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6.2 IceCube Glossary				
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1 INTRODUCTION

1.1 Purpose

This IceCube Engineering Requirements Document (ERD) specifies the functional, constraint, and verification requirements for the PMT Modular High Voltage Power Supply Configuration Item (CI) including the source traceability (justification) for each requirement.

1.2 Scope

This requirements document shall be applicable to the design, development, integration, verification, production, logistics, field deployment and disposal of the PMT Modular High Voltage Power Supply.

1.3 Responsibility and Records

1.3.1 Document Responsibility

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

1.3.2 Document and Verification Records

Records of this document and CI verification records shall be maintained as follows:

- a. The approved and signed original of this document shall be maintained per 9000-0004, Document Management Process.
- b. Changes to this document shall be via Engineering Change Notices (ECN's) as described in 9000-0004, Document Management Process.
- c. Verification records shall be maintained as described in Section 4 of this document in compliance with 9000-0003, IceCube Quality Plan.

1.4 Item's Function in the IceCube System

The PMT (Photomultiplier Tube) Modular High Voltage (HV) Power Supply is an adjustable modular two-printed circuit board (PCB) power supply that creates and supplies approximately 2000 volts maximum anode bias and multiple dynode bias voltages to the PMT inside each Digital Optical Module (DOM). These multiple high voltages provide acceleration and focusing of electrons inside the PMT that flow in response to impinging photons from a nearby photonic event. This PMT electron flow is the critical sole detection mechanism for the IceCube system. By digital control a range of high voltages can be commanded that adjust the PMT for different photon sensitivities. There are 5120 Digital Optical Modules in the IceCube system, each containing a PMT Modular HV Power Supply. The IceCube system has 4800 DOMs deployed over a kilometer deep in the Antarctic ice with 320 additional DOMs installed on the ice surface, all used for scientific research.

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2 APPLICABLE DOCUMENTS

The following documents of the exact issue shown are applicable requirements for this Configuration Item only to the extent they are invoked by specific requirements herein.

2.1 Government Requirements

```
{National Science Foundation, xxxxxxxx}
{Occupational Safety and Health Administration, xxxxxxxx}
```

{Federal Communications Commission, xxxxxxxx}

{Federal Aviation Administration, xxxxxxxx}

{Customs – import/export}

{Hazardous materials storage and handling}

{International Trafficking in Arms Regulation (ITAR)}

{Standard government test methods}

{Regulations for packing and shipping to Antarctica}

{Etc.}

2.2 University Policy Requirements

```
{Personnel and equipment safety}
```

{Test equipment calibration}

{Hazardous material storage and handling}

{Protecting intellectual property}

{Etc.}

2.3 Industry Requirements

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{ASTM, ASME, EIA, NEC, ANSI, IEEE, JDEC, NFPA}
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{Building codes}

{Standard on printed wiring board design}

 $\{Standard\ test\ methods\}$

{Standard for soldering}

{Packing and shipping containers for commercial shipping}

{Etc.}

2.4 Certifications and Approvals

{Underwriters Laboratory, xxxxxxxx}

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{European Union CE Marking, EC Directive xx/xx/EEC} {Etc.}

Project Requirements

PMT HV Base Board Dimensional and Component Placement Requirements, PSL 5549B020 [TBR] Rev ?, [TBD] Physical Sciences Lab, University of Wisconsin – Madison [To be updated using 5549020B f nk1.pdf]

Component Envelope Drawing, PSL 5549C021 Rev G, [TBR] Physical Sciences Lab, University of Wisconsin – Madison *[To be updated using 5549021C g nkl.pdf]*

{Top level IceCube System specification, Document No. 9000-xxxx}

{Interface Requirements, Document No. 9000-xxxx}

PMT HV Base Board—DOMMB Interface Document (9000-0006 11/13/2002—To be updated)

{Etc.}

Reference Documents

{Reports or analyses from associated, similar or prior projects}

{Textbooks, symposia proceedings, or other associated references of record}

{White papers relating to the CI specified in this document}

Hamamatsu PMT Datasheet (R7081-02, Ver.4, July 2003)

{Etc.}

Order of Precedence 2.7

Conflicts within this document shall be resolved as directed by the IceCube System Engineer in collaboration with the Project Lead responsible for this Configuration Item.

In the event of a conflict between this document and any other documents, this document shall govern. An annotation of the nature of the conflict shall be placed in this document.

Conflicts between other documents as they relate to or impact this document shall be resolved as directed by the IceCube Project Manager in collaboration with the IceCube System Engineer.

REQUIREMENTS

Item Identification

3.1.1 Definition

The PMT (Photomultiplier Tube) Modular High Voltage (HV) Power Supply is a modular two-printed circuit board (PCB) 2000 volt high voltage power supply with a digitally

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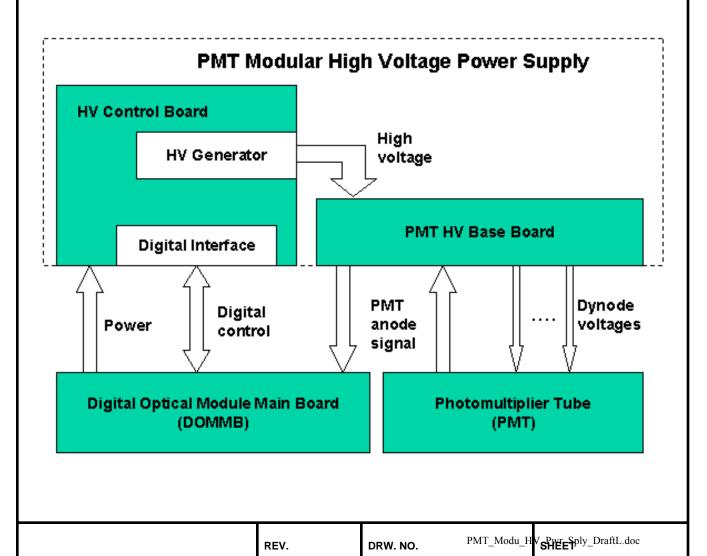
controlled and adjustable output, mounted inside a Digital Optical Module (DOM). The Power Supply consists of the High Voltage Control Board and the High Voltage Base Board.

3.1.2 Functional Description

The PMT (Photomultiplier Tube) Modular High Voltage (HV) Power Supply is an adjustable power supply that creates and supplies approximately 2000 volts DC anode bias to the PMT inside each Digital Optical Module (DOM). The PMT Modular HV Power Supply also supplies multiple DC bias high voltages to the PMT dynodes and focusing electrodes. The high voltages provide energy for e-fields inside the PMT that control the flow of electrons in response to impinging photons from a nearby photonic event. The PMT Modular HV Power Supply also provides functional monitoring for diagnostic voltage measurements and a transformer coupled circuit for extracting the analog output signal from the PMT anode.

3.1.3 Functional Block Diagram

The following block diagram illustrates the functional relationships of the PMT Modular High Voltage Power Supply with the DOM Main Board and the PMT in the IceCube system.



3.1.4 Functional External Interfaces

The PMT Modular High Voltage Power Supply has seven external functional interfaces:

- 1. Power input from the DOM Main Board
- 2. Bidirectional digital command, control, and monitoring to and from the DOM Main Board
- 3. Analog anode signal input from the PMT
- 4. PMT analog anode signal output to the DOM Main Board
- 5. High voltage outputs to the PMT's anode, dynodes, and focusing electrodes
- 6. Structural mounting of the HV Base Board by attachment to the PMT pins
- 7. Structural mounting of the HV Control Board by attachment to the Flasher Board

These interfaces are illustrated in the figure.

3.2 Performance Requirements

3.2.1 Functional Requirements

3.2.1.1 High Voltage Generation

The PMT Modular High Voltage Power Supply shall generate a series of high voltages for the individual dynodes, focusing electrodes and the anode of the PMT, using the power provided by the DOM Main Board.

REQUIREMENT'S SOURCE:

Preliminary Design Document (PDD), Section 7.2, Digital Optical Module

REV.

VERIFICATION METHOD:

Inspection

3.2.1.2 PMT Signal Output

The PMT Modular High Voltage Power Supply shall transfer the anode signal pulses from the PMT to the DOM Main Board through a coaxial cable.

REQUIREMENT'S SOURCE:

Coaxial cable is a straightforward way of implementing an impedance-controlled transmission line that transfers the PMT pulses with high fidelity.

VERIFICATION METHOD:

Inspection

3.2.1.3 Command Response

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The PMT Modular High Voltage Power Supply shall respond to the digital control commands issued by the DOM Main Board for High Voltage on/off and for the adjustment of the high voltages.

REQUIREMENT'S SOURCE:

Preliminary Design Document (PDD), Section 7.2, Figure 65

VERIFICATION METHOD:

Test

3.2.1.4 High Voltage Readings Output

The PMT Modular High Voltage Power Supply shall provide a digital reading output of the values of the high voltage to the DOM Main Board upon request.

