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

PROGRAMMABLE ENERGETIC PARTICLE SPECTROMETER

MEP-2

FOR SPACE PROJECT

SPECTRUM - RADIOASTRON

TECHNICAL DESCRIPTION

and

USER'S GUIDE

(v 2.4)

Ján Baláž, Igor Strhárský

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CONTENT

LIST OF ACRONYMS

A/D	Analog to Digital
ADC	Analog to Digital Converter
BCC	Checksum
CMOS	Complementary Metal-Oxid-Silicon semiconductor technology
CSA	Charge Sensitive Amplifier
D/A	Digital to Analog
DAC	Digital to Analog Converter
DCDC	DC (direct current) to DC converter
DLT	Discrimination Level Table
DSP-IEP-SAS	Department of Space Physics, Inst. of Experimental Physics SAS
EC	Event counter
EEPROM	Electrically Eraseable Programmable Read Only Memory
EL	Electron Lower discrimination level
EMI	ElectroMagnetic Interference
EPROM	Eraseable Programmable Read Only Memory (by UV)
EU	Electron Upper discrimination level
FM	Frame Mode
GSE	Ground Support Equipment
GSE-MEP-2	Ground Support Equipment of the MEP-2
HK	HouseKeeping information
I/F	Interface
IC	Integral counter
ID	IDentifier
IEP-SAS	Institute of Experimental Physics, Slovak Academy of Sciences
IGI	Interactive Graphic Interface
ITG	Inflight Test Generator
MEP-2	Monitor of Energetic Particles
MGSE	Mechanical Ground Support Equipment
MLI	Multi-Layer Insulation (thermal blanket)
PA	Pulse Amplifier
PC	Personal computer
PCB	Printed Circuit Board
PIPS	Passivated Ion-implanted Planar Silicon detector
PL	Proton (ion) Lower discrimination level
PROM	Programmable Read Only Memory
PU	Proton (ion) Upper discrimination level
TEM	TEMperature
TM	TeleMetry
TR	Registration period
TT	Telemetry interrogation period
WL	Window Logic

1 INTRODUCTION

The SPECTRUM-Radioastron (Spektr-R) space exploration mission is conducted by Space Research Institute (IKI) of Russian Academy of Sciences. In parallel with essential radioastronomical scientific objectives, interesting space physics projects are conducted on board of the spacecraft using its favourable orbit crossing the Earth's magnetosphere.

The MEP-2 (Monitor of Energetic Particles) is a scientific space device under development at DSP-IEP-SAS (Principal Investigator prof. Karel Kudela, scientific objectives in paragraph 1.1.), dedicated for charged energetic particles temporal and energy sampling on board of SPECTRUM-Radioastron spacecraft. A significant feature of the MEP-2 is its programmability, allowing definition of plenty of various operating modes either during pre-launch operation, either during a flight on the Earth‘s orbit. MEP-2 is a joint international scientific space project of IEP-SAS, Demokritus University of Thrace, Greece and Space Research Institute, Moscow.

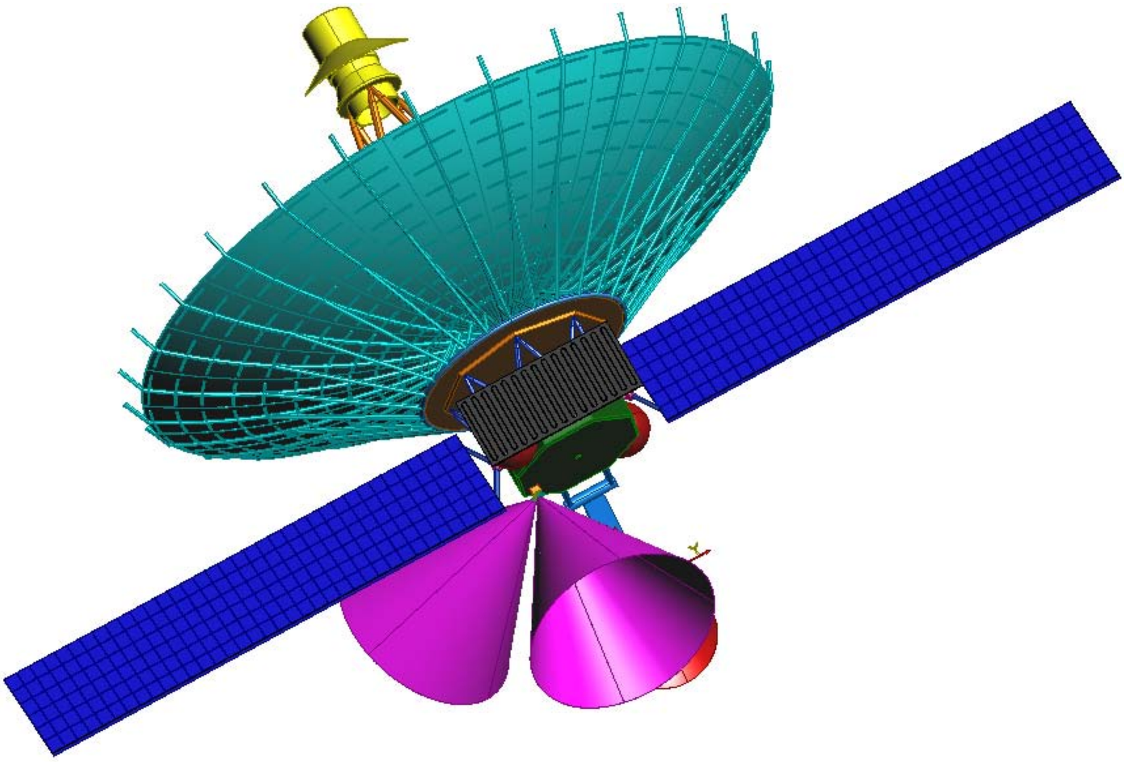

Figure 1. SPECTRUM-Radioastron spacecraft with MEP-2 on board (the diameter of the radioastronomical dish antenna is 10m). The purple cones represent the MEP-2 fields of view.

1.1 SCIENTIFIC OBJECTIVES

The main scientific tasks of the experiment MEP-2 on SPEKTR-R follow from the results of the analysis of both case and statistical type of studies done with DOK-2 instrument on Interball-1 in the region out of the Earth's bow shock. SPEKTR-R with its orbit different from Interball (higher apogee, longer relative time in the region upstream from the bow shock, coverage of larger distances from the shock) will provide better insight into the problem of origin of both proton and electron population in the medium energy range (tens of keV to few MeV) in the foreshock region, it will help to clarify critical parameters controlling the acceleration of those particles and conditions causing the leakage of magnetospheric particles to the region upstream of the bow shock.

Along with that the following objectives are supposed to be studied:

1. Fine Temporal and Spatial Resolution Multispacecraft Observations for the Study of the Acceleration of Energetic Particles at Shock Fronts in the presence of Magnetic Loops and Surface Warps. Short time acceleration events, which are strongly dependent on the local geometry can be identified and distinguished from long duration processes by using simultaneous observations between SPECTR-R and ACE or ULYSSES.

2. Multispacecraft Observations of the Channeling of Solar Energetic Particles in the Interplanetary Space.

3. Multispacecraft Observations of the Dynamics of Large Scale Interplanetary Structures in and out of the Ecliptic

4. Simultaneous Multispacecraft (SPEKTR-R, ACE and CLUSTER) Observations for the Study of a) Solar-Terrestrial Interactions and b) Entry of energetic particles in the magnetosphere

5. Measurements of the Energy Density of Superthermal Particles and Magnetic Field in the Interplanetary Medium.

1.2 BASIC SPECIFICATION OF MEP-2

Weight	2.643 kg
Max. dimensions:	211 x 175 x 182 mm
Power consumption:	1.1 W (at 27 V)
Powering voltage:	16 - 35 V
Technical operating temperature range: ...	-30 °C ... +50 °C
Preferable (low-noise) temperature range:	-30 °C … 0 °C
Number of sensors:	4
Field of view...	50°, conical
Geometrical factor:	0.77 cm^2. ster
Detector type:	silicon, ion implanted, ORTEC
Detector active area:................................	300 mm^2
Ion detectors {1P, 2P) thickness:	100 µm
Ion detector bias voltage:	20 V
Electron detectors (1E, 2E) thickness: ...	500 µm
Electron detector bias voltage:	50 V
Energy range - ions	30keV - 3.2 MeV
Energy range - electrons	30keV - 350 keV
Number of energetic channels:	1 - 32 (programmable)
Electrical thresholds	programmable in range 30 keV - 1270 keV, step of 5 keV
Time resolution:	32 ms
Registration dead time:	10.75 µs
Telemetry rate:	1125 bit/s (1152bit / 1.024s)
Data output spacecraft interface: ………..	RS422, 9600 bps, 8N1
Command interface:…………………….....	serial, 16-bit commands (UKS)
Telemetry interrogation period:	1.024 s (32 x 32ms)
Number of operating modes:	255 (max)
Integral channels accumulation time……..	1.024 s (digital + analog output data)
Integral channels low thresholds ………....	30 keV (default on power-on)
Integral channels high thresholds ……..….	60 keV (set by telecommand)
Integral channels analog output interface:…	0-6V nonlin. compressed f/V conversion
Housekeeping information:	temperature (-80°C...+80°C), internal voltages, status byte
Data monitor on technological connector…	RS232, 9600 bps, 8N1

2 MECHANICAL DESIGN

2.1 INSTRUMENT BOX

An overall mechanical design of the MEP-2 is illustrated in Fig.2. The MEP-2 consists of duraluminum box dimensions of 180 x 130 x 90mm, with four external cylindrical sensors fixed on a special platform on the top of the box. The box is made by machinery (milling) from 5mm-thick duraluminum plates, the surface finishing is performed by „IRIDITE“ process (yellow electrically conductive chromating). All the mechanical components are fixed each other by stainless steel screws (DIN912/A2 and DIN84/A2 specification). Whole instrument is supposed to be covered by a multilayer thermal insulation (MLI), except of the sensor apertures. The box is fixed to dedicated spacecraft platform by four lugs with 5mm screws. The lugs are equipped with circular aluminum washers thickness of 1mm, so there is 1mm gap between the box and the mounting platform - to perform well-defined thermal contact.

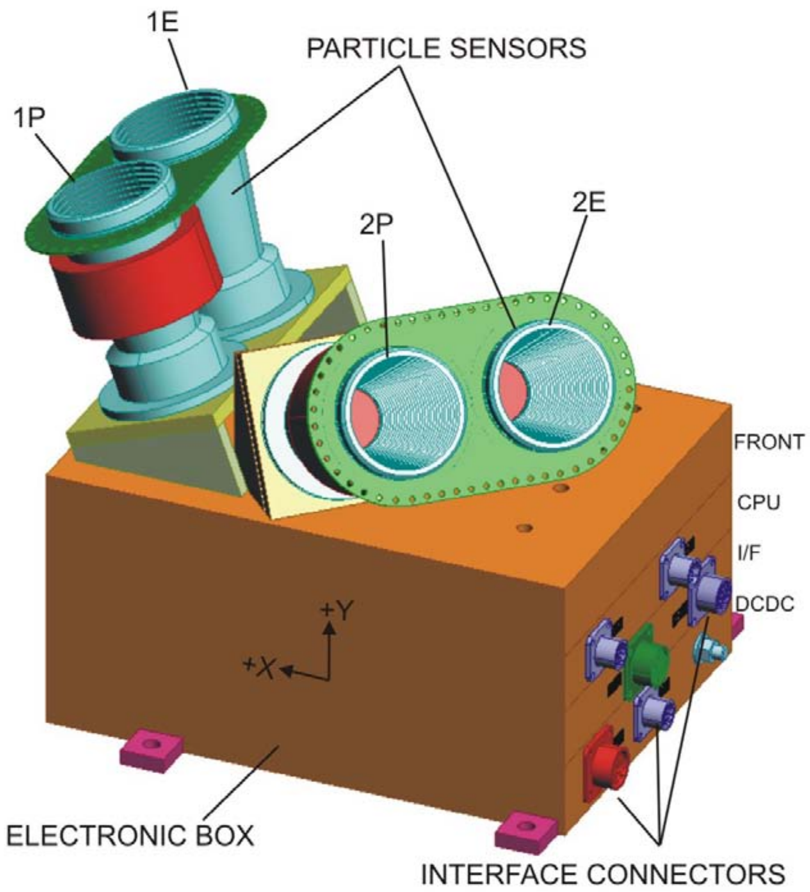

Figure 2. MEP-2 mechanical design (virtual version).

Figure 3a. Photo of the MEP-2 / FM (back-panel view).

Figure 3b. Photo of the MEP-2 / FM (front-panel view)

2.2 PLUG-IN MODULES

There are four plug-in modules inserted in dedicated slots of the MEP-2 box:

- **DC/DC** converter module with the XH7 connector (power 27V, RS-10 type), the XH8 connector (power control, MR1-10 type) and the grounding stud (screw M5) on the module interface panel. The DCDC module includes also analog circuitry dedicated for housekeeping data acquisition.
- **I/F** (analog data and command interface) module with the XH9 connector (Commands, MR1-30 type) and XH10 connector (Analog telemetry, MR1-19 type) on the module interface panel. The module includes also inflight test generator.
- **CPU** module with the ME2 connector (RS-422 data output, MR1-10 type) on the module interface panel. The module includes also stack of the event counters, the DAC and ADC.
- **FRONT**-end electronics module has no connector on the front panel, the sensors are connected to the module PC-board by the shortest way - via MICROCLIC coaxial connectors. There are special holes on the top panel of the box to lead the coaxial cables/connectors. The front module is separated from other modules by additional aluminum shielding baffle.

Each of modules consists of aluminum interface panel, two-sided epoxy fiberglass PC-board dimension of 170 x 125 x 1.5 mm equipped with the FRB-62 edge connector. The modules are electrically interconnected by the motherboard that is fixed on the back wall of the box. The motherboard is also performed as two-sided PC-board. All the PC-boards are metalurgically covered by Sn60Pb38Cu2 alloy layer and finalized by conformal coating layer. More heavy components are additionaly fixed by silicon rubber Dow Corning RTV-3140 and flexible structural epoxy glue Scotch Weld 2216B/A. Mechanical fastening of the PCBs is provided by interface panels, box grooves and motherboard edge connector. Anti-vibration cylindrical spacers are placed in the PCB centers, an additional long screw (90mm) is passing all the PCB spacers throughout the box and fastening them together in the middle points. The MEP-2 mechanical design guarantees excellent mechanical stiffness and high mechanical resonance frequencies.

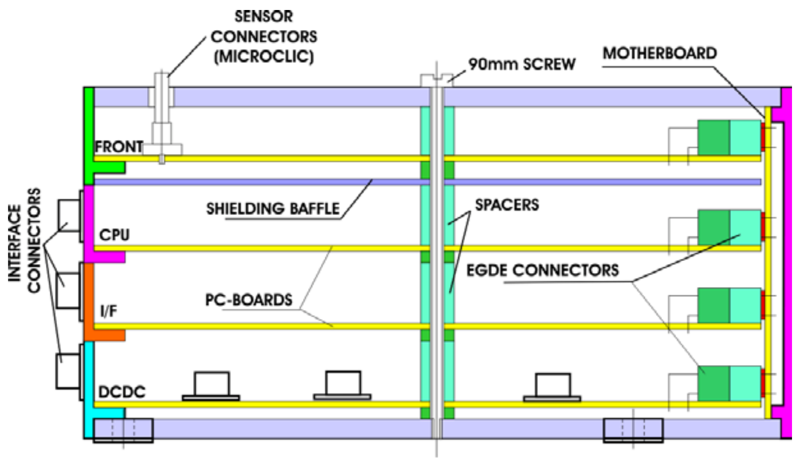

Figure 4. Internal mechanical structure of the electronic box

2.3 SENSOR SYSTEM

The sensor system consists of the axial type PIPS detector mounted in collimator. The detector is insulated against the collimator body, cable connection is performed by the MICRODOT connector. The body of the collimator is manufactured of duraluminum, the internal surface is serrated with black absorbing surface treatment to supress particle reflections. The ion sensors (1P, 2P) are equipped with the NdFeB broom magnets with a magnetic yoke, the electron sensors are equipped with a mylar foil fixed over the detector entrance. External surfaces are finished by IRIDITE process. Each sensor system is equipped with red-color protection cup, which must be discarded before the flight. The sensors are equipped with special collars, where MLI can be fixed (e.g. by sewing). The geometrical factor of each particular sensor is 0.77 cm^2.ster.

