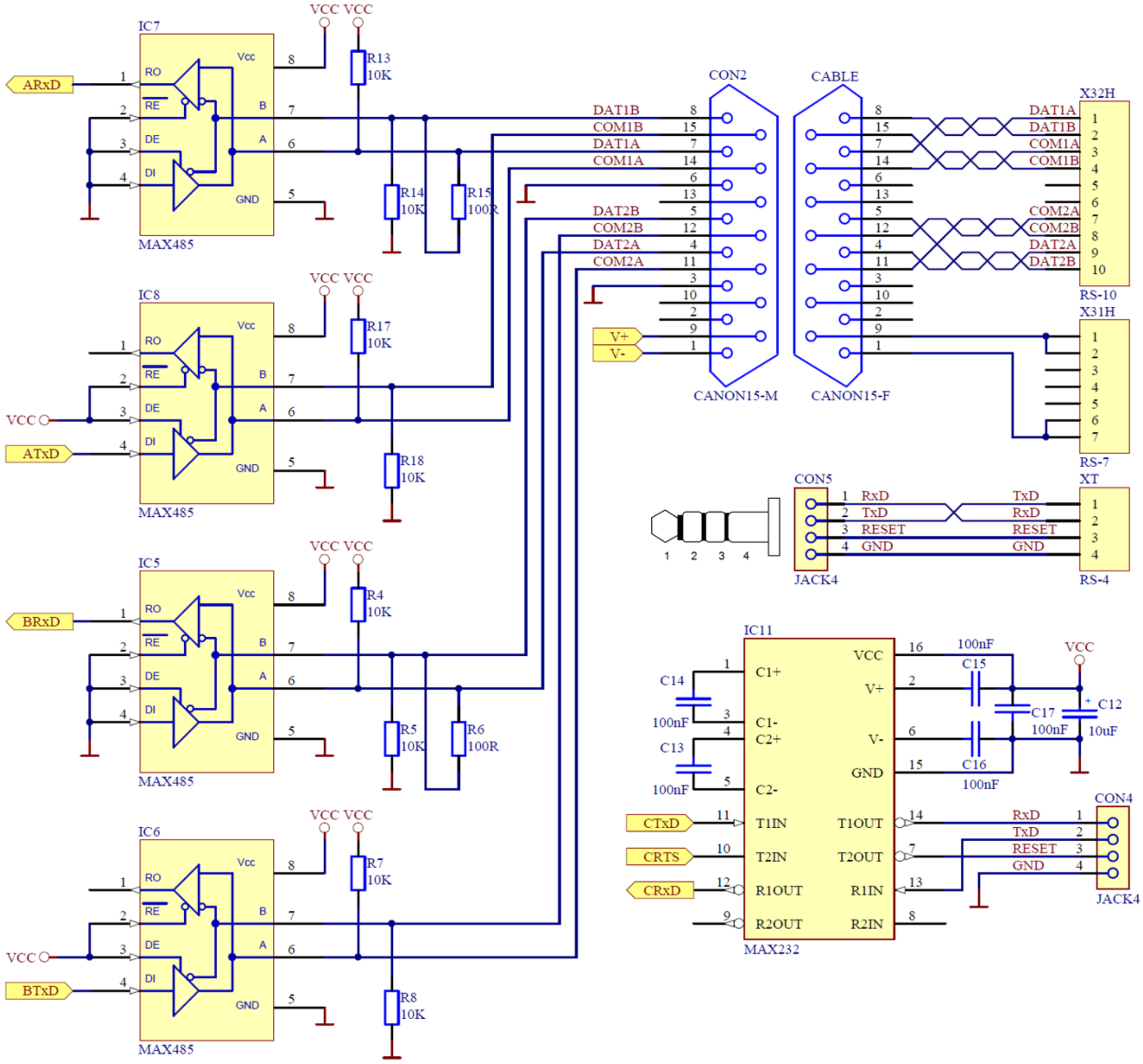

__Figure 16.__ GSE – physical RS422 interface and cables to DOK-M.

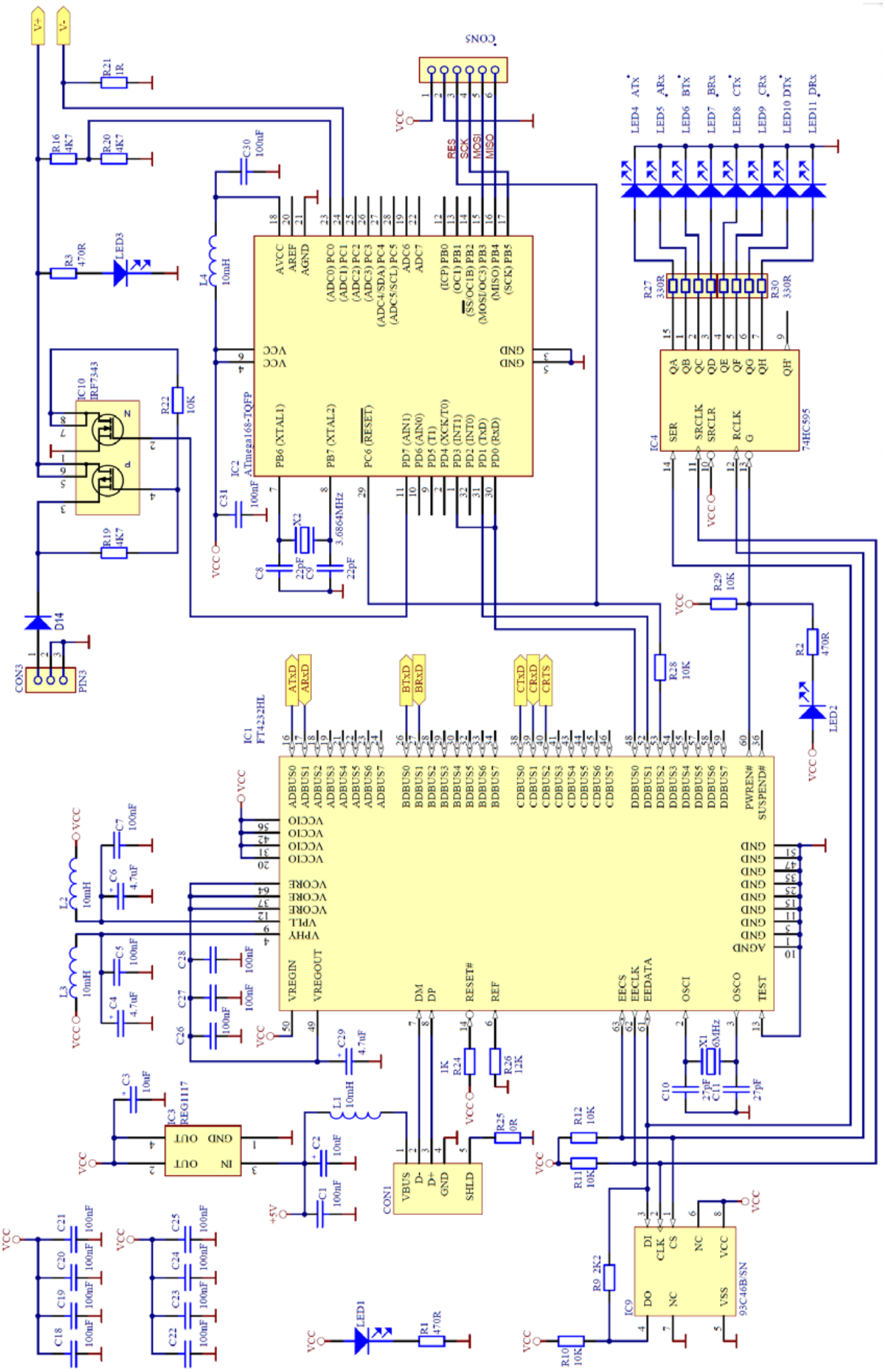

Figure 17. *GSE – main unit (without RS422 interface)*

Figure 18. *Ground Support Equipment of DOK-M (without external power supply.*

The external power source (adapter) provides powering of the DOK-M, while the GSE itself is powered from USB port of standard PC. However, the GSE is able to control the power for DOK-M, i.e. ON/OFF control and voltage-current monitoring.

7 ENGINEERING MODEL DOK-M / EM

The engineering model (EM) was constructed to represent mechanical configuration and electrical interfaces with regard to their basic functionality.

The power interface is very close to expected flight model (FM) performance with power consumption, electromagnetic interference (EMI) performance, inrush current characteristic, etc.

The data-command interface (dual redundant RS422) and embedded software simulates the expected FM performance with regard to particle registration, science data formatting and transferring to the SUSPI telemetry by agreed communication protocol. Also the housekeeping information is collected, formatted and transferred the same way as is expected for FM. The command receiving and processing is the same as expected for FM.

