

Integrating Electronics Update

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PMT Voltage Divider

- requirements and version changes

Design criteria:

- Be switchable between current mode and event mode with the same base

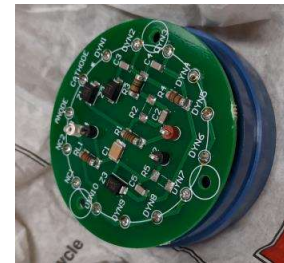
For current mode:

- Cathode current $\sim 10 - 20$ nA (Max. 500 nA)
- Anode ~ 10 μ A (Max. 100 μ A)
- Gain: 500 (Detector Ring #5)

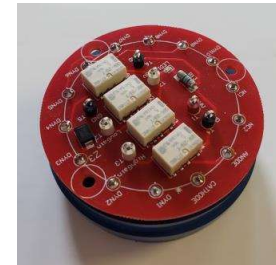
For event mode:

- Gain: $10^6 - 10^7$ (use full 10 stages)

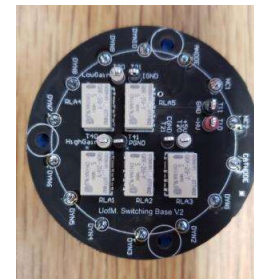
- Use rad-hard components
- Isolate the ground between two modes (to avoid ground loops and the noises that may introduced by event mode cables)



**1st prototype
(3 stage, low gain only)**



**2nd prototype
(switchable between high gain mode and low gain mode)**



**3rd prototype
(switchable, ground isolation between two modes)**

Preamplifier

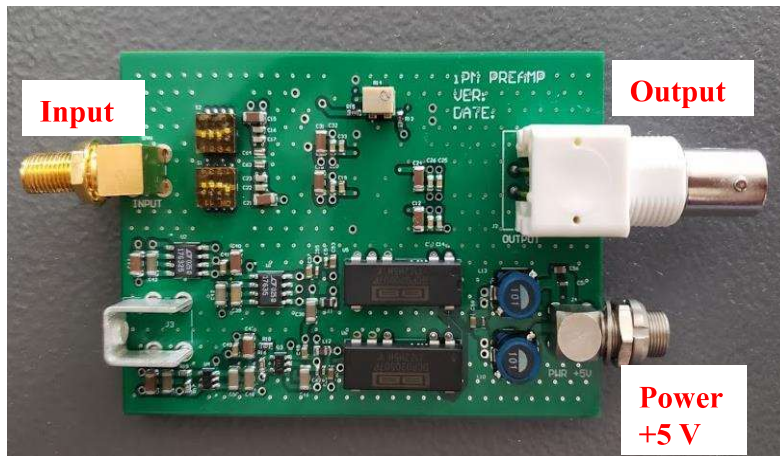
- requirements and version changes

Design criteria:

- Wide bandwidth
- Flexible gain (for various sectors & rings)
- Rad-hard components
- Low noise ($\delta^2_{\text{Elect}} < 1\%$)
- Floating ground

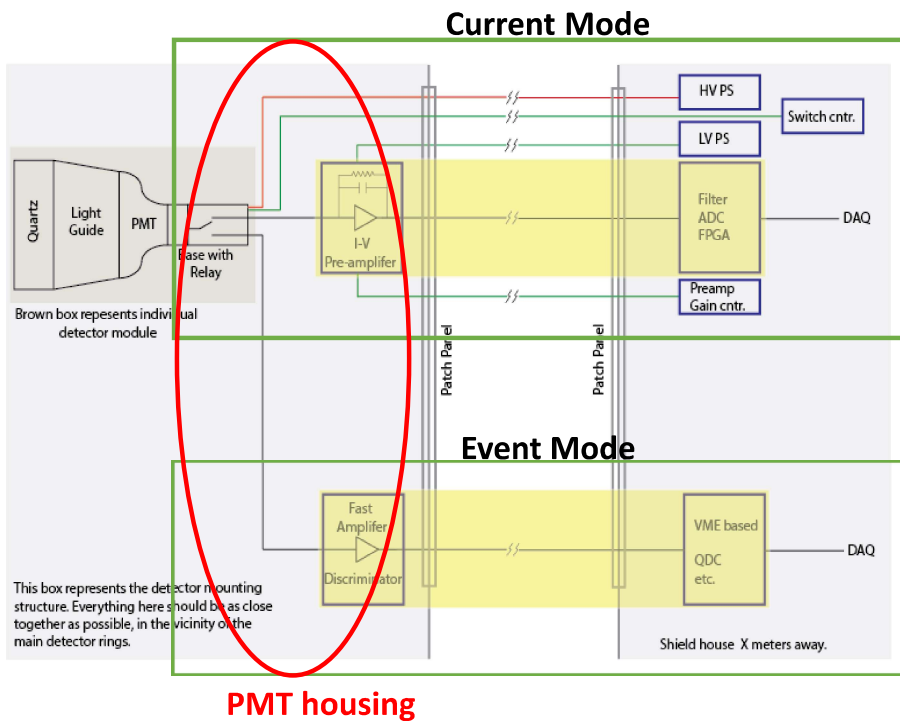
Major version changes:

- 1st, follow Qweak design, but with largely expanded bandwidth (from 26 kHz to 1 MHz)
- 2nd, change to differential output, use ~2 m long input cable so the preamp could be located nearby shielded area, use rad-hard components



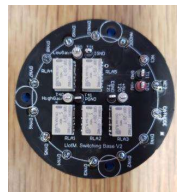
- Single-ended Input
- Differential output (Max. 8.192 Vp-p)
- Select gain (20 k Ω – 1.0 M Ω)
- Bandwidth ~ 1MHz
- Floating ground (isolated DC-DC converter)

New Integrated PMT Base



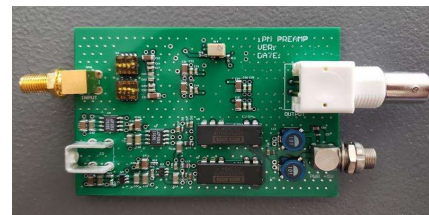
- Current-mode and Event-mode chains share the same PMT voltage divider (switching base)
- The current-mode amplifier should be located as close as possible to PMT; both voltage divider and I-to-V amplifier will be inside PMT housing;
- **Proposed new design – Include the event-mode fast amplifier into the next version of the base design.**

New Integrated PMT Base =



voltage divider

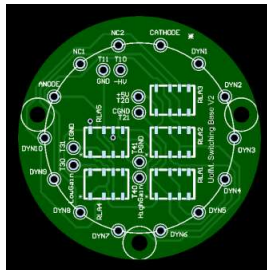
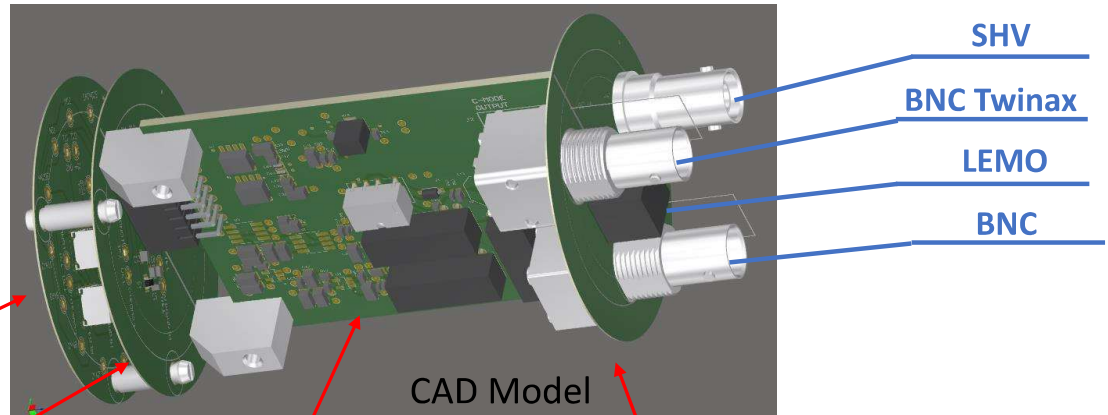
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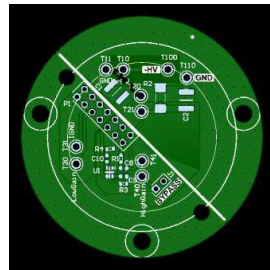
Current-mode preamp