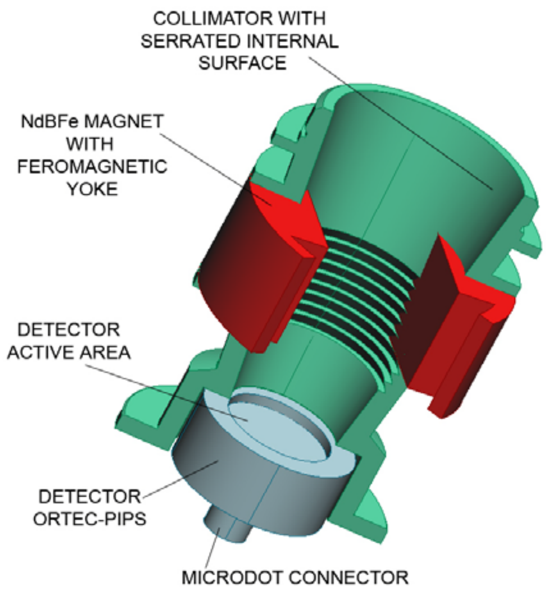

Figure 5a. Ion sensor cross section

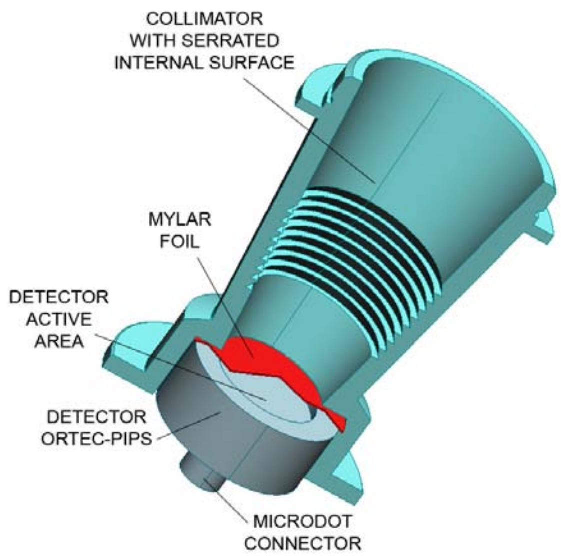

Figure 5b. Electron sensor cross section

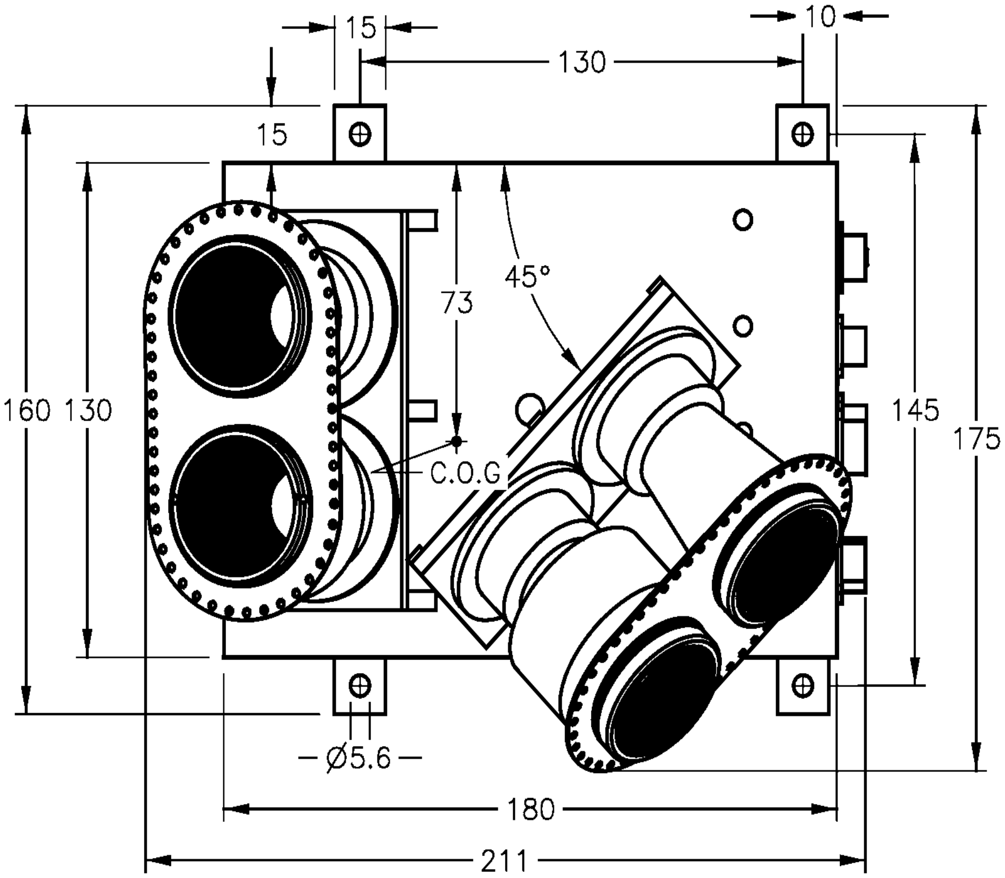

Figure 6a. MEP-2 Mechanical control drawing – top view

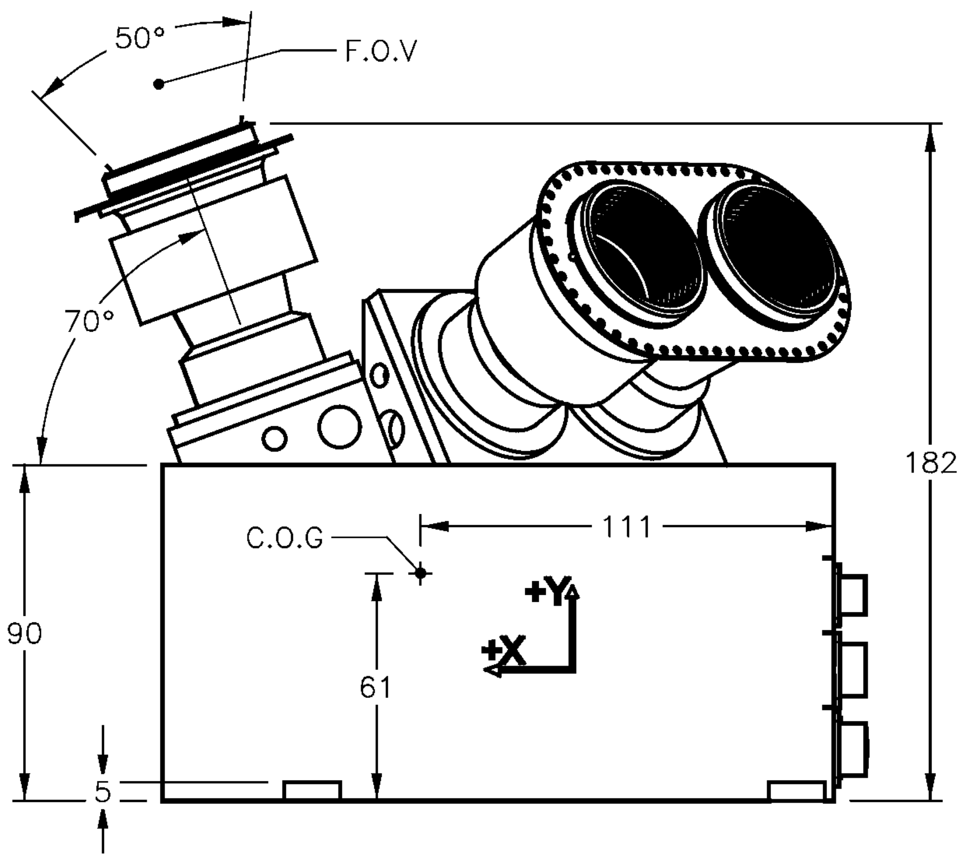

Figure 6b. MEP-2 Mechanical control drawing – side view

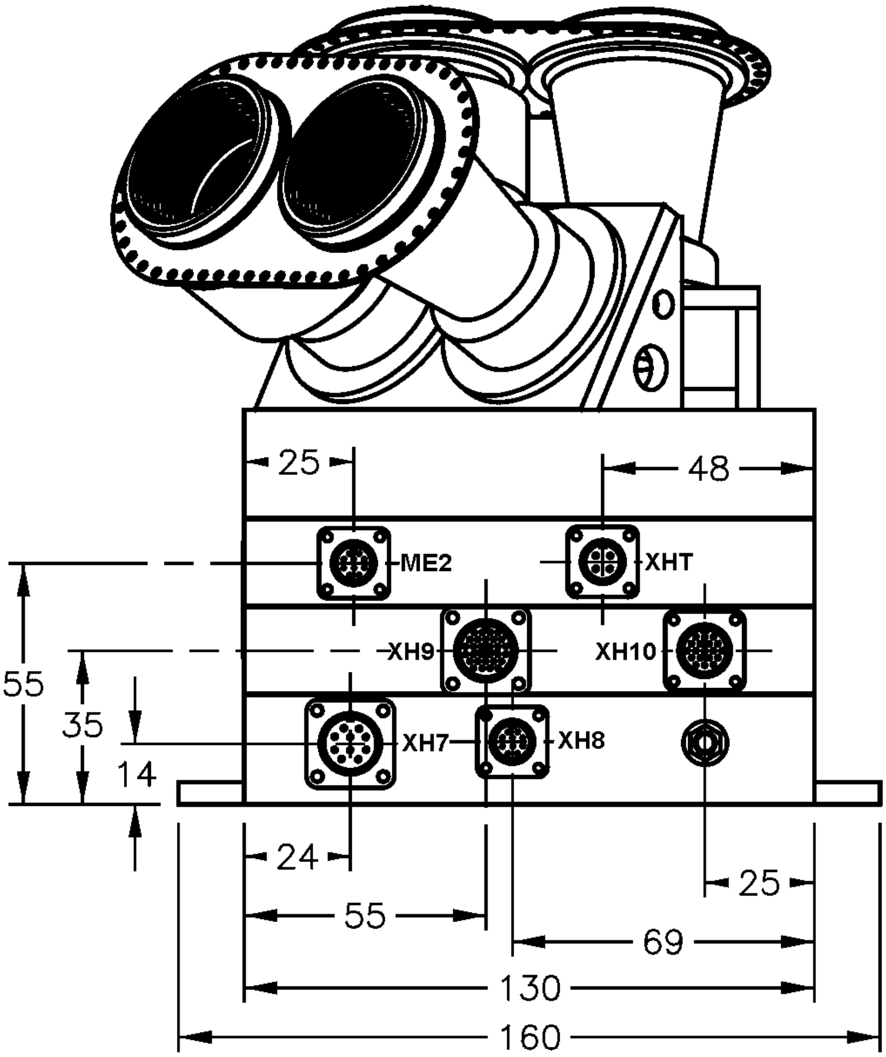

Figure 6c. MEP-2 Mechanical control drawing – back view

3 ELECTRICAL DESIGN

3.1 FUNCTIONAL BLOCK DIAGRAM

Functional diagram of the MEP-2 is illustrated in Fig. 7. Since MEP-2 incorporates 4 sensors, four practically identical analog channels are used. The charged particle, while penetrating through the detector depleted volume, produces a charge amount dependent on the particle energy loss. The detector output charge is converted to a voltage pulse by next stage - the Charge Sensitive Amplifier (CSA). Voltage / energy conversion ratio of the CSA used is 240mV/MeV for silicon detector. The CSA output voltage pulse is amplified by a Pulse Amplifier (PA) with gain of G=13.33, so that 3.2V/MeV is conversion ratio through entire analog channel. This value is a subject of an exact physical calibration. The output of the PA is supplied to both window discriminator and the integral count discriminator. The discrimination levels (thresholds) of the window discriminator are separately presettable by the Digital-to-Analog Converters (DAC). All the DAC-s are under flexibile software control from the Central Processor Unit (CPU). The discimination levels are set separately for protons (PL and PU) and for the electrons (EL and EU). Output of the Window Logic (WL) is supplied to Event Counter (EC). The EC is incremented always at each „positive event“, i.e. when particle energy fits to the current energy window. The integral count discriminator threshold is normally set to 30keV, so that all particles with energy >30 keV are registered by the integral counter (IC). The integral count discrimination level can be switched to the value of 60 keV by telecommand - e.g. in the case of excessive detector noise. Output pulses of the integral discriminators can be also registered directly by the telemetry system (critical redundancy). The EC and IC counters are under SW-control from the CPU as well (gating - readout - reset).

The count of the EC and the IC counters at defined registration discrimination levels and for defined registration period represents main scientific data source. Auxiliary data source is housekeeping information, where instrument operating voltages and temperature are included. Housekeeping information is acquired by an ADC with dedicated analog circuitry . All the data are compressed and formatted by the CPU and transmitted to the spacecraft telemetry system via serial interface in compliance with approved telemetry communication protocol.

The telecommands for the MEP-2 are received by serial command interface and executed by the CPU. The telecommands are used mainly for change of pre-defined operating modes of the instrument, moreover, new operating modes can be introduced to the MEP-2 during the flight by sending a block of telecommands.

The MEP-2 is powered by an insulated DC/DC converter, which produces all the necessary powering voltages. An interference (EMI) filter is inserted to the powering lines to suppress interference emission from DC/DC converter and - on other hand - to suppress interference injection to the MEP-2 from the spacecraft powering system.

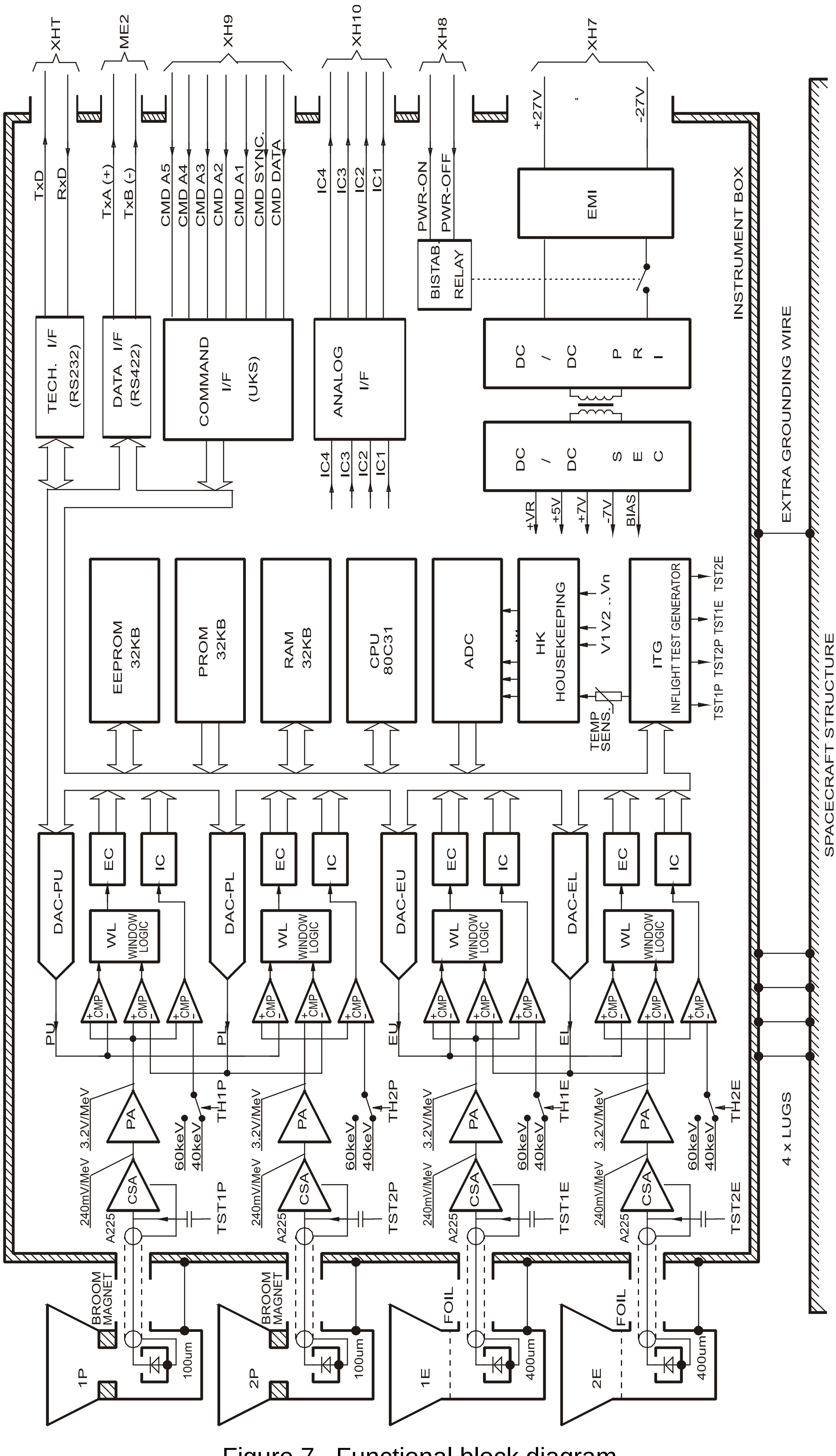

Figure 7. Functional block diagram

3.2 FRONT-END ELECTRONICS

Functional description of the front-end electronics is illustrated by simplified electrical scheme and timing diagram in Fig. 9. The scheme only describes one of the channels, others three channels are functionally identical.