REQUIREMENT'S SOURCE:

Document review (http://icecube.wisc.edu/internal/requirements/pmt_hv_base_erd/) and the subsequent telephone conference with [TBA] on October 3, 2002.

VERIFICATION METHOD:

Test

3.2.1.5 Board Identification Output

The PMT Modular High Voltage Power Supply shall provide digital board identification information output to the DOM Main Board upon request.

REQUIREMENT'S SOURCE: (What source did this requirement come from? Or, what is its justification?)

{enter the traceability answer here}

VERIFICATION METHOD:

Test

3.2.2 Electrical Requirements

3.2.2.1 Input Voltage

3.2.2.1.1 +5 Volts DC

The PMT Modular High Voltage Power Supply shall receive a power input voltage of +5 VDC ±5%.

REQUIREMENT'S SOURCE: (What source did this requirement come from? Or, what is its justification?)

{enter the traceability answer here}

VERIFICATION METHOD:

Test

3.2.2.1.2 -5 Volts DC

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The PMT Modular High Voltage Power Supply shall receive a power input voltage of -5 VDC ±5%.

REQUIREMENT'S SOURCE: (What source did this requirement come from? Or, what is its justification?) {enter the traceability answer here}

VERIFICATION METHOD:

Test

3.2.2.2 Input Current

3.2.2.2.1 +5 Volts Input Current

The PMT Modular High Voltage Power Supply input current for +5 Volt power shall not exceed [TBD] mA.

REQUIREMENT'S SOURCE: (What source did this requirement come from? Or, what is its justification?)

{enter the traceability answer here}

VERIFICATION METHOD:

Test

3.2.2.2.2 -5 Volts Input Current

The PMT Modular High Voltage Power Supply input current for -5 Volt power shall not exceed [TBD] mA.

REQUIREMENT'S SOURCE: (What source did this requirement come from? Or, what is its justification?)

{enter the traceability answer here}

VERIFICATION METHOD:

Test

3.2.2.3 Input Power

The total input power to the PMT Modular High Voltage Power Supply shall not exceed 300 mW.

REQUIREMENT'S SOURCE: (What source did this requirement come from? Or, what is its justification?)

{enter the traceability answer here}

VERIFICATION METHOD:

Test

3.2.2.4 Internal Power Distribution

The PMT Modular High Voltage Power Supply shall ...

REQUIREMENT'S SOURCE: (What source did this requirement come from? Or, what is its justification?)

{enter the traceability answer here}

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PMT Modular High Voltage Power S Document # 9000-0039-02	Supply	Page 17 of 58 Revision: draft		
VERIFICATION METHOD:T		Inspection Demonstration Similarity		
3.2.2.5 Internal Grounds				
3.2.2.5.1 Analog Grounds				
3.2.2.5.1.1 HV Control Board	Analog Ground			
The low noise analog signal grou connected to the negative (low signerator, the negative (low side	and on the HV Con (de) input power p) input power pin(ntrol Board shall be referenced by and in and metal case of the high voltage s) of the DAC and ADC and Reference, oard interface connector pin(s) designated		
REQUIREMENT'S SOURCE: (What	source did this requir	ement come from? Or, what is its justification?)		
{enter the traceability answer}				
VERIFICATION METHOD:				
nspection				
3.2.2.5.1.2 HV Base Board An	alog Ground			
	he HV negative lir	se Board shall be referenced by and ne from the HV generator on the HV capacitors and resistors.		
REQUIREMENT'S SOURCE: (What	source did this require	ement come from? Or, what is its justification?)		
{enter the traceability answer}				
VERIFICATION METHOD:				
nspection				
3.2.2.5.2 Power and Digital G	rounds			
3.2.2.5.2.1 HV Control Board	Power and Digita	l Ground		
interface connector pin(s) design	ated as DGND; ar DC and the DAC;	CB and connected to the DOM Main Board ad, referenced by the digital control and and, referenced by the negative (low side) r.		
REQUIREMENT'S SOURCE: (What	source did this requir	ement come from? Or, what is its justification?)		
(enter the traceability answer)				
VERIFICATION METHOD:				
nspection				

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3.2.2.5.2.2 HV Base Board Power and Digital G	round		
Power ground shall be referenced by and connected conductor from the HV generator on the HV Controgrounded capacitors and resistors. (With no digital	ol Board, and the ground end of all circuitry, there is no digital ground.)		
REQUIREMENT'S SOURCE: (What source did this require	ment come from? Or, what is its justification?)		
{enter the traceability answer}			
VERIFICATION METHOD:			
Inspection			
3.2.2.5.3 RF Grounds			
The PMT Modular High Voltage Power Supply hig connected to an RF ground plane area on the HV C conductor as the negative power to the high voltage	ontrol Board (which will be the same		
REQUIREMENT'S SOURCE: (What source did this require	ement come from? Or, what is its justification?)		
{enter the traceability answer here}			
VERIFICATION METHOD: Test Analysis I	nspection Demonstration Similarity		
{enter one of the above methods}			
3.2.2.6 PMT Cathode			
3.2.2.6.1 PMT Cathode Potential			
The PMT Modular High Voltage Power Supply sha for the PMT cathode.	all provide a low impedance zero voltage		
REQUIREMENT'S SOURCE: (What source did this require	ement come from? Or, what is its justification?)		
{enter the traceability answer here}			
VERIFICATION METHOD:			
Inspection			
3.2.2.6.2 PMT Cathode Ground Reference			
The PMT Modular High Voltage Power Supply sha cathode by direct connection of the cathode to the I	1 0		
REQUIREMENT'S SOURCE: (What source did this require			
{enter the traceability answer here}			
VERIFICATION METHOD:			
Inspection			
•			
3.2.2.7 PMT Anode High Voltage Generation			
 			
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3.2.2.7.1 Adjustable Voltage Ra	nge		
The PMT Modular High Voltage F minimum range of 1000 to 2048 V		-	•
REQUIREMENT'S SOURCE: (What so	_	ement come from	? Or, what is its justification?)
{enter the traceability answer here		namaatian DD	our another Circilanita
VERIFICATION METHOD: Tes {enter one of the above methods}	t [Allalysis []	nspection D	emonstration Similarity
3.2.2.7.2 Minimum Adjustment	Voltage		
The low end of the adjustable anoc	de voltage range	shall not be le	ss than 800 VDC.
REQUIREMENT'S SOURCE: (What so	ource did this require	ement come from	? Or, what is its justification?)
{enter the traceability answer here	}		
VERIFICATION METHOD: Tes	t Analysis I	nspection De	emonstration Similarity
{enter one of the above methods}			
3.2.2.7.3 Maximum Adjustment	t Voltage		
The high end of the adjustable ano	de voltage range	shall not exce	ed 2100 VDC.
REQUIREMENT'S SOURCE: (What so	ource did this require	ement come from	? Or, what is its justification?)
{enter the traceability answer here	}		
VERIFICATION METHOD: Tes	t Analysis 1	nspection De	emonstration Similarity
{enter one of the above methods}			
3.2.2.7.4 Voltage Adjustment D	AC Resolution		
The DAC used for digitally setting	the anode voltag	ge shall have a	12-bit resolution.
REQUIREMENT'S SOURCE: (What so	ource did this require	ement come from	? Or, what is its justification?)
{enter the traceability answer here	}		
VERIFICATION METHOD: Tes	t Analysis 1	nspection D	emonstration Similarity
{enter one of the above methods}			
3.2.2.7.5 Voltage Adjustment Li	inearity		
The digital command code value a a linear relationship in the voltage <i>[TBD]</i> Volts per bit.	-		•
REQUIREMENT'S SOURCE: (What so	ource did this require	ement come from	? Or, what is its justification?)
{enter the traceability answer here	}		
VERIFICATION METHOD: Tes	t Analysis 1	nspection Do	emonstration Similarity
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{enter one of the above methods}				
3.2.2.8 High Voltage Quality				
3.2.2.8.1 Voltage Stability				
The drift rate for the voltage across Dy1 and anode shall operation. (i.e. The maximum excursion over any given	S			
REQUIREMENT'S SOURCE: (What source did this requirement	come from? Or, what is its justification?)			
{enter the traceability answer here} VERIFICATION METHOD:				
Test				
3.2.2.8.2 Anode Voltage Ripple (Noise)				
The ripple voltage observed at the output of the secondar transformer shall not exceed 0.5mVpp when the output i	, , , , , , , , , , , , , , , , , , , ,			
REQUIREMENT'S SOURCE: (What source did this requirement	come from? Or, what is its justification?)			
{enter the traceability answer}				
VERIFICATION METHOD:				
Test				
3.2.2.9 Anode Voltage Monitoring				
3.2.2.9.1 Voltage Monitoring Output				
There shall be a provision for monitoring the anode voltavalue to the DOM Main Board as a digital code.	age using an ADC and transmitting its			
REQUIREMENT'S SOURCE: (What source did this requirement come from? Or, what is its justification?)				
{enter the traceability answer}				
VERIFICATION METHOD:				
Inspection				
3.2.2.9.2 Voltage Monitoring ADC Resolution				
The ADC used for monitoring the anode voltage shall ha	ve a 12-bit resolution.			
REQUIREMENT'S SOURCE: (What source did this requirement	come from? Or, what is its justification?)			
{enter the traceability answer}				
VERIFICATION METHOD: Test Analysis Inspect	ion Demonstration Similarity			
Inspection				
3.2.2.9.3 Voltage Monitoring Linearity				
	DMT Made UV Door Cally Door La-			
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The monitored anode voltage and the corresponding d relationship in the voltage range specified in 3.2.2.4.1. per bit.	-
REQUIREMENT'S SOURCE: (What source did this requireme	nt come from? Or, what is its justification?)
{enter the traceability answer}	
VERIFICATION METHOD: Test Analysis Insp	ection Demonstration Similarity
{enter one of the above methods}	
3.2.2.10 Anode Current Sourcing Capability	
3.2.2.10.1 Current Sourcing at Minimum Operating	g Temperature
The PMT Modular High Voltage Power Supply shall papability of a minimum of 12 nA, at the minimum op determined by the output anode voltage changing less zero to the specified minimum current.	erating temperature specified herein, as
REQUIREMENT'S SOURCE: (What source did this requireme	nt come from? Or, what is its justification?)
(Relates to In-Ice noise rate)	
VERIFICATION METHOD: Test Analysis Insp	ection Demonstration Similarity
{enter one of the above methods}	
3.2.2.10.2 Current Sourcing at Maximum Operatin	g Temperature
The PMT Modular High Voltage Power Supply shall peapability of a minimum of 240 nA, at the maximum of as determined by the output anode voltage changing leftom zero to the specified minimum current.	operating temperature specified herein,
REQUIREMENT'S SOURCE: (What source did this requireme	nt come from? Or, what is its justification?)
(Relates to room-temperature noise rate)	
VERIFICATION METHOD: Test Analysis Insp	ection Demonstration Similarity
{enter one of the above methods}	
3.2.2.10.3 Pulsed Current Sourcing	
The PMT Modular High Voltage Power Supply shall paper capability of a minimum of 100 mA for a single 1 µsecoperating temperature specified herein, as determined less than 10V when the current is changed from zero to pulse time.	c square-pulse, at the minimum by the output anode voltage changing
REQUIREMENT'S SOURCE: (What source did this requireme	nt come from? Or, what is its justification?)
{enter the traceability answer here}	
	
