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	

Note:
- AK = Albrecht Karle
- NK = Nobuyoshi Kitamura
- KW = Kurt Woschnagg

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 **3.2**) 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

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.

2.2.2 Digital Board ID Device

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

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.

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

The maximum power dissipation of the Flasher Board drawn from the default power source shall be 110 mW.

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

- 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.
- The ON/OFF switching of the optional power shall be controlled by the DOMMB.

3.1.2 Electrical Connections

3.1.2.1 Ribbon cable

The electrical connections between the Flasher Board and the DOMMB shall be facilitated by a 1-mm-pitch IDC ribbon cable with (***TBD***) conductors.

Justification: The small pitch helps reduce the connector footprint on the DOMMB side.

Note: If the ribbon cable carries the flasher strobe signal, or any other timing-critical signals, the characteristic impedance of the cable and the connecting PCB traces must be carefully designed.

3.1.2.2 Connector

The Flasher Board shall have a keyed IDC connector for the ribbon cable specified in the previous paragraph on the PCB location specified in a later section (**3.2**).

3.1.2.3 Signal assignment

3.1.2.3.1 Redundancy requirement

Each signal, ground and power in the ribbon cable shall have two connector pins allocated to it.

3.1.2.3.2 Connector signal assignment (*TBD*)

Table 3.1 Connector signal assignment

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). The said communication shall be in full-duplex with serial clock and four (4) bit address wires.

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:

- Optical flasher (**3.1.4**)
- Digital board ID device (**3.1.5**)
- 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**. (This is just a tentative idea.)

Table 3.2 Device address

Address	Device
0000	(reserved)
0001	Optical flasher (Trigger)
0010	Optical flasher (Amplitude)
0011	(reserved)
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 selects one of the Flasher modes
2. DOMMB sets up parameters for the selected mode
3. DOMMB issues a trigger
4. The Flasher fires
5. The Flasher sends timing pulse to the DOMMB
6. The Flasher writes a status code to a register

3.1.4.2 LED requirements

3.1.4.2.1 General

There shall be six (6) identical LED's mounted 60° apart on the periphery of the Flasher Board, as specified in **3.2.2**. The peak direction of the light emission for each LED shall be met by satisfying the requirements for the mechanical installation of the LED's specified in **3.2.2**.

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 370-450 nm.

> **Note:** Nichiha NSHU550 has the peak wavelength of 375nm. Longer wavelength LEDs (blue) tend to be available with higher intensity output.

3.1.4.2.3 Maximum ratings

The manufacturer's rated maximum operating conditions of the LED's shall be consistent with the rest of the requirements in this document.

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 LED's 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.

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
- Intensity: Variable from $1x10^2$ - $2x10^4$ photons per ns

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 Maximum pulse intensity

The Flasher Board shall support the maximum peak pulse energy of $5x10^9$ photons per pulse.

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

3.1.4.4.2 Minimum pulse intensity

The Flasher Board shall support the minimum peak pulse energy of $1x10^3$ photons per pulse.

3.1.4.4.3 Adjustability

The pulse intensity shall be adjustable by presetting a value via digital communication prior to triggering. The pulse intensity shall be adjustable in logarithmically uniform steps over the minimum required intensity to the maximum required intensity with a minimum of 8-bit resolution (255 steps).

Note: We may need only 32 steps.

3.1.4.4.4 Intensity accuracy

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

3.1.4.4.5 Spatial profile

The light emission shall have a peak in approximately the horizontal direction, where the horizontal plane is defined by the Flasher Board PCB. 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.

Note: It is permissible for the beam to be narrower than this, according to AK.

3.1.4.4.6 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:

A. 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.
B. Deviations from a spherical pattern in any direction shall be no greater than 50%.

3.1.4.4.7 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

1. inter-string geometry calibrations
2. linearity measurements
3. 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 5 orders of amplitude, there are always overlapping regions of linear OMs which can be used to cross-calibrate.

3.1.4.5 Electrical (Flasher)

3.1.5 Digital Board ID Device

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

3.2 Physical

3.2.1 General

3.2.2 PCB Dimensions

(To be specified by PSL)

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

Both the storage temperature and continuous operating temperature for the Flasher Board shall be in the range of –55°C to +(***TBD***)°C.

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