The EM software functionality is in compliance with the description in Chapter 5.

The EM is equipped with the DPU board only, the particle sensors and front-end electronic board are only simulated.

Figure 19. *DOK-M / EM (engineering model) - front view.*

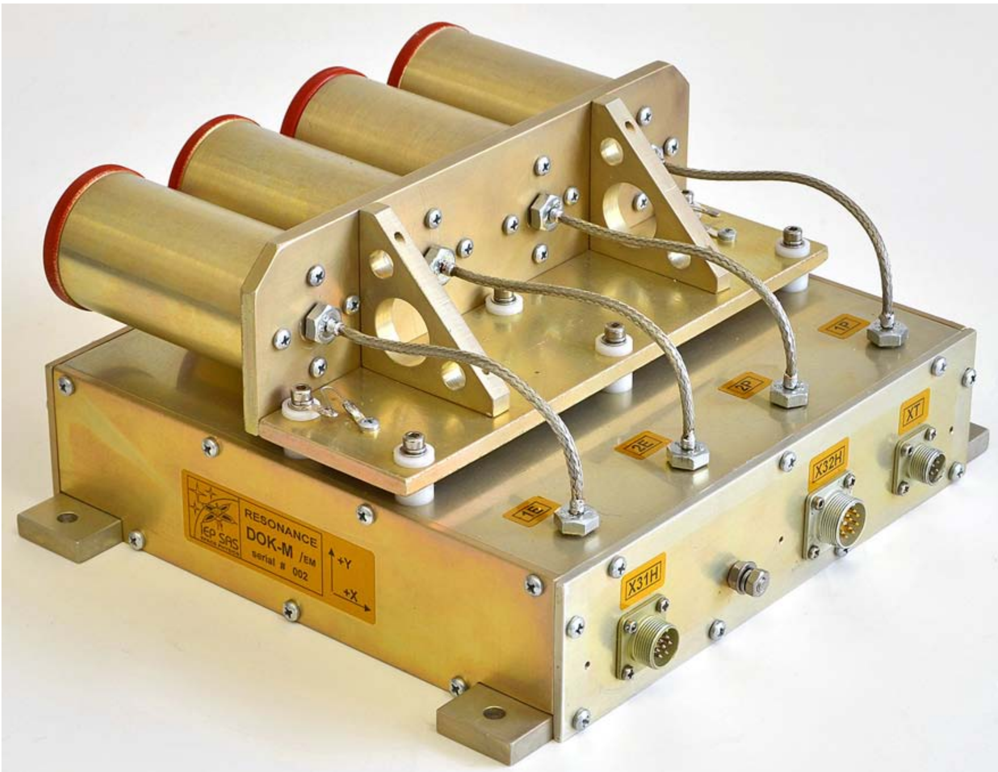

Figure 20. *DOK-M / EM (engineering model) - rear panel view.*

8 AUTONOMOUS TESTING

The autonomous testing allows on-desk verification of the instrument functionality apart of the spacecraft power and telemetry system. The testing configuration is in Figure 19.