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VERIFICATION METHOD: Test Analysis [{enter one of the above methods}	☐ Inspection ☐ Demonstration ☐ Similarity				
3.2.2.11 PMT Dynode and Focus Voltages					
3.2.2.11.1 Dynode Chain Voltage Distribution					
The PMT Modular High Voltage Power Supply the PMT successive dynode stages according to Chain Voltage Distribution. Voltage values are by the voltage across Dynode 5 and Dynode 6 (I	the values specified in Table [TBD], Dynode expressed in terms of a factor to be multiplied				
REQUIREMENT'S SOURCE: (What source did this requirement)	uirement come from? Or, what is its justification?)				
Hamamatsu tentative datasheet ver. 4, July 2003 ICECUBE Experiment, Table 2.	, Photomultiplier Tube R7091-02 for				
VERIFICATION METHOD: Test Analysis [☐ Inspection ☐ Demonstration ☐ Similarity				
{enter one of the above methods}					
3.2.2.11.2 Voltage Source Impedance					
The electrical source impedance of the voltage seless than [TBD] ohms in order to meet the anode [TBD].					
REQUIREMENT'S SOURCE: (What source did this requ	uirement come from? Or, what is its justification?)				
{enter the traceability answer here}					
VERIFICATION METHOD: Test Analysis	☐ Inspection ☐ Demonstration ☐ Similarity				
{enter one of the above methods}					
3.2.2.11.3 PMT Focus Voltages					
The PMT Modular High Voltage Power Supply PMT focusing electrodes, denoted as F1, F2 and the following table, multiplied by the voltage acr	F3, as determined by the factor specified in				
Dynode Interval Voltage Relative to Dy5 – Dy6					
	Tolerance = [TBD] %				
K - Dy1	16.80				
Dy1 - Dy2	4.00				

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Dy2 - Dy3	5.00
Dy3 - Dy4	3.33
Dy4 - Dy5	1.67
Dy5 - Dy6	1.00 (Reference)
Dy6 - Dy7	1.20
Dy7 - Dy8	1.50
Dy8 - Dy9	2.20
Dy9 - Dy10	3.00
Dy10 - P	2.40
Dy1 - F1	0.60
Dy1 - F2	0.00
Dy1 - F3	0.60
	<u> </u>

Table Title - Dynode Chain Voltage Distribution

	REV.	DRW. NO.	PMT_Modu_HVSPEE1ply_DraftL.doc	2		
3.2.2.12 Dynode Damping Resistors						
{enter one of the above methods}						
VERIFICATION METHOD:						
{enter the traceability answer}						
REQUIREMENT'S SOURCE: (What source did this requirement come from? Or, what is its justification?)						
Table Note 5: All voltages are diff	ferentially meası	ired relative to	o a node pair, not to ground.			
Table Note 4: F1 and F3 are at the	same potential.					
Table Note 3: Dy1 and F2 are at the	Table Note 3: Dy1 and F2 are at the same potential.					
Table Note 2: "Fn" denotes the n-th focusing electrode or Electrode n.						
Table Note 1: "Dyn" denotes the n-th dynode or Dynode n.						

PMT Modular High Voltage Power Sup Document # 9000-0039-02	pply		Page 24 of 58 Revision: draft
3.2.2.12.1 HV Damping Resistors			
A resistor that is designed to minimplaced in series with each of the lashigh-voltage sources.		•	•
REQUIREMENT'S SOURCE: (What sou	arce did this require	ement come from?	Or, what is its justification?)
{enter the traceability answer}			
VERIFICATION METHOD: Test	Analysis	Inspection De	monstration Similarity
{enter one of the above methods}			
3.2.2.12.2 Resistor Value			
Each damping resistor shall have a	value of 100Ω :	± 5%, rated at a	minimum of 1/16 Watts.
REQUIREMENT'S SOURCE: (What sou	arce did this requir	ement come from?	Or, what is its justification?)
{enter the traceability answer}			
VERIFICATION METHOD: Test	Analysis .	Inspection De	monstration Similarity
{enter one of the above methods}			
3.2.2.12.3 Resistor Accessibility			
The damping resistors shall be mounted or relocation of any parts to allow the HV Base Board has been mounted or the state of the state	he shunting or ronto the PMT.	replacement of	the resistors after the PMT
REQUIREMENT'S SOURCE: (What sou	arce did this requir	ement come from?	Or, what is its justification?)
{enter the traceability answer}	□ Anologia □	Instruction Do	manatustian Dimilarita
VERIFICATION METHOD: Test {enter one of the above methods}	Analysis	Inspection De	monstration Similarity
3.2.3 Mechanical Requirements	,		
3.2.3.1 Force Inputs			
3.2.3.1.1 Linear			
3.2.3.1.2 Rotational			
3.2.3.2 Force Outputs			
3.2.3.2.1 Linear			
3.2.3.2.2 Rotational			
3.2.3.3 Loading			
<u> </u>			
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3.2.3.3.1 Structural Load					
3.2.3.3.2 Tensile Strength					
3.2.3.3.3 Compressive Strength					
3.2.3.3.4 Elasticity					
3.2.3.3.5 Compressibility					
3.2.3.4 Thermal Transfer					
3.2.4 Mass Properties Require	ments				
3.2.4.1 Size					
3.2.4.1.1 HV Base Board Size					
The PMT Modular High Voltage Power Supply HV Base Board shall be circular with a maximum diameter of 100 mm. The maximum height of the HV Base Board including all solder leads and component part heights shall not exceed <i>[TBD]</i> mm. The height (and volume) constraints shall apply to the mated pieces of the ribbon connectors.					
REQUIREMENT'S SOURCE:					
Component Envelope Drawing, Pa University of Wisconsin - Madiso		nk1.pdf, Physi	cal Sciences Lab,		
VERIFICATION METHOD: Tes	st Analysis	Inspection De	monstration Similarity		
{enter one of the above methods}					
3.2.4.1.2 HV Control Board Siz	e				
The PMT Modular High Voltage	Power Supply H	V Control Boar	d shall be		
REQUIREMENT'S SOURCE: (What so	ource did this requir	ement come from?	Or, what is its justification?)		
{enter the traceability answer}		_	_		
VERIFICATION METHOD: Test Analysis Inspection Demonstration Similarity					
{enter one of the above methods}					
3.2.4.2 Shape					
3.2.4.2.1 HV Base Board Shape	<u>}</u>				
The overall shape of the printed ci Supply HV Base Board shall be ci outline for accommodation of spec	rcular. A greate	diameter or a	deviation from the circular		
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shall be permitted provided that the interior surface of the pressu			ponents and	
REQUIREMENT'S SOURCE: (Wha	t source did this require	ement come from? Or, what is its	justification?)	
The circular board distributes the uneven distribution. Also, the I of the board tends to be circular	OOM enclosure is s	pherical and the maximum a		
VERIFICATION METHOD:	Test Analysis 1	nspection Demonstration	Similarity	
{enter one of the above method:	s}			
3.2.4.2.2 HV Control Board S	Shape			
The PMT Modular High Voltag	•	Control Board shape shall	be	
REQUIREMENT'S SOURCE: (Wha	11.5	•		
{enter the traceability answer}	•		,	
•	Γest ∏Analysis ∏1	nspection Demonstration	Similarity	
{enter one of the above method:			,	
3.2.4.3 Weight				
The PMT Modular High Voltage REQUIREMENT'S SOURCE: (What {enter the traceability answer}) VERIFICATION METHOD: [17] {enter one of the above methods	t source did this require	. ,	justification?)	
3.2.4.4 Center of Gravity				
3.2.4.5 Momentum				
3.2.5 External Interface Req	uirements			
3.2.5.1 Electric Power				
The PMT Modular High Voltag DOM Main Board via conducto Board.	11.			
REQUIREMENT'S SOURCE: (Wha	t source did this require	ment come from? Or, what is its	justification?)	
{enter the traceability answer}				
VERIFICATION METHOD:	Test Analysis	nspection Demonstration	Similarity	

