Partial Operational Readiness Clearance (Non-beam operation)
2/07/2012

AUTHORIZATION TO PROCEED WITH THE ATTENDED OPERATION OF MICROBOONE PMT TEST STAND AT PAB

REVIEWED AND APPROVED BY: **DATE**

[signature] 2/8/2012
Particle Physics Division Head - Michael Lindgren
Comments/Exceptions:

[signature] 13747N 2.8.2012
Particle Physics Senior Safety Officer
Comments/Exceptions:

[signature] 13747N 2.8.2012
Committee Chair
Comments/Exceptions: For Leo Bellantoni

Submitted By:
L. Bagby 2.8.2012
PMT Test Stand Representative - Linda Bagby

Electronic approvals for this form are acceptable. Please forward your responses to all recipients. A signed paper form (copy) of this document will exist in the Particle Physics Division Office. The original signed document will stay with the experiment requesting clearance.

Rev Aug 2008

Fermilab

January 24, 2012

To: Mike Lindgren
Particle Physics Division

From: Thomas Page
Chair, Village & Misc. Cryogenic Safety Review Panel

Subject: MicroBoone PMT Test Stand

Dear Mike,

The Village & Misc. Cryogenic Safety Review Panel has completed its review of the modified cryogenic setup of the MicroBoone PMT Test Stand in the Proton Assembly Building (PAB). This is similar to the setup approved in 2010 with the exception of a new top plate designed to hold four PMT's instead of one.

Our review consisted of:

- A meeting and walk-through with Teppei Katori at PAB on January 23, 2012. Committee members present: Tom Page, Eric McHugh, Brian DeGraff and Bill Soyars
- Review of safety related documentation provided to us for our review of this setup.
    - Description of intended set-up and operation, revised 12/25/2011.
    - ODH calculations, dated 12/12/2011.

Based on our review and the previous PMT test experience, we are satisfied that the proposed operation in PAB can be conducted safely.

Regards,

Thomas Page

Thomas Page
On behalf of the Village & Misc. Cryogenic Safety Review Panel

Copy: Teppei Katori
Panel Members (Brian DeGraff, Eric McHugh, Tom Page, Dave Pushka, Bill Soyars)
Arkadiy Klebaner, Cryogenic Safety Subcommittee Chair

Eric D McHugh

From: Steve Chappa <chappa@fnal.gov>
Sent: Tuesday, February 07, 2012 4:50 PM
To: Eric D McHugh; Leo Bellantoni
Cc: Karen M Kephart; Linda F Bagby
Subject: RE: MicroBoone PMT Test Stand review findings

Hi Eric. Dr. Leo,

I have completed a follow-up review of the MicroBoone test stand, located at PAB, with Linda. From this follow-up (correlated with the review findings items listed previously):

1) The panel is now secured. –OK

2) The caution label is placed on the front panel of the crate. –OK

3) I have looked at a spare (and identical) interlock chassis and cross-referenced it with the now updated drawings in the supplied document. The fabrication and description in the document all looks OK. The interlock and reset operations are not controlled by a PLC.

4) The HV caution labels are now placed on the four RG180 cables. –OK

5) The HV grounding is now understood and the custom splitter boxes, cable shield connections now match with the document supplied. Due to the operational requirements, the rule contained in FESHM 5043-3(5) is mitigated through the use of external grounding braids and the use of a "soft" grounding for the cable shields using a 500-ohm isolating resistor. Rough calculations indicate that even if all four cables were to short to the dewar vessel wall, the maximum voltage induced on the dewar metal will be about 1.5 V (3mA x 500-ohms) before the HV pods would trip on an over-current. –OK

6) The AC cord is now restrained at the IEC connection. –OK

With these concerns addressed, I can now recommend this installation be issued the ORC.

Regards,
Steve

From: Steve Chappa [mailto:chappa@fnal.gov]
Sent: Monday, January 23, 2012 7:46 PM
To: 'Eric D McHugh'
Cc: 'Karen Kephart'; 'Linda Bagby'; 'jamieson@fnal.gov'
Subject: MicroBoone PMT Test Stand review findings

Hi Eric,

During the review of the PMT test stand at PAB this afternoon at 2:00 PM, I found:

1) Secure the G10 blank front panel, for the VME crate, with screw hardware to prevent it from falling off and thus allow access to the interior of the crate with the HV module installed.

2) Since the VME back plane, especially the J2 segment, is customized from the standard pin out, there should be a sign or label indicating that VME modules should not be inserted in this crate.

3) The custom-built interlock control chassis did go through a design review. However, being custom, I need to look inside to verify that "best practices" wiring methods are implemented inside the chassis with respect to the AC power, fusing, grounding, etc.

4) HV caution labels are needed for the brown RG180 cables used for the HV going into the dewar.

5) The grounding of the cable shields seems to be confusing. Starting with the rule (FESHM 5045-3, requirement No. 5) that the HV chassis connector shall be solidly grounded to the panel to which it is mounted, the isolating HV outputs and splitter circuit box needs to be further understood.

6) Provide cord restraint for the AC power IEC connector going into the Lambda power supply chassis: If moving the cord moves the cord connector when seated, restraint of the cord is required.

OK. I have looked inside the interlocks control chassis and the fabrication itself looks OK. However, the circuit did not quite match up with the supplied document. There is an updated drawing on a website that Jamison sent. --OK.

Linda and I will be going over the HV shield grounding sometime tomorrow.

Once the corrective actions, listed above, are complete, I will conduct a follow-up review. Once that is completed, I can then submit my recommendation.

Any questions, please let me know.
Regards,
Steve

Linda Bagby
Engineering Note

Date: 1.17.2012
Rev Date: 1.24.2012 REVISED

Project: Microboone General Support
Doc. No: B011712B_Bagby_PMT_TS_PAB

Subject: Electrical safety documentation required to obtain ORC approval of PMT test stand at PAB

Introduction:

The Microboone Photomultiplier Tube (PMT) test stand consists of one electronics rack and a cryogenic vessel in which PMTs are submerged in liquid Nitrogen. The test stand is used to characterize the operation of the PMTs which will be used in the experiment. Recent gain studies have shown that the PMTs require a longer amount of time to stabilize than what was expected. Therefore, we seek Operational Readiness Clearance to operate the test stand unattended.

Location:

The MicroBoone test stand is located in the Proton Assembly Building (PAB), shown in Figure 1.

Figure 1: Picture of test stand (rack and vessel).

The electronics rack houses a VME HV crate with a mother board containing high voltage 'pods' and the supporting VME infrastructure. The VME HV module and pods were developed by Fermilab for DZero Run 1 and were once commercially available from BiRa Corporation, Model 4877PS. In addition to the VME HV crate, the rack contains a commercially available LAMBDA power supply, +5V Interlock power supply, network switch, and a fan tray. The device under test, Hamamatsu R5912-02, is located inside the cryogenic vessel. Specifications for the PMT are in Appendix A.

AC Distribution:

AC power is provided to the LAMBDA supply, +5V Interlock power supply, network switch, and fan tray by the switched power sources in the SurgeX SX1120RT Surge Suppressor AC Distribution unit. The specifications for the SurgeX can be found in Appendix B. Figure 3 illustrates the AC Distribution in the rack. The LAMBDA supply is fused at 10A and the +5V Lambda Interlock supply is fused at .5A. The Network switch is a commercial unit.

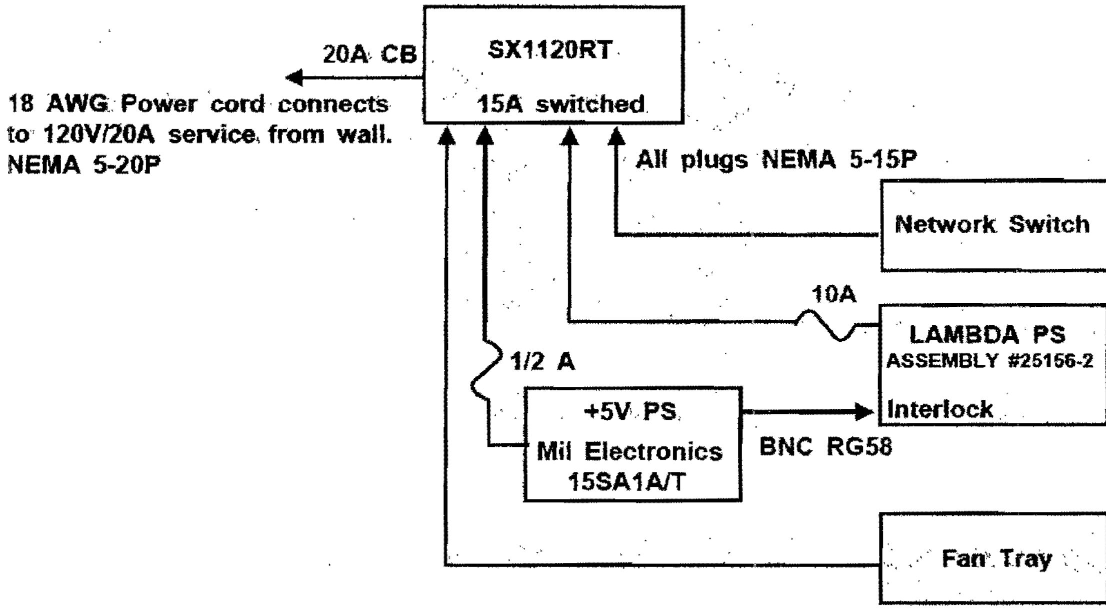


Figure 3: AC Distribution

DC Distribution:

The LAMBDA power supply assembly # 25156-2 and wiring harness are shown in Figure 5. The commercially available LAMBDA power supply assembly provides DC power to the VME HV crate backplane via a wiring harness which is designed to carry the maximum available current from each supply within the assembly. 10AWG wire is capable of handling 35A and 14 AWG cable is capable of handling 20A. The 14 AWG +5V sense lines are fused at 10A with in-line fuses. The power returns for all modules are tied to the chassis ground within the LAMBDA mainframe.

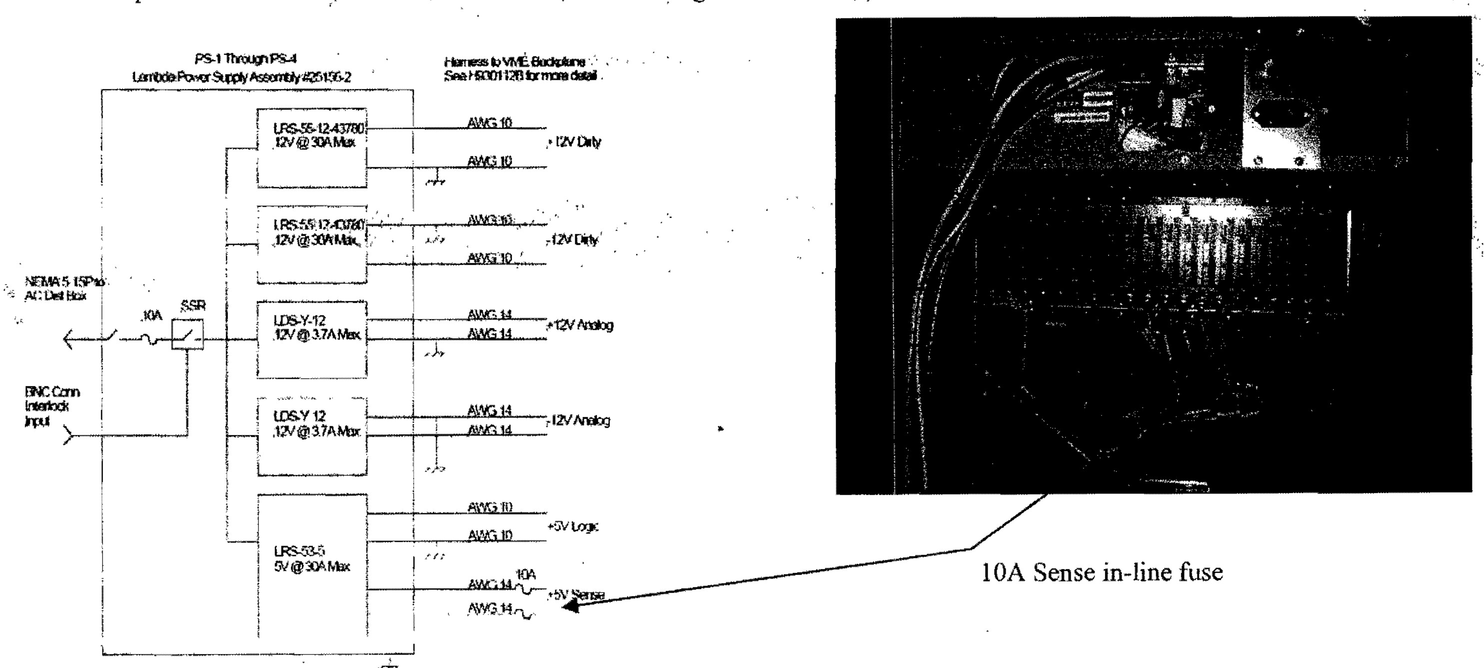


Figure 5: LAMBDA Assembly and wiring harness

Figure 6 illustrates the fuse value and pin designations for the power rails located on the Mother Board which holds the HV pods. +5V and +/-12V bulk are fused with 5A pico fuses. +/-12V Analog is fused with 2A pico fuses.