The detector is biased from the bias source by high-resistance (10 MΩ) resistor and connected to the input of charge sensitive amplifier CSA (the AMPTEK A225) 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 pulse amplifier PA (HARRIS HA5114). The gain of the PA (approx. 13.33) is set during calibration to the value, which guarantees 3.2V/MeV conversion gain of entire analog channel. The typical shape of the signal on the analog channel output (if no overload) is also described in the scheme. The signal shape is defined by the A225 amplifier (which includes also shaping stage) and features 2.5 μs peaking time and approx. 7.5 μs decay time. The pulse amplitude is discriminated in window discriminator based on the MAXIM MAX908 comparators. The comparators drive window electonics based on the 4013, 4520, 4022 and 4011 CMOS integrated circuits. A special input FF (controlled by CPU) is introduced to disable upper discrimination theshold - while active, all events above lower threshold will generate an output pulse. Window logic operation is functionally described by a timing diagram in the same figure.

Detailed electrical scheme of the complete front-end electronics module is illustrated in Fig.10. Except of window logic mentioned above, also integral count (IC) discriminators are shown. The IC discriminators are based on the LM139 comparators. Basic discrimination level of the comparators is derived from precise bangap reference (2.50V) by resistor divider and corresponds to 30keV electrical threshold. The threshold can be shifted to 60keV by control bit (TH) from the CPU. As an analog switch the 4066 CMOS is used.

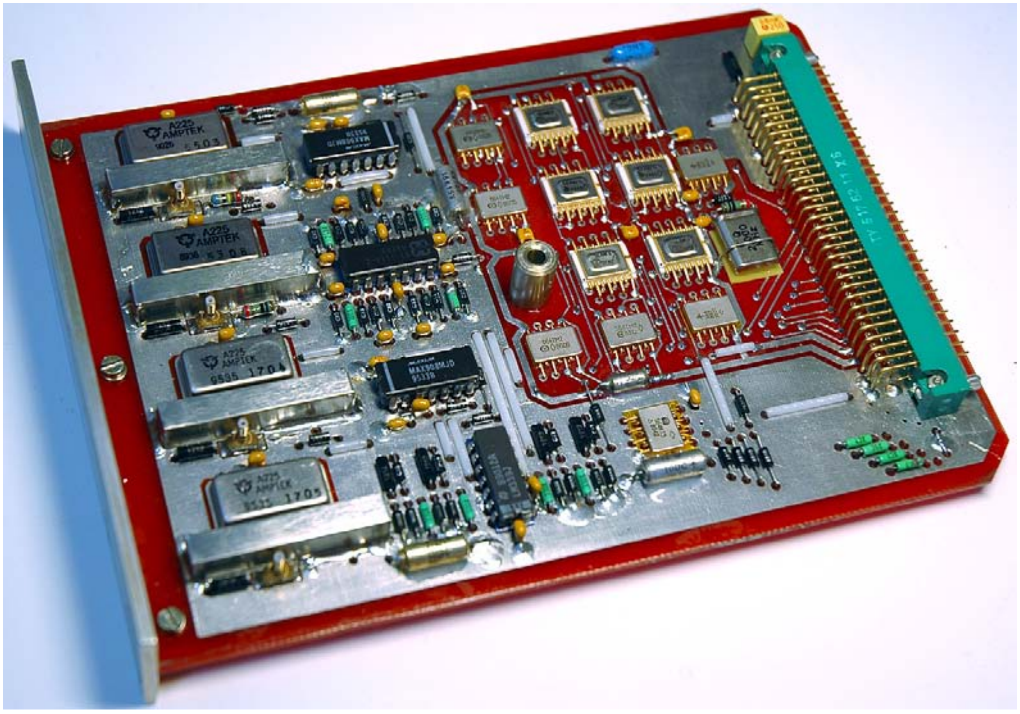

Figure 8. Front-end electronics plug-in module

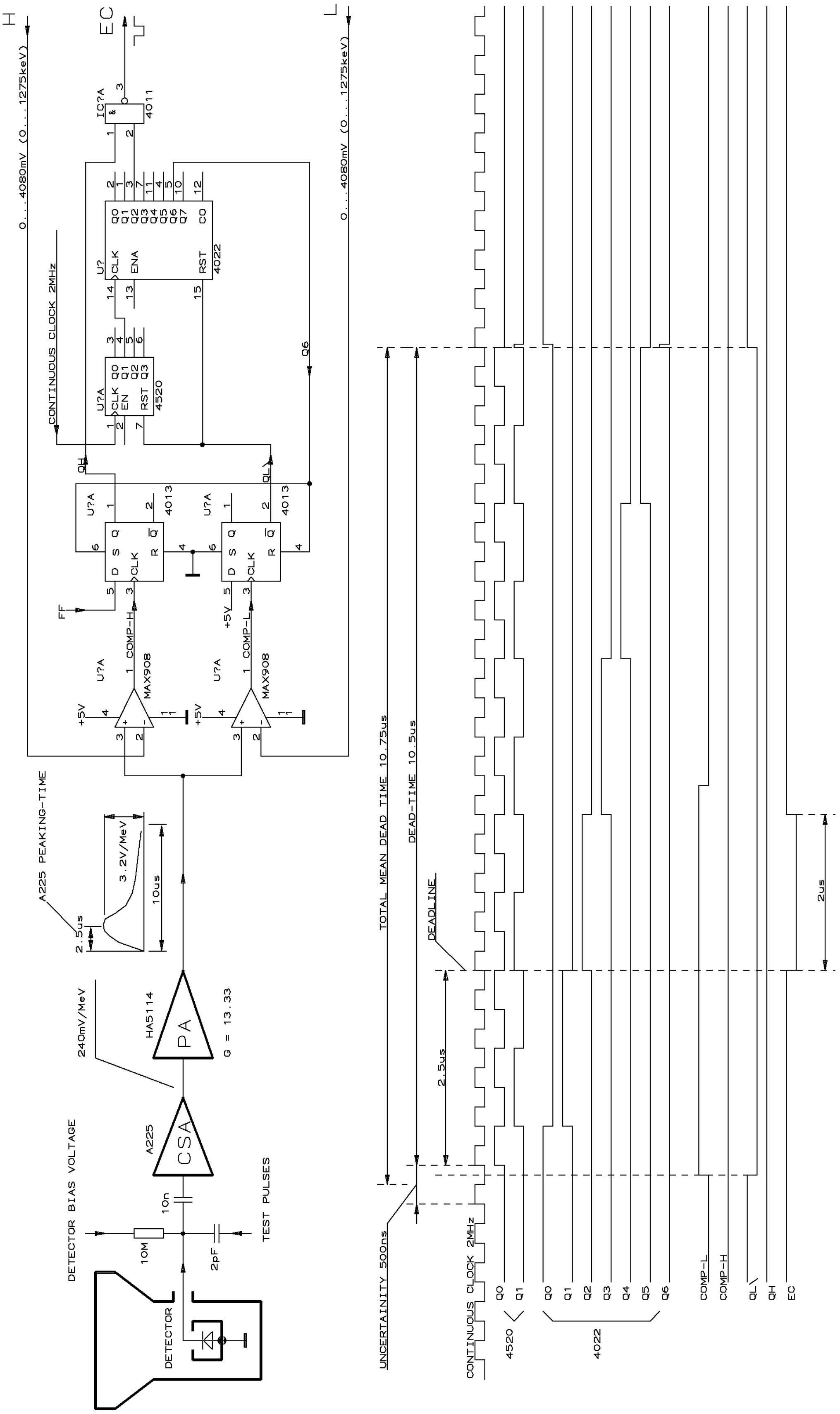

Figure 9. Functional description of the front-end electronics

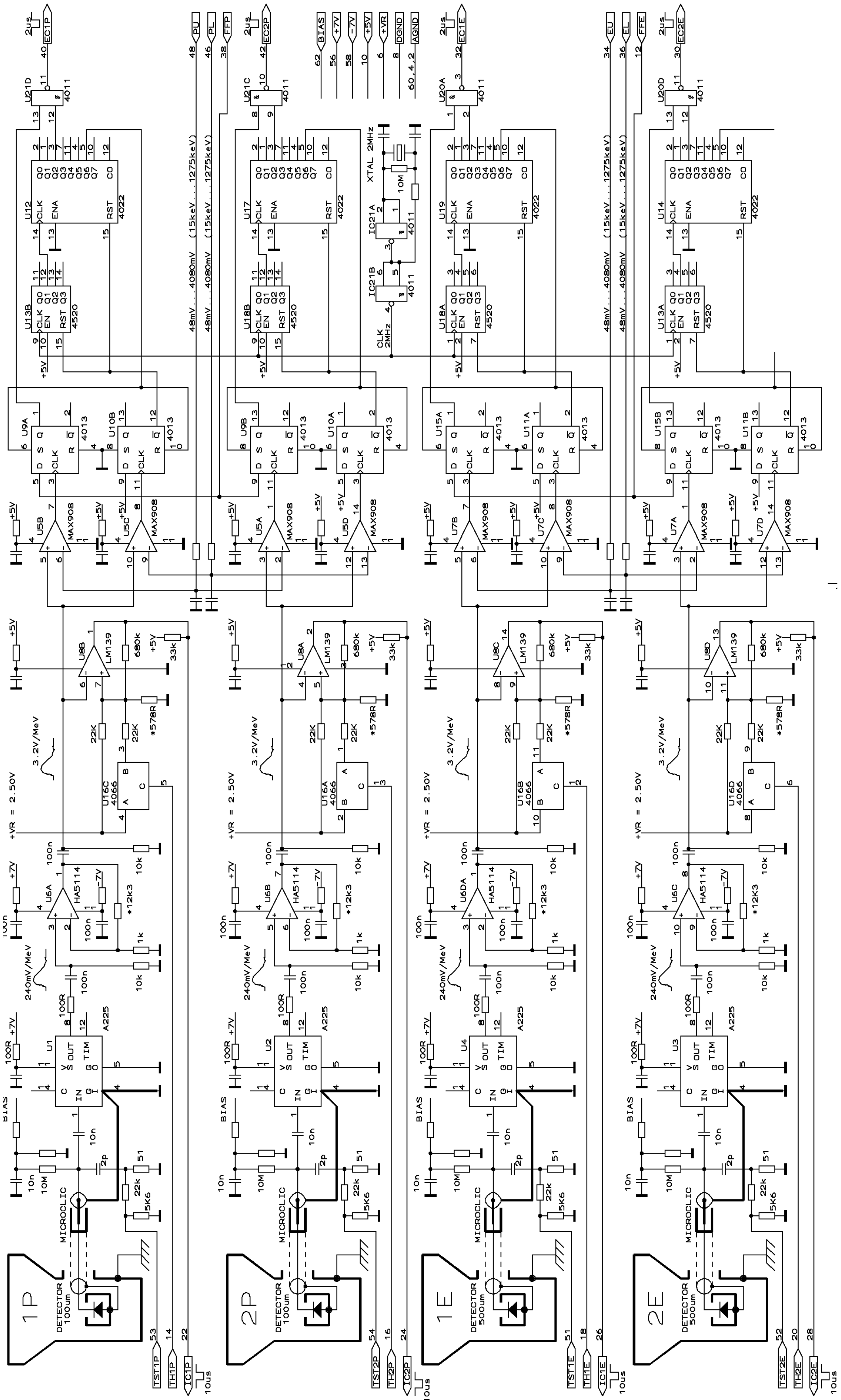

Figure 10. Detailed diagram of the Front-end electronics module.

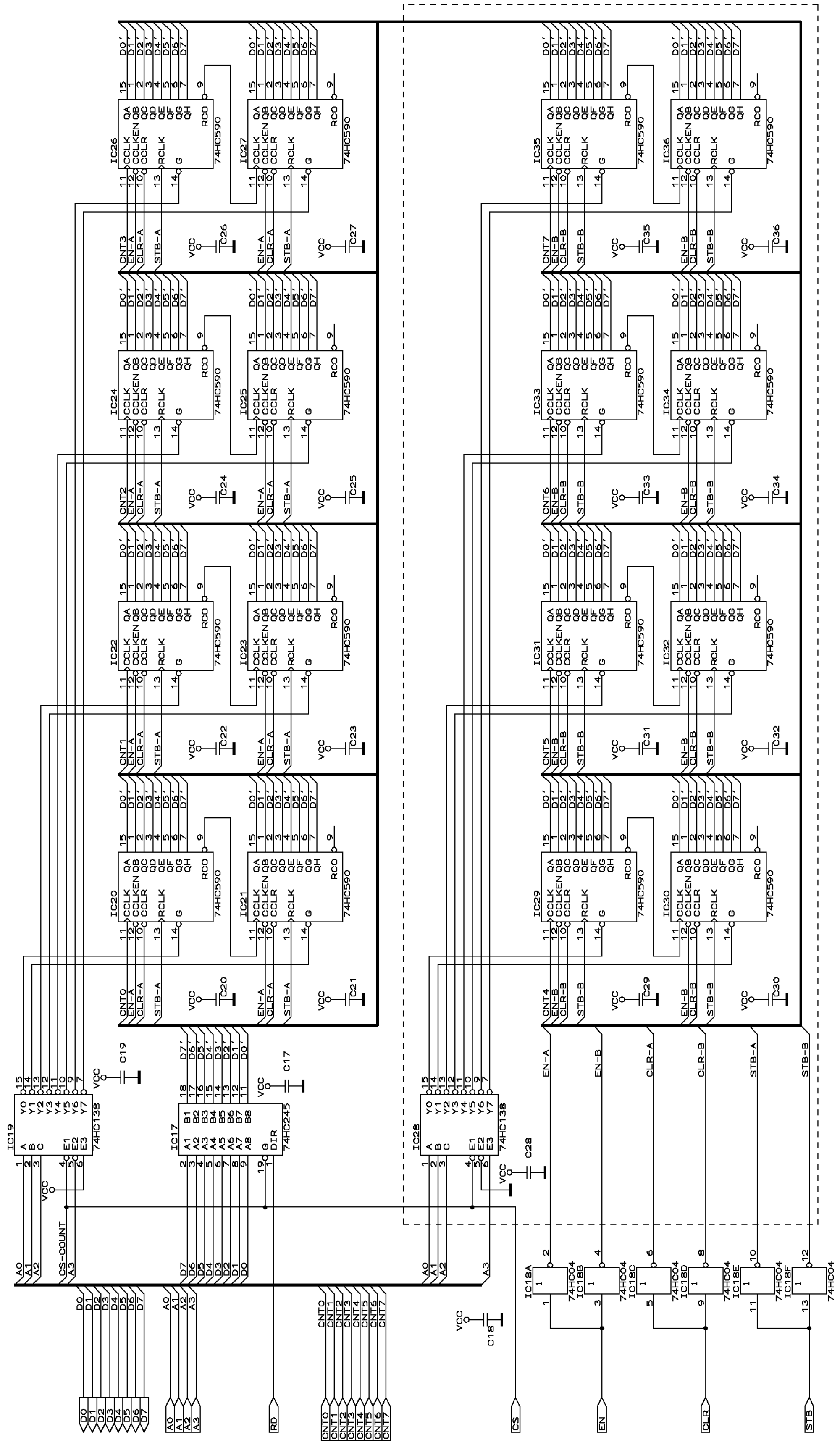

Figure 11. Event counters

3.3 EVENT COUNTERS

Detailed electrical scheme of the EC - IC counter block is illustrated in Fig.11. There are eight independent 16-bit counters, each of them is based on two pieces of 54HC590 CMOS (8-bit) integrated counters connected in the ripple mode. The counters are under software control from the CPU (gating-readout-reset). There is 54HC245 bidirectional bus driver used for the separation from the processor bus (to insure CPU fanout). The address decoder for the counters is based on the 54HC138 CMOS integrated decoders. The counters are physically placed on the CPU module.