PMT Modular High Vo Document # 9000-0039			Page 27 of 58 Revision: draft
3.2.5.2 Discrete Si	gnals		
3.2.5.2.1 High Vol	tage Power Supply ON/	OFF	
3.2.5.2.1.1 High Vo	oltage Power Supply ON	/OFF Control	
HV Power Supply by		oly shall support Power ON hrough a discrete signal wird.	
REQUIREMENT'S SOU	URCE: (What source did this	requirement come from? Or, wh	nat is its justification?)
{enter the traceabilit	,		
VERIFICATION METH	HOD:		
Test			
3.2.5.2.1.2 High Vo	oltage Power Supply ON	V/OFF Signal Logic Level	
ONTORE	ha IIV Cantral Daged also	11 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	
ON/OFF control to t	Logic Level	Meaning	below.
ON/OFF control to t			below.
ON/OFF control to t	Logic Level	Meaning POWER OFF	below.
ON/OFF control to t	Logic Level	Meaning	below.
	Logic Level 0 1 URCE: (What source did this by answer) HOD: Test Analysis	Meaning POWER OFF	nat is its justification?)
REQUIREMENT'S SOU {enter the traceabilit VERIFICATION METH	Logic Level 0 1 URCE: (What source did this by answer) HOD: Test Analysis ove methods)	Meaning POWER OFF POWER ON requirement come from? Or, where the second control of the	nat is its justification?)
REQUIREMENT'S SOU {enter the traceabilit VERIFICATION METH {enter one of the about 3.2.5.3 Analog Sig	Logic Level 0 1 URCE: (What source did this ty answer) HOD: Test Analysis ove methods)	Meaning POWER OFF POWER ON requirement come from? Or, where the second control of the	nat is its justification?)
REQUIREMENT'S SON {enter the traceability verification method of the about the solution of the about the solution of the about the shall be provided in the shall be provi	Logic Level 0 1 URCE: (What source did this sy answer) HOD: Test Analysis ove methods) spals Inding Wire Interface for sions on the HV Control 1	Meaning POWER OFF POWER ON requirement come from? Or, white Inspection Demonstrates	hat is its justification?) ation Similarity se Boards ard for connecting a 9
REQUIREMENT'S SOL {enter the traceability of the state of the about the state of the about the state of the	Logic Level 0 1 URCE: (What source did this sy answer) HOD: Test Analysis ove methods) sy and wire Interface for sions on the HV Control baided wire between the H	Meaning POWER OFF POWER ON requirement come from? Or, what is Inspection Demonstration The Demonstr	hat is its justification?) Intion Similarity See Boards and for connecting a Soil and the HV Base

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VERIFICATION METHOD:

Inspection

3.2.5.3.2 PMT Output Voltage

The PMT Modular High Voltage Power Supply shall employ a toroidal transformer coupling to output the analog PMT signal pulses from the HV Base Board to the DOM Main Board.

REQUIREMENT'S SOURCE: (What source did this requirement come from? Or, what is its justification?)

{enter the traceability answer}

VERIFICATION METHOD:

Inspection

3.2.5.4 Digital Signals

3.2.5.4.1 Digital Signal Definitions

3.2.5.4.1.1 CMOS Standard

The digital signals (logic levels and voltages) between the PMT Modular High Voltage Power Supply HV Control Board and the DOM Main Board shall comply with the 3.3V CMOS signal standard, [TBD standard document reference in Section 2].

REQUIREMENT'S SOURCE: (What source did this requirement come from? Or, what is its justification?)

All the digital interface on the DOMMB side is implemented in a CPLD that employs a 3.3V logic, hence this requirement.

VERIFICATION METHOD:

Inspection

3.2.5.4.2 High Voltage Control

3.2.5.4.2.1 HV Adjustment Digital Command Code

The digital command code for setting the anode voltage shall be in 12-bit unsigned straight binary with the digital value 000(hex) representing 0 Volts DC.

REQUIREMENT'S SOURCE: (What source did this requirement come from? Or, what is its justification?)

{enter the traceability answer here}

VERIFICATION METHOD:

Inspection

3.2.5.4.2.2 HV Monitoring Digital Output Code

The digital output code for monitoring the anode voltage shall be in 12-bit unsigned straight binary with the digital value 000(hex) representing 0 Volts DC.

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REQUIREMENT'S SOURCE: (What source did this requirement come from? Or, what is its justification?)

{enter the traceability answer}

VERIFICATION METHOD:

Inspection

3.2.5.4.3 Chip Select

3.2.5.4.3.1 Chip Select Signals (CS0, CS1)

The two chip-select signals, CS0 and CS1, shall be used in combination to select one of the following three digital devices residing on the PMT Modular High Voltage Power Supply HV Control Board:

DAC - Digital-to-analog converter

ADC - Analog-to-digital converter

IDENT - Board identification device

REQUIREMENT'S SOURCE: (What source did this requirement come from? Or, what is its justification?)

{enter the traceability answer}

VERIFICATION METHOD:

Inspection

3.2.5.4.3.2 Chip Selection Codes

The logic level chip selection codes for CS0 and CS1 shall be as follows:

CS0	CS1	Function
1	1	IDENT
0	1	DAC
1	0	ADC
0	0	(not allowed)

REQUIREMENT'S SOURCE: (What source did this requirement come from? Or, what is its justification?)

{enter the traceability answer}

VERIFICATION METHOD:

Test

3.2.5.4.4 MOSI, MISO, and SCLK Signals

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3.2.5.4.4.1 DAC Signals

DAC shall use MOSI and SCLK for data and serial clock, respectively.

REQUIREMENT'S SOURCE: (What source did this requirement come from? Or, what is its justification?)

{enter the traceability answer}

VERIFICATION METHOD:

Inspection

3.2.5.4.4.2 ADC Signals

ADC shall use MISO and SCLK for data and serial clock, respectively.

REQUIREMENT'S SOURCE: (What source did this requirement come from? Or, what is its justification?)

{enter the traceability answer}

VERIFICATION METHOD:

Inspection

3.2.5.4.4.3 IDENT Signals

IDENT shall use MISO.

REQUIREMENT'S SOURCE: (What source did this requirement come from? Or, what is its justification?)

{enter the traceability answer}

VERIFICATION METHOD:

Inspection

3.2.5.4.5 Board Digital Identification [TBR]

3.2.5.4.5.1 Board Digital Identification Number

The PMT Modular High Voltage Power Supply HV Control Board shall provide a unique digital board identification number (board ID) upon request from the DOM Main Board.

REQUIREMENT'S SOURCE: (What source did this requirement come from? Or, what is its justification?)

{enter the traceability answer}

VERIFICATION METHOD:

Test

3.2.5.4.5.2 Board Identification Protocol

The PMT Modular High Voltage Power Supply HV Control Board digital board ID device shall comply with the Dallas 1-Wire protocol to communicate with the DOM Main Board serving as the bus master.

REQUIREMENT'S SOURCE: (What source did this requirement come from? Or, what is its justification?)