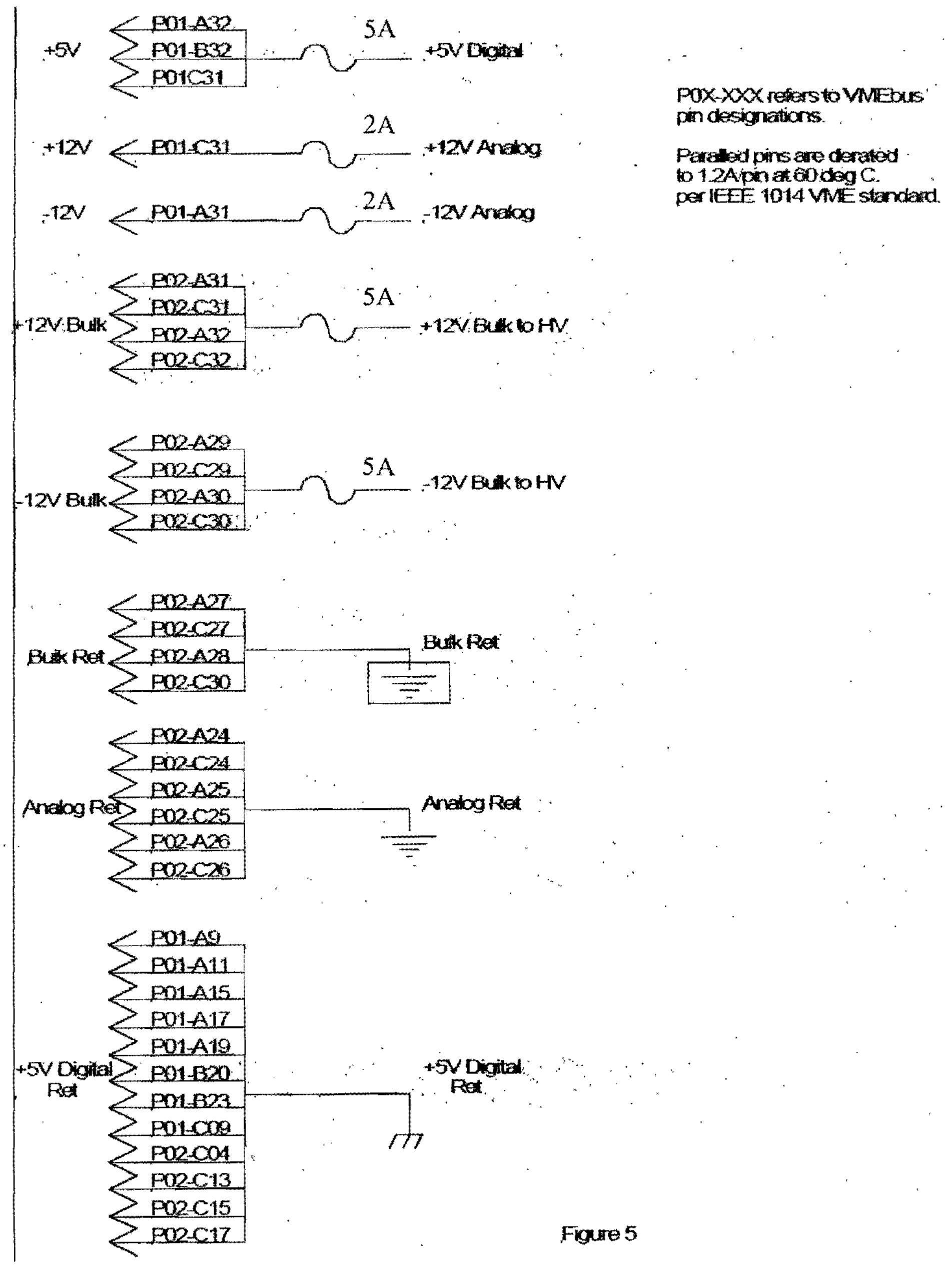


Figure 6: Mother Board Fusing

High Voltage Circuit:

The high voltage circuit schematic is shown in Figure 7. This schematic illustrates one of four identical circuits at the test stand. All four Splitter circuits are housed in an aluminum Bud box. All boxes are connected to the rack metal with ground braid. Figure 8 is the PMT base circuit schematic.

The output of the PMT base is connected to the vessel feed-through with a RG180 cable. This cable is terminate on the base end with a pin to match the base socket (Mill-Max Manufacturing Corp., pin part #: 3117-2-00-21-00-00-08-0, socket part #0326-2-19-15-06-27-10-0). The other end is terminated into a SHV connector which plugs into the feed-through. The cryogenic vessel is connected to earth ground via cryogenic piping and the level sensor signal conditioning electronics.

On the warm side of the feed-through, RG180 connects the PMT base to the Splitter box on an isolated SHV, labeled PMT. The high voltage input to the Splitter, labeled +HV In, is connected to the T4 High Voltage pod (+2kV @ 3mA) with a red RG58, SHV terminated cable. The Signal pick-off, labeled Anode on the Splitter box, is connected to a scope (Tektronix TDS5054-NV-T) with a green RG58, BNC terminated cable. All connectors on the Splitter box are isolated from the box housing.

The over voltage protection trip point is set with a potentiometer accessible from the front panel of the HV pod. Each HV pod also has an over current trip circuit which monitors the +/- 12V Bulk power supply used to generate the high voltage.

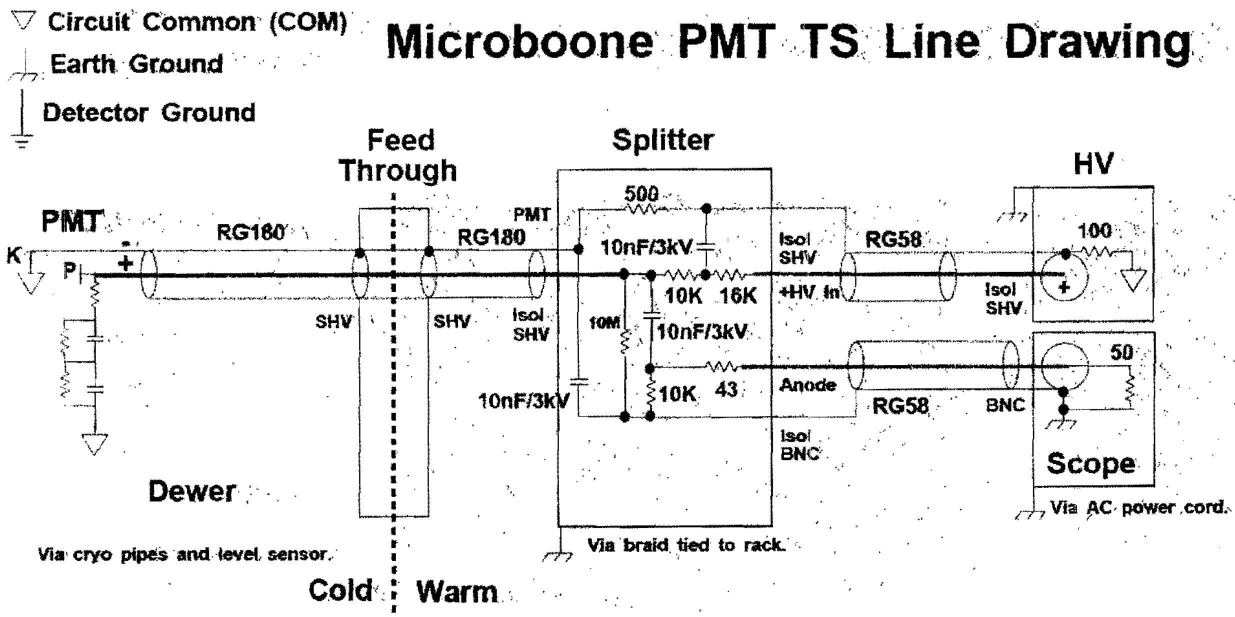
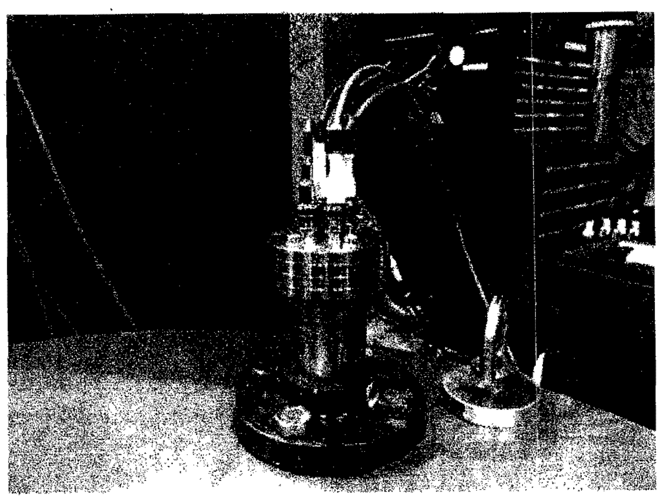
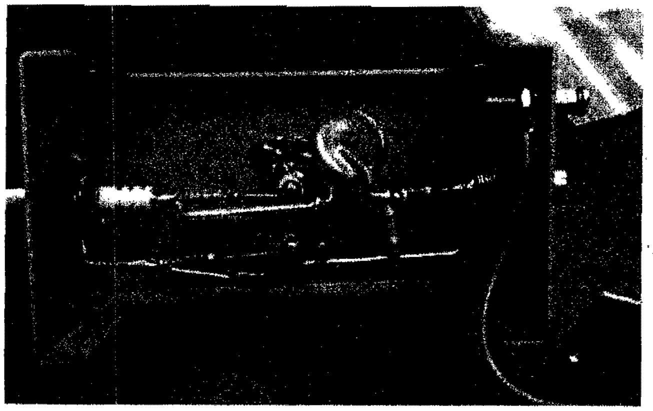