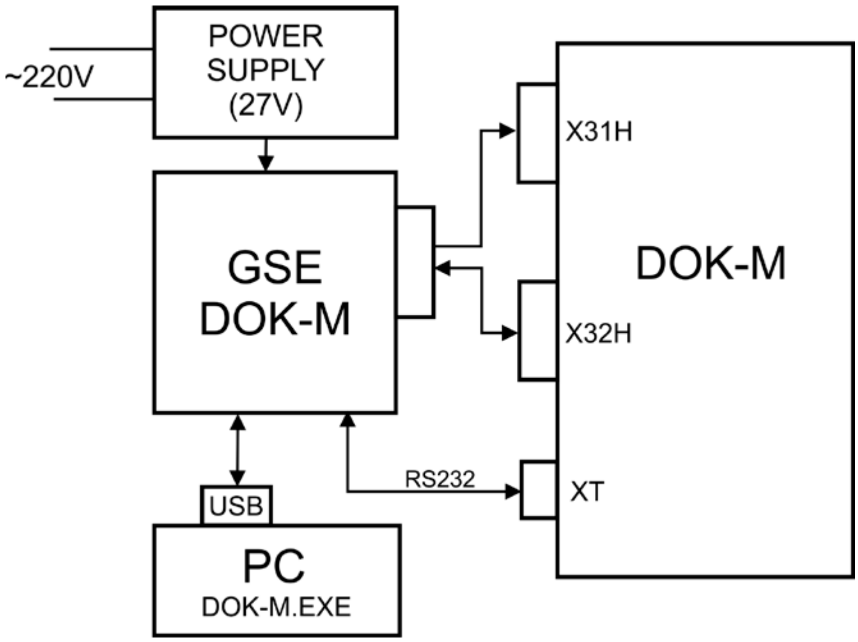

Figure 19. *Autonomous test configuration.*

The DOK-M is connected to GSE with dedicated shielded cable (DSUB-15 to RS-7 and RS-10) with the shield grounding leads. The external power supply for DOK-M is connected to GSE with standard 6,3/2.1mm jack connector (plus pole on central contact). The GSE is connected to control PC with standard USB cable. The technological connector XT of DOK-M can be connected with GSE with dedicated cable (3,5mm-four pole jack to RS-4), however, this connection is reserved for software development and debugging only.

8.1. SOFTWARE INSTALLATION

Software doesn't require any special installation, just the DOK-M.EXE software needs to be copied to dedicated folder together with all associated files (supplied in DOK-M.ZIP file). For communication via USB port (FTDI-chip technology), the PC computer needs installed FTDI-chip drivers (this is already included in Windows 7 operating system). The drivers are normally installed/activated automatically on first connection of the GSE to the PC, the confirming message is USB-QUAD SERIAL CONVERTER installed. In the case of problems with other operating systems, the driver can be installed from the FTDI-chip website http://www.ftdichip.com/FTDrivers.htm. The quad serial converter has all four serial channels occupied as follows:

Channel 1 = Link 1 (RS422 operating at 125 kbps), main GSE-DOK communication link

Channel 2 = Link 2 (RS422 operating at 125 kbps), redundant GSE-DOK comm. link

Channel 3 = Technological link to XT connector (RS232 operating at 115,2 kbps)

Channel 4 = Power on-off control, voltage-current monitor (serial at 115,2 kbps)

8.2 RUNNING THE TEST

After loading the DOK-M.EXE software the main window "DOK-M Control center" appears:

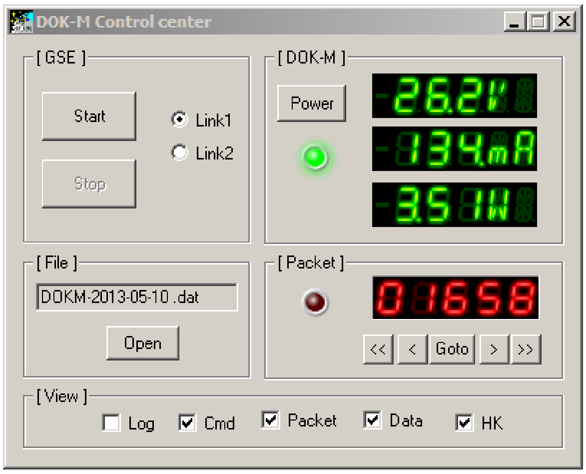

Figure 20. *The main window DOK-M Control Centre.*

The Control center allows DOK-M power ON/OFF control by the POWER button. While the DOK-M is powered, the green lamp is ON and three green displays indicate powering voltage [V], the current [mA] and the power [W] consumed by DOK. The RS422 communication link (Link 1, Link 2) can be selected by respective checkbox. The overall communication between GSE and DOK is controlled by START and STOP buttons. When communication starts, GSE is recording all received data to the file DOKM-YYYY-MM-DD.dat. It means that all the data are recorded to the same file in the current day (next day a new file will be created). The DOK-M.EXE software also serves as an off-line viewer for all the recorded data. The check boxes in the bottom line of the Control center allow to display following windows.

LOG - shows general log of performed on-line activities, the quantity of details depends on the level preset from 0 to 5 (the higher level, the more details). The activity is recorded to DOK-M. LOG file. LOG serves for diagnostics and debugging only. At normal condition, only level 1 should be displayed/recorded (error messages). The figure below shows details at top (5) level.