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{enter the traceability answer}		
VERIFICATION METHOD:		
Test		
3.2.5.5 RF Signals		
3.2.5.6 Fiber Optic Signals		
3.2.5.7 External Grounding		
3.2.5.7.1 Discrete Signal Ground	ding	
3.2.5.7.2 Analog Signal Ground	ing	
3.2.5.7.3 Digital Signal Groundi	ing	
3.2.5.7.4 RF Signal Grounding		
3.2.5.7.5 Secondary Power Grou	unding	
3.2.5.7.6 Primary Power Groun	ding	
3.2.5.7.7 High Energy Groundin	ng	
3.2.5.7.8 Safety Grounding		
3.2.5.8 Test and Maintenance		
3.2.5.8.1 Test Points		
Voltage measurement test points sl measuring the anode voltage and fi relocation of any parts for access to	irst dynode volta	age without the need for removal or
	ource did this require	rement come from? Or, what is its justification?)
{enter the traceability answer}	A	Instruction Demonstration DOI 11 1
VERIFICATION METHOD: Tes Demonstration	t [Analysis []	Inspection Demonstration Similarity
	a4a)	
3.2.5.8.2 Access (Doors, Panels,	etc.)	
3.2.5.9 Interconnections		
3.2.5.9.1 Cables and Harnesses		
3.2.5.9.1.1 Cable Interface – HV	Control Board	to DOM Main Board
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The PMT Modular High Voltage F connections with the DOM Main F ground, and digital signal connecti	Board through a			
REQUIREMENT'S SOURCE: (What so	ource did this requir	ement come from	? Or, what is its justification?)	
{enter the traceability answer}				
VERIFICATION METHOD:				
Inspection				
3.2.5.9.1.2 Signal Duplication –	HV Control Bo	ard to DOM M	Iain Board	
Each signal, ground and power in a Board to DOM Main Board cable			11.5	
REQUIREMENT'S SOURCE: (What so	ource did this require	ement come from	? Or, what is its justification?)	
{enter the traceability answer}				
	t Analysis	Inspection De	emonstration Similarity	
{enter one of the above methods}				
3.2.5.9.1.3 Cable Type – HV Con	ntrol Board to I	OOM Main Bo	ard	
The PMT Modular High Voltage F cable shall be a 1mm-pitch flat ID	110			
REQUIREMENT'S SOURCE: (What so	ource did this require	ement come from	? Or, what is its justification?)	
{enter the traceability answer}				
VERIFICATION METHOD: Tes	t Analysis	Inspection De	emonstration Similarity	
{enter one of the above methods}				
3.2.5.9.2 Connectors				
3.2.5.9.2.1 HV Control Board to	DOM Main Ro	ard Connecto	r Tyne	
The PMT Modular High Voltage I male connector, Samtec STMM-11	Power Supply rib	bon connector	shall have a 2mm-pitch	
REQUIREMENT'S SOURCE: (What so	ource did this require	ement come from	? Or, what is its justification?)	
{enter the traceability answer}	-		,	
VERIFICATION METHOD:				
Inspection				
3.2.5.9.2.2 Connector Locations				
C Connector Locations				
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		-:····· ito.	O'ILL'	

See PSL Drawing 5549B020 f nk1.pdf. PMT Modular High Voltage Is dimensional and component placement requirements. The figure identifications for the coaxial cable attachment. The PCB material thickness REQUIREMENT'S SOURCE: PMT Modular High Voltage Power Supply Dimensional and Component Requirements, PSL 5549B020 Rev?, Physical Sciences Lab, University Madison VERIFICATION METHOD: Test Analysis Inspection Demonstrate (enter one of the above methods) 3.2.5.9.2.3 Other Connector Locations Other connector locations shall be as shown in PSL Drawing [TBD] REQUIREMENT'S SOURCE: Component Envelope Drawing, PSL 5549C021 Rev G, Physical Science Wisconsin - Madison VERIFICATION METHOD: Test Analysis Inspection Demonstrated Demonstrated Inspection Demonstrated Demonstrated Demonstrated Inspection Demonstrated Demonstrated Inspection Demonstrated Demonstrated Inspection Demonstrated Inspection Demonstrated Demonstrated Inspection Dem	Revision: draft
dimensional and component placement requirements. The figure identications for the coaxial cable attachment. The PCB material thickness REQUIREMENT'S SOURCE: PMT Modular High Voltage Power Supply Dimensional and Component Requirements, PSL 5549B020 Rev?, Physical Sciences Lab, University Madison VERIFICATION METHOD: Test Analysis Inspection Demonstrate (enter one of the above methods) 3.2.5.9.2.3 Other Connector Locations Other connector locations shall be as shown in PSL Drawing [TBD] REQUIREMENT'S SOURCE: Component Envelope Drawing, PSL 5549C021 Rev G, Physical Science Wisconsin - Madison	
PMT Modular High Voltage Power Supply Dimensional and Componer Requirements, PSL 5549B020 Rev ?, Physical Sciences Lab, University Madison VERIFICATION METHOD: Test Analysis Inspection Demonstrate {enter one of the above methods} 3.2.5.9.2.3 Other Connector Locations Other connector locations shall be as shown in PSL Drawing [TBD] REQUIREMENT'S SOURCE: Component Envelope Drawing, PSL 5549C021 Rev G, Physical Science Wisconsin - Madison	fies suggested
Requirements, PSL 5549B020 Rev ?, Physical Sciences Lab, University Madison VERIFICATION METHOD: Test Analysis Inspection Demonstr {enter one of the above methods} 3.2.5.9.2.3 Other Connector Locations Other connector locations shall be as shown in PSL Drawing [TBD] REQUIREMENT'S SOURCE: Component Envelope Drawing, PSL 5549C021 Rev G, Physical Scienc Wisconsin - Madison	•
{enter one of the above methods} 3.2.5.9.2.3 Other Connector Locations Other connector locations shall be as shown in PSL Drawing [TBD] REQUIREMENT'S SOURCE: Component Envelope Drawing, PSL 5549C021 Rev G, Physical Scienc Wisconsin - Madison	
3.2.5.9.2.3 Other Connector Locations Other connector locations shall be as shown in PSL Drawing [TBD] REQUIREMENT'S SOURCE: Component Envelope Drawing, PSL 5549C021 Rev G, Physical Scienc Wisconsin - Madison	ation Similarity
Other connector locations shall be as shown in PSL Drawing <i>[TBD]</i> REQUIREMENT'S SOURCE: Component Envelope Drawing, PSL 5549C021 Rev G, Physical Scienc Wisconsin - Madison	
REQUIREMENT'S SOURCE: Component Envelope Drawing, PSL 5549C021 Rev G, Physical Scienc Wisconsin - Madison	
Component Envelope Drawing, PSL 5549C021 Rev G, Physical Scienc Wisconsin - Madison	
Wisconsin - Madison	
VEDICICATION METHOD: Test Applying Inspection Demonstr	es Lab, University of
VERIFICATION METHODTestAnalysis inspectionDemonstr	ation Similarity
{enter one of the above methods}	
3.2.5.9.3 Modular HV Power Supply and DOM Main Board Interf	aca Cables
The following interface table summarizes the electrical connections between Modular High Voltage Power Supply and the DOM Main Board.	
Wioddiai High Voltage Fower Supply and the BOW Walli Board.	
REV. DRW. NO. PMT_	

Connection method	Explanation	Section
Plated-thru mounting holes	The HV Base Board is physically mounted to the PMT by inserting and soldering the pins in these holes, which also makes electrical connections.	
Coaxial RG-180B/U or equivalent	Connection between the secondary of the anode signal coupling transformer and the DOM main board. The board shall be manufactured with one end of the coaxial cable attached to it. The other end of the coaxial cable shall have a SMB <i>[TBR]</i> type connector attached.	
IDC Ribbon cable	Digital signals DC power Power & digital ground A male [TBR] connector is required on board.	
9 mm flat braided wire	RF noise reduction low-Z connection. Each board shall provide a grounding wire pad on its analog ground plane.	

3.2.5.9.4 Pin Outs
{enter one of the above methods}
VERIFICATION METHOD: Test Analysis Inspection Demonstration Similarity
{enter the traceability answer}
REQUIREMENT'S SOURCE: (What source did this requirement come from? Or, what is its justification?)

3.2.5.9.4.1 Ribbon Cable Connector Pin Assignments

Pin assignments for the ribbon cable between the PMT Modular High Voltage Power Supply and the DOM Main Board are shown in the below table. For increased reliability each signal, ground and power conductor in the PMT Modular High Voltage Power Supply to DOM Main Board cable shall have a minimum of two redundant pins allocated as shown.

<u> </u>		
REV.	DRW. NO.	PMT_Modu_HVSPEEPply_DraftL.doc

Pin #	Signal Name	Description
01	DGND	Digital and power ground
02	SCLK	Serial clock
03	SCLK	
04	MOSI	Master-out-slave-in
05	MOSI	
06	MISO	Master-in-slave-out
07	MISO	
08	DGND	
09	CS0	Chip-select bit 0
10	CS0	
11	CS1	Chip-select bit1
12	CS1	
13	ON/OFF	Board enable/disable
14	ON/OFF	
15	+5V	Main power (+)
16	+5V	
17	DGND	
18	DGND	

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19	-5V	Main power (-)
20	-5V	

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REQUIREMENT'S SOURCE: (What source did this requirement come from? Or, what is its justification?)

