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A proposal for High Voltage Power Supply system for HCAL of LHCb experiment

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Abstract

An approach to design and construct a High Voltage power supply system for the HCAL's PMTs is presented. The main features of this system are given.

1. Introduction

During 1997-1999 we have developed a High Voltage (HV) distribution system [1]-[2] for the HCAL prototype of 6-modules [1] which consists in two parts:

1) HV distribution boards - 6HVD2001 and - 4HVD2501;

2) a control box which includes the Low Voltage Power Supply LVPS, the RS232 interface and 3 High Voltage Power Supplies 3HVPS.

For the 1999-2000 tests the control box contained 2×HVPS 2020(3 boards/module - for two HCAL prototype modules (modules 4 and 6 in figure 2 in [1]) and 1×HVP 2520 (4 boards/module) for the shorter module equipped with PMs FEU-115m. The HV distribution system uses the remote control for setting the voltages.

Based on the experience got during the construction and experimentation of the prototype, a High Voltage power supply system is designed for PMTs of the LHCb Hadron Calorimeter.

Some of the major constrains for the HV power supply are simplicity and low costs. The designed system fulfils these demands by supplying with the same high voltage 40 PMTs sorted by similar characteristics as gain and sensitivity. Each PMT has a classical resistive divider between cathode and dynode D7. The cathode is powered through a rezistor selected to compensate small gain differences between those 40 PMTs. Inside HV power system there is a resistor connected between HV4(output voltage for D7) and ground. There are no resistive divider between D7, D8, D9, D10 and ground. Between D7-D8, D8-D9, D9-D10 and D10-ground there are only capacitors. Because of the high rates (≈40MHz) supported by the PMTs there are necessary booster voltage sources to supply current for the last 4 dynodes of the PMTs. The PMTs are Russian FEU-115m10 type with good long term stability characteristics.

For 40 PMTs the following are necessary:

HV ....(-1900±10%) V / 10mA
D7-D8................(-150±10%) V / 2mA
D8-D9................(-170±10%) V / 4mA
D9-D10................(-280±10%) V / 7mA
D10-A.................(-200±10%) V / 10mA
stability ....3*1E-4 / (5 degrees temperature range)
output power.........26W

2. Description of the HV system

We present a first version for parallel powering a group of PMTs with booster current sources for dynodes D7...D10.

There are 5 high voltage power sources for cathode and dynodes, each of them having a reference voltage (the output voltage is a multiple of the reference voltages). These reference voltages are connected in a way that permits to adjust independently the voltages between dynodes. The output voltages are taken in respect to the ground.

Name	Nominal Value	Maximal Value
HV5 for photo-cathode	-1900 V / 10mA	-2090 V / 10mA
HV4 for dynode7	-800 V / 2mA	-880 V / 2mA
HV3 for dynode8	-650 V / 4mA	-715 V / 4mA
HV2 for dynode9	-480 V / 7mA	-528 V / 7mA
HV1 for dynode10	-200 V / 10mA	-220 V / 10mA

Each source is on one card and all 5 cards are in one crate. On the front panel there are 5 variable resistors to manually adjust HV1, HV2-HV1, HV3-HV2, HV4-HV3, HV5-HV4 within ±10% range, 2 displays with 5 digits for voltage and 3 1/2 digits for current, and 5 LEDs to indicate that the high voltage is within normal parameters. On the crate back panel there are 5 HV connectors, fuses and a line connector. The HV sources have over-current protection.
The HV sources rise and fall down syncronously at power on and respectively power down. HV sources are of a switching type, no line transformer, high efficiency. Line voltage is rectified and after that chopped at 40kHz. This AC voltage is then fed to a ferrite transformer. At a secondary transformer there are several multiplier cells. The resulting HV voltage is divided and applied to an error amplifier which commands a pulse width modulator. The pulse width modulator commands the chopper (power MOS) and so the negative feedback loop is completed. The separation between line and chassis is performed by an optocoupler. The reference voltage for the error amplifier has a fixed part and a variable part. The variable part is set manually.

