

IceCube**Flasher Board****Engineering Requirements Document (ERD)**

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1 GENERAL

1.1 Scope

This IceCube Engineering Requirements Document (ERD) specifies the physical, functional and performance requirements of the Flasher Board.

1.2 Purpose

This ERD is applicable to the development, prototyping, testing, and verification of the Flasher Board.

1.3 Precedence

In the event of a conflict between the provisions of this document and any prior IceCube documentation, the provisions in this document shall supersede. Conflicts between this and non-IceCube documents shall be resolved by the Change Control Board.

1.4 Authority

Approval of this document for initial release and the subsequent revisions are authorized only by the Change Control Board.

1.5 Responsibilities

- (a) Physics/Engineering is responsible for writing and updating these requirements to ensure they are correct, complete and current.
- (b) Quality Assurance is responsible for ensuring this document and changes to it are properly reviewed, approved and maintained.

1.6 Records

Records of initial review, approval and changes (Engineering Change Notices, ECN's) in design shall be maintained according to the established processes.

1.7 Units

Weights and measures in this document are expressed in the MKS International System of Units (SI).

1.8 Definitions

CCB	Change Control Board
DOM	Digital Optical Module
DOMMB	Digital Optical Module Main Board
DAQ	Data Acquisition
ECN	Engineering Change Notice
ERD	Engineering Requirements Document
FWHM	Full-Width-at-Half-Maximum
HV	High Voltage

IDC	Insulation Displacement Connector
ns	Nano-second (10^{-9} s)
OM	Optical Module
PCB	Printed Circuit Board
PE	Photoelectron
PMT	Photomultiplier Tube

2 FUNCTIONAL OVERVIEW

2.1 General

The Flasher Board is a modular PCB component to be integrated into each of the Digital Optical Modules.

Justification: That each DOM will house a Flasher Board was decided at the In-Ice Devices Meeting at UW (August 2002).

The Flasher Board has electrical connections with the Digital Optical Module Main Board (DOMMB). The Flasher Board receives electrical power from the DOMMB. The Flasher Board and the DOMMB communicate via a serial digital link.

2.2 Required Components and Functions

2.2.1 Optical Flasher

Each Flasher Board has light-emitting diodes (LED's) arranged at the specified PCB locations (See 3.1.6) for the purpose of generating the optical flash described below.

The Flasher Board generates optical flashes using the LED's at timings specified by the DOMMB. The optical flashes are used for the following purposes:

- **Optical Module (OM) self-calibration**
- Local coincidence and time/space offset calibrations
- Inter-string calibrations
- Optical properties verification of the ice

Note for self: Should OM self-calibration be removed since we don't have the wide-pulse mode?

2.2.2 Digital Board ID Device

The Flasher Board presents a unique digital code identifying itself to the DOMMB when requested.

Explanation: Uniformity of components is seen as an important goal for IceCube optical sensors and DAQ. It is anticipated, however, that optical flashers will be implemented in more than one design over the IceCube array. Flashers may be produced with different light generators. A self-identification

of the flasher board version will be a requirement. It is crucial however, that the communications interface to the DOMMB is well defined and unchanged over the entire production.

2.2.3 User Devices

The Flasher Board provides a board area, electrical connectivity and power for the possible installation of a small circuitry (“**user device**”) of yet-to-be-defined functionality in order to implement future revisions of the design.

Justification: The idea here is that future ideas may lead to wishes, requests for additional instrumentation. Acoustic sensors would be an example of such an instrument.

2.2.4 Passive PMT HV Base Support Devices

The flasher board shall provide a board space for the high-voltage generator and related components, such as DAC, ADC, connectors, etc. (collectively referred to as “**passive PMT HV Base support devices**”) for the PMT HV Base employing a passive resistive bleeder chain. The said board space shall be electrically isolated from the rest of the Flasher Board circuitry. The electrical power consumed by the passive PMTHV Base support devices shall not be part of the Flasher Board power budget. The requirements for the passive PMT HV Base support devices are described in the **Supplement to the PMT HV Base Board ERD**.

Note: The electrical signal interface between the DOMMB and the PMT HV Base will be identical regardless of the PMT HV Base design. In the default requirements, the PMT HV Base is an “all-in-one” PCB component mounted on the PMT. In the “passive” approach, defined in the *Supplement*, the PCB mounted on the PMT will likely contain only the resistive bleeder chain and other passive components. The passive PMT HV Base support devices could be implemented through the “user device” mechanism; however, doing so will make the PMT HV Base design non-transparent to the DOMMB, and is undesirable.

