

IceCube PMT HV Base Development Status

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August 12, 2003

0. Introduction

This report summarizes the most up-to-date comparison among the three distinct PMT HV Base prototype designs mainly in performance aspects. Other known characteristics associated with the designs, such as the cost factor, are also outlined here.

The three designs are referred to as:

1. Old Iseg* Base—Prototypes received from Iseg in August, 2002.
2. New Iseg Base—The latest prototype from Iseg with a split-ground design.
3. EMCO Base**—Passive base implementation consisting of the passive base, the HV generator, and the digital interface.

*Iseg Spezialelektronik, GmbH, Rossendorf, Germany (www.iseg-hv.com)

**EMCO High Voltage Corp., Sutter Creek, CA, USA (emcohighvoltage.com)

1. The Designs

A. The “Old Iseg Base” integrates a Cockroft-Walton generator, output stabilizer (regulator), and digital interface (DAC, ADC) on a single PCB, and is to be directly mounted on the PMT. (See [diagram](#) from Iseg). In this design, the first dynode voltage is fixed to an optimum value (600V) regardless of the cathode-to-anode voltage.

A similar design with an analog control interface (i.e., without DAC and ADC) has been used in AMANDA String 18.

B. The “New Iseg Base” employs essentially the same HV circuitry as the Old Iseg Base, however, it is distinct from the old version in that it implements a split-ground configuration using an isolation amplifier, whereby two DC-isolated grounds are created: the “noisy section” consisting of the digital interface and the oscillator for HV generation and the “analog” section consisting of the cathode and the dynode chain circuitry.

The requirement for the isolated grounds was described to NK by Jerry Przybylski (JP) during the In-Ice Devices Workshop at UW-Madison in August, 2002. See the [sketch](#) created by NK from that conversation.

The split-ground design is intended to allow experimentation with various grounding configurations in the integrated DOM. The two grounds, for instance, may be jumpered with a wire so that the both grounds share the same DC ground. Alternatively, the analog ground may be connected to the ground at the analog front-end of the DOM Main Board, whereas the digital ground is referenced to the DOM Main Board through the ribbon cable.

As in the Old Iseg Base design, the first dynode voltage in the New Iseg Base is fixed, regardless of the cathode-to-anode voltage.

C. The “EMCO Base” is a design approach consisting of three component groups: the passive resistor chain PCB mounted on the PMT; the modular HV generator; and the digital interface controlling the HV generator. The HV generator, Model 9730, an EMC0 product customized from Model CA20P, is a regulated HV supply with analog program input and monitor output. The passive resistor chain is a custom product from EMC0. The digital interface is of NK’s design. The HV generator is mounted on the digital interface board, which, in turn, is mounted on the flasher board.

The total resistance of the passive bleeder chain is approximately $150\text{M}\Omega$, which leads to a considerably low bleeder current that is uniquely permissible for IceCube where the PMT is operated in the photon-counting mode. The low bleeder current also leads to a smaller output current requirement for the HV generator and low power consumption.

The first dynode voltage in the EMC0 Base design is proportional to the cathode-to-anode voltage, and therefore, the peak-to-valley ratio, the collection efficiency and the PMT gain are not independently adjustable.

2. Key Design Considerations

The components / assembly and/or vendor selection have been subject to the following considerations.

- **Reliability and quality** is being addressed in part by selecting the vendors with a high level of experience and confidence in high-voltage products. (This discussion is out of the scope of this report.)
- Low operating **temperature** (-40C) and storage temperature (-55C)
- **Low power** consumption (~300mW)
- Stable output with a known value without calibration (requires **output regulation**)
- **Low noise**
- Programmability (compatibility with **digital control and monitor**)
- **Uniform interface*** to DOM Main Board (all three designs have the same interface to DOM Main Board)

*The New Iseg Base interface was taken as the baseline and the interface for the Old Iseg Base and the EMCO base were created to match the baseline.

3. The Prototype Performance Evaluation Results

A. Oscilloscope Measurements

The Method

The PMT HV Base was digitally controlled by a DOM Main Board and the analog output was observed with an oscilloscope (50 Ω input). The analog output cable (RG180—100 Ω) was replaced by an RG58 (50 Ω) cable and a 50 Ω resistor was inserted between the analog output (transformer secondary) and the RG58 cable to realize a 100 Ω load. The measurements were done at room temperature.