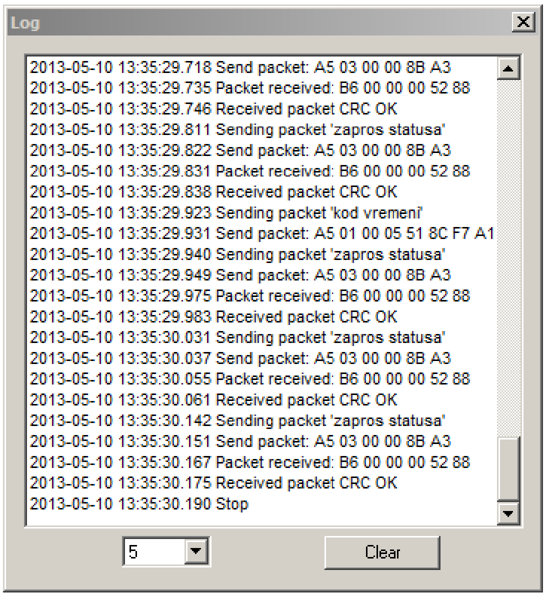

Figure 21. *The LOG window.*

CMD - allows sending of the commands to DOK according to the list in section 5.7.

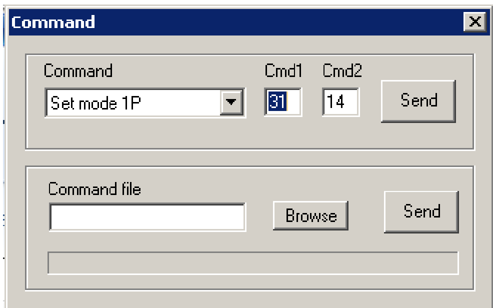

Figure 22. *The Command window.*

The command window also allow to run the command file where respective commands and their timing is recorded.

PACKET - shows statistics of the current (recorded) packet and its content in hexadecimal and ASCII form.

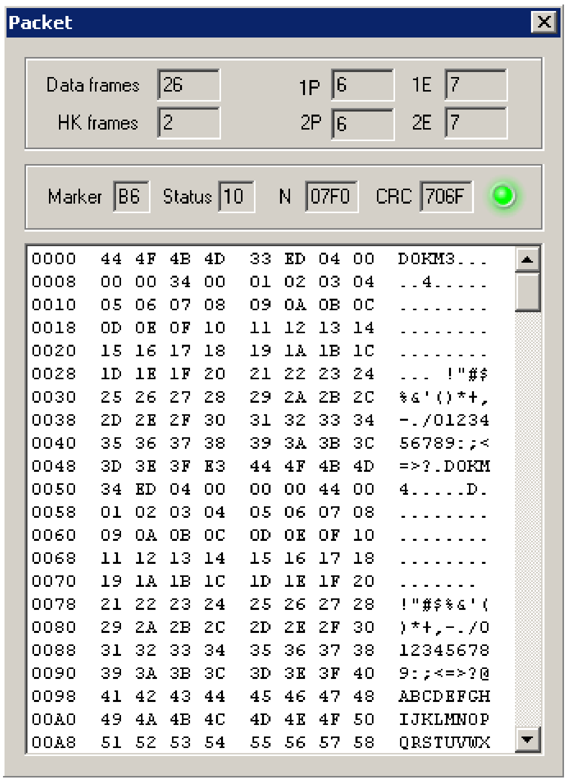

Figure 23. *The Packet window.*

The statistics indicates how many data frames and how many housekeeping (HK) frames are included in the packet, the data frames are moreover divided according to respective sensors 1P, 1E, 2P, 2E. The proper CRC code is confirmed by green indicator, the CRC error is indicated by red indicator.

DATA - shows content of the science data inside the current packet frame by frame.