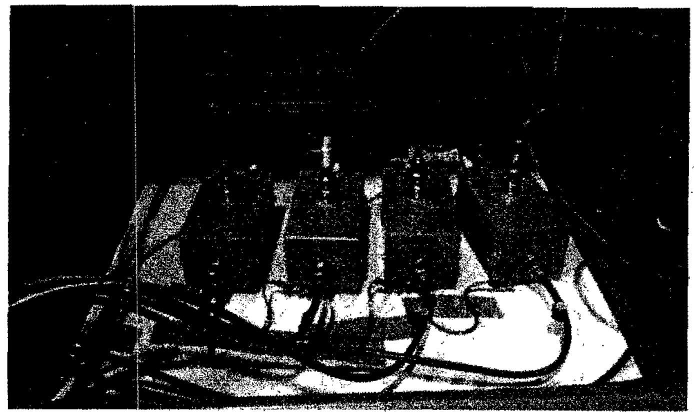
Figure 7: HV Circuit



Cryogenic vessel HV feed-through



Splitter circuit



Ground braid connecting floating Bud boxes to safety ground

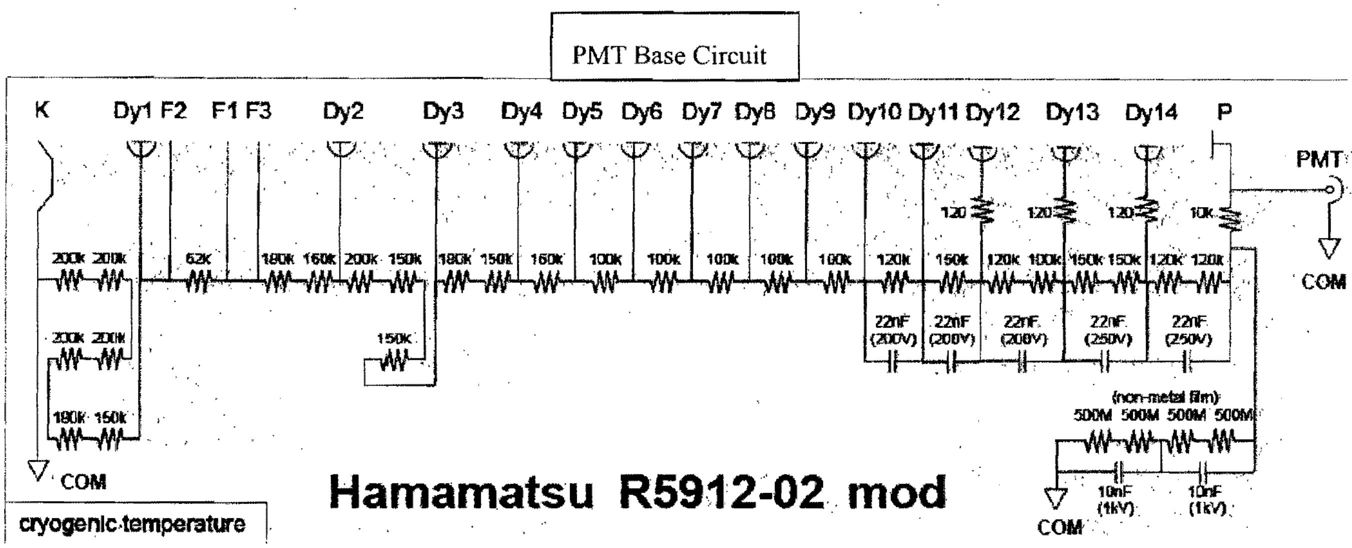


Figure 8: PMT Base circuit schematic.

Voltage Cable Testing:

The maximum voltage on the PMTs is 2kV. They are typically biased at 1.7kV. To insure the cable used to connect the PMT base to the cryostat feed-through will handle the maximum output of the HV Pod, 2kV, RG180 was tested by Walt Jaskierny. The details of his test are in the Microboone DocDB #1806. In summary, Walt measured leakage currents less than 10nA throughout the tested voltage range, 0-8kV. Corona occurred at 9kV.

Cooling:

Forced air cooling is provided by a fan tray located under the VME crate.

Fire Protection:

Figure 9 illustrates the connections from the Rack Protection System to the AC Distribution SurgeX unit. The electronics shown are enclosed within a cabinet. The unused slots in the VME crate are covered with panels. Rack protection is provided with a Rack Protection System (RPS) design by Jamieson Olsen. The Engineering Note documentation can be found in Appendix C. If the smoke sensor detects smoke, the interlock to the SurgeX AC distribution unit is dropped, whereby AC to the 5V power supply is removed and the LAMBDA power supply turns off.

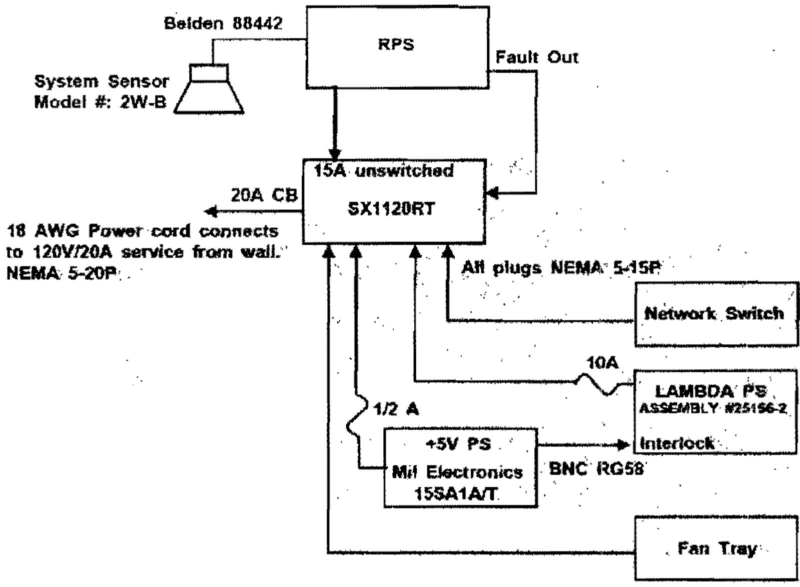


Figure 9: Rack Protection block diagram

Shock Hazard:

A Safety Analysis has been written by Marvin Johnson for the D0 High Voltage System. This document is in Appendix D. According to his references, danger from a momentary current pulse is proportional to I^2t. I represents the current in amperes and t represents the time in seconds. The maximum safe value of I^2t for 150 lb man is .027.

The power supply pods used in the PMT System are type T4 which provide +2kV at 3mA. If the output cable of the high voltage pod is shorted with a 1K ohm resistor, representative of a human body, the supply trips off from an over current fault. If the over current fault circuit is disabled, an over voltage fault will occur. Using a conservative trip time and current of 250ms and 50mA, the I^2t value is $6.25\ 10^{-4}$ which provides a safety factor of 43.

The I^2t value due to a stored charge is represented by $V^2C/2R$. V is the pod voltage (2kV), C is the filter capacitor on the pod (3nF), R is the discharge resistance (human body lower limit is 200 Ohms). $I^2t = 3\ 10^{-5}$. Combining this value with the power supply value and dividing into .027 gives a safety factor of 41which includes the double fault condition of a disabled over current circuit and shorting the pod output. With no failures the safety factor is 900.

Another source of stored charge is in the cables connected to the pods. In the test stand, each pod is connected to a single load with two types of cable, RG58 (26.5pF/ft) and RG180 (17.4pF/ft). Each channel has approximately 5 ft of RG58 from the pod to the Splitter circuit. The cable length of RG180 from the Splitter circuit to the feed-through is 10ft. The RG180 cable length from the feed-through to the base of the PMT is 5ft. The total capacitance due to cable is 5ft*26.5pF added in parallel with 15ft * 17.4pF for a value of 88pF. This is 34 times smaller than the pod filter capacitor. Therefore, the stored charge contribution due to cable capacitance is negligible.

Appendix A: Hamamatsu Photomultipler Tube Specifications

Appendix B: SurgeX Specifications

Appendix C: Rack Protection and Engineering Design Review Report

Appendix D: Safety Analysis of the D0 High Voltage System

HAMAMATSU

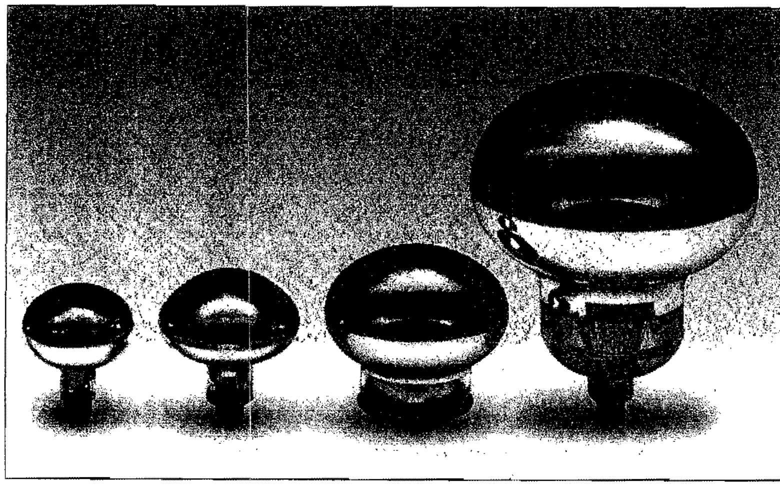
LARGE PHOTOCATHODE AREA PHOTOMULTIPLIER TUBES

APPLICATION

- Neutrino Physics

FEATURES

- Large Photocathode Area
- Fast Time Response
- High Stability
- Less Dark Count



R5912 R5912-02 | R7081 R7081-20 | R8055 | R3600-02 R7250

SPECIFICATIONS

Type No.	Diameter (mm) / (inch)	Minimum Effective Area (mm)	Surface Area Min. (cm²)	Surface Area Typ. (cm²)	Dynode Structure	Dynode Number of Stages	Weight (g)
R5912	202 / 8	ϕ190	330	380	Box & Line	10	approx. 1100
R5912-02	202 / 8	ϕ190	330	380	Box & Line	14	approx. 1100
R7081	253 / 10	ϕ220	470	530	Box & Line	10	approx. 1400
R7081-20	253 / 10	ϕ220	470	530	Box & Line	14	approx. 1400
R8055	332 / 13	ϕ312	960	1080	Box & Line	10	approx. 3000
R3600-02	508 / 20	ϕ460	2030	2410	Venetian blind	11	approx. 8000
R7250	508 / 20	ϕ430	1680	1740	Box & Line	10	approx. 8000

COMMON SPECIFICATIONS

Spectral Response	300 nm to 650 nm
Peak Wavelength	420 nm
Photocathode Material	Bialkali
Window Material	Borosilicate glass

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SPECIFICATIONS

Type No.	Cathode Sensitivity: Luminous (2856 K) Min. (µA/lm)	Cathode Sensitivity: Luminous (2856 K) Typ. (µA/lm)	Cathode Sensitivity: Radiant at 420 nm Typ. (mA/W)	Cathode Sensitivity: Blue Sensitivity Index (CS 5-58) Min.	Cathode Sensitivity: Blue Sensitivity Index (CS 5-58) Typ.	Cathode Sensitivity: Quantum Efficiency at 390 nm Typ. (%)	Anode Sensitivity: Luminous (2856 K) Typ. (A/lm)	Anode Sensitivity: Radiant at 420 nm Typ. (A/W)	Anode Sensitivity: Gain Typ.	Applied Voltage for Typical Gain Typ. (V)
R5912	40	80	80	6.0	10.0	25	700	7.2×10^5	1.0×10^7	1500
R5912-02	40	80	80	6.0	10.0	25	70 000	7.2×10^7	1.0×10^9	1700
R7081	40	80	80	6.0	10.0	25	800	8.0×10^5	1.0×10^7	1500
R7081-20	40	80	80	6.0	10.0	25	80 000	8.0×10^7	1.0×10^9	1700
R8055	35	60	65	5.5	8.0	20	3000	3.25×10^6	5.0×10^7	2000
R3600-02	35	60	65	5.5	8.0	20	600	6.5×10^5	1.0×10^7	2000
R7250	35	60	65	5.5	8.0	20	600	6.5×10^5	1.0×10^7	2000

NOTE: Anode characteristics are measured with the voltage distribution ratio shown below.
( ): Measured with the special voltage distribution ratio (Tapered Divider) shown below.