+ Fast Pulse Amplifier

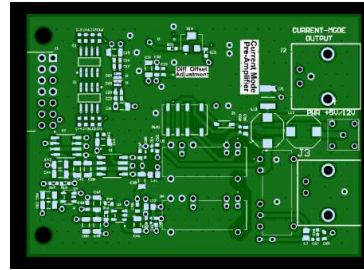
Integrated Base Design



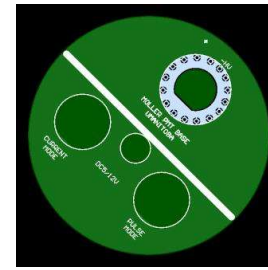
**Mode-switchable
voltage divider**



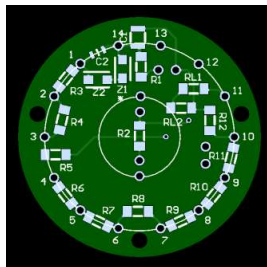
**Counting mode
fast amplifier**



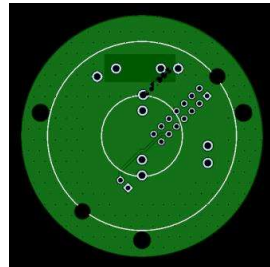
**Current model
pre-amplifier**



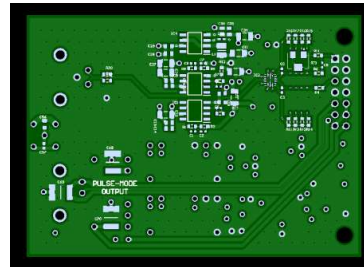
End-plate



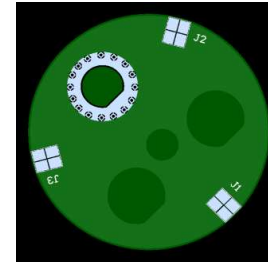
**Mode-switchable
voltage divider**



**Counting mode
fast amplifier**



**Current model
pre-amplifier**



End-plate

Top-view

Bottom-view

Prototype of the Integrated PMT Base

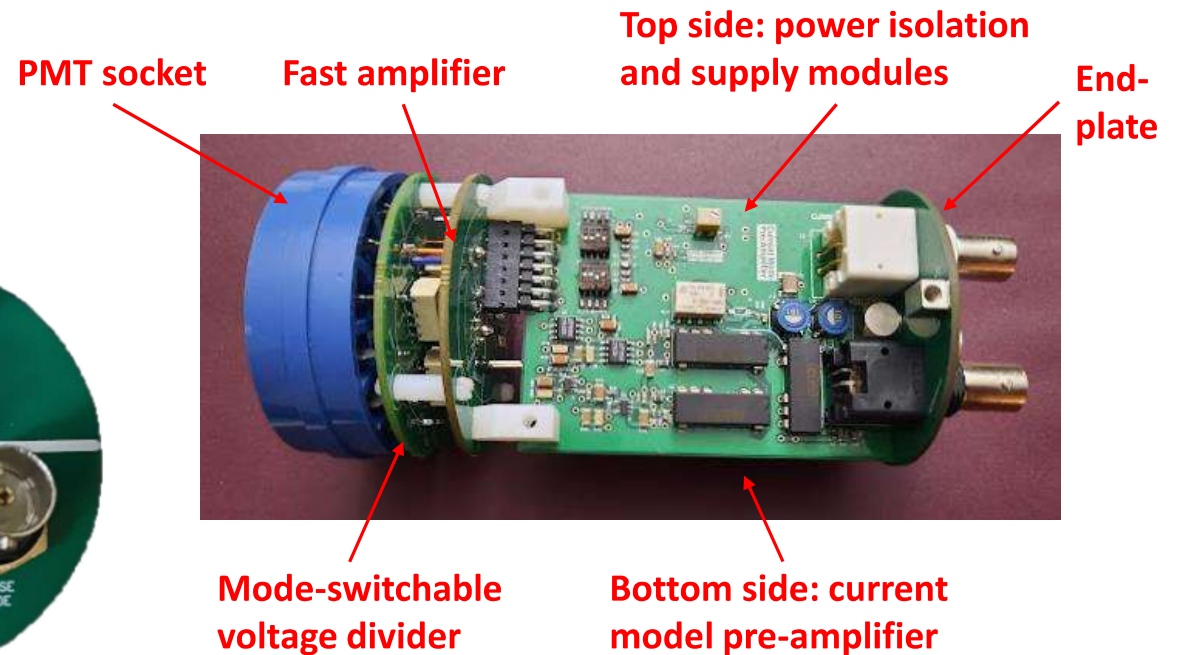
- Having five integrated bases
- Cost: \$355 USD each, including shipping (without PMT socket and SHV connector)