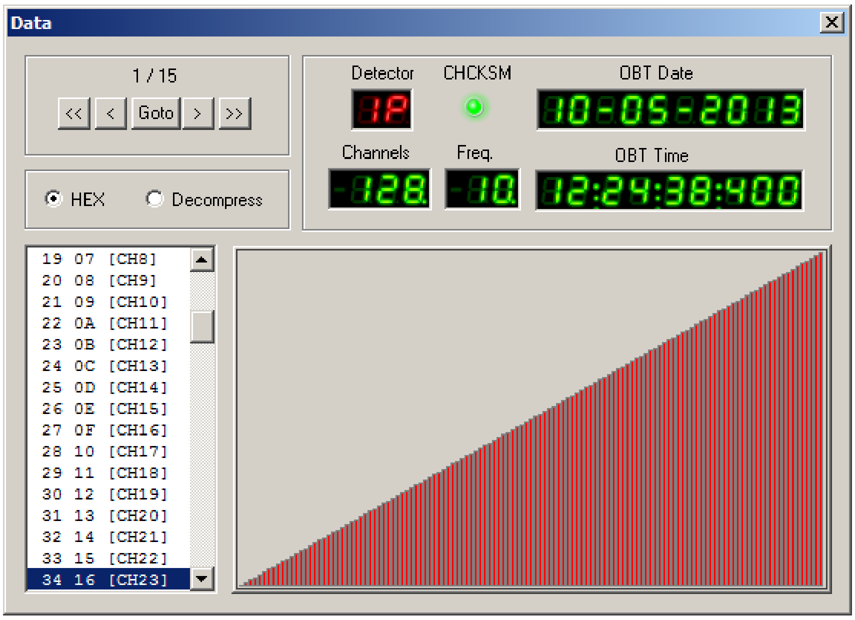

Figure 24. *The DATA window.*

The data are displayed in hexadecimal mode and the channels counts also in graphic plot. In the engineering model (EM) the channel counts are just simulated - generated as a incremental sequence from 0 to MAX, providing simple ramp function. There is also an option for displaying the data in decompressed mode (switch by checkbox). The Data window also shows respective detector, number of energy channels, sampling frequency and onboard Date and Time. The respective data frames are selected for review by <<, <, Goto, >, >> buttons. As the OBT format was not known at the time of the DOK-M/EM delivery, there was provisionally UNIX-like format used (number of seconds from 1st January 1970) for four most significant bytes while fifth (least significant) byte is counter with 100ms increment.

HK - displays content of all housekeeping frames contained in current packet. The data are displayed in hexadecimal code as well as in the form decoded according to table in section 5.6.

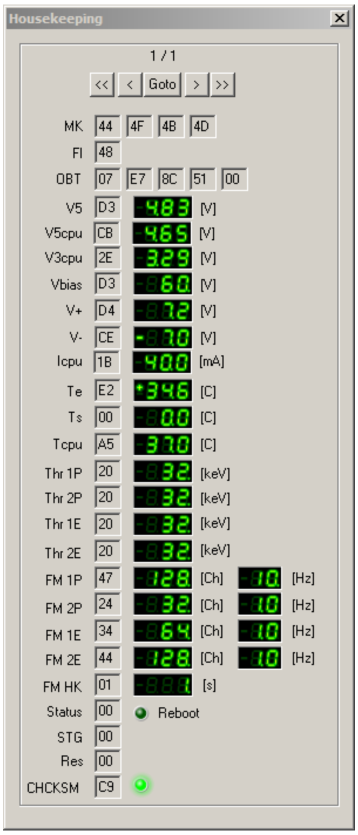

Figure 25. *The Housekeeping Data window.*

8.3 POWER CONSUMPTION TEST

The power consumption test can be performed by an external laboratory regulated power source that is connected to GSE instead of supplied standard 27V power unit by standard 6,3/2.1mm jack connector (plus pole on central contact). There is polarity protection diode embedded inside the GSE, so there is about 0,6 V voltage drop on this diode. The on-off switching and voltage-current-power monitoring is provided by the GSE under DOK-M.exe software control. The DOK-M consumption values are verified in the voltage range 21V - 33V and at normal condition (25°C) should be in compliance with the following table:

V [V]	21	23	25	27	29	31	33
I [mA]	160	149	139	131	125	120	115
P [W]	3,38	3,43	3,49	3,54	3,62	3,72	3,79

(Test was performed with EM at 25°C with external power supply Agilent E3634A).

At normal circumstances, practically no influence should be observed on DOK-M functionality and Housekeeping parameters over the full voltage range 21 - 33 V.

8.4 INRUSH CURRENT TEST

The inrush current test was performed with the RS-7 breakbox, Tektronix P6042 current probe and Tektronix TDS3044B oscilloscope. The GSE was connected to external laboratory power supply with 2200 µF capacitor in parallel to provide low dynamical output impedance.

The power ON-OFF switching was provided by the GSE under DOK-M.EXE control. The inrush current was recorded at the current scale 200mA/div on two time scales:

- 10µs/div- recording of the short spike due to charging of EMI filter small capacitances.
- 1ms/div - to record startup of the DCDC converter with active inrush current limiter.