The Results

These results have been reported at Instrumentation Workshop, LBNL, July 23-24, 2003.

[LBNLworkshopJuly23-03.pdf](#)

Summary

- The New Iseg Base cannot be operated stably without a jumper bridging the grounds. The instability is observed as random voltage fluctuations over several hundred volts, as seen in Slide #3.
- The HV output of the New Iseg Base can be stabilized by bridging the grounds with a large resistor (Slide #4).
- Bridging the split grounds with a zero ohm jumper, however, introduces regular noise spikes (2mVpp, 1.4 μ sec period). See Slide #5.
- Bridging the split grounds with a 1M Ω resistor eliminates the noise spikes. See Slide #6.
- Triggering on the Cockroft-Walton oscillator (~150kHz), the analog output was observed. The result is shown in page 1 of [073103data_1.pdf](#). The comparison of the power spectrum of the oscillator pick-up and that of the coaxial output reveals a match at ~50kHz.
- Both the Old Iseg Base and the EMCO Base showed the analog output noise levels similar to the New Iseg Base with the 1M Ω jumper. These noise levels are close to the oscilloscope noise itself. No power spectrum analyses have been done on these bases.

B. DOMMB ATWD Measurements

The Method

The measurements were done with the integrated DOMs at room temperature. The data were taken from ATWD#0 with CPU trigger. The analog MUX value was set to 2 (chan 3 for LED current).

Each curve presented here is after the subtraction of the baseline obtained by averaging 100 scans captured while the analog front-end was shunted with a 100 Ω load and the HV base ribbon cable disconnected.

The data were captured using a Python script written by Kael Hanson. Additional Tkinter script by NK allowed continuous data capture and display on the screen. The data presented here were the screen shots taken at random intervals.

The Results

[PMTBaseComparisonWithATWD1.pdf](#)

- pp 5-9: DOMMB with no HV base cables attached.
- pp 10-14: EMCO Base with DAC=0
- pp 15-19: EMCO Base with DAC=2000 (1000V)
- pp 20-24: Old Iseg Base with DAC=0
- pp 25-29: New Iseg Base with DAC=0

Summary

- There is a clear, periodic structure in the noise in the ATWD readings even with no input (**no base attached**). The noise pattern is several ATWD counts in peak-to-peak amplitude for the highest gain channel. This noise structure is smaller than but similar to some of the noise observed with the **EMCO Base** and the **Old Iseg Base**.
- The noise patterns and amplitude for the **EMCO Base** do not depend on the output HV it is generating. The noise amplitude is ~5 ATWD counts peak-to-peak, which is ~2 times larger than reported by Kael Hanson at the LBNL Workshop (July, 2003).
- The noise levels observed with the **Old Iseg Base** is comparable to or slightly higher than those with the **EMCO Base**.
- The **New Iseg Base** exhibits oscillatory noise patterns with amplitude reaching tens of ATWD counts (>100mV). Shifts in the baseline is observed, possibly due to the large noise amplitudes (i.e., possibly a symptom related the ATWD front-end pathology being addressed at LBNL).

C. Performance Evaluation Summary

- The ATWD data show markedly increased noise levels than the oscilloscope measurement data.
- The EMCO Base and the Old Iseg Base perform comparatively in terms of noise levels.
- The New Iseg Base has a serious noise problem.
- The ATWD channel readings alone show distinct noise patterns.
- The read operation on the PMT Base ADC introduces noise in the analog signal.

4. Overall Comparison of the Prototypes

	EMCO	Old Iseg	New Iseg
Noise levels	~5 counts p-p in high-gain channel		problematic
1 st Dynode Voltage	Scales with output	Fixed (desirable)	
Power dissipation at max output (mW)	250	130	280
Cost (US\$)	~600	~150	~260

The EMCO Base performs comparably as the Old Iseg Base in terms of noise. The EMCO Base, however, does not have the performance advantage of the fixed first dynode voltage. It is also that the high power consumption and component cost of the EMCO Base translate into an overall cost that is significantly higher than that of the Old Iseg Base. With the exception of the fixed first dynode voltage, the New Iseg Base does not exhibit any desirable characteristics comparable to the others.

5. Conclusion

The above comparative studies show that the Old Iseg Base is the most desirable in overall characteristics.

/nk