{enter the traceability answer}

VERIFICATION METHOD:

Inspection

3.2.5.9.4.2 Board Connector Physical Pin Layout

DGND	1	2	SCLK	
SCLK	3	4	MOSI	
MOSI	5	6	MISO	
MISO	7	8	DGND	
CS0	9	10	CS0	
CS1	11	12	CS1	
ON/OFF	13	14	ON/OFF	
+5V	15	16	+5V	
DGND	17	18	DGND	
-5V	19	20	-5V	
'			'	

(TOP VIEW)

REQUIREMENT'S SOURCE: (What source did this requirement come from? Or, what is its justification?)

{enter the traceability answer}

VERIFICATION METHOD:

Inspection

3.2.5.9.4.3 PMT Pin Assignment

REV.	DRW. NO.	PMT_Modu_H	V SHEET Ply_DraftL.doc

The PMT Modular High Voltage Power Supply HV Base Board shall electrically mate and function with the PMT using the pin assignments shown in the table below.

Pin #	Signal name	Description
01	NC	No connection
02	Dy1	Dynode #1
03	F3	Focus #3
04	NC	No connection
05	Dy3	Dynode #3
06	NC	No connection
07	Dy5	Dynode #5
08	Dy7	Dynode #7
09	Dy9	Dynode #9
10	Р	Anode
11	NC	No connection
12	NC	No connection
13	NC	No connection
14	Dy10	Dynode #10
15	Dy8	Dynode #8
16	Dy6	Dynode #6
17	Dy4	Dynode #4
18	NC	No connection
19	Dy2	Dynode #2
20	F1	Focus #1
21	F2	Focus #2
22	NC	No connection
23	NC	No connection
24	K	Cathode

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		_
Fi	gure: PMT Pin A	Assignment
REQUIREMENT'S SOURCE: (What so	ource did this requir	ement come from? Or, what is its justification?)
{enter the traceability answer}		
VERIFICATION METHOD: Tes	t Analysis	Inspection Demonstration Similarity
{enter one of the above methods}		
3.2.5.10 Grasping/Mounting Poi	nts	
3.2.5.10.1 Production		
3.2.5.10.1.1PMT Collar Position	ing Pins Cleara	nce
The HV Base Board shall provide accommodate the three positioning respect to the PMT base.	-	learance areas on the PWB to T collar used to position the PWB with
REQUIREMENT'S SOURCE: (What so	ource did this requir	ement come from? Or, what is its justification?)
{enter the traceability answer}		
VERIFICATION METHOD:		
Inspection		
3.2.5.10.1.2HV Base Board Mou	nting to PMT	
pattern that matches the PMT pin 1	pattern that will a	gh soldering holes and solder pads in a allow the HV Base Board to be securely punting that will survive the physical
REQUIREMENT'S SOURCE: (What so	ource did this require	ement come from? Or, what is its justification?)
{enter the traceability answer}		
VERIFICATION METHOD:		
Test		
3.2.5.10.2 Shipping Transport		
3.2.5.10.3 Installation		
3.2.5.11 Human		
3.2.5.12 Solar		
	REV.	DRW. NO. PMT_Modu_HV_SPEESply_DraftL.

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3.2.5.13 Thermal

3.2.5.14 Optical

3.2.5.15 Photonic

3.2.5.16 Hydraulic

3.2.5.17 Pneumatic

3.2.6 Environmental Requirements

3.2.6.1 Temperature

3.2.6.1.1 Operating Temperature

The HV Base Board shall meet all performance requirements when operating over an ambient temperature range of -40 °C to +27 °C.

REQUIREMENT'S SOURCE: (What source did this requirement come from? Or, what is its justification?)

{enter the traceability answer}

VERIFICATION METHOD:

Test

3.2.6.1.2 Non-Operating Temperature

The PMT Modular High Voltage Power Supply shall withstand a non-operating temperature range of **[TBD]** °C to **[TBD]** °C for a period up to **[TBD]** months without any degradation in performance.

REQUIREMENT'S SOURCE: (What source did this requirement come from? Or, what is its justification?)

{enter the traceability answer}

VERIFICATION METHOD:

Test

3.2.6.1.3 Storage/Transport Temperature

The PMT Modular High Voltage Power Supply shall withstand a storage and transport temperature range of –55 °C to +45 °C for a period of *[TBD]* months without any degradation in performance.

REQUIREMENT'S SOURCE: (What source did this requirement come from? Or, what is its justification?)

{enter the traceability answer}

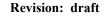
VERIFICATION METHOD:

Test

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Document # 7000-0037-02		Revision: urait
3.2.6.2 Thermal Shock		
3.2.6.2.1 Operating Thermal Sh	ock	
3.2.6.2.2 Non-Operating Therm	al Shock	
3.2.6.2.3 Storage/Transport The	ermal Shock	
3.2.6.3 Pressure		
3.2.6.3.1 Operating Pressure		
	air or while ope	rating inside a pressure vessel with a of 40,000 Pa to 100,000 Pa.
REQUIREMENT'S SOURCE: (What so	ource did this require	ement come from? Or, what is its justification?)
{enter the traceability answer}		
VERIFICATION METHOD: Tes	t Analysis	Inspection Demonstration Similarity
{enter one of the above methods}		
3.2.6.3.2 Non-Operating Pressu	re	
The PMT Modular High Voltage I	Power Supply sha [TBD] Pa to [TB	all withstand a non-operating atmospheric [D] Pa for a period up to [TBD] months
REQUIREMENT'S SOURCE: (What so	ource did this require	ement come from? Or, what is its justification?)
{enter the traceability answer}		
VERIFICATION METHOD: Tes	t Analysis	Inspection Demonstration Similarity
{enter one of the above methods}		
3.2.6.3.3 Storage/Transport Pre	essure	
The PMT Modular High Voltage I	Power Supply shand a s	all withstand a storage and transport D /Pa to [TBD] Pa for a period up to ance.
REQUIREMENT'S SOURCE: (What so	ource did this require	ement come from? Or, what is its justification?)
{enter the traceability answer}		
VERIFICATION METHOD: Tes	t Analysis	Inspection Demonstration Similarity
{enter one of the above methods}		
3.2.6.4 Vibration		
3.2.6.4.1 Operating Vibration		
		DMT Mode, IIV Door Cale, Dood Jo-
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3.2.11 Storage	
3.3 Design and Construction Requirements (parts, mate	rials, and processes)
3.3.1 Electrical Parts (wire, connectors, solder, insulation	n, switches, batteries, etc.)
To the extent practical, all electrical components used for the Power Supply shall meet the lowest operating temperature of component manufacturer. "Practical" means that this require material; conformal coating; and any electrical components the operating temperature of -55°C or lower.	-55°C, as specified by the ement applies to all PCB
The vendor of the PMT Modular High Voltage Power Supply of electrical components used that do not meet the -55°C or le	
REQUIREMENT'S SOURCE: (What source did this requirement come to	from? Or, what is its justification?)
{enter the traceability answer}	
VERIFICATION METHOD:	
Inspection	
3.3.2 Electronic Parts (resistors, capacitors, inductors, so	emiconductors, tubes, etc.)
To the extent practical, all electronic components used for the the lowest operating temperature of -55° C, as specified by the "Practical" means that this requirement applies to all resistors other electronic components that are readily available for the or lower.	e component manufacturer. , capacitors and diodes and any
The vendor of the PMT Modular High Voltage Power Supply of electronic components used that do not meet the -55°C or 100 cm.	
REQUIREMENT'S SOURCE: (What source did this requirement come to	from? Or, what is its justification?)
{enter the traceability answer}	
VERIFICATION METHOD: Test Analysis Inspection	Demonstration Similarity
{enter one of the above methods}	
3.3.2.1 PMT Signal Output Transformer	
3.3.2.1.1 Transformer Signal Definition	
The PMT signal output interface on the HV Base Board shall bifilar toroidal transformer whose two wires shall be designat secondary with dot phase polarities as designated in Figure [7]	ed P for primary and S for
See the figure below. [TBR]	



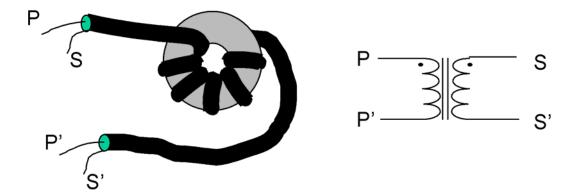


Figure: Anode signal coupling transformer signal definition (Illustration purpose only. See text for correct winding requirements).

REQUIREMENT'S SOURCE: (What source did this requirement come from? Or, what is its justification?)

{enter the traceability answer}

VERIFICATION METHOD:

Test

3.3.2.1.2 Transformer Construction

3.3.2.1.2.1 Bifilar Wound Toroid

The transformer shall consist of a bifilar wound ferrite toroid of [TBD] turns.