3.4 CENTRAL PROCESSOR UNIT (CPU)

Detailed electrical scheme of the CPU unit is illustrated in Fig.12. The CPU is based on the 80C31 processor operating over 32kbyte RAM (62256 type), 32kbyte PROM (28C256 write protected) and 32kbyte EEPROM (28C256). The processor is synchronized by external quartz oscillator on 11.0592 MHz. Address latch is performed by 54HC573 CMOS latch chip. The address decoding is performed by common CMOS gates and 54HC138/139 integrated decoders. The MAX705 supervising chip performes watchdog function and power supply reset (threshold 4.65 V). The 54HC259 chip serves as bit-addressable output buffer. The CPU unit incorporates also MAX506 quad 8-bit D/A converter for the discrimination levels setting and also MAX186 8-input / 12 bit A/D converter (only 8-bit resolution used) for the housekeepind analog data acquisition. The D/A and A/D circuitry uses separate analog ground, connected to digital ground only on the system motherboard. The CPU software performes the following operations:

- discrimination levels setting
- readout of the scientific data from the EC and IC counters,
- readout of the housekeeping data
- data compression, formatting and transmission to the telemetry via s/c interface unit
- telecommand execution (change mode, inflight test on/off, etc...)
- debugging routins execution (via RS232 interface)

The output scientific data are transferred into the SSNI telemetry directly from the CPU plug-in module via RS422 interface and ME2 connector. The software operation description is out of frame of this document and is available as commented source code file in assembler ASM-51.

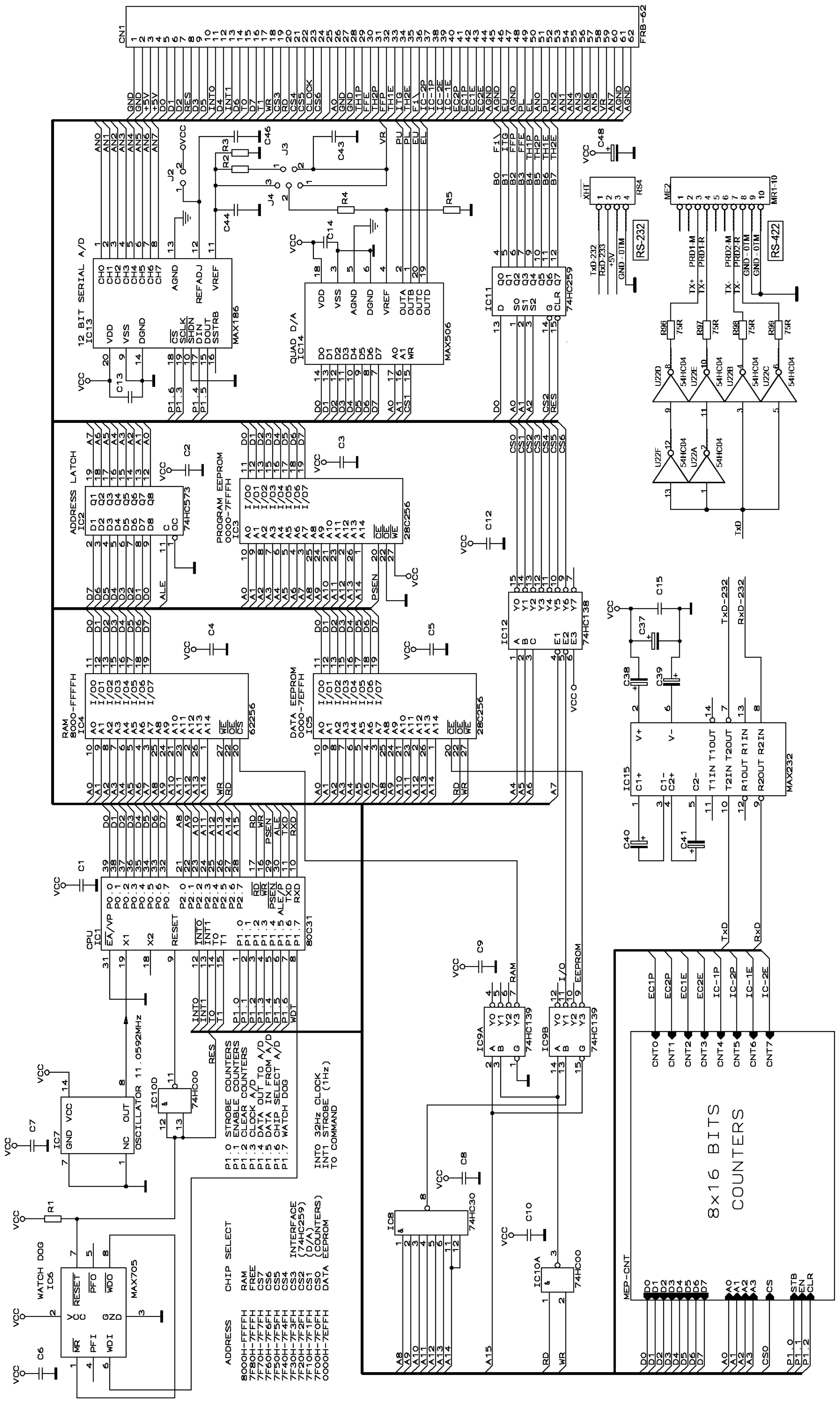

Figure 12. Central Processor Unit

3.5 COMMAND INTERFACE

Command interface (input) provides receiving of the telecommands (UKS) directly from the spacecraft system. There are serial 16-bit telecommands adopted for the MEP-2 (lower 16bits of a standard 30-bit UKS). The interface is based on line circuitry (564LN2) followed by 16-bit serial-in / parallel-out shift register (4 × 4015 CMOS + 2 × 54HC573 CMOS). For synchronized transfer of the telecommands to the MEP-2, following signals are used:

- CMD A1-A5 5-bit command strobe (UKS 1…5)
- CMD DATA command data ,16bit, MSB first, (UKS informat)
- CMD SYNC command synchronization (UKS synchr.)

3.6 ANALOG OUTPUT INTERFACE

The analog interface (output) provides transfer of redundant analog scientific data into the spacecraft analog telemetry. The interface provides information for integral particle intensity of the particular sensors. The information is passed into an independent analog telemetry of the Spektr-R spacecraft, thus a backup information is provided in the case of the instrument CPU or SSNI telemetry malfunction. The information for analog channels is derived by a dedicated hardware directly from the integral discriminators and completely baypasses the nominal scientific data chain (i.e. Counters – CPU – RS422 – SSNI). The conversion between the interface output voltage and incoming integral particle flux intensity is depicted by the plot:

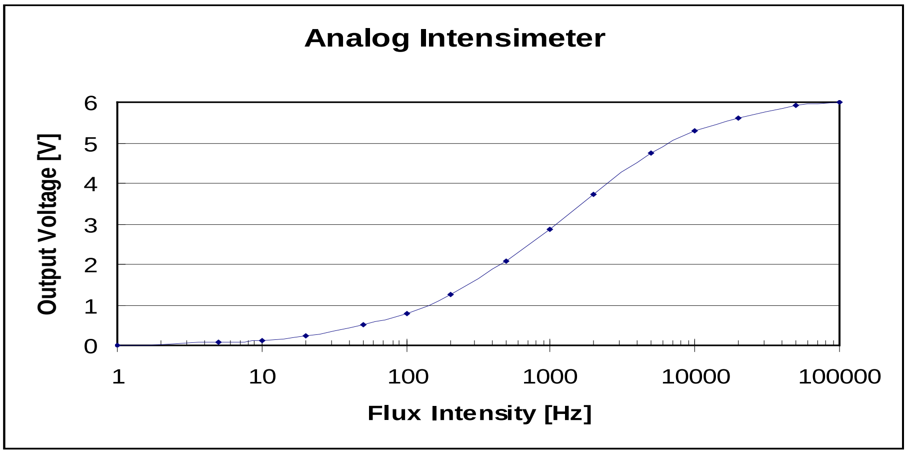

Figure 13. Plot Voltage vs. Intensity of the Analog intensimeters

The particle intensity readout from the Analog output interface is governed by a formula:

$$I = 16736 \frac{V_{out}}{1 - 64.\ln(0{,}16736.V_{out})}$$

where I is the particle intensity in respective detection channel in counts per second and V_{out} is the voltage readout on the Analog interface output in Volts.

3.7 INFLIGHT TEST GENERATOR (ITG)

Composite mode: The generator is activated by a single dedicated telecommand (F1XY – see command list) and performs particle simulation by a charge injection to the CSA inputs. The particles simulated are monoenergetic with energy of 100 keV and the frequency 10240 Hz. The ITG automatically switches the simulation for each front-end channel separately with the period of 0.256 second, synchronized with the frame generation, so that all the front-end analog channels are consequentially tested during one telemetry interval in following order:

0 - 256 ms	256 - 512 ms	512 - 768 ms	768 - 1024 ms
1P	2P	1E	2E

Specific mode: The ITG can be set by an individual telecommand (FCXY – see telecommand list) to inject a specified frequency to specified front-end channel(s).

D7	D6 D5 D4	D3	D2D1	D0	
STG	Frequency	2E	1E	2P	1P
0=off	000 =40Hz	0=off	0=off	0=off	0=off
1=on	001= 80Hz	1=on	1=on	1=on	1=on
	010=320Hz				
	011=640Hz				
	100=1280Hz				
	101=2560Hz				
	110=5120Hz				
	111=10240Hz				

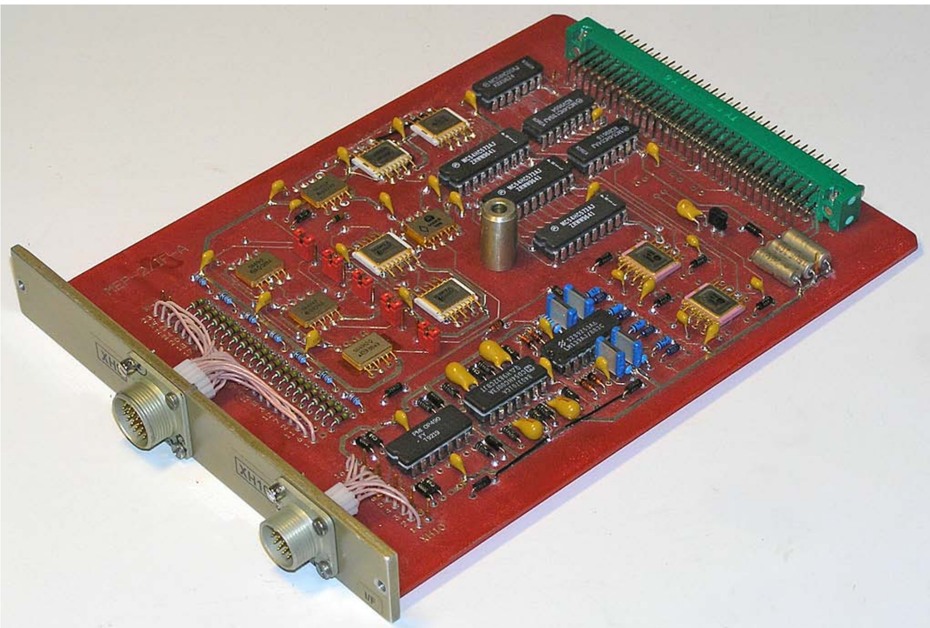

Figure 14. I/F electronics plug-in module (Commands, Analog outputs, Inflight test generator)

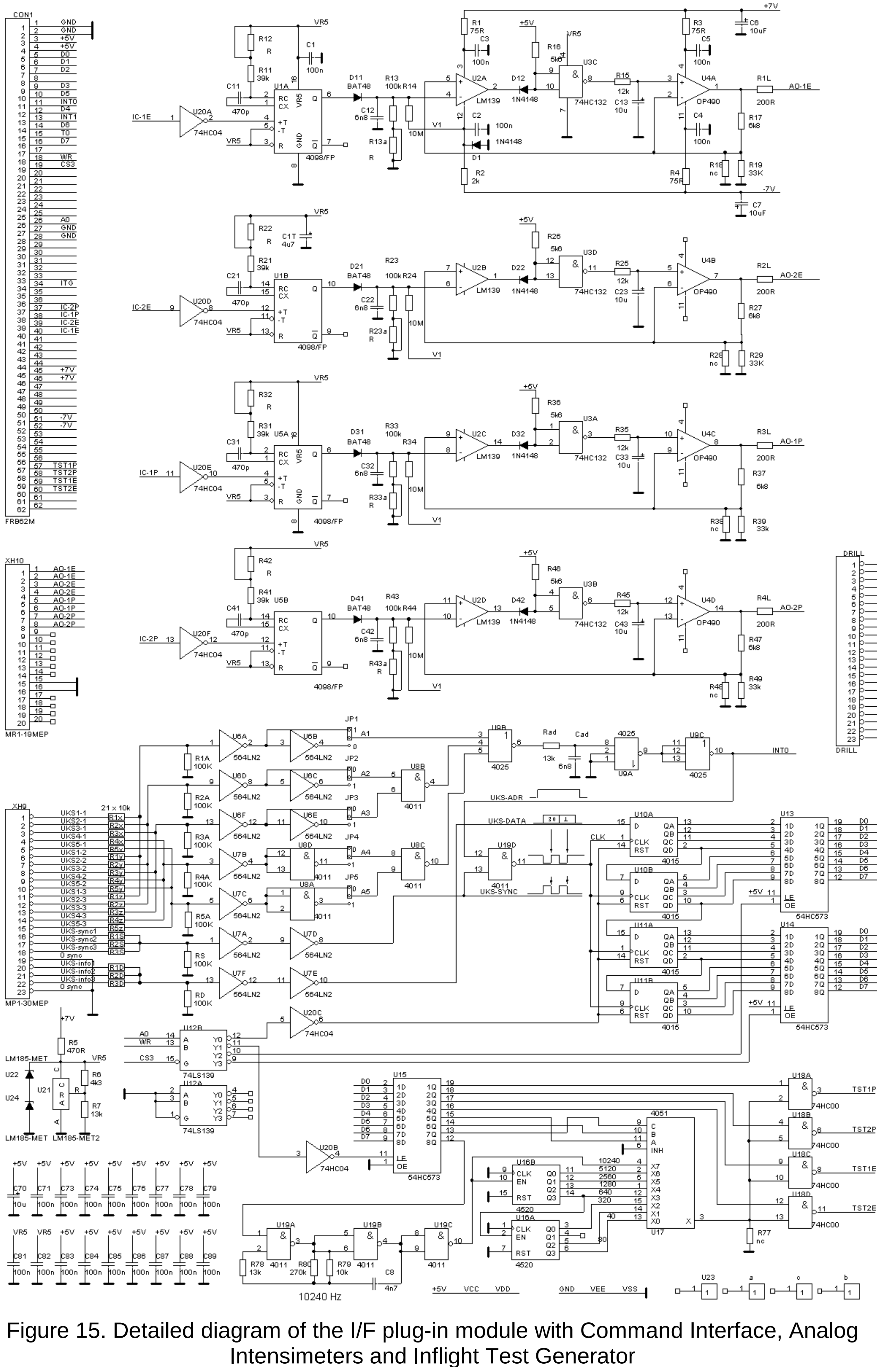

Figure 15. Detailed diagram of the I/F plug-in module with Command Interface, Analog Intensimeters and Inflight Test Generator

The powering of the MEP-2 is performed by fully insulated DC/DC converter, working in flyback operation mode with current mode pulse-width modulation. The converter operates at frequency 100kHz. Acceptable input voltage is in the range 15-35V, total efficency is about 75%. The converter output voltages are as follows:

- +5V for the digital electronics powering
- +7V for the analog electronics powering
- -7V for the analog electronics powering
- +2.50V a precision bandgap reference voltage
- +50V detectors bias voltage

A detailed electrical scheme of the DC/DC is illustrated in Fig.14. An common-mode EMI filter is placed immediately by input (PWR) connector. The polarity protection is performed by a Schottky diode. The converter primary side is galvanically fully insulated from the rest of MEP-2 electronics. Powering of the primary side circuitry (6V) is derived from primary voltage by linear regulator (MAA723 type). The oscillator and RS flip-flop is based on the 54HC132 Schmitt gates. The oscillator runs on 100kHz frequency with 3% duty cycle and on the begining of each period sets the RS flip-flop. The RS switches power HEXFET (2N6788) to on-state through transistor booster (2N2222 + 2N2907). The current across primary winding of the transformer arises linearly with the time and is monitored by a small resistor (1.5 Ω). When the current exceeds the threshold of the MAX907 comparator, the RS flip-flop is turned back and the duty period of the cycle is terminated. The threshold of the comparator is controlled by optical feedback (via optocoupler) from the converter secondary side. Another MAX907 comparator performes soft-start function, its threshold exponentially arises from the moment of power-on - from zero to 0.6V with the time constant of 90ms.