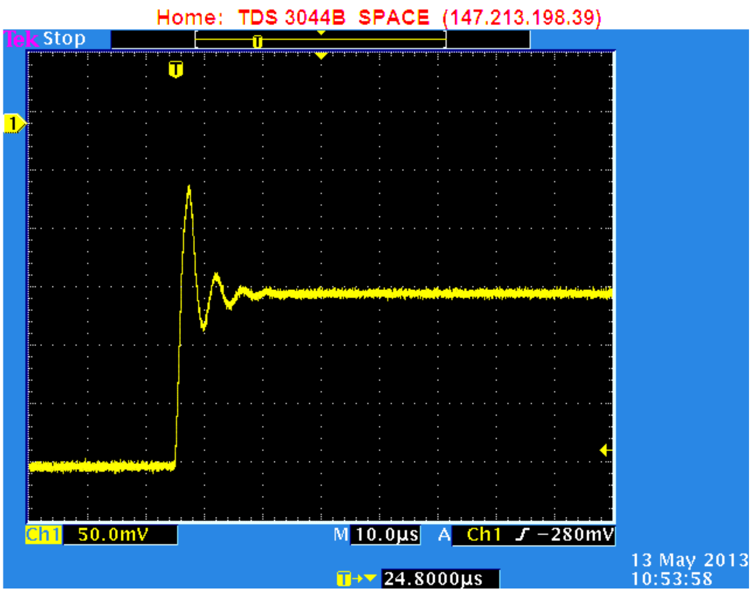

Figure 26. *Inrush current (200mA/div) at the time scale 10µs/div.*

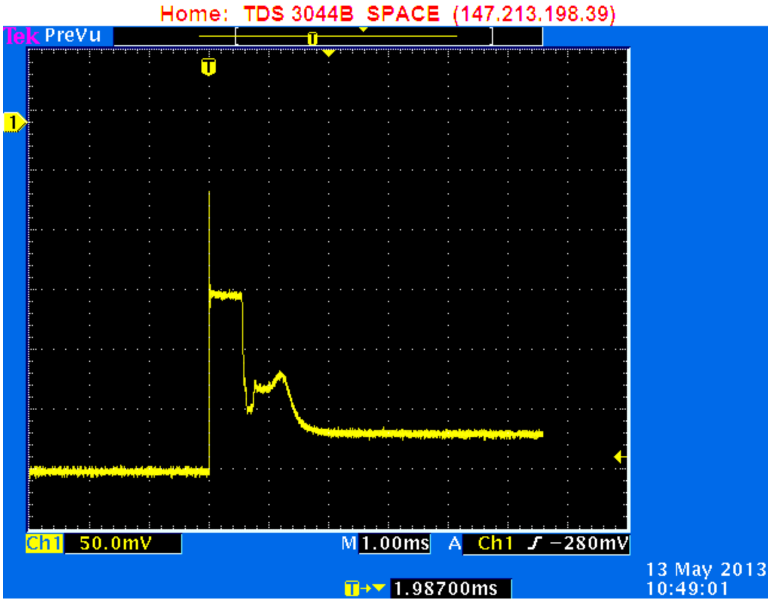

Figure 27. *Inrush current (200mA/div) at the time scale 1ms/div.*

8.5 BURN-IN TEST

The EM was tested for reliable operation for extended time at normal temperature (20°C - 25°C for 4000 hours during software development. The burn-in test proved flawless, stabile start-up and continuous operation over the entire testing time.

8.6 AMBIENT TEMPERATURE TEST

The EM was tested for reliable operation at three temperature cycles between -25°C and +60°C at normal atmospheric pressure and reduced humidity.