REQUIREMENT'S SOURCE: (What source did this requirement come from? Or, what is its justification?)

{enter the traceability answer}

VERIFICATION METHOD:

Inspection

3.3.2.1.2.2 Transformer Wire Type

The wire type used for both primary and secondary windings shall be [18 or 20 AWG] [TBR] high voltage type silicone insulated stranded wire with a minimum continuous operating voltage rating of [5 or 10 kV] [TBR].

REQUIREMENT'S SOURCE: (What source did this requirement come from? Or, what is its justification?)

{enter the traceability answer}

VERIFICATION METHOD:	Test [Analysis	Inspection	☐ Demonstration	Sımıları Sımıları	ty
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{enter one of the above methods}			•
3.3.2.1.2.3 Toroidal Core Type			
The transformer toroidal magnetic inc.com) [TBR] or equivalent.	core shall be Ma	agnetics Model ZH-42206-TC (www.m	nag-
REQUIREMENT'S SOURCE: (What so	ource did this requir	ement come from? Or, what is its justification	?)
{enter the traceability answer}			
VERIFICATION METHOD: Tes	t Analysis	Inspection Demonstration Similarity	
{enter one of the above methods}			
3.3.2.1.2.4 Winding Retention			
There shall be a means to hold the toroidal center, or a "belly-band" a		ce (such as a plastic plug pressed into the former)	ne
REQUIREMENT'S SOURCE: (What so	ource did this requir	ement come from? Or, what is its justification	?)
{enter the traceability answer}			
VERIFICATION METHOD:			
Inspection			
3.3.2.1.3 Primary Side Require	ments		
3.3.2.1.3.1 Primary Resistor Tei	mination		
The primary side of the bifilar tran primary terminals ("back terminate		terminated with a 100Ω resister across	the
REQUIREMENT'S SOURCE: (What so	ource did this requir	ement come from? Or, what is its justification	?)
{enter the traceability answer}			
VERIFICATION METHOD:			
Inspection			
3.3.2.1.3.2 PMT Anode Primary	Termination		
The "dotted" side of the primary to		nect to the PMT anode terminal.	
1 ,		ement come from? Or, what is its justification	?)
{enter the traceability answer}	1"		,
VERIFICATION METHOD:			
Inspection			
-	L D: 5		
3.3.2.1.3.3 PMT Anode High Vo	Itage Primary [Termination	
		PMT Modu HI/ Dur Sply Dro	ftI doe
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The "un-dotted" side of the primary terminal shall connect to the source of the PMT anode high-voltage.

REQUIREMENT'S SOURCE: (What source did this requirement come from? Or, what is its justification?)

{enter the traceability answer}

VERIFICATION METHOD:

Inspection

3.3.2.1.4 Secondary Side Requirements

3.3.2.1.4.1 Coaxial Output Secondary Interface

The secondary side of the bifilar transformer shall be connected to the DOM Main Board using a coaxial medium.

REQUIREMENT'S SOURCE: (What source did this requirement come from? Or, what is its justification?)

{enter the traceability answer}

VERIFICATION METHOD:

Inspection

3.3.2.1.4.2 Output Coax Type

The output coax type shall be RG-180B/U or a similar coaxial cable with a nominal characteristic impedance of 95Ω .

REQUIREMENT'S SOURCE: (What source did this requirement come from? Or, what is its justification?)

{enter the traceability answer}

VERIFICATION METHOD:

Test

3.3.2.1.4.3 Output Coax Secondary Connections

The center conductor and the shield conductor of the said coaxial cable shall connect to the "dotted" side and the "un-dotted" side of the secondary terminal of the transformer, respectively.

REQUIREMENT'S SOURCE: (What source did this requirement come from? Or, what is its justification?)

{enter the traceability answer}

VERIFICATION METHOD:

Inspection

3.3.2.1.5 Coaxial Cable Installation

3.3.2.1.5.1 Coax Cable Delivery With High Voltage Base Board

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The PMT Modular High Voltage P coaxial cable specified in 3.3.1.3.4			shall be delivered with the
REQUIREMENT'S SOURCE: (What so	urce did this require	ement come fron	n? Or, what is its justification?)
{enter the traceability answer}			
VERIFICATION METHOD:			
Inspection			
3.3.2.1.5.2 Soldered Coax Conne	ections		
Electrical connections of the coaxi	al cable shall be	accomplished	by direct soldering.
REQUIREMENT'S SOURCE: (What so	urce did this require	ement come fron	n? Or, what is its justification?)
{enter the traceability answer}			
VERIFICATION METHOD:			
Inspection			
3.3.2.1.5.3 Electrical Connection	s Mechanical I	ntegrity	
The coaxial electrical connections of 5kg of force in any direction.	shall not degrad	e when the ca	ole is pulled with a maximum
REQUIREMENT'S SOURCE: (What so	urce did this require	ement come fron	n? Or, what is its justification?)
{enter the traceability answer}			
VERIFICATION METHOD:			
Test			
3.3.2.1.5.4 Length of Coax Cable	ę.		
The length of the coaxial cable sha		TBR	
REQUIREMENT'S SOURCE: (What so	•	-	n? Or, what is its justification?)
{enter the traceability answer}	•		,
· · · · · · · · · · · · · · · · · · ·	t Analysis	Inspection \[\Bar{\Bar{\Bar{\Bar{\Bar{\Bar{\Bar{	emonstration Similarity
{enter one of the above methods}		_	
3.3.2.1.5.5 Coax Cable Free End	Connector		
The end of the said coaxial cable n [TBD] connector.	ot attached to th	e PCB shall h	ave a right-angle, crimp-type
REQUIREMENT'S SOURCE: (What so	urce did this require	ement come fron	n? Or, what is its justification?)
{enter the traceability answer}	-		,
VERIFICATION METHOD: Test	t Analysis	Inspection	pemonstration Similarity
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			DMT Mode UV Proce C. L. D. OV. L.
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gold plated coax crimp type; or, Se	ne Applied Engineralectro 51-128-9	neering Products (AEP) 2715-1521-004, 9511. ement come from? Or, what is its justification?)		
VERIFICATION METHOD: Inspection				
3.3.3 Mechanical Parts (structu	ires, fasteners, l	holders, containers, valves, etc.)		
3.3.4 Coatings, Platings, Corros	sion Prevention			
3.3.5 Adhesives and Sealants				
3.3.6 Printed Circuit Boards				
3.3.6.1 HV Base Board Layout				
PMT leads are inserted. The "top s	side" of the PMT erms "top view"	er to the side of the PCB from which the THV Base board shall refer to the side and "bottom view" shall refer to the views HV Base board, respectively.		
Note: The "ice top view" is a view	v of the Digital (Optical Module components in ice seen Board, the "ice top view" and the "top		
REQUIREMENT'S SOURCE: (What so	urce did this require	ement come from? Or, what is its justification?)		
{enter the traceability answer} VERIFICATION METHOD: Test {enter one of the above methods}	: Analysis]	Inspection Demonstration Similarity		
3.3.6.1.2 Component Placement				
-	either the top si	de or the bottom side of the PCB within the the following items		
Anode signal coupling trans	• Anode signal coupling transformer (Bottom side)			
• Coaxial cable for the anode	• Coaxial cable for the anode signal connection			
• Ribbon cable connector (To	• Ribbon cable connector (Top side.)			
RF grounding connection w	vire pad			
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The following items shall be installed at locations who for modification after the HV Base Board has been me	-
 Damping resistors 	
 RF grounding connection wire pad 	
REQUIREMENT'S SOURCE: (What source did this requirement	ent come from? Or, what is its justification?)
{enter the traceability answer}	
VERIFICATION METHOD: Test Analysis Insp	pection Demonstration Similarity
{enter one of the above methods}	
3.3.6.1.3 Excluded Area	
No PWB components shall be mounted in the areas so	specified in [TBD] figure.
REQUIREMENT'S SOURCE: (What source did this requirement	ent come from? Or, what is its justification?)
{enter the traceability answer}	
VERIFICATION METHOD: Test Analysis Insp	pection Demonstration Similarity
{enter one of the above methods}	
3.3.6.1.4 Minimum Trace Spacing Requirements	
In compliance with the circuit board trace layout rules conditions shall be met for both DC voltages and AC	
• For voltage difference greater than 100 V and spacing shall be <i>[TBD]</i> mm.	less than 300 V, the minimum trace
• For voltage difference greater than 300 V and spacing shall be <i>[TBD]</i> mm.	less than 500 V, the minimum trace
• For voltage difference greater than 500 V, the mm plus <i>[TBD]</i> mm per every volt exceeding	1 0 1
REQUIREMENT'S SOURCE: (What source did this requirement	ent come from? Or, what is its justification?)
{enter the traceability answer}	
VERIFICATION METHOD: Test Analysis Insp	pection Demonstration Similarity
{enter one of the above methods}	
3.3.6.1.5 Plated-thru Holes	
The HV Base Board shall have plated-thru holes.	
REQUIREMENT'S SOURCE: (What source did this requirement	ent come from? Or, what is its justification?)
{enter the traceability answer}	
VERIFICATION METHOD: Test Analysis Insp	pection Demonstration Similarity
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{enter one of the above methods}

3.3.6.1.6 Hole Pattern

The HV Base Board shall have a hole pattern as specified in the figure below to provide mechanical mating with the pins on the PMT.

