

Multi-channel High Voltage Power Supply System for the Focal Surface Detector of the EUSO Telescope

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The focal surface detector of the EUSO telescope consists of a few hundred thousand pixels of photodetectors which are assembled to about 150 photodetector modules (PDM). Multi-channel high voltage power supply (HV PS) system for the MAPMTs used for the detector has been developed. Individual HV PS is installed in each PDM. This system will be used in outer space for 3 years at high altitude of about 420 km. Therefore, various crucial conditions are imposed. Design concept of the HV PS system and some test results are described.

1. Introduction

The Extreme Universe Space Observatory (EUSO) telescope on board the International Space Station (ISS) aims to detect Extreme Energy Cosmic Rays (EECR) with energies $E > 4 \times 10^{19}$ eV by observing the fluorescence and the Cherenkov light produced by air showers which develop in the Earth's atmosphere when the cosmic rays interact with nuclei in it.

EUSO is a collaboration of scientists from Europe, USA, and Japan. The phase-A study (conceptual design) under ESA has been successfully finished in July 2004 and the international negotiations for phase-B (detailed design) are in progress.[1]

A field of view of the EUSO telescope is super wide with 60 degree, which is realized by using specially designed Fresnel lenses and a focal surface detector with 2.5m diameter. The focal surface detector consists of a few hundred thousand pixels of multi-anode photomultipliers (MAPMT) which are assembled to about 150 photodetector modules (PDM).

To supply high voltage to the MAPMTs of the focal surface two kinds of solutions have been proposed, centralized and modular systems. Multi-channel high voltage power supply (HV PS) system for these MAPMTs based on the solution of the modular system is described hereafter. [2]

The distributed modular HV system consists of about 150 separate HV PS modules which are mounted on individual PDMs. The HV PS system feed the HV to enormous number of about 6,000 MAPMTs at the focal surface of the EUSO telescope. This system will be operated in outer space for 3 years at high altitude of about 420 km. Reliability of the HV PS system is, therefore, very important to keep the quality of the observed data. Various stringent conditions such as light weight, low power consumption, high conversion efficiency, high stability, radiation tolerance and so on are imposed to work on the space mission.

Detail design of the multi-channel HV PS system for the EUSO telescope and required specifications are described in this paper.

2. The Modular HV PS System

Figure 1 shows a basic diagram of the electric power supplied from the International Space Station and the modular HV PS system for the EUSO focal surface detector. Total power supplied from the ISS for the HV PS is very limited to be 60W. Each HV PS module is mounted on the PDM which consists of 36 MAPMTs. Each MAPMT has 36 pixels.

Nominal HV value to operate the MAPMTs is -900V to observe UV photons generated from the Extreme Energy Cosmic Rays. EUSO is also able to observe atmospheric UV phenomena such as meteors, lightning, elves, sprites, etc. The atmospheric observation by EUSO will provide significant contributions to climatology and ambient surveillance. The HV PS system is designed to set any voltage up to -1000 V to accommodate such various observation requirements.

The high voltage of each module can be changed from 0 V to -1000 V by V_{set} signal. Applied voltage can be monitored by V_{mon} signal. Each high voltage can be turned on and off by On/Off signal. The HV PS module can be operated by applying power supply of single +5 V.

Very low electric power consumption of 320 mW/PDM is required, which drives 36 MAPMTs, and high conversion efficiency of the voltages is also required for this system.

Basic block diagram of each modular HV PS system for the EUSO focal surface detector and relevant units are shown in Figure 2.

Fundamental function of the module is as follows.

The Trigger Control Unit (TCU) sends the V_{set} serial TTL data signal with 12 bit resolution and clock signal to a Digital to Analog Converter (DAC) which converts the digital signal to an analog signal with a voltage from 0 V to +5 V. This output signal is fed to one input of an op amp and it works as a reference voltage for feeding current to drive ultra-miniature DC to HV DC converter which gives the high voltage from 0 V to -1000 V with a resolution of 0.24 V.

The gain G of the PMT is generally expressed as a function of the applied high voltage HV by a formula

$$G = a \times HV^b, \quad (1)$$

where the parameters a and b are measured to be $\log(a) = -21.04 \pm 3.75$, and $b = 9.26 \pm 1.27$ for R8900-03-M16.[3] Therefore, the gain is about 2×10^6 at a nominal high voltage of -900 V.

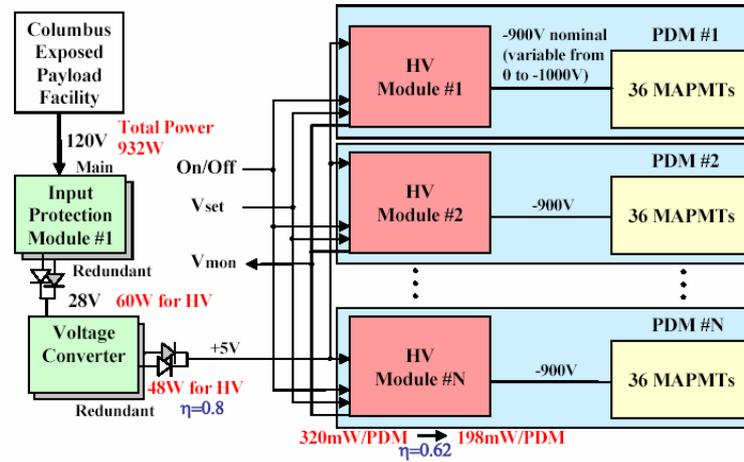


Figure 1. Basic block diagram of the electric power supplied from the ISS and the modular HV PS system for the EUSO focal surface. Each HV PS module is mounted on the PDM and each HV PS module drives 36 MAPMTs of each PDM.