3 PERFORMANCE REQUIREMENTS

3.1 Electrical and Electro-optical

3.1.1 Power

3.1.1.1 Power source

The Flasher Board shall receive electrical power from the DOMMB.

3.1.1.1.1 “Default power” source

The default power source provided by the DOMMB shall be a ± 5 VDC voltage source with a voltage uncertainty of $\pm 5\%$.

3.1.1.1.2 “Optional power” source

There shall be an unregulated power source of 100 VDC provided by the DOMMB.

3.1.1.2 Power dissipation

- (a) The maximum power dissipation of the Flasher Board drawn from the default power source shall be **110 mW**.
- (b) The maximum power dissipation of the Flasher Board drawn from the optional power source shall be (**TBD**).

Status: Currently (11/12/02) the DOMMB design assumes that the Flasher Board takes 110mW. It is likely that the total power consumption of the Flasher Board to exceed 110mW significantly. JP suggests the Flasher Board to “have its own on-board DC-DC converter with an input voltage up to 100V” (email 11/7/02).

Notes from Telephone conference (12/18/02): It should be permissible to increase the power for the Flasher Board, since it is operated only a fraction of the time. The maximum allowance for the instantaneous power from the DOMMB should be determined and the Flasher Board’s power spec should be determined accordingly. It is desirable to operate the Flasher Board without the optional power source as long as possible.

3.1.1.3 Power ON/OFF control

- (a) The ON/OFF switching of the default power to the Flasher Board shall be established by a one-bit digital signal controlled by the DOMMB.
- (b) The ON/OFF switching of the optional power shall be controlled by the DOMMB.

3.1.2 Electrical Connections

The following electrical connections are present between the DOMMB and the Flasher Board:

- (a) Board-to-board connector for default power, ground and digital signals.
- (b) Coaxial cable connection for the optical flasher return timing pulse.
- (c) Optional power connection

Note: There will also be a differential signal pair carrying the trigger pulse from the DOMMB to the Flasher Board. The pair could be part of the board-to-board connector. (*TBD*)

Justification: Board-to-board connectors are more reliable and easier to assemble than ribbon cable connectors for a short distance such as between the Flasher Board and the DOMMB.

The Flasher Board is to send a pulse marking the actual timing at which the pulse is generated to the DOMMB. The coaxial connection is suitable for this timing-critical signal.

3.1.2.1 Board-to-board connector signal assignment

3.1.2.1.1 Redundancy requirement

At least two pins of the connector shall be assigned for each ground, power and signal.

3.1.2.1.2 Connector signal assignment (*TBD*)

Table 3.1 Board-to-board connector signal assignment (*Preliminary*)

Pin #	Signal name	Explanation
1	DGND	Digital & power ground
2	SCLK	Serial clock
3	SCLK	
4	MOSI	Master-out-slave-in
5	MOSI	
6	MISO	Master-in-slave-out
7	MISO	
8	DGND	
9	CS0	Chip-select bit 0
10	CS0	
11	CS1	Chip-select bit 1
12	CS1	
13	CS2	Chip-select bit 2
14	CS2	
15	CS3	Chip-select bit 3
16	CS3	
17	ON/OFF	Power ON/OFF
18	ON/OFF	
19	+5V	Main power (+)
20	+5V	
21	DGND	
22	DGND	
23	-5V	Main power (-)
24	-5V	Main power (-)

3.1.3 Digital Commands

3.1.3.1 Digital communication

The Flasher Board (Slave device) shall be capable of digitally communicating with the DOMMB (Master device).

3.1.3.2 On-board devices

The following devices on the Flasher Board shall be supported by the digital communication in the previous paragraph:

- (a) Optical flasher (**3.1.4**)
- (b) Digital board ID device (**3.1.5**)
- (c) User devices

3.1.3.3 Device address (**TBD**)

The address for the devices on the Flasher Board is as shown in **Table 3.2**.

Table 3.2 Device address (*Preliminary*)

Address	Device
0000	(reserved)
0001	Optical flasher (Trigger)
0010	Optical flasher (Amplitude)
0011	Optical flasher (Status)
0100	(reserved)
0101	(reserved)
0110	(reserved)
0111	(reserved)
1001	Digital board ID
1010	(reserved)
1011	(reserved)
1100	(reserved)
1101	(reserved)
1110	(reserved)
1111	(reserved)

3.1.4 Optical Flasher

3.1.4.1 Functional requirements

Operation

1. DOMMB issues a "Get Ready" signal
 - 1.1 DOMMB selects one of the Flasher modes
 - 1.2 DOMMB sets up parameters for the selected mode
2. Flasher writes "Ready" to the status register.
3. DOMMB issues a trigger
4. Flasher fires
5. Flasher sends timing pulse to the DOMMB
6. Flasher writes a status code to a register

Note to self: Consider implementing this using a CPLD. The protocol must be worked out.