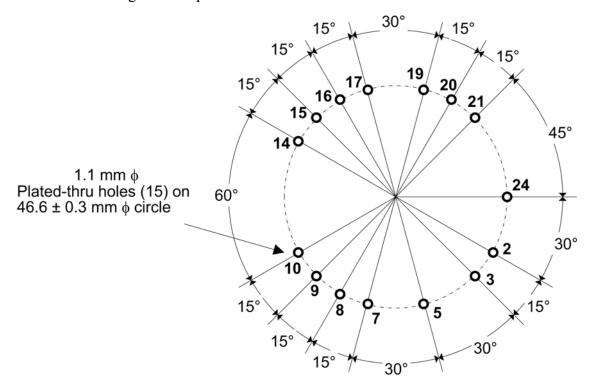


Figure: Plated-thru PMT mounting hole locations viewed from the top-side of the HV Base Board. The numerical labels associated with the holes mark the corresponding PMT pin number whose signal assignments are defined in the pin assignment table.

3.3.6.1.7 Annular Ring

Each of the HV Base Board plated-thru holes shall have top and bottom annular ring soldering pads as specified in the below figure.

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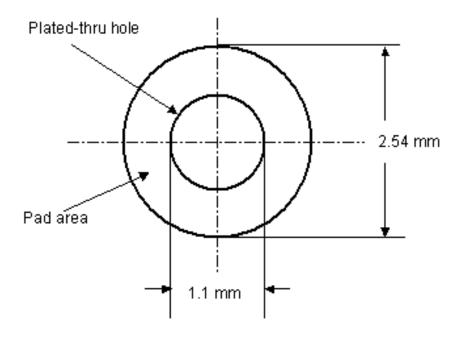


Figure: Solder Pad Specification

REQUIREMENT'S SOURCE: (What source did this requirement come from? Or, what is its justification?)
{enter the traceability answer}
VERIFICATION METHOD:
{enter one of the above methods}
3.3.6.2 Manual Soldering Compatibility
The PCB shall be compatible with the increased temperature during the manual soldering of the PMT pins at the solder pads specified in <i>[TBD]</i> .
REQUIREMENT'S SOURCE: (What source did this requirement come from? Or, what is its justification?)
{enter the traceability answer}
VERIFICATION METHOD:
{enter one of the above methods}
3.3.6.3 Solder Mask
A solder mask shall be applied to both the top and bottom sides of the Printed Circuit Board (PCB) with masked clearance including, but not limited to, the following items:
All solder pads
Through holes for component pins and leads

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Test points	
Designated clear solder pad areas for jumpers, changeable calibrates	ation resistors, etc.
REQUIREMENT'S SOURCE: (What source did this requirement come from	n? Or, what is its justification?)
{enter the traceability answer}	
VERIFICATION METHOD: Test Analysis Inspection C	Demonstration Similarity
{enter one of the above methods}	
3.3.6.4 Silk Screen Marking	
Silk screen markings shall include, but not be limited to, the following	owing items:
• Supplier identifier	
• IceCube Project identifier	
Part number and revision number	
Component reference designators	
• Connector reference designators with pin 1 and the higher	st pin number marked
• Test points	
PMT pin numbers	
REQUIREMENT'S SOURCE: (What source did this requirement come from	n? Or, what is its justification?)
{enter the traceability answer}	
VERIFICATION METHOD: Test Analysis Inspection D	Demonstration Similarity
{enter one of the above methods}	
3.3.6.5 Conformal Coating	
[TBD]	
REQUIREMENT'S SOURCE:	2
DOM production meeting at DESY-Zeuthen, Germany, May 200	
VERIFICATION METHOD: Test Analysis Inspection C	Demonstration Similarity
{enter one of the above methods}	
3.3.7 Soldering	
The Printed Circuit Board design shall be compatible with the in the manual soldering of the PMT pins at the solder pads specified	
the mandar soldering of the 11411 pins at the solder pads specified	a iii paiagiapii [A.A.A.A].
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REQUIREMENT'S SOURCE: (What sometimes of the above methods)	est Analysis	ement come from? Or, Inspection Demons	
3.3.8 Welding			
3.3.9 Machining			
3.3.10 Restricted Parts, Materi	als and Processe	s	
3.3.10.1 Beryllium			
3.3.10.2 Cadmium			
3.3.10.3 CFC			
3.3.10.4 Lead			
3.3.10.5 Mercury			
3.3.11 Reliability			
3.3.12 Maintainability			
3.3.13 Interchangeability			
3.3.14 Manufacturability			
3.3.15 Workmanship			
3.3.16 Human Engineering			
3.4 Quality Requirements			
3.5 Safety Requirements			
3.5.1 Personnel			
3.5.2 Equipment			
3.5.3 Environment			
3.6 Special Test Equipment			
3.6.1 Engineering			
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2 (2) Duodustion	
3.6.2 Production3.6.3 Field	
3.7 Tools, Jigs, and Fixtures	
3.7.1 Engineering	
3.7.2 Production	
3.7.3 Shipping	
3.7.4 Logistics	
3.7.5 Deployment	
3.7.6 Installation	
3.8 Support	
3.8.1 Logistics	
3.8.2 Preventative Maintenance	
3.8.3 Special Tools	
3.8.4 Spares	
3.8.5 Repair Methods	
3.8.6 Documentation/Manuals	
3.9 Personnel and Training	
3.10 End of Life Disposition	
3.10.1 Retirement	
3.10.2 Disposal	
3.11 System Security	
4 VERIFICATION	
4.1 Responsibility	
4.2 Special Tests and Examinations	
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4.3 Requirement vs. Verification	Cross Reference with Sec	etion 3
5 PREPARATION FOR DELIV		
5.1 Identification Nameplates and	d Marking	
5.1.1 Part and Serial Numbers		
The PMT Modular High Voltage Povrevision, serial number and manufact		y marked with part number,
REQUIREMENT'S SOURCE: (What source	ce did this requirement come from	m? Or, what is its justification?)
{enter the traceability answer} VERIFICATION METHOD: Test [{enter one of the above methods}	Analysis Inspection I	Demonstration Similarity
5.1.2 Nameplate		
5.1.3 Cable and Connector ID Ta	gs	
5.2 Acceptance Inspection and T	ests	
5.3 Packaging		
5.4 Recording Sensors		
5.5 Crating		
5.6 Labeling		
5.7 Shipping		
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DEFINITIONS

6.1 IceCube Acronyms

ADC Analog-to-Digital Converter

ATWD Analog Transient Waveform Digitizer

AWG American Wire Gauge

Centimeter cm

CMOS Complementary Metal Oxide Semiconductor

CS0 Chip-select bit 1

CS1 Chip-select bit 0

DAC Digital-to-Analog Converter

DAQ Data Acquisition System

DC Direct Current

DOM Digital Optical Module

DOMMB Digital Optical Module Main Board

EM Electromagnetic

Electromagnetic Compatibility **EMC**

ERD Engineering Requirements Document

HV High Voltage

Hz Hertz

Inside Diameter ID

Insulation Displacement Connector IDC

IPC Institute for Interconnecting and Packaging Electronic Circuits

k Kilo (103

Kilogram kg

Light-Emitting Diode LED

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MKS Meter-kilogram-second

M Mega (106)

Meter m

Milliampere mA

Master-Out-Slave-In **MOSI**

Master-In-Slave-Out **MISO**

mVMillivolt

mWMilliwatt

Nano (10-9) n

OD Outside Diameter

OM Optical Module

Pascal Pa

PCB Printed Circuit Board

Photoelectron PE

Pico Farad pF

Photomultiplier Tube **PMT**

P/N Part Number

PSL Physical Sciences Laboratory, University of Wisconsin-Madison

Peak-to-valley ratio P/V ratio

s, sec Second

SCLK Serial Clock

SI Système International d'Unités

Sub-Miniature B **SMB**

Single Photoelectron SPE

TBD To Be Determined

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UL	Underwriters Laboratory	
V	Volt	
VDC	Volt DC	
W	Watt	

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6.2 IceCube Glossary

Anode A PMT dynode, the last in the multiplier chain and typically

larger than the preceding dynodes, that collects the final

charge pulse.

Cathode The active surface of the photomultiplier from which

photoelectrons are initially liberated.

Zero The temperature, in degrees Celsius, at which water changes

state from a liquid into a solid.

7 APPENDIX