# IceCube

# Flasher Board

# Engineering Requirements Document (ERD)

| | | | | |
|---|---|---|---|---|
| AK | 10/1/2002 | Version | 0.00 | |
| NK | 10/7/2002 | | 0.00a | |
| | 10/8/02 | | 0.00b | |
| | 10/10/02 | | 0.00c | |
| | | | 0.00d | |
| | 11/6/02 | | 0.01 | After AK, KW phone conf. |
| | 11/12/02 | | 0.01a | |
| | 12/10/02 | | 0.01b | |
| | 12/16/02 | | 0.01c | |

Note:
AK = Albrecht Karle
NK = Nobuyoshi Kitamura
KW = Kurt Woschnagg
GP = Jerry Przybylski
DW = Dan Wahl

**Table of Contents**

# 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

### 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. <u>It is anticipated, however, that optical flashers will be implemented in more than one design over the IceCube array</u>. 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 ±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).

#### 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

**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 (Mode) |
| 0100 | Optical flasher (Status) |
| 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 examines the Optical Flasher status
2. DOMMB selects one of the Flasher modes
3. DOMMB sets up parameters for the selected mode
4. DOMMB issues a trigger
5. The Flasher fires
6. The Flasher sends timing pulse to the DOMMB
7. The Flasher writes a status code to a register

#### 3.1.4.2 LED requirements

##### 3.1.4.2.1 General

(a) There shall be six (6) identical light **emitters** mounted 60° apart on the periphery of the Flasher Board, as specified in **3.2.2**.
(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.

##### 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 1 µs.

**Note:** GP says this should be more like 10ns, but DJW wants something greater than 1µsec.

##### 3.1.4.3.2 Trigger jitter

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

##### 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.

#### 3.1.4.3.4 Temporal profile

The Optical Flasher shall operate either in "**narrow pulse mode**" or a "**wide pulse mode**". The two modes are defined by the temporal profile of the light output as follows:

**A. Narrow pulse mode**

The temporal profile of the light output in narrow pulse mode operation shall be a narrow pulse with the full-width at half the maximum (FWHM) of 15 ns or less.

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

**B. 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).

**C. 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.

### 3.1.4.4 Intensity requirements

#### 3.1.4.4.1 Narrow pulse mode

(a) The Flasher Board shall support the **maximum pulse energy** of $5 \times 10^9$ photons per pulse.

(b) The Flasher Board shall support the **minimum pulse energy** of $1 \times 10^3$ 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 Wide pulse mode

The pulse intensity in wide pulse mode shall be variable in the range of $1x10^2$ - $2x10^4$ photons per ns.

> **Justification:** The intensity requirement assumes that 1% of emitted photons reach the PMT photocathode by channeling through the OM glass or by scattering in the ice.

#### 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.

#### 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. <u>Absolute intensity</u>**

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

**B. <u>Linearity</u>**

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

**(a)** The light emission shall have a peak in approximately the horizontal direction, where the horizontal plane is defined by the Flasher Board PCB.
**(b)** The emission shall be 50 % of the peak in the directions 30 degrees above and below the horizontal, and 10 % of the peak in the directions 60 degrees above and below the horizontal.

**(c)** The emission profile within the horizontal plane shall be similar to (b): 50% of the peak in the directions 30 degrees off the peak direction.

.

### 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:

**(d)** 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.
**(e)** 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.

#### 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°C.
(b) The operating temperature of the Flasher Board shall be in the range of –40°C to +27°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