Type No.	Maximum Ratings: Supply Voltage Anode to Cathode (V)	Maximum Ratings: Supply Voltage Anode to Last Dynode (V)	Maximum Ratings: Average Anode Current (mA)	Maximum Ratings: Operating Ambient Temperature (°C)	Maximum Ratings: Storage Temperature (°C)	Maximum Ratings: Ambient Pressure (Gauge) (MPa)	Direct Interelectrode Capacitances: Anode to Last Dynode (pF)	Direct Interelectrode Capacitances: Anode to All Other Dynodes (pF)
R5912	2000	300	0.1	-30 to +50	-30 to +50	0.7	approx. 3	approx. 7
R5912-02	2000	300	0.1	-30 to +50	-30 to +50	0.7	approx. 3	approx. 7
R7081	2000	300	0.1	-30 to +50	-30 to +50	0.7	approx. 3	approx. 7
R7081-20	2000	300	0.1	-30 to +50	-30 to +50	0.7	approx. 3	approx. 7
R8055	2500	300	0.1	-30 to +50	-30 to +50	0.15	approx. 10	approx. 20
R3600-02	2500	300	0.1	-30 to +50	-30 to +50	0.6	approx. 36	approx. 40
R7250	2500	300	0.1	-30 to +50	-30 to +50	0.6	approx. 10	approx. 15

Anode Sensitivity

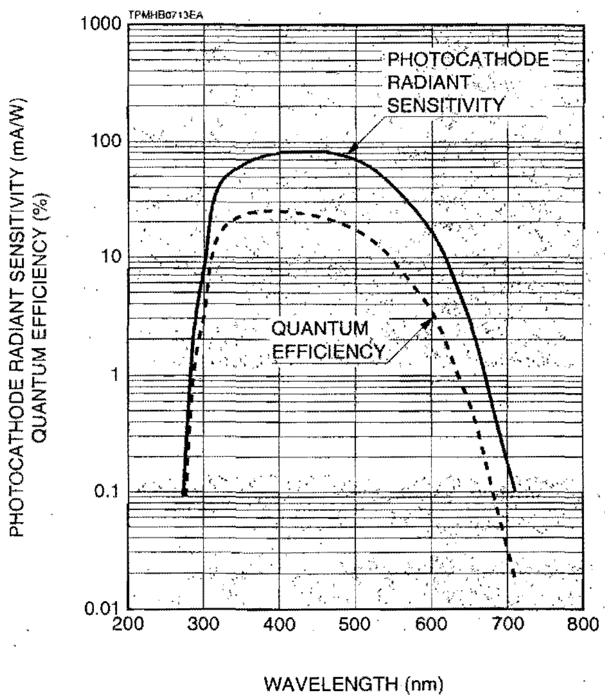
(at +25 °C)

Dark Current (After 30 min storage in darkness)		Dark Count (After 15 hours storage in darkness)		Time Response			Single Photo-electron (Peak to valley ratio)		Pulse Linearity		Type No.
				Rise Time	Electron Transit Time	Transit Time Spread (FWHM)			at ±2 % Deviation	at ±5 % Deviation	
Typ. (nA)	Max. (nA)	Typ. (s^{-1})	Max. (s^{-1})	Typ. (ns)	Typ. (ns)	Typ. (ns)	Min.	Typ.	Typ. (mA)	Typ. (mA)	
50	700	4000	8000	3.8	55	2.4	1.5	2.5	20 (60)	40 (80)	R5912
1000	5000	6000	12 000	4	68	2.8	1.5	2.5	40	70	R5912-02
50	700	7000	15 000	4.3	63	2.9	1.5	2.5	20 (60)	40 (80)	R7081
1000	5000	9000	19 000	4.5	78	3.3	1.5	2.5	40	70	R7081-20
200	1000	15 000	30 000	5.3	88	2.8	1.5	2.5	60	80	R8055
200	1000	25 000	80 000	10	95	5.5	1.1	1.7	20	40	R3600-02
200	1000	25 000	80 000	7	110	3.5	1.5	2.5	60	80	R7250

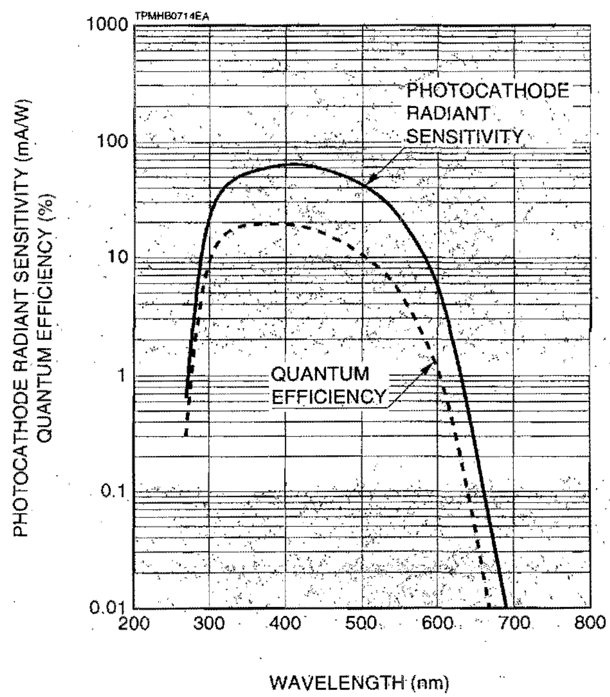
Type No.	Supply Voltage (V)	Voltage Distribution Ratio K: Photocathode Dy: Dynode P: Anode F: Focus																		
		K	Dy1	F2	F1	F3	Dy2	Dy3	Dy4	Dy5	Dy6	Dy7	Dy8	Dy9	Dy10	P				
R5912, R7081	1500	11.3	0	0.6	0	3.4	5	3.33	1.67	1	1	1	1	1	1					
												Capacitors in µF	0.01	0.01	0.01					
R5912, R7081 (Taperd Divider)	1500	11.3	0	0.6	0	3.4	5	3.33	1.67	1	1.2	1.5	2.2	3	2.4					
												Capacitors in µF	0.01	0.01	0.01					
R8055	2000	18.5	0	0.6	0	3.4	5	3.3	1.7	1	1	1	2	3	4					
												Capacitors in µF	0.01	0.01	0.01					
R7250	2000	18.5	0	0.6	0	3.4	5	3.3	1.7	1	1	1	2	3	4					
												Capacitors in µF	0.01	0.01	0.01					
		K	F2	F1	F3	Dy1	Dy2	Dy3	Dy4	Dy5	Dy6	Dy7	Dy8	Dy9	Dy10	Dy11	P			
R3600-02	2000	5	1	2	0.02	3	1	1	1	1	1	1	1	1	1	1				
														Capacitors in µF	0.01	0.01	0.01			
		K	Dy1	F2	F1	F3	Dy2	Dy3	Dy4	Dy5	Dy6	Dy7	Dy8	Dy9	Dy10	Dy11	Dy12	Dy13	Dy14	P
R5912-02 R7081-20	1700	11.3	0	0.6	0	3.4	5	3.33	1.67	1	1	1	1	1	1.2	1.5	2.2	3	2.4	
															Capacitors in µF	0.01	0.01	0.01	0.02	0.02