Note: The trigger issued by the DOMMB occurs with a 25nsec granularity. The return timing pulse from Flasher to DOMMB is used for time stamping.

3.1.4.2 LED requirements

3.1.4.2.1 General

- (a) There shall be six (6) or more identical light **emitters** mounted at equal angular spacings on the periphery of the Flasher Board.
- (b) Each emitter shall consist of one or more LEDs.

Note: Each emitter may consist of more than one LED. Individual LEDs of a given emitter may be assigned a different intensity range or a different mode of operation (if more than one mode is to be implemented). A minimum of six emitters are necessary to assure the axial symmetry of the light pattern.

3.1.4.2.2 Peak wavelength

The peak wavelength (the wavelength at which the optical output is maximum) shall be in the range of **370-420 nm**.

Note: Nichiha NSHU550 has the peak wavelength of 375nm. Longer wavelength LEDs (blue) tend to be available with higher intensity output. Attenuation in ice at 470nm (blue) is a factor of two greater than at 400nm. The UV range better approximates the Cherenkov photons than blue light.

3.1.4.3 Timing requirements

3.1.4.3.1 Trigger-to-flash delay

The time interval between the optical flash trigger command issued by the DOMMB and the actual emission of the LED light shall be less than **10 nsec**.

Note: The timing accuracy is to be accomplished using a differential signaling.

Note to self: The trigger occurs with 25nsec granularity. The delay of 10nsec is about ½ of the granularity, a value once mentioned by GP.

3.1.4.3.2 Trigger jitter

The trigger-to-flash delay shall not vary more than (**TBD**) ns from trigger to trigger.

Note to self: This has to be a fraction of the value in the previous paragraph.

3.1.4.3.3 Trigger spread among the LED's

The timing of the flash among all the six emitters shall be within **5 ns**.

Note: This value comes from the IceCube time resolution.

3.1.4.3.4 Temporal profile

- (a) The temporal profile of the light output of the optical flasher shall be approximately Gaussian.
- (b) The full-width at half the maximum (FWHM) of the light pulse shall be **15 ns** or less.

Note: The narrow intense pulses are to be observed at different strings.

Note: Two other modes of operation, wide pulse mode and DC mode have been considered, however, they have been removed from the requirements due to cost and complexity concerns (Telephone conference 12/18/02).

Wide pulse mode

The temporal profile of the light output in wide pulse mode operation shall be that of a square pulse with the following properties:

Rise-time:	30 ns or less
Fall-time:	50 ns or less
Pulse width:	800±10 ns

Note: The wide pulses are to be used for calibrating the PMT (nearest neighbors and self).

DC mode

The Flasher Board shall support operation of the LED's at a constant light level for a minimum of (**TBD**) sec.

Justification: Is this okay for "Supernova" calibration?

3.1.4.3.5 Repetition rate

The maximum pulse repetition rate of **1 kHz** shall be supported for both narrow pulse mode and wide pulse mode.

Note: This level of repetition rate for the Flasher Board is feasible from the engineering standpoint. A higher rate may be unnecessary in any case from the data-handling standpoint. (Telephone conference 12/18/02)

3.1.4.4 Intensity requirements

Note: **PHYSICISTS** must make sure that the numbers are correct. They must also document justification for future reference. Are these intensity requirements or energy requirements?

3.1.4.4.1 Physical definition of the intensity requirements

- (a) The Flasher Board shall support the **maximum pulse energy** of 5×10^9 photons per pulse.
- (b) The Flasher Board shall support the **minimum pulse energy** of 1×10^3 photons per pulse.

Justification: The maximum intensity requirement corresponds to one (1) photoelectron generated in the OM at 200 m in average ice. (Single pe distance of 200m.)

The six decades of intensity range allows a “boot-strap linearity calibration” performed in photon counting mode (AK).

3.1.4.4.2 Engineering definition of the intensity requirements

- (a) **THE MAXIMUM ENERGY PULSE** output shall be such that the combined output of all the light emitters firing at once produces 1×10^9 photoelectrons in the standard PMT when all the emitted photons strike the photocathode. The said standard PMT shall be defined to be one employing a bialkali photocathode with a combined quantum efficiency and collection efficiency of 23% at the wavelength of 400nm.
- (b) **THE MINIMUM ENERGY PULSE** output shall be 1×10^{-6} times smaller than the maximum energy pulse output.