The secondary voltages are generated by transformer secondary windings equipped with dedicated rectifiers and filters. The +5V secondary voltage is monitored by analog circuitry and stabilized via optical feedback to the primary side of the converter. As reference for the stabilization and also for external use (+2.50V) there is a precision bandgap reference chip (LM185) used.

3.9 HOUSEKEEPING ANALOG CIRCUITRY

The housekeeping analog circuitry provides accomodation of monitored technical parameters of the MEP-2 to the voltage range, suitable for the A/D converter. Voltage range of the ADC is defined by its internal reference 4096mV, so that input voltage range 0 - 4080mV is converted to the 0 - FF_{hex} output code. The housekeeping analog data include following parameters:

- VB ... made by resistor divider (attenuation koef. = 0.016) from the bias voltage

- V+ ... made by resistor divider (attenuation = 0.33333) from +7V power. voltage
- V5 ... made by resistor divider (attenuation = 0.5) from +5V powering voltage
- V- ... made by active inverter (gain = - 0.33333) from -7V powering voltage
- TEMP ... made by AD590 integrated temperature sensor and a special analog circuitry, which linearly converts input temperature range -80...+80deg to the output voltage range of 0...4V.
- VR - the precision bandgap reference +2.50 V is monitored directly.

The detailed HK circuitry is included in Figure 17.

Figure 16. Powering (DC/DC) and Housekeeping plug-in module

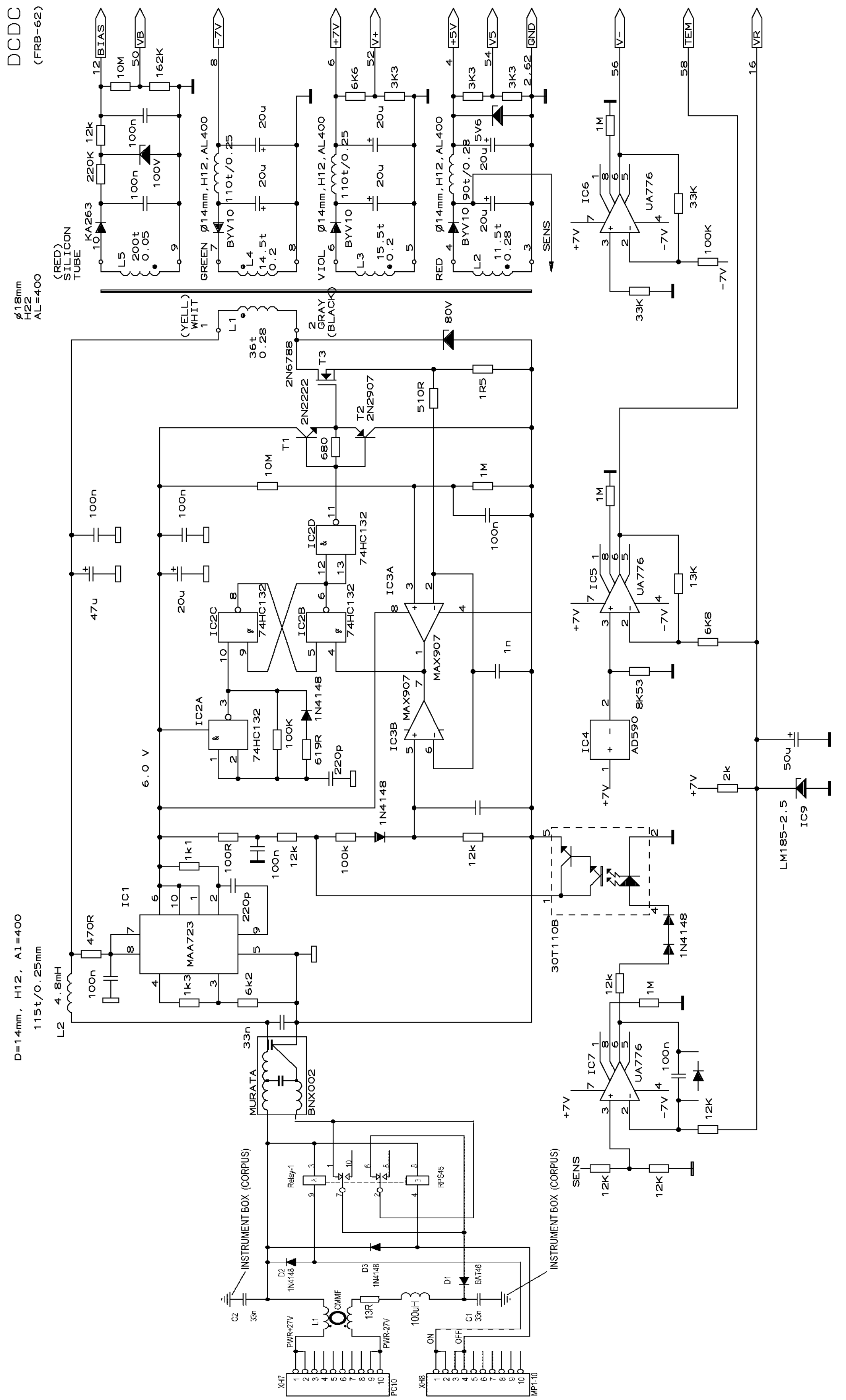

Figure 17. Detailed diagram of Powering (DC/DC) plug-in module

3.10 INTERFACE CONNECTORS

XH7 (RS-10)	
1	+27V
2	+27V
3	-
4	-
5	-
6	-
7	-
8	-
9	-27V
10	-27V

XH8 (MR1-10)	
1	MEP-ON
2	MEP-ON
3	MEP-OFF
4	MEP-OFF
5	-
6	-
7	-
8	-
9	-
10	-

XH9 (MR1-30)	
1	CMD A1-1
2	CMD A2-1
3	CMD A3-1
4	CMD A4-1
5	CMD A5-1
6	CMD A1-2
7	CMD A2-2
8	CMD A3-2
9	CMD A4-2
10	CMD A5-2
11	CMD A1-2
12	CMD A2-2
13	CMD A3-2
14	CMD A4-2
15	CMD A5-2
16	CMD SYNC 1
17	CMD SYNC 1
18	CMD SYNC 1
19	0 TM
20	CMD DATA 1
21	CMD DATA 1
22	CMD DATA 1
23	0 TM
24	-
25	-
26	-
27	-
29	-
29	-
30	-

XH10 (MR1-19)	
1	IC-1E
2	IC-1E
3	IC-2E
4	IC-2E
5	IC-1P
6	IC-1P
7	IC-2P
8	IC-2P
9	-
10	-
11	-
12	-
13	-
14	-
15	0TM
16	0TM
17	-
18	-
19	-

ME2 (MR1-10)	
1	-
2	-
3	TxAM
4	TxAR
5	-
6	-
7	TxBM
8	TxBR
9	0 TM
10	0 TM

XHT (RS-4)	
1	TxD
2	RxD
3	+5V
4	0 TM

Note:
TxAM (+) with TxBM (-) create the Main data output (balanced RS422 line),
TxAR(+) with TxBR(-) create an independent, identical Redundant data output.

Table 1. Specification of the MEP-2 interface connectors
(the XHT is a Technological connector)

4 OPERATIONAL DESCRIPTION

4.1 TELEMETRY MODE

There is only one telemetry mode agreed for MEP-2 with constant data flow of 1148bit/s. The data are organized in uniform frames size of 147 byte. The data transfer to the SSNI telemetry is asynchronous, the instrument provides one frame per 1.024 second by its own internal timing. The real onboard time reference data is only added in the SSNI telemetry. In the interest of data transfer reliability and electromagnetic compatibility (EMC), an unidirectional RS422 serial interface (balanced twisted pair) is provided for the data transfer.

4.2 REGISTRATION MODE - THE DLT

Each telemetry interrogation period TT (1.024 second) is divided into 32 equal registration periods TR1...TR32, so that each registration period TRi lasts 32 msec. The current registration mode of the MEP-2 is defined by current (active) discrimination level table (DLT), which defines PL, PU, EL, EU threshold setting separately for each registration period, so that DLT is organized as a table with 32 lines and 4 columns:

TRi	PLi	PUi	ELi	EUi
1	PL01	PU01	EL01	EU01
2	PL02	PU02	EL02	EU02
3	PL03	PU03	EL03	EU03
.		...		
32	PL32	PU32	EL32	EU32

where:

PL = Proton (ion) Lower discrimination level

PU = Proton (ion) Upper discrimination level

EL = Electron Lower discrimination level

EU = Electron Upper discrimination level

Each item (1 byte) of the DLT represents threshold setting value in the linear range of 35...1270 keV (07... FE_{hex}) with the minimum step of 5 keV. Except of that, for the PU (EU) setting can be a special value 1275keV (FF_{hex}) used - in this case the upper discrimination threshold is not 1275 keV, but it is disabled and all events exceeding current PL (EL) threshold are registered. The lower limit (35keV) is determined by technical limitations due to detector and analog channel noise level.

At the beginning of the registration period TRi the CPU reads the PLi, PUi, ELi, EUi values (4 bytes) from the actual DLT and sets the thresholds of the window discriminators by DAC. The thresholds are constant during whole registration period (32ms) and number of the positive events is registered by event counters. The count is read-out by the CPU at the end of the registration period, then counters are reset and a new registration period starts (generally with new thresholds).

There is possibility to pre-programm 128 different DLT tables (DLT0...DLT127) in the PROM and 127 (DLT128...DLT254) in the EEPROM memory of the CPU. While DLT0...DLT127 are permanently fixed already during pre-launch operation, the DLT128...DLT254 can be moreover edited also during the flight by the telecommands. The DLT0 is „default“ and is activated allways after power-on of the MEP-2. Any DLT can be activated (set as current) by a single telecommand. Index of current DLT determines the MEP-2 current operation mode. The same index is used as a frame mode (FM) byte and is placed at the first position of the MEP-2 output data frame.

Table 2 shows four examples of the DLT definition (although with impractical values due to real noise level of the large-area detectors used):

- Operating mode „PQ“ represents registration in one energy range 20 - 100 keV with full time resolution (32 samples / second) for protons. The same time resolution is for electrons, but in energy range 35 - 225 keV.
- Operating mode „QR“ represents an opposite extrem - 32 channel energy analysis of ions in the range 20...340 keV with 10 keV channel width. The same is implemented for electrons, but in the range 15...175 keV and 5keV channel width. This operating mode is practically usable only for quite high particle intensities, since narrow channels cannot acumulate statistically significant number of events during 32 ms.
- Operating mode „RS“ - in this mode 8-channel pulse-height analysis is implemented for the ions (20-30-40-50-70-100-140-200-800 keV) and 4-channels analysis is implemented for the electrons (20-50-100-200-300 keV).
- Operating mode „ST“ represents more special mode. The ions are sampled for 28 registration periods in the same energy range 15 - 80 keV (full time resolution), while during last four periods a quick energetic analysis of higher energies is implemented. The „1275 keV“ used as the last threshold has a special meaning (inhibits PU threshold), i.e. during TR32 all particles over 500keV are registered. Similar mode is used for electrons, but it is repeated 2-times per second and only with 2-channel analysis (100-200-350 keV) after high time resolution sequence.

The examples show unusual flexibility in use of the MEP-2. It is up to all participants of the experiment and their scientific goals, how to define the operating modes. The problem of coarse is - that the MEP-2 can only work in one operating mode at the same time.

4.3 DATA PROCESSING AND FORMATTING

Because the entire telemetry period TTn is fully occupied by the registration intervals TR1...TR32, data from this period are processed and formatted during next telemetry period TTn+1 and transmitted to the telemetry at the beginning of the TTn+2 period. Because the SSNI adds the onboard time code (OBT) related to the time of the data transmission, there is constant time shift (2.048 seconds) between real beginning of the registration and the accompanying OBT.

Data from integral counters IC are accumulated for entire TT (1.024 sec) and are truncated at the end of the frame (4 bytes).

4.4 *DATA FRAME STRUCTURE (147 byte).*

4.4.1 Standard frame

ID1	Fixed identifier $4D_{hex}$ = M (ASCII)
ID2	Fixed identifier 45_{hex} = E (ASCII)
ID3	Fixed identifier 50_{hex} = P (ASCII)
ID4	Fixed identifier 32_{hex} = 2 (ASCII)
FM	Frame mode (00...FE) = index of current DLT
HK1	Digital status byte (see table)
HK2	STG status
HK3	Reserve (fixed value AB_{hex})
HK4	Housekeeping data Vbias = 1.0 * val(HK4) [V]
HK5	Housekeeping data V+ = 0.048 * val(HK5) [V]
HK6	Housekeeping data V5 = 0.032 * val(HK6) [V]
HK7	Housekeeping data V- = -0.048 * val(HK7) [V]
HK8	Housekeeping data Temp = 0.64 * val(HK8) – 80 [°C]
HK9	Housekeeping data Vref = 0.016 * val(HK9) [V]
1P01 2P01 1E01 2E01	count during TR01; thresholds PL01, PU01, EL01, EU01
1P02 2P02 1E02 2E02	count during TR02; thresholds PL02, PU02, EL02, EU02
1P03 2P03 1E03 2E03	count during TR03; thresholds PL03, PU03, EL03, EU03
...etc…	...
1P32 2P32 1E32 2E32	count during TR32; thresholds PL32, PU32, EL32, EU32
IC1P IC2P IC1E IC2E	integral count (for whole telemetry period TT = 1 sec.)
CSM	checksum (XOR operation over all the bytes)

All data bytes (except ID, FM and HK) represent count of the positive events during respective registration period with thresholds set according to the current DLT and are processed 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.

4.4.2 Special frame (DLT download) :

ID1	Fixed identifier $4D_{hex}$ = M (ASCII)
ID2	Fixed identifier 45_{hex} = E (ASCII)
ID3	Fixed identifier 50_{hex} = P (ASCII)
ID4	Fixed identifier 32_{hex} = 2 (ASCII)
FM	Frame mode FF_{hex} – fixed value indicating spec. frame
HK1	Digital status (see table)
HK2	STG status
HK3	Reserve (Fixed value AB_{hex})
HK4	Housekeeping data Vbias = 1.0 * val(HK4) [V]
HK5	Housekeeping data V+ = 0.048 * val(HK5) [V]
HK6	Housekeeping data V5 = 0.032 * val(HK6) [V]
HK7	Housekeeping data V- = -0.048 * val(HK7) [V]
HK8	Housekeeping data Temp = 0.64 * val(HK8) – 80 [°C]
HK9	Housekeeping data Vref = 0.016 * val(HK9) [V]
XY	index of downloaded DLT (00...FE)
PL01 PU01 EL01 EU01	threshold values of the DLTXY (03...FF)
PL02 PU02 EL02 EU02	threshold values of the DLTXY (03...FF)
PL03 PU03 EL03 EU03	threshold values of the DLTXY (03...FF)
…etc...	...
PL32 PU32 EL32 EU32	threshold values of the DLTXY (03...FF)
PQ	actual DLT edit pointer (80...FE)
NU NU	not used

Each frame is accompanied (by addition in SSNI) with current spacecraft onboard time code.