SPECTRAL RESPONSE CHARACTERISTICS

●R5912, R5912-02
●R7081, R7081-20

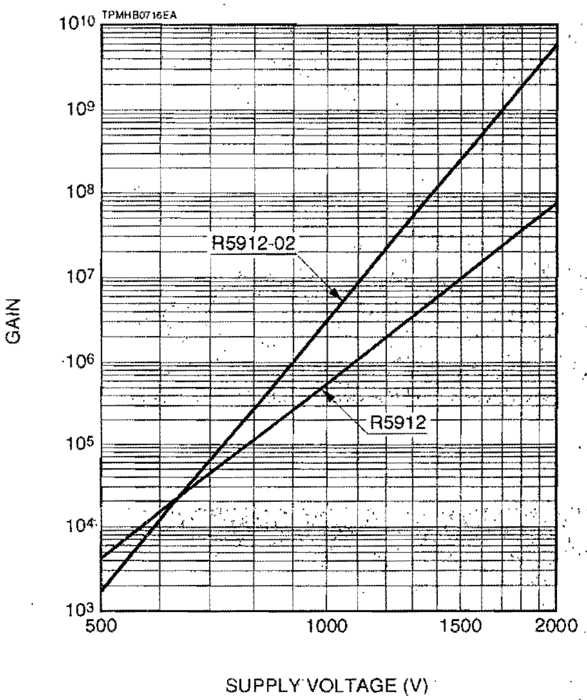


●R8055, R3600-02, R7250

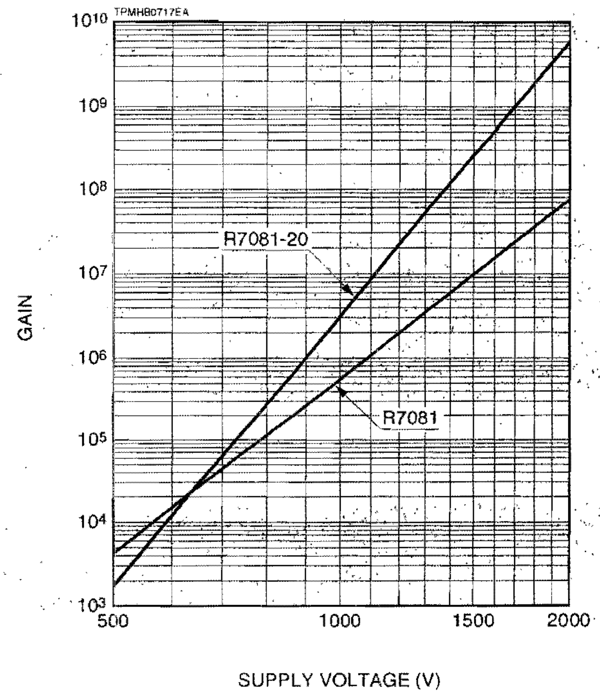


GAIN

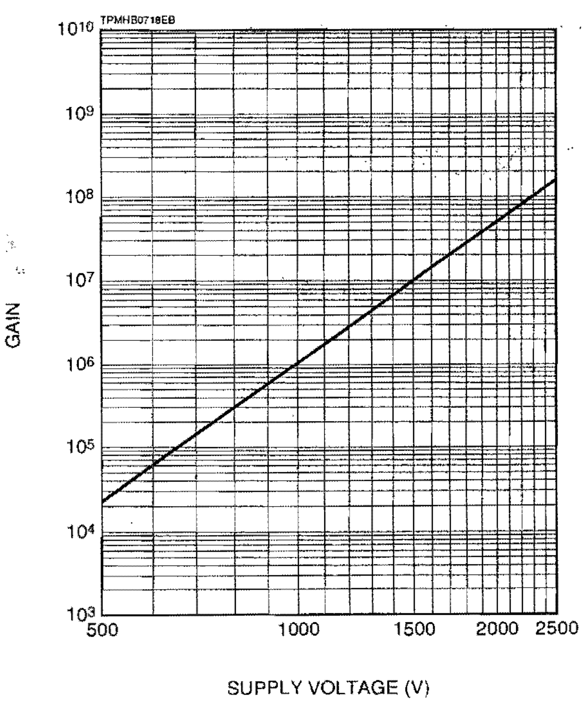
●R5912, R5912-02



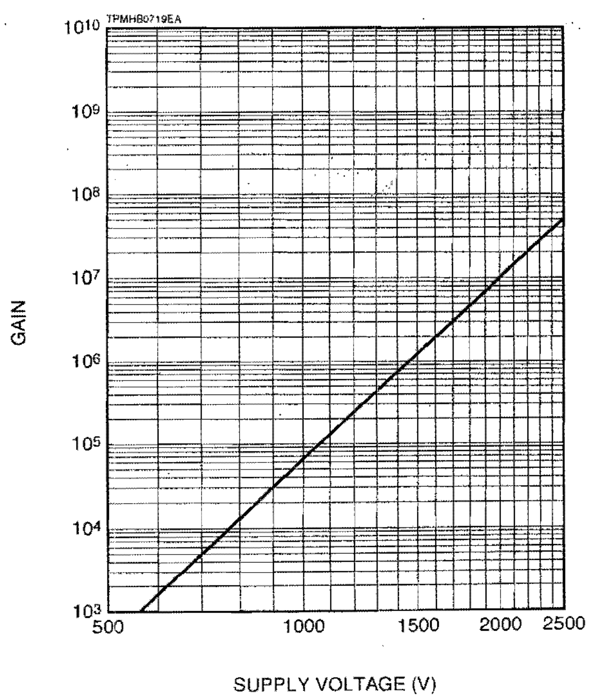
●R7081, R7081-20



●R8055

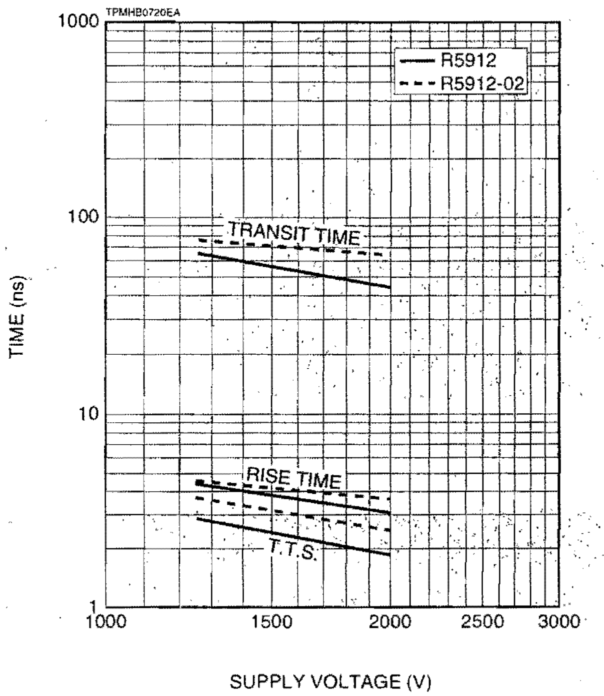


●R3600-02, R7250

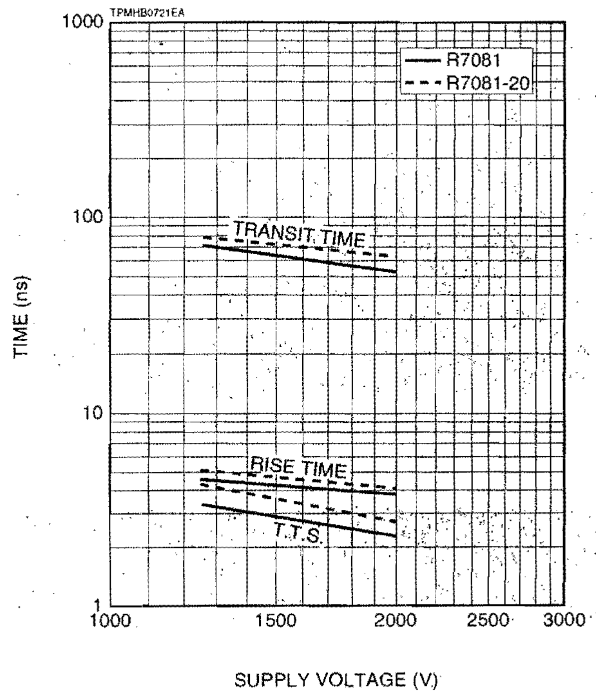


TYPICAL TIME RESPONSE

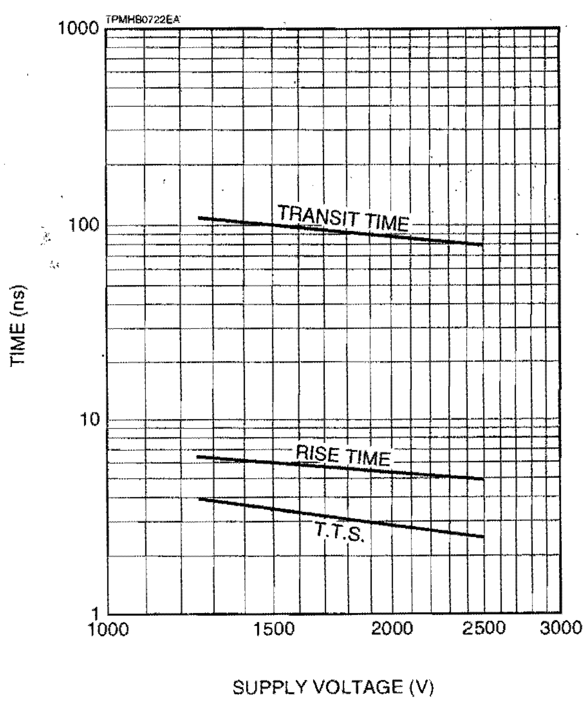
●R5912, R5912-02



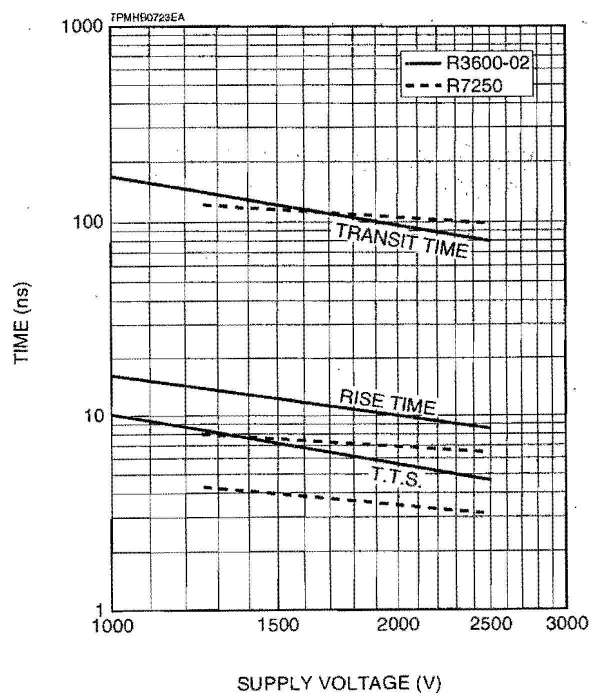
●R7081, R7081-20



●R8055

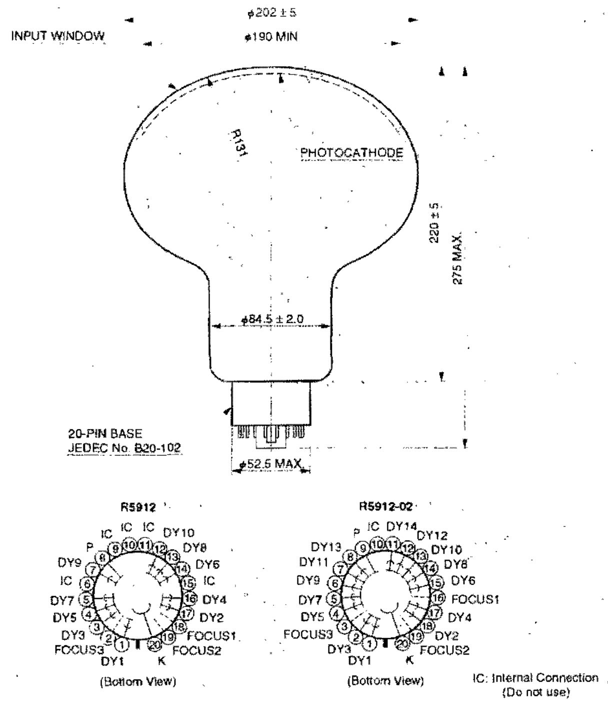


●R3600-02, R7250



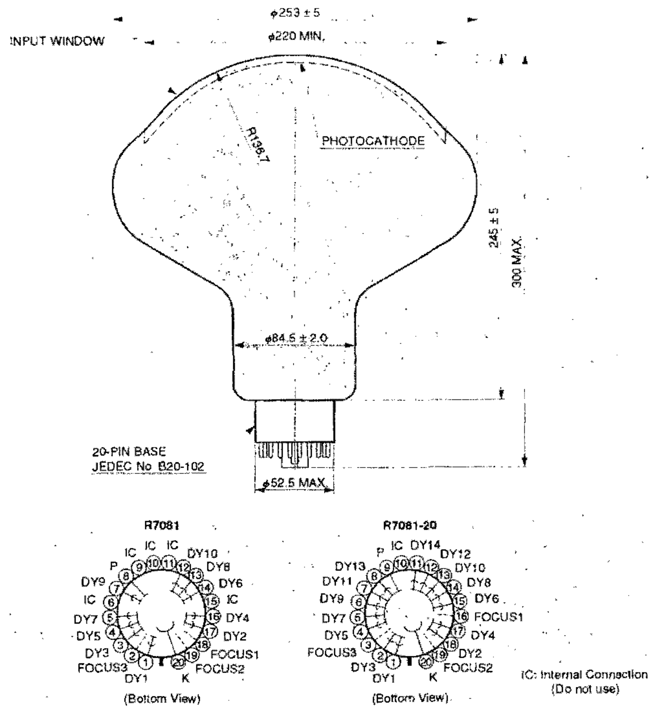
DIMENSIONAL OUTLINE (Unit: mm)