The ratio of the gain change as a function of the ratio of the high voltage change is expressed using the formula (1) as

$$dG/G = b \times d(HV)/HV. \quad (2)$$

Therefore, the high voltage resolution of 0.24 V corresponds to the gain change of 0.25 % which sufficiently satisfies the requirement of the gain change for the EUSO experiment.

The output voltage from the DC to HV DC converter is provided to MAPMT bleeder resistors. The output voltage is fed back to another input of the op amp to output precise high voltage. It is also fed into an analog to digital converter (ADC) with 12 bit resolution to monitor the high voltage. The ADC output signal is controlled by TTL serial data and gives a monitor voltage V_{mon} of the high voltage. The clock signal is also given to the ADC from the TCU.

Required main specification for the HV PS system per PDM is listed in Table 1.

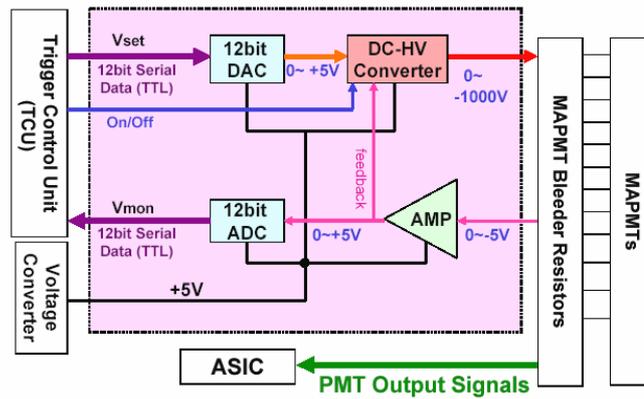


Figure 2. Basic block diagram of each modular HV PS system for the EUSO focal surface detector.

The clock signal is also given to the ADC from the TCU.

Table 1. Required specification for the HV PS system for the EUSO focal surface detector

Item	Specification
Number of PMTs	36/PDM
Mass	20g/PDM (harness, connector 250g), Total 270g
Input voltage	+5V
Power consumption	320mW/PDM
Output voltage	-900V (-800~-1000V)
Output power	200mW/PDM
Output ripple	0.05% p-p
Vibration tolerance	Random vibration 12.7G(RMS) 120sec
Operation temperature	0°C~40°C

3. Results and Discussion

An experimental manufacture of the HV PS module based on the above idea was made to drive 36 MAPMTs on the trial PDM.[4,5] A picture of the circuit board on the trial PDM is shown in Figure 3. The high voltage values are controlled and monitored by a computer through serial lines.

Measured conversion efficiency was 53% at -900 V. Other measured electric characteristics are well satisfied.

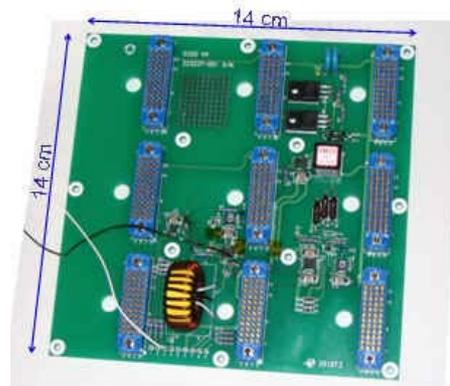


Figure 3. Experimental manufacture of the HV PS module on a circuit board.

Vibration test of this HV board was made as a part of the trial model of the PDM. Experimental result from this vibration test was satisfied under the conditions of random vibration with 20G rms accelerations to the directions of X, Y and Z axis for 120 sec.

Radiation damage of the electric parts used for the HV PS module was measured by irradiating 70 MeV proton beam up to 100 krad at National Institute of Radiological Sciences in Japan.[6] Various types of the effect of the damage for respective parts were observed. These results show the HV parts can be operated well for 3 years of observation period in outer space by using 2.54 mm thick aluminum shield with which the EUSO experiment suppose to prevent the radiation effect on the electronic devices.

There is a possibility of continuous measurements of lightning-associated transient luminous events (TLEs) by EUSO telescope.[7] Estimated number of photons irradiated by a lightning and a sprite reach to an order of 10^5 /pixel/2.5 μ s which is 2-3 orders of magnitude larger than that of the extensive air showers generated by UHECRs with energies of 1.0×10^{20} eV. To avoid damages of the MAPMTs caused by light flushes from such phenomena, a HV divider for the MAPMTs with auto-gain controlling system with fast response is designed.

The present HV PS system will be combined with this auto-gain controlling system to avoid strong light flush and to observe TLEs.

4. Conclusions

We have developed a multi-channel HV PS system for the focal surface detector of the EUSO telescope based on an idea of distributed modular solution. The experimental manufacture of the module of this system was made and various tests have been done. Measured electric characteristics are almost well satisfied the requirements. Results of the vibration test are also well satisfied under the acceleration of 20G. The radiation damage on the HV PS system for an operation period of at least 3 years will be suppressed by using 2.54 mm thick aluminum. Observation of TLEs will be possible by setting lower HV. The damages of the MAPMTs by the strong light flush will be suppressed by using auto-gain controlling system with fast response together with the present HV PS system.

5. Acknowledgements

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