The digital status byte (HK1) provides information for low/high thresholds of particular detectors and for on/off status of the Internal test generator as follows:

D7	D6	D5	D4	D3	D2	D1	D0	= LSB
0	0	0	0=off 1=on	0=low 1=high	0=low 1=high	0=low 1=high	0=low 1=high	(30keV) (60keV)
			ITG	TH2E	TH1E	TH2P	TH1P	

4.5 TELECOMMANDS

There are 16-bit telecommands used for the MEP-2 remote control. The command list is as follows (hexadecimal notation):

FFXY (XY=00...FE)	set DLT XY as current (set operating mode XY)
FEXY (XY=80...FE)	activation of DLT XY for edit (set edit pointer)
PQXY (PQ=00...7F, XY=03...FF)	set byte with index PQ to value XY (edit)
F0XY (XY=00...FE)	send DLT XY to telemetry (DLT download)
F1XY (XY=don't care)	inflight test generator ON (composite test)
F2XY (XY=don't care)	inflight test generator OFF
F3XY (XY=don't care)	set TH1P to low (30 keV)
F4XY (XY=don't care)	set TH1P to high (60 keV)
F5XY (XY=don't care)	set TH2P to low (30 keV)
F6XY (XY=don't care)	set TH2P to high (60 keV)
F7XY (XY=don't care)	set TH1E to low (30 keV)
F8XY (XY=don't care)	set TH1E to high (60 keV)
F9XY (XY=don't care)	set TH2E to low (30 keV)
FAXY (XY=don't care)	set TH2E to high (60 keV)
FBXY (XY= see table below)	set all status bits at once

D7	D6	D5	D4	D3	D2	D1	D0	
0	0	0	0=off 1=on	0=low 1=high	0=low 1=high	0=low 1=high	0=low 1=high	(30keV) (60keV)
			ITG	TH2E	TH1E	TH2P	TH1P	

FCXY (XY= see 3.7) Inflight generator ON with specific simulation

PQ OPERATING MODE

TR	PROTONS [keV] PL	PU	ELECTRONS [keV] EL	EU
1	20	100	35	225
2	20	100	35	225
3	20	100	35	225
4	20	100	35	225
5	20	100	35	225
6	20	100	35	225
7	20	100	35	225
8	20	100	35	225
9	20	100	35	225
10	20	100	35	225
11	20	100	35	225
12	20	100	35	225
13	20	100	35	225
14	20	100	35	225
15	20	100	35	225
16	20	100	35	225
17	20	100	35	225
18	20	100	35	225
19	20	100	35	225
20	20	100	35	225
21	20	100	35	225
22	20	100	35	225
23	20	100	35	225
24	20	100	35	225
25	20	100	35	225
26	20	100	35	225
27	20	100	35	225
28	20	100	35	225
29	20	100	35	225
30	20	100	35	225
31	20	100	35	225
32	20	100	35	225

QR OPERATING MODE

TR	PROTONS [keV] PL	PU	ELECTRONS [keV] EL	EU
1	20	30	15	20
2	30	40	20	25
3	40	50	25	30
4	50	60	30	35
5	60	70	35	40
6	70	80	40	45
7	80	90	45	50
8	90	100	50	55
9	100	110	55	60
10	110	120	60	65
11	120	130	65	70
12	130	140	70	75
13	140	150	75	80
14	150	160	80	85
15	160	170	85	90
16	170	180	90	95
17	180	190	95	100
18	190	200	100	105
19	200	210	105	110
20	210	220	110	115
21	220	230	115	120
22	230	250	120	125
23	250	240	125	130
24	240	260	130	135
25	260	270	135	140
26	270	280	140	145
27	280	290	145	150
28	290	300	150	155
29	300	310	155	160
30	310	320	160	165
31	320	330	165	170
32	330	340	170	175

RS OPERATING MODE

TR	PROTONS [keV] PL	PU	ELECTRONS [keV] EL	EU
1	20	30	20	50
2	30	40	50	100
3	40	50	100	200
4	50	70	200	300
5	70	100	20	50
6	100	140	50	100
7	140	200	100	200
8	200	800	200	300
9	20	30	20	50
10	30	40	50	100
11	40	50	100	200
12	50	70	200	300
13	70	100	20	50
14	100	140	50	100
15	140	200	100	200
16	200	800	200	300
17	20	30	20	50
18	30	40	50	100
19	40	50	100	200
20	50	70	200	300
21	70	100	20	50
22	100	140	50	100
23	140	200	100	200
24	200	800	200	300
25	20	30	20	50
26	30	40	50	100
27	40	50	100	200
28	50	70	200	300
29	70	100	20	50
30	100	140	50	100
31	140	200	100	200
32	200	800	200	300

ST OPERATING MODE

TR	PROTONS [keV] PL	PU	ELECTRONS [keV] EL	EU
1	15	80	15	80
2	15	80	15	80
3	15	80	15	80
4	15	80	15	80
5	15	80	15	80
6	15	80	15	80
7	15	80	15	80
8	15	80	15	80
9	15	80	15	80
10	15	80	15	80
11	15	80	15	80
12	15	80	15	80
13	15	80	15	80
14	15	80	15	80
15	15	80	100	200
16	15	80	200	350
17	15	80	15	80
18	15	80	15	80
19	15	80	15	80
20	15	80	15	80
21	15	80	15	80
22	15	80	15	80
23	15	80	15	80
24	15	80	15	80
25	15	80	15	80
26	15	80	15	80
27	15	80	15	80
28	15	80	15	80
29	80	150	15	80
30	150	250	15	80
31	250	500	100	200
32	500	1275	200	350

Table 2. Example of some operating modes

5 GROUND SUPPORT EQUIPMENT GSE-MEP-2

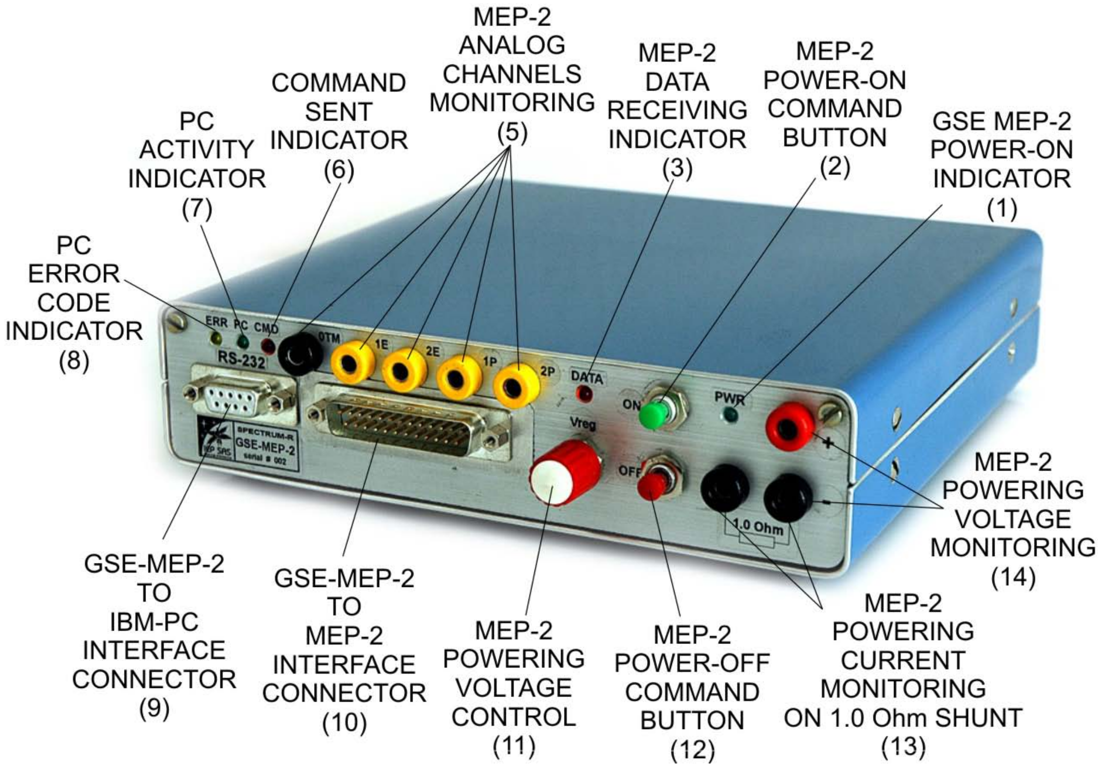

Fig. 18. Ground support equipment GSE-MEP-2

The GSE-MEP-2 consist of a single unit connected to the MEP-2 interface connectors by a dedicated cable. The unit incorporates:

- Powering simulator
- Functional commands (power ON/OFF) simulator
- UKS-digital command simulator,
- Digital data receiver
- Analog data monitoring.

For powering monitoring and analog data monitoring an external standard voltmeter (multimeter) is required (not supplied with the GSE).

5.1 POWER SIMULATOR

For autonomous „on-desk“ testing of the instrument functionality, the GSE-MEP-2 power supply provides a regulated DC voltage in the 16-35V range. The regulation is provided by a rotary knob on the front panel. The real powering voltage is monitored by a standard voltmeter (multimeter) on the dedicated front panel sockets. The real MEP-2 current consumption is monitored as a voltage drop on the 1.0 Ohm shunt resistor available on the front panel sockets.

5.2 FUNCTIONAL COMMAND SIMULATOR (POWER ON-OFF)

The simulator is performed by simple push-buttons that provide short connection of dedicated command lines to the negative socket of the powering simulator. The short connection of the command line provides turnover of the bistable polarized relay inside the MEP-2 instrument to required position.

5.3 DIGITAL COMMAND (UKS) SIMULATOR

The command simulator of the GSE provides sending of standardized UKS commands to the MEP. The simulator is under full control from the PC and will send a standard UKS automatically after receiving an appropriate character sequence via RS232 interface. The UKS command simulator is based on ATMEL AT90S433 microcontroller.

5.4 DIGITAL DATA INTERFACE

The only function that GSE provides with the data generated by the MEP-2 instrument is conversion of the physical levels from RS422 standard (balanced twisted pair) to RS232 standard (bipolar, unbalanced). The converted data are then supplied directly to the PC via RS232 interface. Note: The same data with RS232 levels are available on the XHT technological connector of the MEP-2 for direct monitoring by any standard PC equipped with COM (RS232) interface.

5.5. ANALOG CHANNELS INTERFACE

There is no automatized checkout of the analog channels voltage levels by the GSE. The check of the analog channels consist from measurement of the output voltages on the dedicated panel sockets with a standard multimeter while the input particle intensities are simulated by various frequencies from the STG generator.

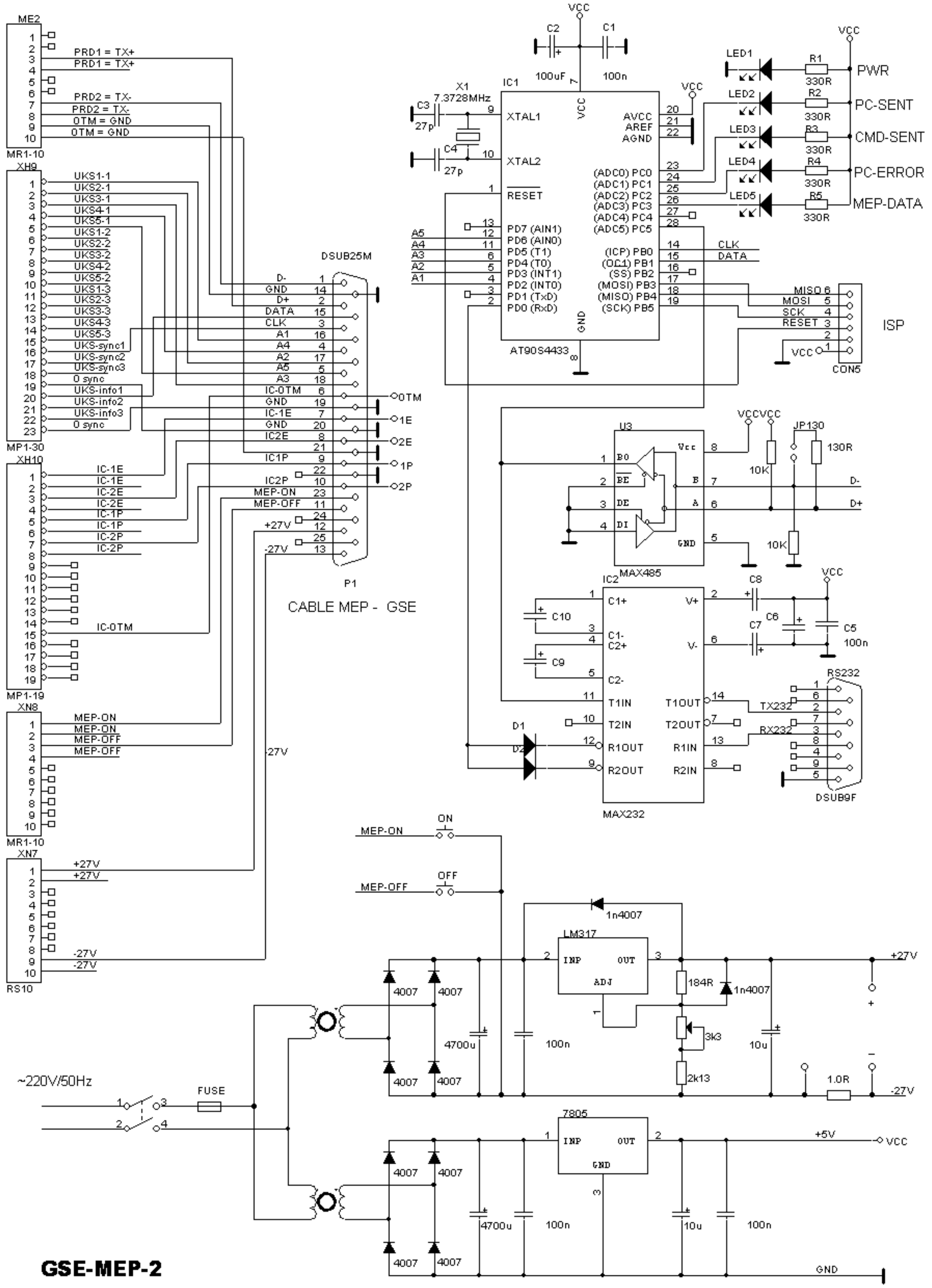

Figure 18. Detailed electrical diagram of the GSE-MEP-2

6. ON-DESK TESTING WITH THE GSE-MEP-2

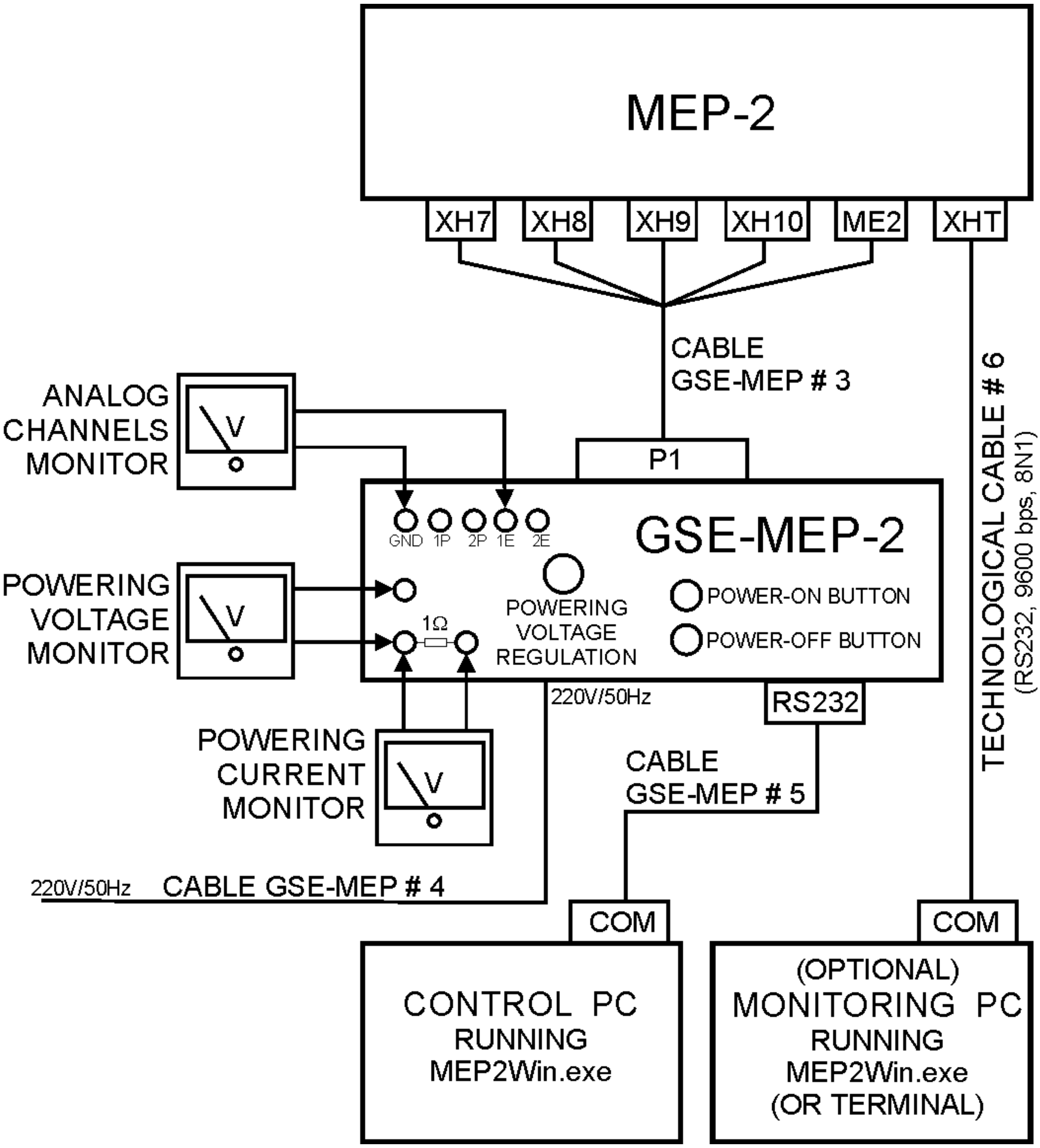

Figure 19. Working configuration for on-desk testing of the MEP-2

6.1 TESTING SOFTWARE MEP2Win.exe

The MEP2Win software runs under OS Windows and provides user comfortable graphic interface for receiving, recording and review of the recorded MEP-2 data and sending the UKS telecommands to the MEP-2 device.