The HV power supplies characteristics are the following:

- Input line voltage range:......... (220 +10% -15%) V
- Input line frequency: 50Hz
- Output DC nominal voltage:

  HV1.............. -200V
  HV2.............. -480V
  HV3.............. -650V
  HV4.............. -800V
  HV5.. .... -1900V

- Adjusting range of DC nominal voltage... maximum ±10%
- Output voltage accuracy......................... ±0.5%
- Line regulation...................................... ±0.01%
- Load regulation...................................... ±0.01%
- Long term stability................................. ±0.01%
- Temperature coefficient......................... 60 ppm/C

• Ripple and noise in the band up to 20MHz peak to peak....max. 20mV
• Response time of current protection .... max. 10ms
• Load characteristics :

for HV5 : cable of 20m with distributed capacitance 100-200pF/m

for HV4,HV3,HV2,HV1 : 1000nF capacitive load

• Operating temperature range.................... 5-40 C

For an increased number of PMTs from one crate of the final system, with computer control, we propose :

• increase the power of HV sources (4 times)
• add 4 channels HV distributors for each HV1...HV5
• microcontroller card for automatically control of each HV distributor channel
• Remote control...................CAN-bus
• Protections ....against output short-circuit; PMTs will be protected against excessive voltages between dynodes (max 400V allowed between dynodes in case of short-circuit)
• Software:

the main program is a Visual C++ Windows application.

the program for micro-controller 83c591 is written in C and Assembler; the 83c591 micro-controller has a CAN controller.

In this way one crate can power 4 groups of 40 PMTs each (160 PMT's). For $\approx$ 1500 PMTs of HCAL there will be necessary 10 crates and 1 spare crate.The total output power is 1kW. The HV crates are located on one or two 19 inch racks.

3. Description of automatic mode

Each crate is controlled by 83c591 micro-controller card. The micro-controller performs periodically self-testing at power up (RAM, EPROM, EEPROM, 83c591). The result of the self-testing is stored in one byte which is sent to the PC. The 83c591 card monitors that:

- the high voltage is within normal limits;
- the output current is within normal limits.

The monitoring results is sent periodically to the PC. In case of a HV failure an alarm message is sent immediately to the PC. The 83c591 card controls the HV distributed values within 10% limits of the nominal value. The communication between PC and 83c591 card complies with CAN-bus specifications.

In the automatic mode the micro-controller performs the next tasks (if control code is sent by the PC):

- self-test
- HV power down, power up
- adjust HV channel with maximum 10

The values for High Voltage channels can be set in a Window on the PC and can be stored in a file. The program runs in a Windows session under a Windows environment on a compatible IBM- PC. The micro-controller sends data to the PC with a rate established by the user (1s..100s). The user sets the HV values and the PC computes the differences to the pedestal values and send them to the 83c591 micro-controller. There is a file on the PC with all the nominal values (which are set on HV cards manually).

4. Conclusions

The HV power supply system proposed for parallel powering PMTs for the hadron calorimeter of the LHCb experiment supports high counting rates ($\approx$ 40 MHz) by supplying additional current to the last four dynodes of the PMT. The final main unit of the system that has to be designed will be a 19 inch box with 5 HV sources (one for photo-cathode and four for dynodes) each with 4 distributed channels, one crate has to power 160 PMTs. The HV diferences (between cathode and D7 as well as between the other dynodes D7, D8, D9, D10, A respectively) can be independently adjusted up to 10% of the nominal value, in the automatic mode.
The HVPS experimental model developed this year has been tested at CERN and used during the calorimeter combined test to power a group of 9 PMs FEU-115m10 installed in 3 HCAL prototype modules.

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References

[1] LHCb Note, LHCb 2000-035 CALO

[2] D.T. Dumitru presentation in CALO meeting, October 12, 1999.