●R5912, R5912-02



TPMHA0500EA

●R7081, R7081-20



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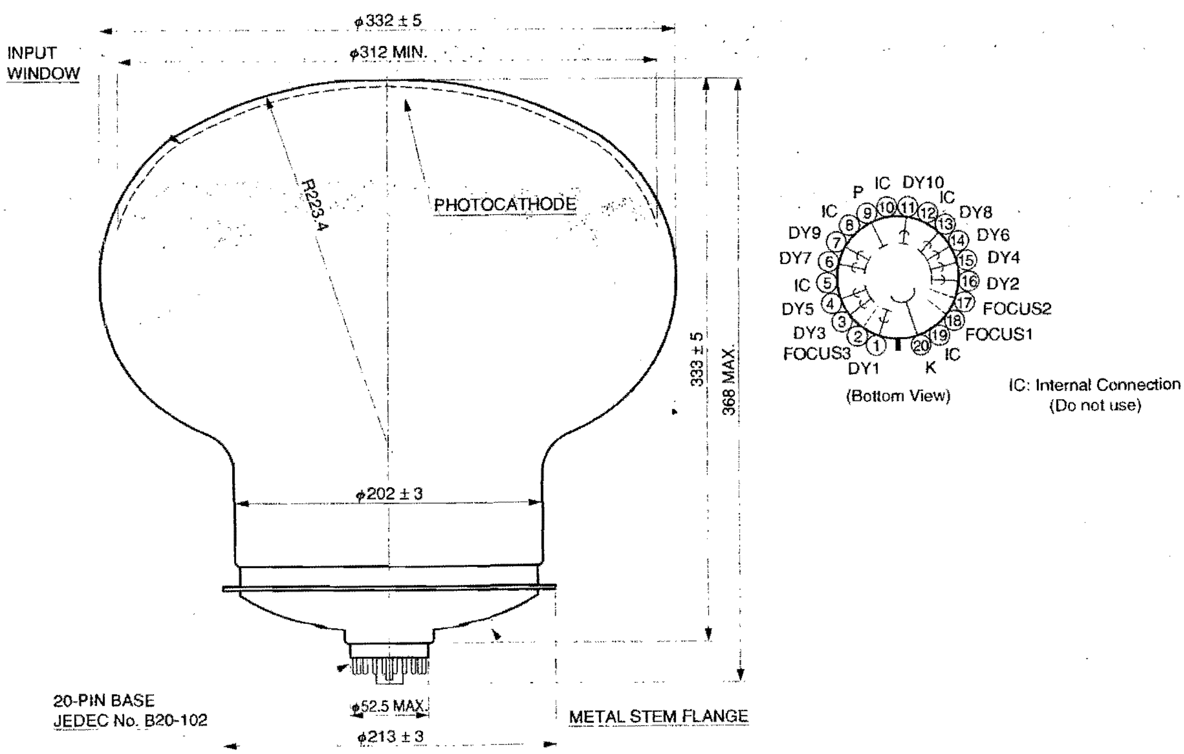
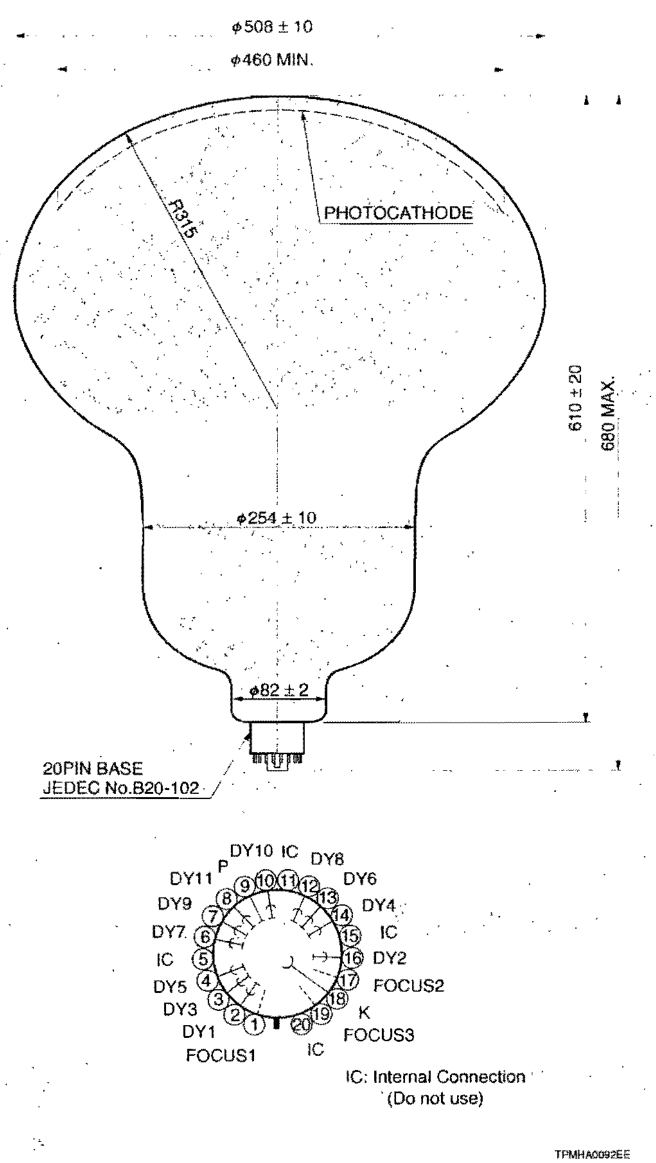
●R8055



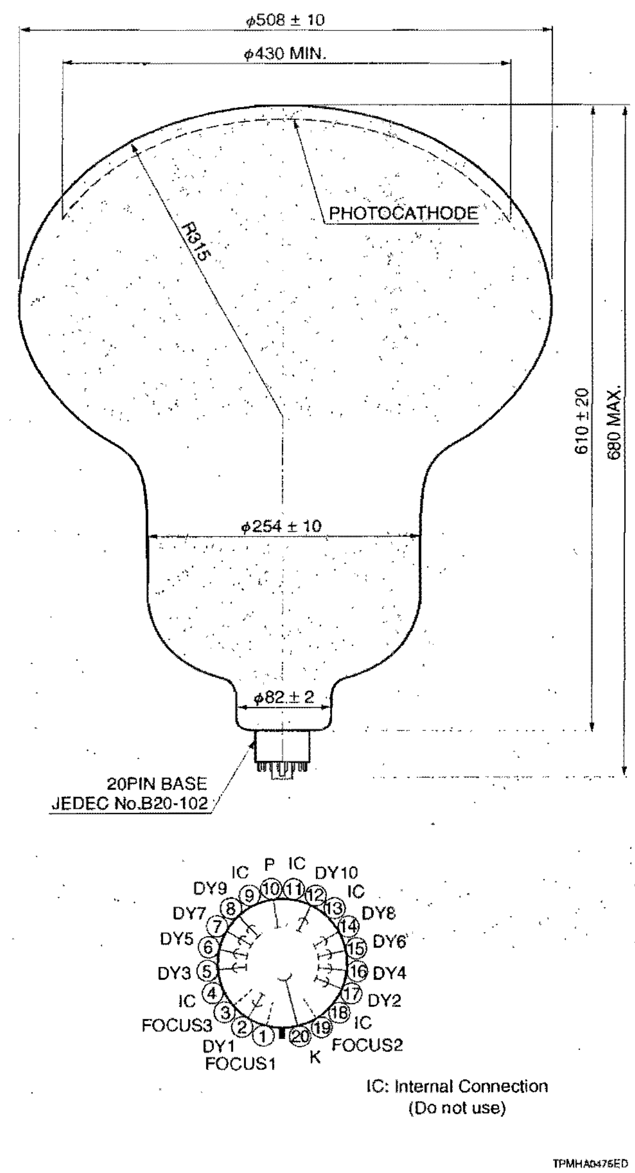
TPMHA0502EA

DIMENSIONAL OUTLINE (Unit: mm)

●R3600-02



●R7250



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TPMH1286E05
JAN. 2008 IP

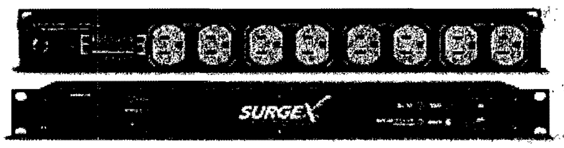
SX1120RT SURGE ELIMINATOR & POWER CONDITIONER

With Advanced Series Mode® Surge Protection

Impedance Tolerant® EMI/RFI Filtering

SurgeX ICE® Inrush Current Elimination, and

COUVS® Catastrophic Over/Under-Voltage Shutdown



Switched receptacles can be controlled with an Switched receptacles can be controlled with an applied voltage (5-30 vdc) or contact closure switch connected to the Phoenix connector on the back panel. The connector can also be used to cascade multiple units or provide status to a central controller.

The SX1120RT provides guaranteed surge protection and power conditioning for audio, video, broadcast and computer equipment. The units are 20-amp load-capable and have 8 industrial grade grounded AC receptacles (6 switched, 2 always on) plus a front panel courtesy receptacle.

The unit features both common mode and normal mode *Impedance Tolerant* EMI/RFI filtering, *SurgeX ICE* -Inrush Current Elimination and *COUVS* - Catastrophic Over/Under Voltage Shutdown for a complete power conditioning solution.

SurgeX Advanced *Series Mode* technology is superior to conventional MOV circuitry or MOV-Hybrid designs and is completely non-sacrificial. Our zero let-through technology provides the most reliable protection available. It stops all surges up to 6,000 volts (unlimited surge current) without producing harmful side effects such as ground contamination or common-mode disturbances.

DOWNLOAD SPECS - INSTALLATION GUIDE

The SX1120RT has remote control capability for use in AC power distribution systems and can be interfaced with a sequential controller such as the SurgeX SEQ.

SPECIFICATIONS

Load Rating: 20 amps @ 120 volts

Power Requirement (no load): 15 watts

Surge Let-Through Voltage (6000-volt surge): 0 volts

UL 1449 Adjunct Classification Test Results:
1000 surges, 6000 volts, 3000 amps, B3 pulse.
Measured suppressed voltage: 170 volts, no failures

Federal Guidelines: Grade A, Class 1, Mode 1 (CID A-A-55818)

EMI/RFI Filter, Normal Mode (50-ohm load):
40 dB @ 100 kHz; 50 dB @ 300 kHz;
50 dB @ 3 MHz; 50 dB @ 30 MHz

EMI/RFI Filter, Common Mode (50-ohm load):
18 dB @ 300 kHz; 30 dB @ 1 MHz;
50 dB @ 5 MHz; 50 dB @ 20 MHz

Maximum Applied Surge Voltage: 6000 volts*

Maximum Applied Surge Current:
Unlimited, due to current limiting*

Maximum Applied Surge Energy:
Unlimited, due to current limiting*

Endurance (C62.41-1991 Category B3 pulses):
1 kV>500,000; 3 kV>10,000; 6 kV>1000

Undervoltage Shutdown: 90 volts (resume at 100 v)

Overvoltage Shutdown: 145 volts (resume at 135 v)

Maximum Load Inrush Current During Power-up:
1000 Joules

Remote Turn-on Applied Voltage Range: 5 to 30 volts DC

Remote Turn-on Current Draw:
Contact Closure: 1.5 mA

FEATURES

- Magnetic shielding steel enclosure
- 9' grounded 3-wire #12 line cord
- 8 grounded AC outlets on rear panel (6 switched, 2 always on)
- Front panel courtesy receptacle
- Advanced *Series Mode* surge protection
- Advanced *Impedance Tolerant* EMI/RFI filtering
- *SurgeX ICE* inrush current elimination technology
- *COUVS* catastrophic over/under-voltage shutdown
- Remote turn-on
- Thermal circuit breaker overload protection
- Self-test circuit with visual indicator
- 10-year warranty
- **Made in U.S.A.**

TECHNICAL DESCRIPTION

The SX1120RT shall be a one-rack-space unit in a magnetic shielding steel enclosure. It shall operate from 120 volts AC and have a 9-foot, grounded, 3-wire #12 line cord. There shall be 8 grounded AC receptacles on the back panel, with 6 switched and 2 always on. The unit shall have a front-panel courtesy receptacle and remote-control capability with a visual indicator. Overall dimensions shall be 1.75" H x 19" W x 10.5" D. Weight shall be 11 pounds.

The SX1120RT shall have a load rating of 20 amps at 120 volts, a self-test circuit with visual indicator, and provide EMI/RFI filtering, inrush current elimination and catastrophic over/under-voltage shutdown. It shall meet Federal Grade A, Class 1, Mode 1 guidelines for powerline surge suppressors and withstand at least 1000 occurrences of surge pulse voltages up to 6000 volts.

5 V DC Applied Voltage: 0.1 mA
12 V DC Applied Voltage: 1.5 mA
24 V DC Applied Voltage: 5.0 mA

Auxiliary Relay Contact Rating: 30 Volts at 1 Amp

LED Output: 12 volts DC, maximum 20 mA (resistor required)

Dimensions: 1.75" H x 19" W x 10.5" D (4.5 x 48.3 x 26.7 cm)

Weight: 11 lbs (5 kg)

Temperature Range: 5° to 35° C

Humidity Range: 5% to 95% R.H., non-condensing

Agency Listings: ETL and cETL (UL 1449, 2nd edition; CSA C22.2 No.8-M1986, R2000)

* 1.2 x 50 µs pulse, industry standard combination wave surge, as per IEEE C62.41

Specifications subject to change without notice. SurgeX is a division of Electronic Systems Protection, Inc.

This product, including its components and/or processes carried out thereby, are covered by one or more of the following: U.S. Pat. No. 4,870,534, 4,870,528, 6,728,089, 6,744,613, 7,068,487, Can. Pat. No. 1,333,191, 1,332,439. Other Patents Pending.

NO MOVs

CERTIFIED A-1-1 SURGE PROTECTION TECHNOLOGY

SURGEX ICE Inrush Current Elimination

THE WORLD LEADER IN POWER CONDITIONING TECHNOLOGIES

All SurgeX® products are backed by a 11 year warranty.