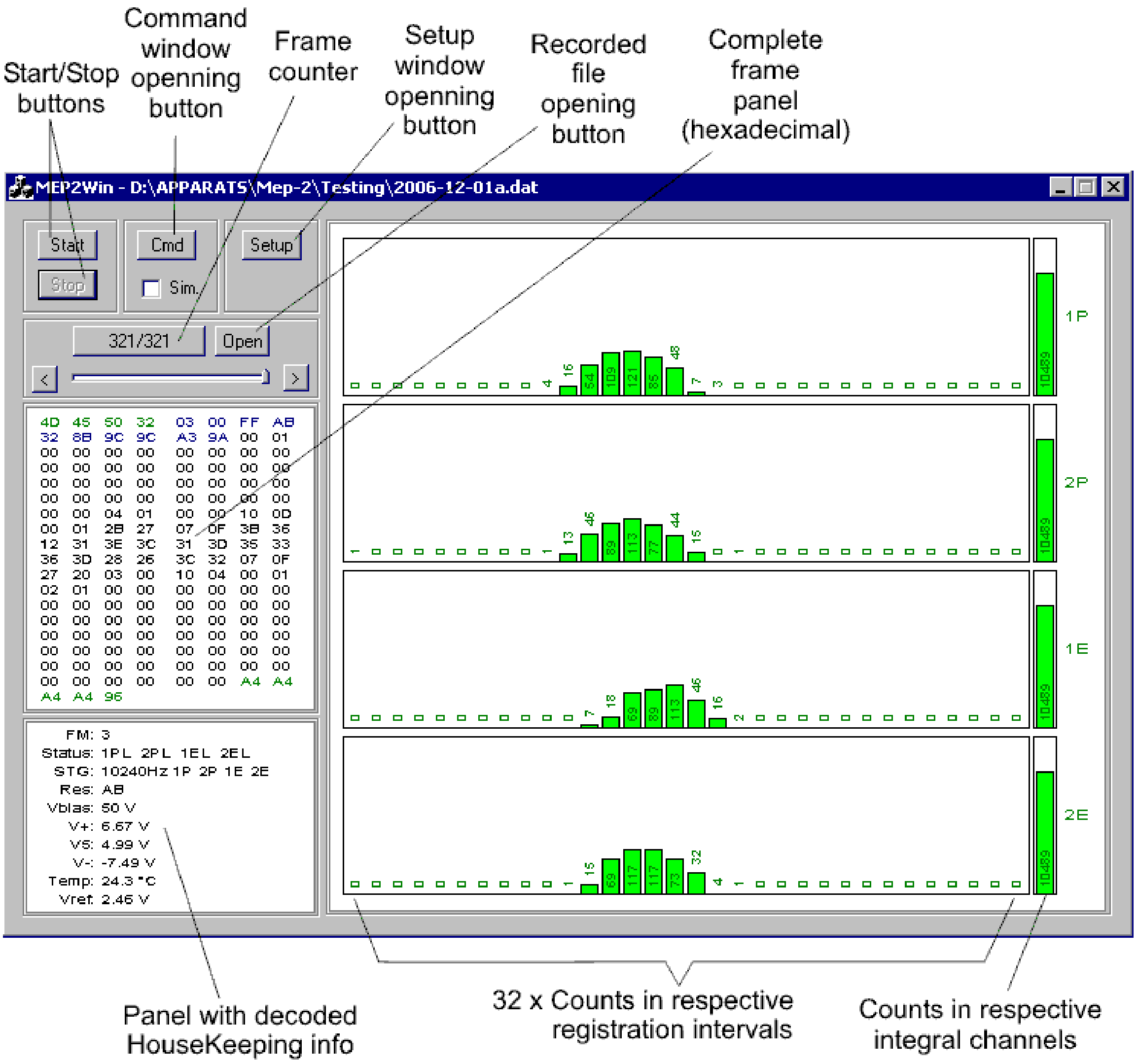

Figure 20. MEP2Win software graphic interface – main window (with FM=3, i.e. 32 channel PHA, STG=10240Hz to all detectors)

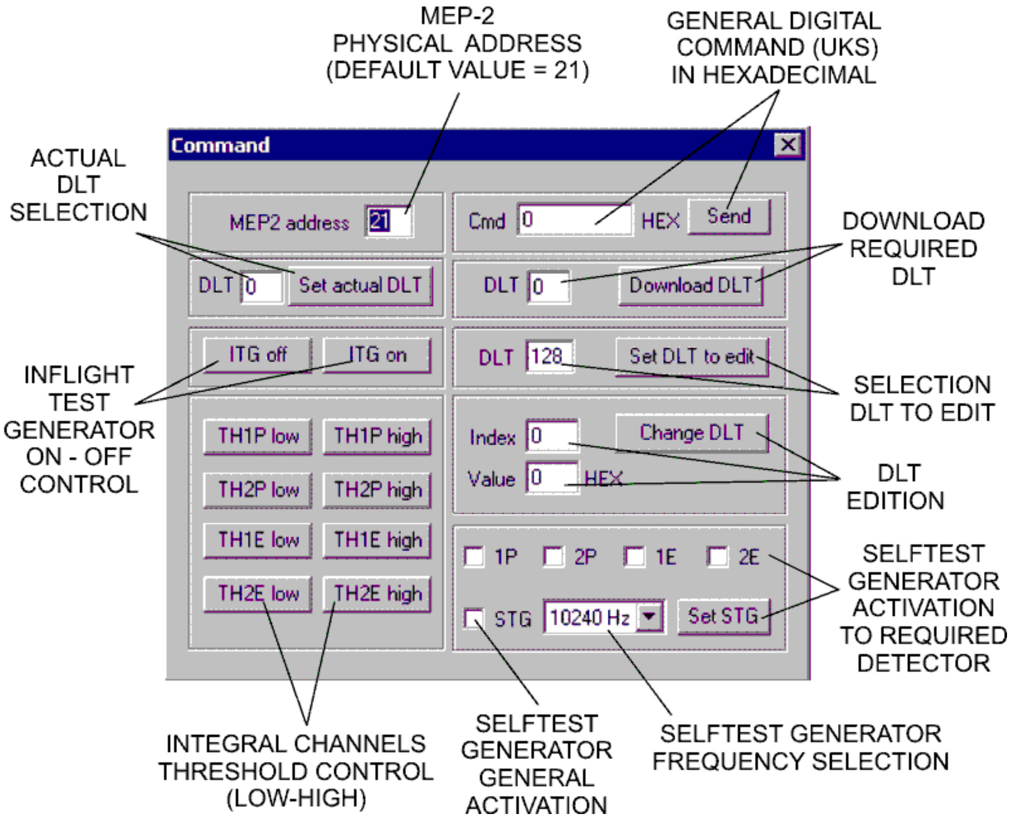

Figure 21. Command window

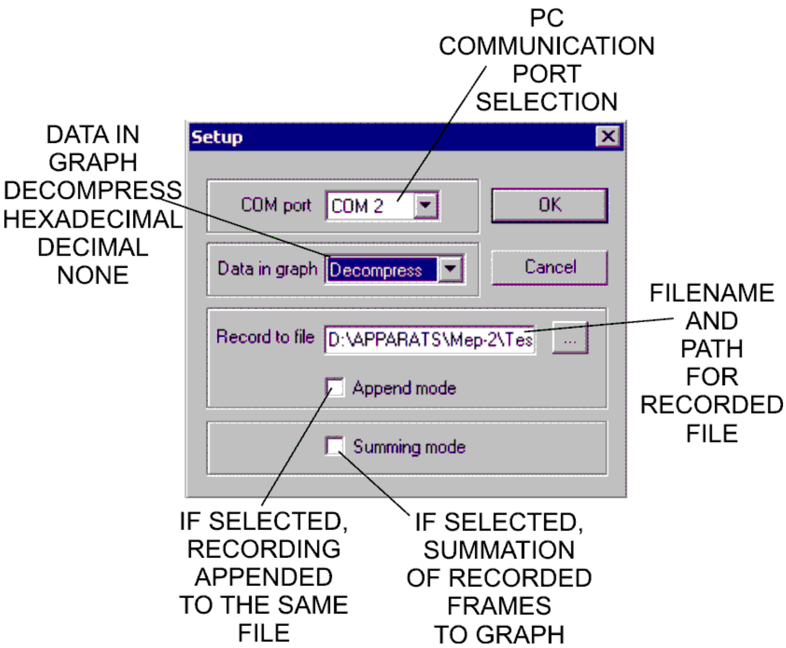

Figure 22. Setup window

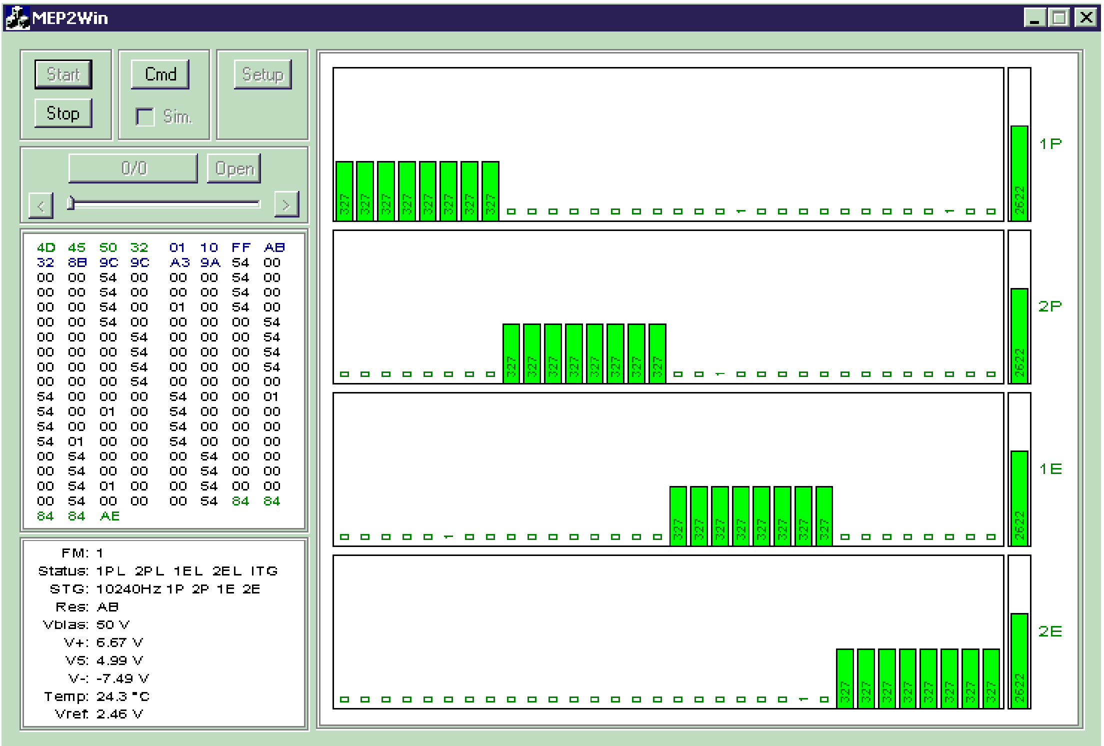

Figure 23. Main window with FM=1 and Inflight Test Generator ON

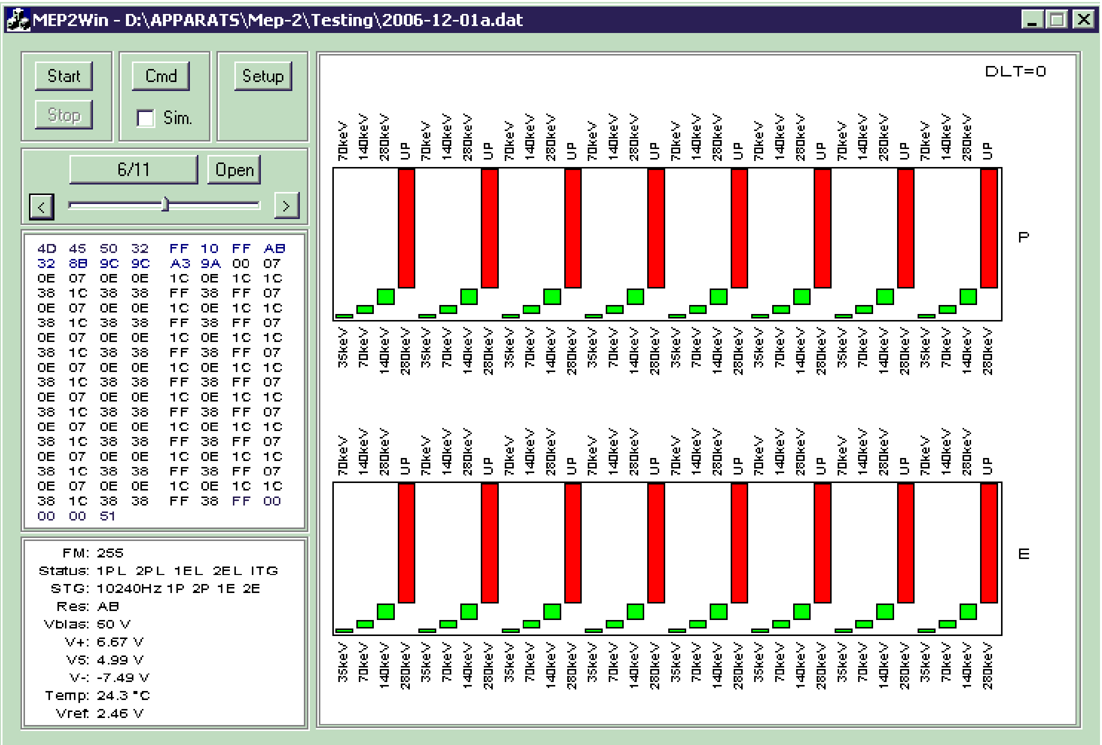

Figure 24. Main window with download of DLT0

6.2 TESTING OF FUNCTIONAL COMMANDS (POWER ON-OFF)

After connection of the testing setup according to the scheme in Fig. 19 and powering of the GSE-MEP-2 (back panel switch button), the MEP-2 power ON/OFF functionality can be excercized by alternate pushing the respective buttons on the GSE front panel. The turnover switching of the MEP-2 power relay is audible with characteristic noise. The DATA indicator on the GSE front panel flashes with 1 second period (MEP is sending data unconditionally while powered-ON).

6.3 POWER CONSUMPTION TEST

The instrument power consumption shall be characterized at various powering voltages and (eventually) other conditions (temperatures, etc…). The powering voltage is directly monitored by a voltmeter on dedicated front panel sockets while powering current is monitored as a voltage drop on dedicated 1Ω shunt resistor. The typical power consumption of the MEP-2/FM at normal temperature (25ºC) is illustrated in the table:

U [V]	16	18	20	23	27	30	35
I [mA]	60	52,7	47,7	43,2	38,4	36,6	33,1
P [W]	0,96	0,95	0,954	0,994	1,06	1,10	1,16

6.4 SETUP OF THE MEP2Win SOFTWARE

After loading the MEP2Win.exe software in the PC, it is essential to select the proper physical communication port of PC (COM1, 2,…) to establish the communication between the PC and the GSE. The port shall be selected in the SETUP window (see Fig. 22). The setup window also allows to define the filename and respective path to record the monitored data. The APPEND checkbox allows to append all the monitored data to the same file regardless the monitoring was stopped/run repeatingly. The SUMMING checkbox allows summation of the data frames to single graph. This feature is used mainly for instrument amplitude/energy calibration to provide high statistics with low active particle sources. The setup window also allows to select the numerical values mode of the data in the graph. The options include HEXADECIMAL, DECIMAL, DECOMPRESSED and NONE numerical values.