3.1.4.4.3 Adjustability

- (a) The pulse intensity shall be adjustable by presetting a value via digital communication prior to triggering.
- (b) The pulse intensity shall be adjustable in logarithmically uniform steps over the minimum required intensity to the maximum required intensity in **32 steps** or more.

Note to self: Where does this 32 come from?

3.1.4.4.4 Intensity accuracy

- (a) For a given intensity preset value, the actual output intensity shall vary no more than **15 %**.
- (b) The mean value of the actual output intensity shall vary no more than **3 %** per week.

3.1.4.4.5 Calibrated performance

A. Absolute intensity

Absolute light output of the maximum intensity pulse shall be known to 20% accuracy by laboratory calibration.

B. Linearity

The relationship between the actual output intensity versus digital code for intensity adjustment shall be calibrated to within 10 %.

Note: The above requirements are adequate for

- (a) inter-string geometry calibrations
- (b) linearity measurements
- (c) verification of the dust structure below 2050m.

The linearity and energy measurements will be approached by the “bootstrap distance interval calibration”, proposed by AK. This method relies on the linearity calibration of the OMs within the specified range from 1 to 200 PE/15ns. While changing the amplitude over 6 orders of amplitude, there are always overlapping regions of linear OMs which can be used to cross-calibrate.

3.1.4.4.6 Spatial profile

3.1.4.4.6.1 Emission profile

- (a) The emission pattern shall be axially symmetric.
- (b) The angular profile of the emission of the individual emitters shall be such that the intensity towards 30 degrees off the peak axis and that towards 60 degrees off the peak axis are, respectively, 50% and 10% of the intensity towards the peak direction.

3.1.4.4.6.2 Peak direction

The optical flasher shall be implemented in two different types.

- (a) **THE HORIZONTAL-BEAM TYPE** flasher shall have the emitters installed in such a way that the peak intensity directions are in the horizontal plane, where the horizontal plane shall be parallel to the Flasher Board PCB.
- (b) **THE NON-HORIZONTAL-BEAM TYPE** flasher shall have the emitters installed in such a way that the peak intensity directions are 48 degrees above the horizontal plane, where “above” refers to the direction towards ice-top.

Note: The decision to make the Flasher Board in two varieties was made during the conference call on 12/18/02. The non-horizontal-beam type is intended to produce a light pattern simulating a Cherenkov radiation of a known energy.

3.1.4.4.7 Spatial uniformity

The optical intensity observed at 3m distance from the center of the Flasher Board (center of the OM?) shall meet the following uniformity requirements:

- (c) Symmetry with respect to the plane of the Flasher Board PCB shall be such that the integrated intensity over the upper hemisphere is to within 20% of that over the lower hemisphere.
- (d) Deviations from a spherical pattern in any direction shall be no greater than 50%.

3.1.5 Digital Board ID Device

The digital board ID device shall be a **Dallas Semiconductor DS2401**.

3.1.6 “User devices” electrical requirements

- (a) The user devices shall operate within the power budget of the Flasher Board.
- (b) The electrical interface between the user devices and the DOMMB shall be implemented using the board-to-board connection, defined in this document.
- (c) The rate of data traffic between the user devices and the DOMMB shall be (**TBD**).

3.2 Physical

3.2.1 General

3.2.2 PCB Dimensions

3.2.3 LED Mounting Requirements

3.2.4 “User Device” Area

3.2.5 PCB Material

3.2.6 Component Placement

3.2.7 Minimum Trace Rules

3.2.8 Conformal Coating

Conformal coating is required on both sides of the PCB.

Note to self: True?

3.2.9 Other PCB Requirements

3.3 Environmental

3.3.1 Temperature

- (a) The storage temperature of the Flasher Board shall be in the range of -55°C to $+45^{\circ}\text{C}$.
- (b) The operating temperature of the Flasher Board shall be in the range of -40°C to $+27^{\circ}\text{C}$.

Justification: These temperatures are the same as in the requirements for the PMT HV Base board.

3.3.2 Pressure

Both the storage pressure and continuous operating pressure for the Flasher Board shall be in the range of 40,000 Pa to 100,000 Pa.

3.4 Miscellaneous

4 REFERENCES

- DOMMB-Flasher Board Interface Engineering Requirements Document
- Digital Optical Module Assembly ERD
- DOM Main Board Hardware Requirements (Document No. 9000-0007).
- Supplement to the PMT HV Base Board ERD