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Smoke Detector Interlock

Jamieson Olsen
14 March 2011

Introduction

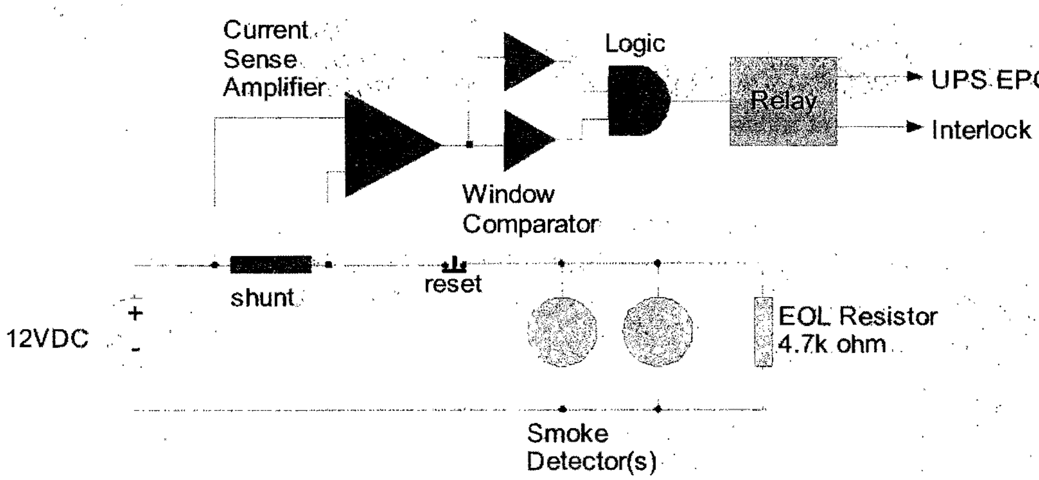
There is a need for a simple, low cost rack protection system (RPS) that will interface to a smoke detector and control an interlock signal. If smoke is detected in the rack the RPS box will drop the interlock and a separate AC power distribution unit will drop power to rack components. In some racks an uninterruptable power supply (UPS) is also used, so the proposed RPS interface unit must also provide a contact closure output that will force the UPS to immediately power off and disconnect if smoke is detected.

System Requirements

- No programmable logic, CPU, or software may be used.
- Uses a standard **2-wire** smoke detector (photometric or ionization type)
- Trigger alarm if the smoke detector wiring is disconnected
- Support multiple smoke detectors on the same circuit
- Powered from 120VAC
- 12VDC interlock output
- Power, Alarm, and "Wiring OK" LED indicators
- UPS Emergency Power Off (EPO) contact closure output
- 1U rack mounted chassis
- Push button reset
- Audible alarm indication

Theory of Operation

Modern smoke detectors have moved away from employing a contact closure arrangement and use just two wires for power and alarm notification. Normally the smoke detector draws less than 1mA from a 12VDC supply. If smoke is detected the unit closes a transistor switch and the power supply current increases to a maximum of 250mA. An end-of-line (EOL) resistor (typically 4.7k ohm) is installed after the last detector. This resistor draws a small current to indicate that the wiring loop is intact. Therefore, by monitoring the loop current the control circuit can differentiate between normal, alarm, and open loop status. A sketch of the control circuit is shown below:



A shunt resistor and current sense amplifier produce a voltage proportional the detector loop current. Resistors on the window compactor circuit define thresholds for "wiring OK" and alarm status. If the voltage output of the current sense amplifier is between these thresholds the system is in a normal state and the relay remains off. If the loop current falls below the lower threshold (open circuit) or above the upper threshold (alarm status) the relay is energized, closing the UPS EPO connections and dropping the interlock voltage.

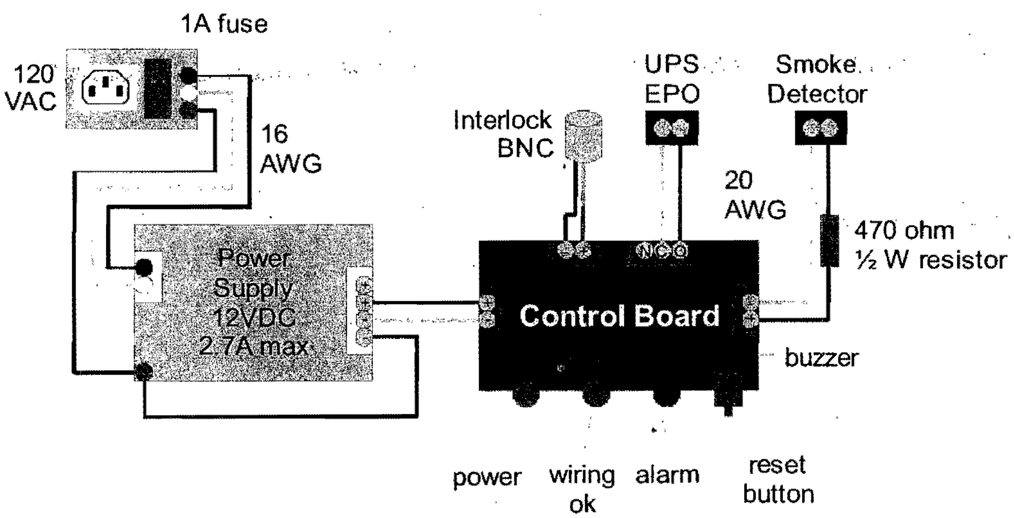
Condition	Loop Current	Status	Relay	UPS EPO	Interlock
Open	0 mA	Alarm	ON	closed	0V
Normal	~5 mA	OK	OFF	open	12VDC
Smoke	25 mA	Alarm	ON	closed	0V

LED indicators for power, "wiring OK", and alarm are provided. A normally-closed pushbutton is used to reset the smoke detector(s).

Circuit Board and Chassis Wiring

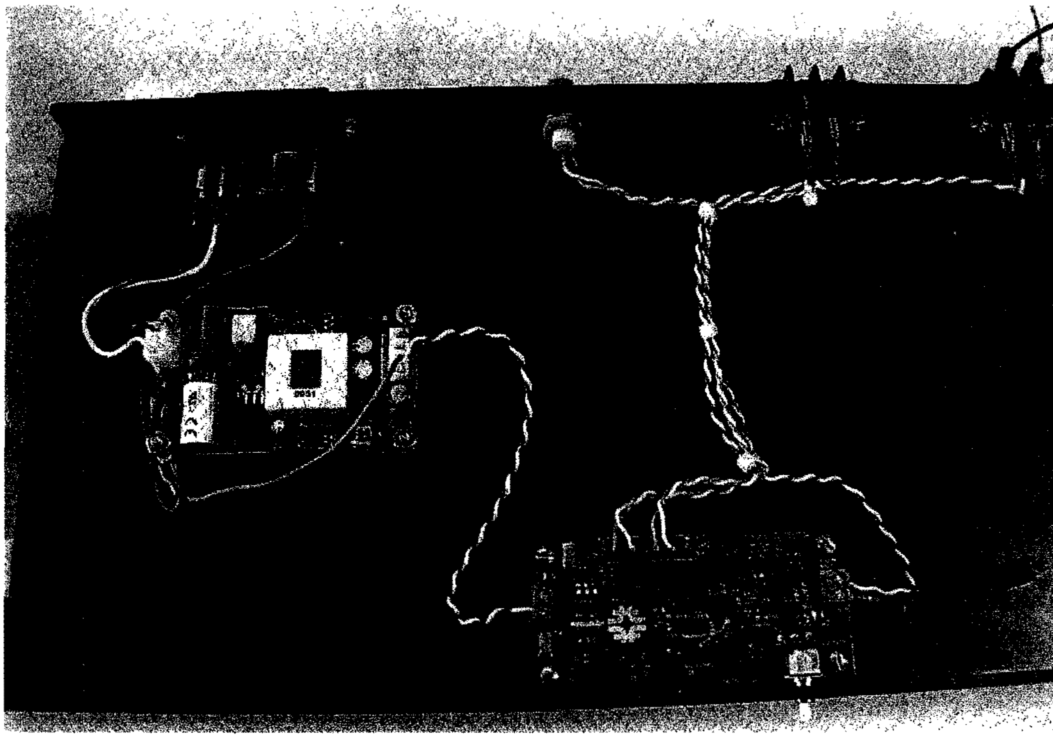
The control circuit is laid out on a 2”x 4” 2 layer PCB shown below:

The control board is powered by a small 12VDC switch mode power supply (TDK-Lambda ZPSA20-12) which has a maximum output current of 2.7A. The 120VAC input to the supply is protected by a 1A fuse integrated into the power receptacle.



Wring between the AC power receptacle and the power supply is 16AWG and all other wiring is 20AWG. A 470 ohm current limiting resistor has been added in series with the smoke detector.

The control board, power supply and other connectors are mounted in a 1U rack mount enclosure shown below:



The interlock output is a BNC type connector, 12VDC center positive. UPS EPO and smoke detector connections use two pin terminal block connectors on the rear panel.

Rec. 6/19/91

Safety Analysis of the D0 High Voltage System

[redacted] M. Johnson

June 1991

First, some background in the physiology of shock hazards. The shock hazard is independent of voltage; it is only dependent on the current. Thus, a 5 KV supply delivering 1 mA is no more dangerous than a 50 volt supply delivering the same current. All that is required is sufficient voltage to drive the current through the resistance of the body. Data indicate[1] that the median sensation threshold for a sample of 167 adult men to be 1.086 mA. At currents up to 3 mA there is only a mild sensation and currents up to 10 mA are painful but not dangerous[2]. The paralysis threshold where one cannot let go of a circuit is taken to be 10 mA.

Shocks are dangerous to life when they cause ventricular filibration. The current where this occurs for 0.5% of the population is 75 mA DC. This is not the entire story for people can sustain much higher currents for short periods of time. Data show that the danger from momentary current pulses is proportional to I^2t where I is the current in amps and t is the time in seconds that the current is flowing[3]. Ref 3 indicates that the maximum safe value of I^2t for a 150 pound man is 0.027. Ref 3 also indicates that the body internal resistance is between 200 and 1000 ohms.

The normal maximum current from the D0 supply is 1 mA for the 5.6 KV supply and 3 mA for the 2 KV supply. Shorting any supply with a 1 K ohm resistor (representing the human body) causes the over current trip to trip immediately. If the over current trip circuit is disabled and the supply shorted with a 1 K resistor, the supply trips on overvoltage. The measured voltage across the 1 K resistor for several different supplies ranged from 8.6 volts to 39 volts so this is clearly not an overvoltage condition. What happens is that even with the current trip disabled, there is a 4.65 K resistor between the low side of the transformer and ground. All current must flow through this resistor so when the supply is delivering a lot of current, the

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[1]Dalziel, Charles F., "Electric Shock Hazard", *IEEE Spectrum*, Feb, 1972.

[2]Lee, Ralph H., "Electrical Safety in Industrial Plants", *IEEE Spectrum*, June, 1971.

[3]Kleronomos, Chris C. and Cantwell, Edward C.,"A Practical Approach to Establish Effective Grounding for Personnel Protection", IEEE Conference Record Paper, CH460-5/79/0000-49, 1979.

transformer is forced below ground potential which in turn forces the voltage readback to the comparator to go negative. The comparator's normal operating voltage is from -0.3 to 36 volts so when it sees a negative voltage less than 0.3 volts, it trips. This trip works on all 3 supply types. The typical trip time is around 200 mS. Using a conservative value of current as 50 mA and a trip time of 250 mS gives $I^2t = 6.25\ 10^{-4}$. Dividing this into 0.027 gives a safety factor of 43. While these currents can cause a painful sensation, they are not at all dangerous. Note that this involves a double failure - a failed current trip circuit and a person touching a high voltage lead.

