

IceCube

**PMT HV Base Board
Engineering Requirements Document (ERD)**

Supplement

Version 0.00c

0.00a	N. Kitamura	November 18, 2002
0.00b		November 20, 2002
0.00c		January 13, 2003

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S1 Administrative

S1.1 Genesis

This supplementary documentation has been created in response to Section 3.1.1.1 (“Note on requirements alternatives”) of IceCube PMT HV Base Board Engineering Requirements Documents.

S1.2 Scope

This ERD supplement defines requirements that replace the contents of Section 3.1.4 (“HV Control”) and its subsections of the *ibid*.

S1.3 Enforcement

The requirements in this ERD supersedes Section 3.1.4 of *ibid* through an appropriate administrative procedure and approval process of IceCube.

S2 Supplementary Requirements for High-Voltage Control

S2.1 Anode-to-cathode voltage

S2.1.1 Cathode potential

The PMT cathode shall be at ground potential.

S2.1.2 Modular HV supply

The anode-to-cathode voltage shall be provided by a single modular high-voltage generator.

S2.1.2.1 Physical location of the modular HV supply

The said modular high-voltage generator shall be located outside the PMT HV Base board.

S2.1.2.2 Floating output requirements

The said modular high-voltage generator shall have a floating HV output and the associated floating reference.

S2.1.2.3 HV connection

The said modular high-voltage supply shall have electrical connections with the PMT HV Base board through an appropriate cable (**TBD**). The said connections are for the following:

- Anode-to-cathode high-voltage
- “Clean ground”

S2.1.2.4 HV output adjustability

- (a) The HV output of the modular HV supply shall be adjustable at least over the range of 1000 to 2000 VDC.
- (b) The HV output adjustment shall be accomplished by an analog control voltage of 0 to 5VDC.

- (c) The linearity relationship between the analog control voltage and the HV output voltage shall be consistent with the 12-bit DAC resolution whose output is used as the control voltage.

S2.1.2.5 Analog HV monitor signal

- (a) The modular HV supply shall provide an analog monitor voltage proportional to the HV being produced.
- (b) There is no minimum output impedance requirements for the analog monitor voltage.
- (c) The voltage range for the monitor signal shall be within 0 to 5V.
- (d) The accuracy of the monitor signal shall be consistent with 12-bit digitization.

S2.1.3 Digital control and monitor

S2.1.3.1 DAC for HV control

- (a) The voltage control signal for the modular HV supply shall be produced by a digital-to-analog converter (DAC).
- (b) The said DAC shall have a 12-bit resolution.

S2.1.3.2 ADC for HV monitor

- (a) The HV output of the modular HV supply shall be monitored by digitizing the analog monitor signal with an analog-to-digital converter (ADC).
- (b) The said ADC shall have a 12-bit resolution.

S2.1.3.3 Digital-to-analog scaling

- (a) The digital code format for the DAC and the ADC shall be in 12-bit unsigned straight binary with the digital value 0x000 representing 0 V.
- (b) The scaling between the digital code and the high-voltage value shall be 0.5 V per bit.

S2.2 Voltage divider chain

A resistive voltage divider chain (“bleeder chain”) shall be used to produce voltages for individual dynodes and focusing electrodes.

S2.2.1 Total bleeder chain resistance

The total resistance of the bleeder chain shall be in the range of 50 – 150M Ω (**TBD**).

S2.2.2 Relative resistor values

S2.2.2.1 Hamamatsu-recommended voltage divider

The relative values of the resistors in the voltage divider chain shall be as specified in **Table S2.1**.

Justification: The values have been provided by Hamamatsu Photonics, the supplier of the PMT, who designate the values as “SPL Divider” values (“S” for special.).

S2.2.2.2 Value tolerances

The values in the Table shall be achieved as closely as possible using standard value resistors with a tolerance of 5% or better.

Note: F2 and Dy1 are at equal potential. F1 and F3 are at equal potential between the potential of Dy1 and the potential of Dy2.

Table S2.1 Relative bleeder chain resistance values

Interval	Relative value
K - Dy1	22.6
Dy1 - F1	0.6
F1 - Dy2	3.4
Dy2 - Dy3	5
Dy3 - Dy4	3.33
Dy4 - Dy5	1.67
Dy5 - Dy6	1
Dy6 - Dy7	1.2
Dy7 - Dy8	1.5
Dy8 - Dy9	2.2
Dy9 - Dy10	3
Dy10 - A	2.4

S2.2.3 Resistor quality requirements

The resistors for the bleeder chain shall be selected from a component supplier specializing in high-value resistors for high-voltage and high-reliability applications.

S2.2.4 Charge-supplying capacitors requirements

A charge-supplying capacitor of the minimum value specified in **Table S2.2** shall be present across each dynode interval.

Table S2.2 Minimum capacitance values

Interval	Minimum capacitance [nF]
K - Dy1	2
Dy1 - Dy2	2
Dy2 - Dy3	3
Dy3 - Dy4	3
Dy4 - Dy5	3

Dy5 - Dy6	5
Dy6 - Dy7	5
Dy7 - Dy8	5
Dy8 - Dy9	10
Dy9 - Dy10	10
Dy10 - A	10