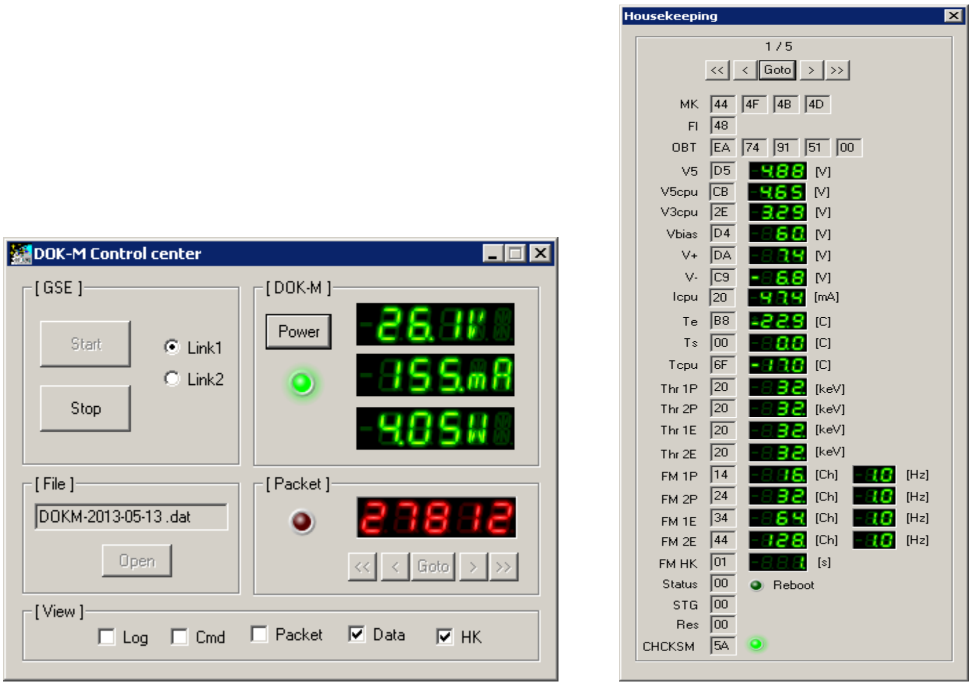

Figure 28*. Ambient temperature test at low extreme -25°C.*

The temperature cycles test proved flawless, stabile start-up and continuous operation over the tested temperatures. Notable is observed dependence of the consumed power on the temperature, showing increasing of consumed power from nominal 3,5 W at normal temperature to 4W at -25°C ambient temperature.

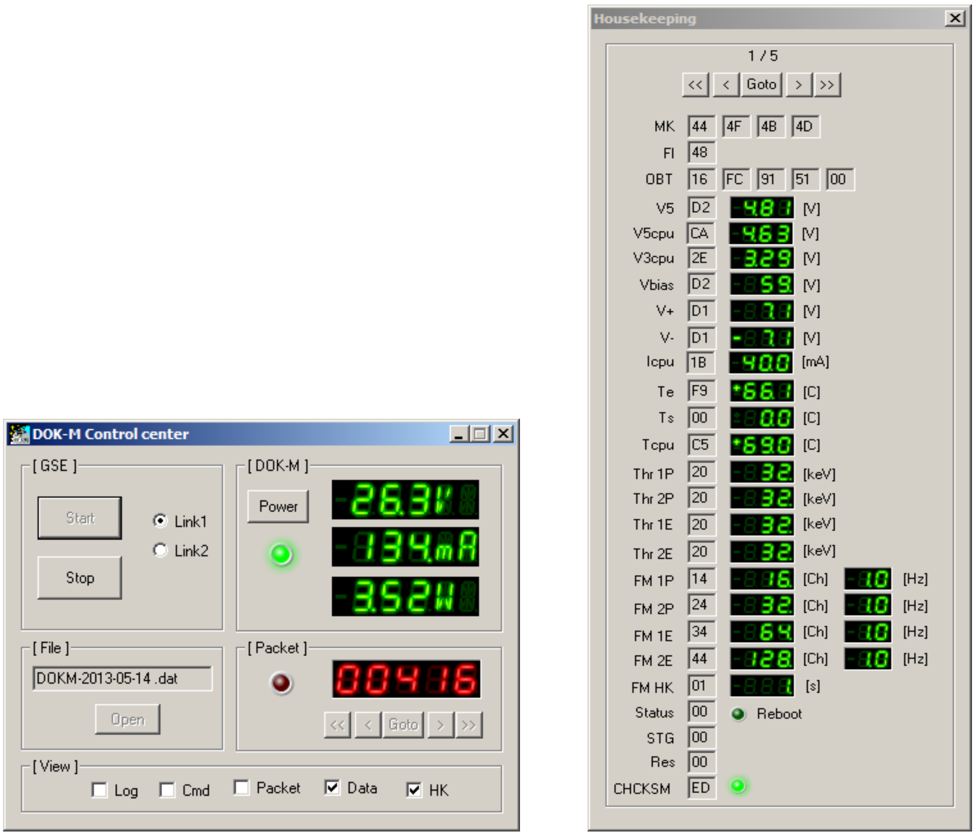

***Figure 29**. Ambient temperature test at high extreme +60°C.*

Acknowledgements

The development of the DOK-M particle spectrometer is supported by Slovak Grant Agency VEGA, project No. 2-0059-13.

REFERENCES

ПРОТОКОЛ №2-Рез информационного обмена по высокоскоростному интерфейсу между блоком СУСПИ и научными приборами космического аппарата «Резонанс». Редакция 1.4. ИКИ 2010.