A second area of concern is the stored charge. This is what normally causes the painful sensation when one touches a high voltage supply. Even small capacitances can deliver substantial amounts of current through the low resistance of the human body. Since this is a pulsed shock, one can calculate I^2t for this case. The current from a capacitor is

$$I = \frac{V0}{R} \exp[-\frac{t}{RC}]$$

where V0 is the applied voltage, R is the discharging resistance and C is the capacitance. Since I is a function of time we compute I^2t by integrating I^2dt from 0 to ∞. This gives

$$I^2t = \frac{V0^2\ C}{2\ R}$$

For V0 = 5.6 KV, C= 3 nF and R= 200 Ohms (lower limit of body resistance) we get $I^2t = 2.35\ 10^{-4}$. Adding the supply value from above to this gives $8.55\ 10^{-4}$. Dividing this result into the maximum safe value for this quantity (0.027) gives a safety factor 32. One must increase the capacitance by a factor of 100 before approaching the lower limit of the a health hazard. Again, this is the safety factor with a failure in the current trip circuit. With no failures. the value of $I^2t = 2.35\ 10^{-4}$ and the safety factor is 115. The 3 nF capacitance is the output filter capacitor. The other 3 nF capacitors have 100 K resistors in the current path so they make a negligible contribution to I^2t.

How does this shock hazard compare with our everyday experience? A good example is the shock from walking on a carpeted floor and then touching a door knob. The voltage that can develop is a function of many things including the humidity and the carpet resistance. The maximum voltage that can be developed is around 20 KV and the capacitance of a human is about 120 pF[4]. Putting these values into the above formula for I^2t gives $I^2t = 1.2\ 10^{-4}$ which is about one half of the value for the power supply with no failures. In other words the maximum shock from a normal power supply is about twice as large as the maximum shock from walking on a carpet.

When the supplies are connected to long cable runs, the danger from the charge stored in the cable increases greatly. The D0 high voltage cable has a capacitance of 30 pF/foot. Cable lengths of 135 feet are used throughout the detector. In the worst cased a single supply feeds up to 20 cables through two levels of fanout. Twenty 135 foot cables gives a capacitance of 81 nF or 27 times the supply capacitance. This reduces the safety factor from 115 to 4 which is still safe. This safety factor is for the maximum supply voltage (5600 V). The detector usually runs at 2500 V and the maximum allowed voltage (voltage limit pot on the HV supply) is 3000 V. Since the shock hazard goes as V^2, this increases the safety margin by a factor of 4 giving a total safety margin of 16. Note that the contribution from a failed current trip is small (10%) compared to the cable capacitance for this case.

6/19/91
Safety analysis looks OK. There is no apparent electrocution hazard. Also, as an extra precaution the equipment is housed in grounded metal enclosure and all HV is transported via shielded cables (coax) with the shield connected to ground.

A.F. Visser

Copy to J. Kyk
R. Hance
E. Dleman.

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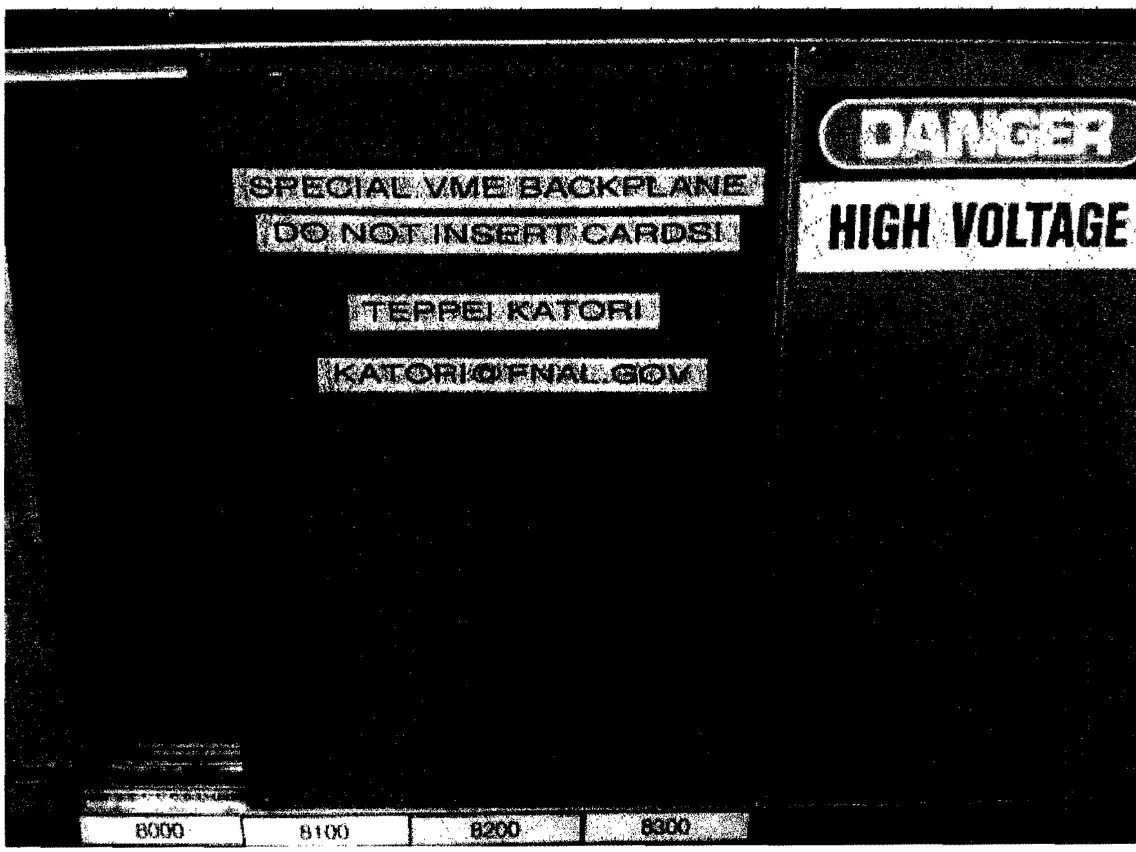
[4]Digital Equipment Corporation, "Installation Guide for Computer Systems".

Microboone PMT Test Stand at PAB pORC Review responses provided by T. Katori, L. Bagby.

1) Secure the G10 blank front panel, for the VME crate, with screw hardware to prevent it from falling off and thus allow access to the interior of the crate with the HV module installed.

2) Since the VME back plane, especially the J2 segment, is customized from the standard pin out, there should be a sign or label indicating that VME modules should not be inserted in this crate.

Response: The panel is secure with two screws. Label is affixed to panel.

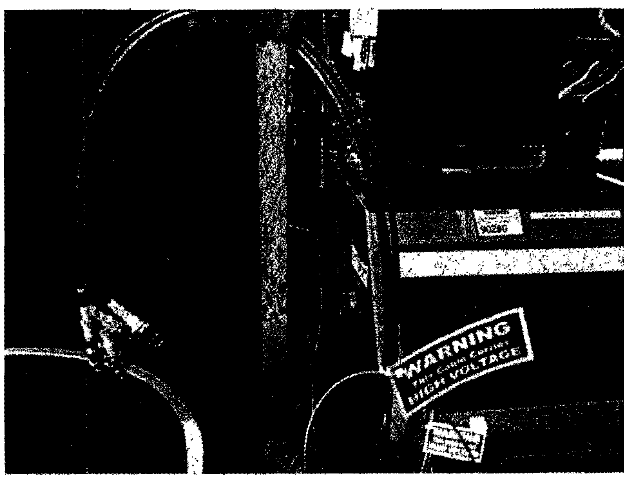


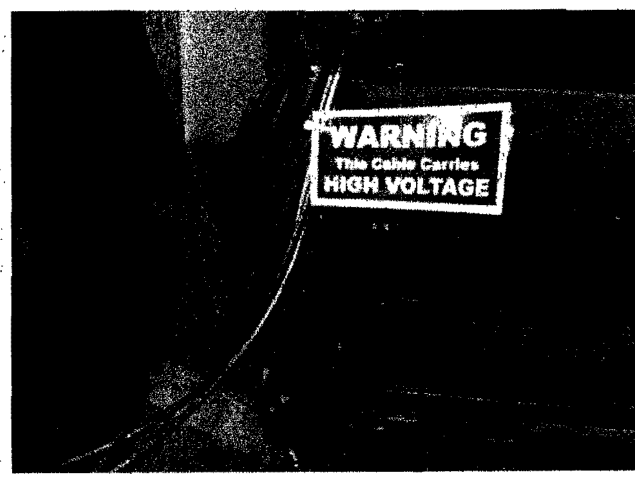
3) The custom-built interlock control chassis did go through a design review. However, being custom, I need to look inside to verify that "best practices" wiring methods are implemented inside the chassis with respect to the AC power, fusing, grounding, etc.

Response: Engineering Design review report included in pORC Appendix. Identical unit provided for inspection. Updated Engineering Note and schematic added to pORC Revision document.

4) HV caution labels are needed for the brown RG180 cables used for the HV going into the dewar.

Response: HV Labels attached to both ends of RG180 cable.

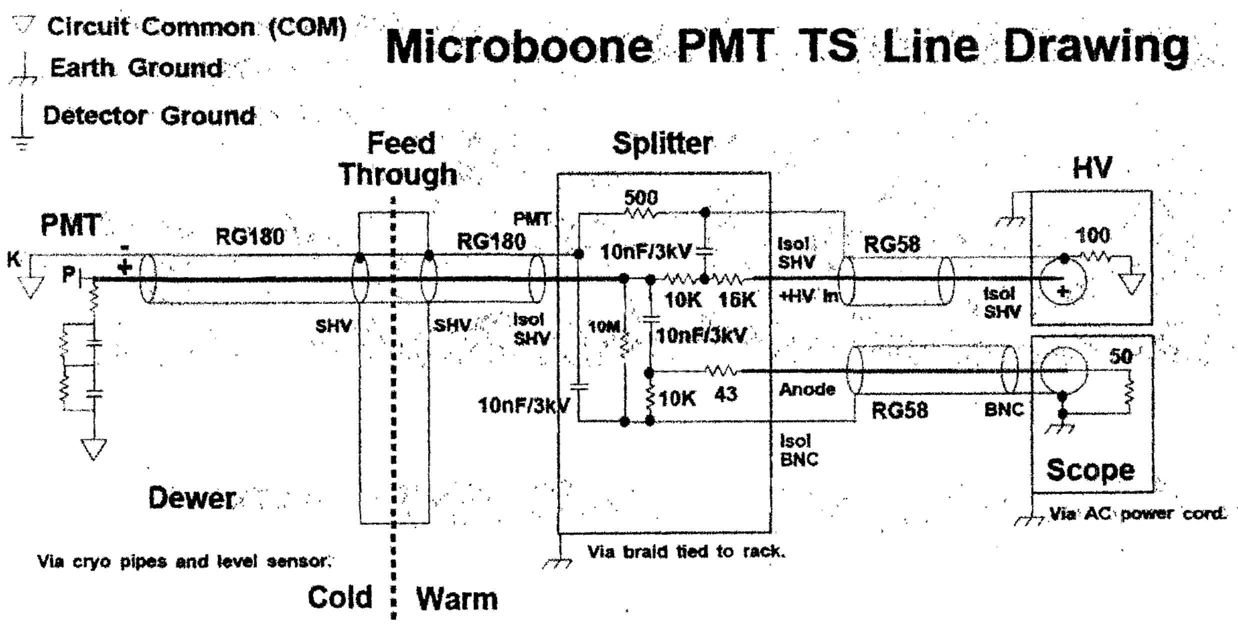




L. Bagby 1.25.12

5) The grounding of the cable shields seems to be confusing. Starting with the rule FESHM 5045-3, requirement that the HV chassis connector shall be solidly grounded to the panel to which it is mounted, the isolating HV outputs and splitter circuit box needs to be further understood.

Response: Reviewed grounding scheme with Steve identifying where and how all ground connections are made in the circuit. We generated an updated schematic and added it to the Revised pORC document. Component functions of the Splitter were explained. Four identical Splitter circuits have been built per the following schematic.



L. Bagby 1.25.12

6) Provide cord restraint for the AC power IEC connector going into the Lambda power supply chassis: If moving the cord moves the cord connector when seated, restraint of the cord is required.

Response: AC line cord restrained with tie wrap.