6.5 DATA STREAM MONITORING AFTER POWER-ON

After the power-on mode the instrument should exhibit following Housekeeping info:

FM:	0 (default Frame Mode is 0, i.e. DLT=0)
Status:	1PL 2PL 1EL 2EL (default LOW thresholds for interal channels)
STG:	(default is OFF after power-on)
Res:	AB (reserve, not used, constant default value = AB)
Vbias:	50V (± 2V in temperature range -30ºC …+40ºC)
V+:	6,7 V (± 0,3V in temperature range -30ºC …+40ºC)
V5:	5 V (± 0,2V in temperature range -30ºC …+40ºC)
V-:	-7,5V (± 0,5V in temperature range -30ºC …+40ºC)
Temp:	25 ºC ± 1ºC (at 25 ºC ambient temperature, shortly after power-on)
Vref:	2.46 V (± 0.02V in temperature range -30ºC …+40ºC)

The data graph shows random variable electronic noise and background particle events. The electronic noise is strongly dependent on the temperature of the detectors. The data refresh period is 1,024 second and is synchronous with the DATA indicator on the GSE front panel. The same data stream can be monitored with an optional PC running the MEP2Win software and connected to the XHT technological connector.

6.6 DIGITAL COMMANDS (UKS) PASSING TEST

The Command window allows to send any 16-bit command to the MEP-2 instrument, including illegal commands (that are normally ignored by the instrument). However, the instrument regular commands are preprogrammed into user-comfortable graphic interface. For successfull command passing the physical address of the command interface must by identical with the MEP-2 physical address (i.e. 21).
The simple passing test can be excersized by the commands that provide immediate feedback response in the STATUS byte of the Housekeeping information. Those include: Set Actual DLT (i.e. FM will change), ITG ON-OFF, TH1P…TH2E high/low turnover, also STG settings.
The command „Download DLT“ will download respective DLT instead of regular physical data frame. The downloaded DLT is graphically displayed in the data graph and can be reviewed later in the recorded data file. As an example, the download of the DLT0 is illustrated in the Figure 24.
The edition of selected DLT (in the range DLT128-254) has no immediate response, the result of the edition can be monitored by download and inspection of the particular DLT.

6.7 TESTS WITH INFLIGHT TEST GENERATOR AND SELFTEST GENERATOR

There is just one physical device providing the injection of the testing pulses to the inputs of the charge sensitive preamplifiers. The amplitude of the pulses is constant, corresponding approximately the energy of 100keV. The simple ITG-on command provides the sequence described in the paragraph 3.7 as „Composite mode". There is just one (maximum) frequency 10240 Hz and the injection is consequently alternated during single telemetry interval over all four detection channels. The response of the detection systems to this stimulation is depending on the actual DLT. The example of the ITG response at FM=1 (DLT1) is illustrated in Figure 23.
The STG generator allows individually set 8 different frequencies from 40 Hz to 10240 Hz and also allows individual setting – which of channels is to be stimulated. The Figure shows stimulation of all four channels with frequency 10240Hz at FM=3 (DLT3), i.e. 32 channel PHA analyzer. The peak broadening is caused by an electronic noise.

6.8 ANALOG CHANNELS TEST

The analog channels test is provided by stimulation of individual detection channels with various frequencies and simultaneous measurement of the voltages on respective analog channels outputs. The stimulation pulses are provided by the STG generator while voltage monitoring is provided by an external voltmeter. As the electronic noise in integral channels at room temperature (25C°) is not negligible, it is necessary to switch all thresholds to HIGH level. The measurement still may be slightly influenced by the particle background events. The normal response of the analog channels to the various STG frequencies is illustrated in the table:

Frequency [Hz]	Voltage [V]			
	1E	2E	1P	2P
10240	5,315	5,324	5,327	5,324
5120	4,794	4,807	4,806	4,803
2560	4,074	4,091	4,087	4,084
1280	3,231	3,248	3,243	3,238
640	2,390	2,405	2,401	2,397
320	1,664	1,676	1,672	1,668
80	0,692	0,697	0,696	0,694
40	0,419	0,422	0,422	0,420
0	0,012	0,012	0,012	0,014

7. CONCLUSION

By the time being (March 2011), the MEP-2 / FM instrument (Flight Model) successfuly passed following procedures:

- tested at Qualification and Acceptance Levels at IEP-SAS Košice
- calibrated with ^{109}Cd an ^{241}Am radioisotopes at IEP-SAS Košice
- formally accepted for the flight on board of the Spectrum-Radioastron spacecraft by visiting representatives of Space Research Institute of Russian Academy of Sciences (IKI-RAN).
- Dispatched to IKI-RAN, Moscow
- Tested at Institute for Space Research (IKI) with the SSNI telemetry
- Tested at Institute for Space Research (IKI) for EMC (electromagnetic compatibility)
- Delivered for integration on board of the RADIOASTRON spacecraft at NPOL - Lavochkin association at Moscow
- Tested on board of the Spectrum-Radioastron spacecraft with good result.
- The launch of the Spectrum-Radioastron is expected in July 2011.

8. ACKNOWLEDGEMET

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APPENDIX

DLT Review
(by 14.03.2011)

DLT=0:
35-70,70-140,
140-280,280-UP
*****8x*****

35,70,35,70
70,140,70,140
140,280,140,280
280,UP,280,UP

DLT=1:
35-140
*****32x*****

35,140,35,140

DLT=2:
35-UP
*****32x*****

35,UP,35,UP

DLT=3:
30-35,35-40,40-45
.... 185-190
*****1x*****

30,35,30,35
35,40,35,40
40,45,40,45
45,50,45,50
50,55,50,55
55,60,55,60
60,65,60,65
65,70,65,70
70,75,70,75
75,80,75,80
80,85,80,85
85,90,85,90
90,95,90,95
95,100,95,100
100,105,100,105
105,110,105,110
110,115,110,115
115,120,115,120
120,125,120,125
125,130,125,130
130,135,130,135
135,140,135,140
140,145,140,145
145,150,145,150
150,155,150,155
155,160,155,160
160,165,160,165
165,170,165,170
170,175,170,175
175,180,175,180
180,185,180,185
185,190,185,190

DLT=4:
30-40,40-50,....
180-190
*****2x*****

30,40,30,40
40,50,40,50
50,60,50,60
60,70,60,70
70,80,70,80
80,90,80,90
90,100,90,100
100,110,100,110
110,120,110,120
120,130,120,130
130,140,130,140
140,150,140,150
150,160,150,160
160,170,160,170
170,180,170,180
180,190,180,190

DLT=5:
30-50,50-75,75-
100,100-125,125-
150,150-175,175-
200,200-UP
*****4x*****

30,50,30,50
50,75,50,75
75,100,75,100
100,125,100,125
125,150,125,150
150,175,150,175
175,200,175,200
200,UP,200,UP

DLT=6:
30-60,60-100,100-
160,160-UP
*****8x*****

30,60,30,60
60,100,60,100
100,160,100,160
160,UP,160,UP

DLT=7:
40-80,80-160,
160-320,320-UP
*****8x*****

40,80,40,80
80,160,80,160
160,320,160,320
320,UP,320,UP

DLT=8:
50-100,100-200
200-400,400-UP
*****8x*****

50,100,50,100
100,200,100,200
200,400,200,400
400,UP,400,UP

DLT=9:
60-100,100-200
200-400,400-UP
*****8x*****

60,100,60,100
100,200,100,200
200,400,200,400
400,UP,400,UP

DLT=10:
35-140
*****32x*****

35,140,35,140

DLT=11:
*****16x*****

35,140,35,140
140,UP,140,UP

DLT=12:
35-UP
*****32x*****

35,UP,35,UP

DLT=13:
35-UP
*****32x*****

35,UP,35,UP

DLT=14:
35-UP
*****32x*****

35,UP,35,UP

DLT=15:
35-UP
*****32x*****

35,UP,35,UP

DLT=16:
32x30 tresh
PETR.
*****32*****

30,110,35,225

DLT=17:
32x 40 tresh
PETR.
*****32x*****

40,120,45,225

DLT=18:
32x 50 tresh
PETR.
*****32x*****

50,120,50,225

DLT=19:
32x 60 tresh
PETR. *****
*****32x*****

60,150,60,225

DLT=20:
32x 60 - exttresh
PETR
*****32x*****

60,200,60,300

DLT=21:
1x low energy
PETR.
*****1x*****

30,40,30,40
40,50,40,50
50,60,50,60
60,70,60,70
70,80,70,80
80,90,80,90
90,100,90,100
100,110,100,110
110,120,110,120
120,130,120,130
130,140,130,140
140,150,140,150
150,160,150,160
160,170,160,170
170,180,170,180
180,190,180,190
190,200,190,200
200,210,200,210
210,220,210,220
220,230,220,230
230,240,230,240
240,250,240,250
250,260,250,260
260,270,260,270
270,280,270,280
280,290,280,290
290,300,290,300
300,310,300,310
310,320,310,320
320,330,320,330
330,340,330,340
340,350,340,350

DLT=22:
1x med energy
PETR. *****
*****1x*****

30,40,30,40
40,50,40,50
50,60,50,60
60,70,60,70
70,80,70,80
80,90,80,90
90,100,90,100
100,110,100,110
110,120,110,120
120,130,120,130
130,140,130,140
140,150,140,150
150,160,150,160
160,170,160,170
170,180,170,180
180,190,180,190
190,200,190,200
200,220,200,210
220,240,210,220
240,260,220,230
260,280,230,240
280,300,240,250
300,330,250,260
330,360,260,270
360,400,270,280
400,440,280,290
440,480,290,300
480,520,300,310
570,630,310,320
630,700,320,330
700,770,330,340
770,850,340,350

DLT=23:
1x high energy
PETR. *****
*****1x*****

30,40,30,40
40,50,40,50
50,60,50,60
60,70,60,70
70,80,70,80
80,90,80,90
90,100,90,100
100,120,100,110
120,140,110,120
140,160,120,130
160,180,130,140
180,200,140,150
200,230,150,160
230,260,160,170
260,300,170,180
300,350,180,190
350,400,190,200
400,450,200,210
450,500,210,220
500,550,220,230
550,600,230,240
600,650,240,250
650,700,250,260
700,750,260,270
750,800,270,280
800,850,280,290
850,900,290,300
900,950,300,310
950,1000,310,320
1000,1100,320,330
1100,1200,330,340
1200,UP,340,350

DLT=24:
2xlow energy
PETR.
*****2x*****

30,40,30,40
40,50,40,50
50,60,50,60
60,70,60,70
70,80,70,80
80,90,80,90
90,100,90,100
100,120,100,115
120,140,115,130
140,160,130,150
160,180,150,170
180,200,170,190
200,230,190,220
230,260,220,260
260,300,260,300
300,350,300,350

DLT=25:
2xmed energy
PETR. *****
*****2x*****

30,40,30,40
40,50,40,50
50,60,50,60
60,70,60,70
70,80,70,80
80,100,80,90
100,120,90,100
120,150,100,115
150,180,115,130
180,220,130,150
220,270,150,170
270,330,170,190
330,400,190,220
400,480,220,260
480,560,260,300
560,660,300,350

DLT=26:
2xhigh energy
PETR.
*****2x*****

30,45,30,40
45,60,40,50
60,80,50,60
80,100,60,70
100,125,70,80
125,160,80,90
160,200,90,100
200,245,100,115
245,300,115,130
300,360,130,150
360,440,150,170
440,530,170,190
530,630,190,220
630,750,220,260
750,950,260,300
950,UP,300,350

DLT=27:
4x high energy
PETR
*****4x*****

30,50,35,55
50,90,55,85
90,150,85,120
150,250,120,160
250,400,160,200
400,800,200,250
800,1200,250,300
1200,UP,300,350

DLT=28:
4x med energy
PETR.
*****4x*****

30,45,35,55
45,70,55,85
70,100,85,120
100,140,120,160
140,200,160,200
200,300,200,250
300,450,250,300
450,600,300,350

DLT=29:
4x small PETR.
*****4x*****

30,40,35,55
40,60,55,85
60,80,85,120
80,105,120,160
105,140,160,200
140,190,200,250
190,240,250,300
240,320,300,350

DLT=30:
8x small PETR.
*****8x*****

30,60,30,60
60,100,60,100
100,200,100,200
200,350,200,350

DLT=31:
8x med PETR.
*****8x*****

30,40,30,60
40,60,60,100
60,90,100,200
90,130,200,350

DLT=32:
8x wide PETR.
****8x*****

30,60,30,60
60,120,60,100
120,250,100,200
250,500,200,350

DLT=33:
8x small-ext PETR.
****8x*****

60,90,60,90
90,130,90,130
130,200,130,200
200,350,200,350

DLT=34:
8x wide -ext
PETR. *****
****8x*****

60,90,60,90
90,130,90,130
130,250,130,250
250,500,250,350

DLT=35:
16x small PETR.
****16x*****

30,100,40,100
100,300,100,300

DLT=36:
16x small-ext1
PETR.
****16x*****

50,100,50,100
100,300,100,200

DLT=37:
16x small-ext2
PETR.
****16x*****

60,120,60,120
120,250,120,200

DLT=38:
8x small+high
PETR.
****8x*****

30,50,30,60
50,80,60,100
80,120,100,200
120,180,200,350

DLT=39:
8x small-ext+high
PETR.
*****8x*****

60,90,60,90
90,130,90,130
130,200,130,200
200,350,200,350

DLT=40:
16x +high PETR.
*****16x*****

30,100,40,100
100,300,100,300

DLT=41:
16x ext1+high
PETR.
*****16x*****

50,100,50,100
100,300,100,200

DLT=42:
16x ext2+high
PETR.
*****16x*****

60,120,60,120
120,250,120,200

DLT=43:
32x high PETR.
*****32x*****

30,110,35,225

DLT=44: 32x ext1+high PETR. *****spec*****	DLT=45: 32x ext2+high PETR *****spec*****	DLT=46: 32x ext3+high PETR. *****spec*****	DLT=47: 32xxt3+high PETR. *****spec*****
45 ,120 ,45 ,225	60,150,60,225	40,70,40,100	60,90,60,120
45 ,120 ,45 ,225	60,150,60,225	40,70,40,100	60,90,60,120
45 ,120 ,45 ,225	60,150,60,225	40,70,40,100	60,90,60,120
45 ,120 ,45 ,225	60,150,60,225	40,70,40,100	60,90,60,120
45 ,120 ,45 ,225	60,150,60,225	40,70,40,100	60,90,60,120
45 ,120 ,45 ,225	60,150,60,225	40,70,40,100	60,90,60,120
45 ,120 ,45 ,225	60,150,60,225	40,70,40,100	60,90,60,120
45 ,120 ,45 ,225	60,150,60,225	40,70,40,100	60,90,60,120
45 ,120 ,45 ,225	60,150,60,225	40,70,40,100	60,90,60,120
45 ,120 ,45 ,225	60,150,60,225	40,70,40,100	60,90,60,120
45 ,120 ,45 ,225	60,150,60,225	40,70,40,100	60,90,60,120
45 ,120 ,45 ,225	60,150,60,225	40,70,40,100	60,90,60,120
45 ,120 ,45 ,225	60,150,60,225	40,70,40,100	60,90,60,120
45 ,120 ,45 ,225	60,150,60,225	40,70,40,100	60,90,60,120
45 ,120 ,45 ,225	60,150,60,225	40,70,40,100	60,90,60,120
45 ,120 ,45 ,225	60,150,60,225	40,70,40,100	60,90,60,120
45 ,120 ,45 ,225	60,150,60,225	40,70,40,100	60,90,60,120
45 ,120 ,45 ,225	60,150,60,225	40,70,40,100	60,90,60,120
45 ,120 ,45 ,225	60,150,60,225	40,70,40,100	60,90,60,120
45 ,120 ,45 ,225	60,150,60,225	40,70,40,100	60,90,60,120
45 ,120 ,45 ,225	60,150,60,225	40,70,40,100	60,90,60,120
45 ,120 ,45 ,225	60,150,60,225	40,70,40,100	60,90,60,120
45 ,120 ,45 ,225	60,150,60,225	40,70,40,100	60,90,60,120
45 ,120 ,45 ,225	60,150,60,225	40,70,40,100	60,90,60,120
45 ,120 ,45 ,225	60,150,60,225	40,70,40,100	60,90,60,120
45 ,120 ,45 ,225	60,150,60,225	40,70,40,100	60,90,60,120
45 ,120 ,45 ,225	60,150,60,225	40,70,40,100	60,90,60,120
45 ,120 ,45 ,225	60,150,60,225	40,70,40,100	60,90,60,120
120 ,200 ,35 ,90	150,300,60,90	70,200,40,90	90,200,60,90
200 ,350 ,90 ,130	300,500,90,130	200,400,90,130	200,400,90,130
350 ,800 ,130 ,200	500,900,130,200	400,800,130,200	400,800,130,200
800 ,UP ,200 ,350	900,UP,200,350	800,UP,200,350	800,UP,200,350

DLT=48:
35-UP
*****32x*****

35,UP,35,UP

....
etc...up to DLT127