Appearance with Aluminium case (shielding shell)



End-plate showing the layout of signal and power connectors

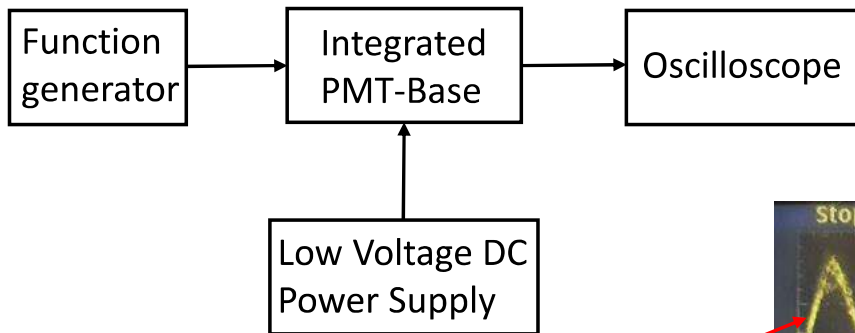


Looking inside

* Measured total power consumption: <math><2.5\text{ W}</math>

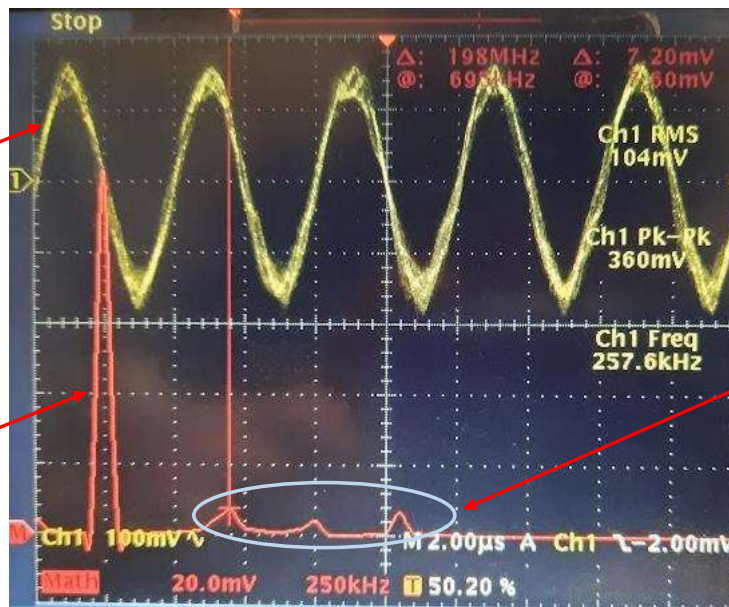
Initial Test - Noise from Interference

Initial Test Setup:



250 kHz Single-ended signal in time domain

250 kHz signal peak in frequency domain



Signal Bandwidth: 1.2MHz

Oscilloscope's switching power supply generated interference to measured signals

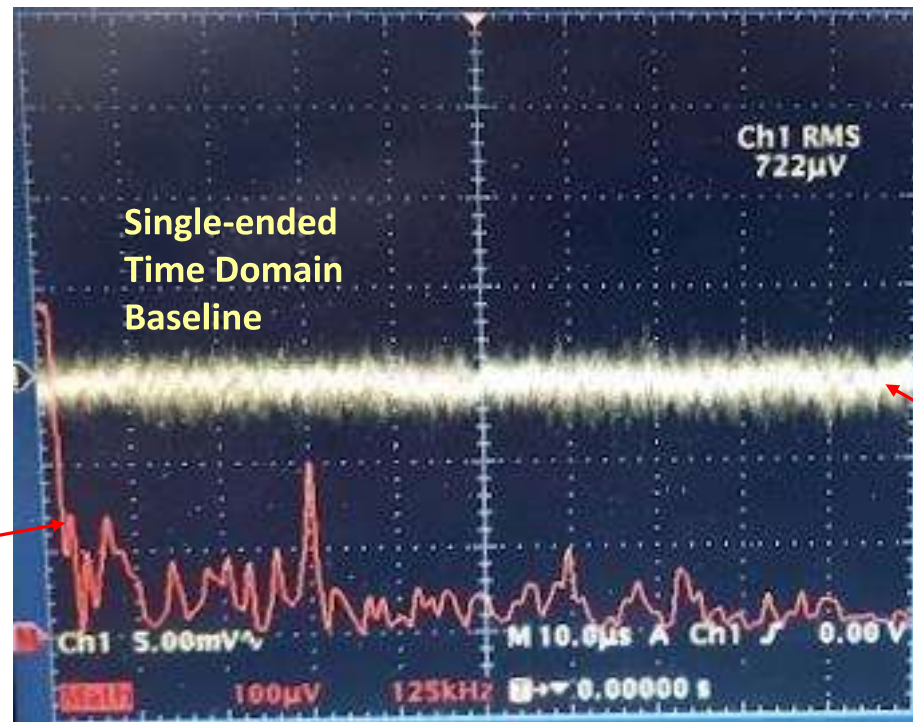
These peaks disappeared after making good shielding and grounding of the PMT base

Baseline Noise – Time & Freq. Domain

Test conditions:

- Baseline test (no input signal)
- PMT socket + voltage divider + preamp (no PMT attached)
- Preamp Gain: 200 k Ω
- Signal Bandwidth: 250 kHz
- Equivalent Noise BW: 400 kHz

Baseline in
freq. domain
(low frequency
spike < 400 μ V)



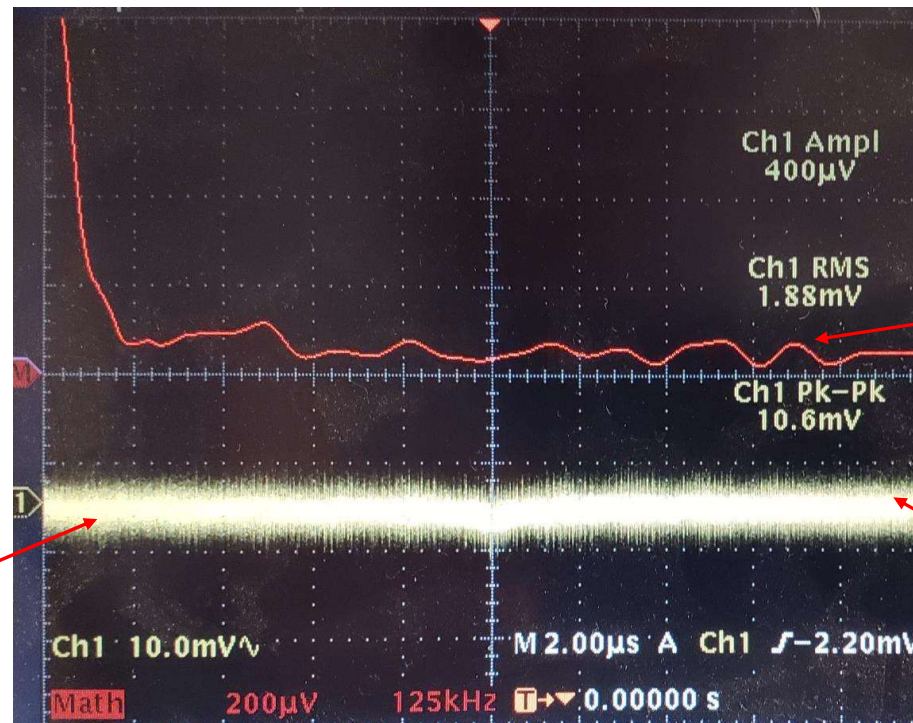
Single-ended
signal Baseline:

Noise RMS < 1 mV
Noise Peak-to-peak < 4 mV

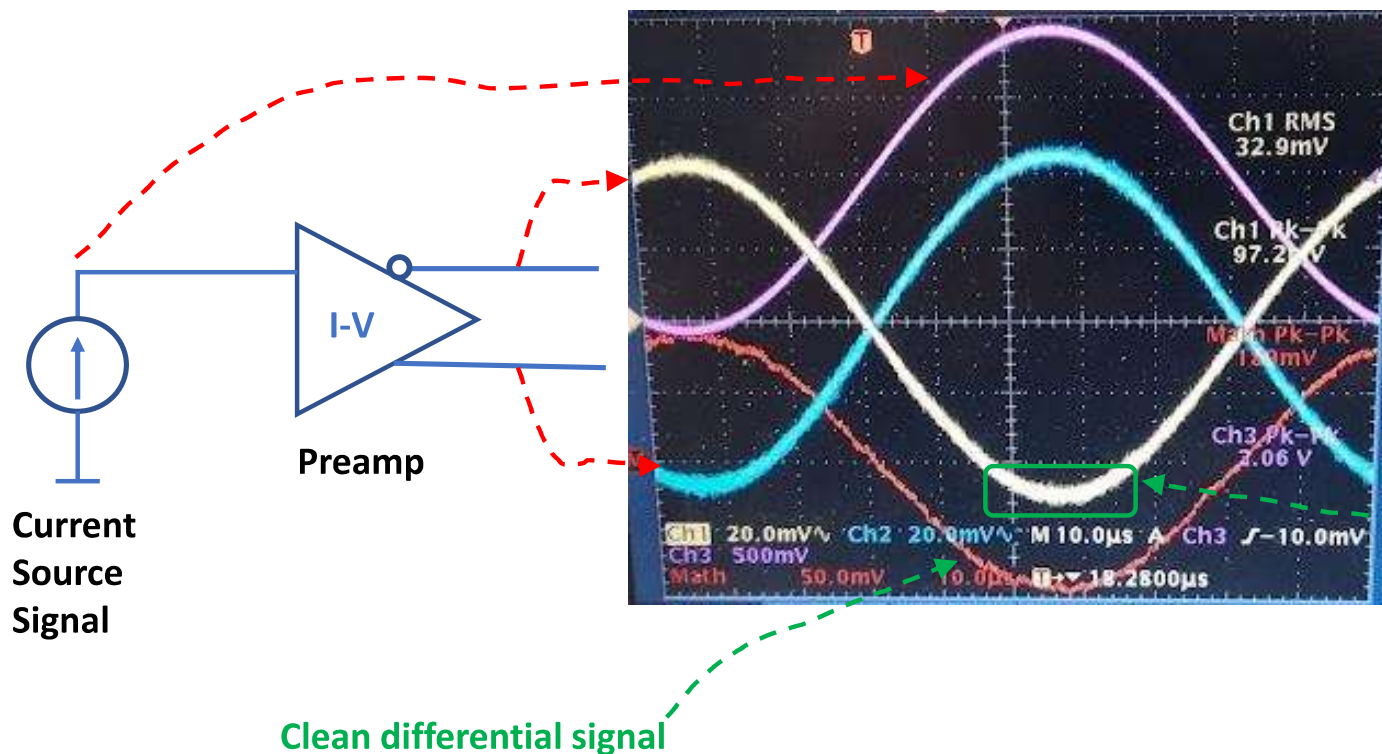
Battery Test – Time & Freq. Domain

Test conditions:

- Battery driven DC current source signal as input
- PMT socket + voltage divider + preamp (no PMT attached)
- Preamp Gain: 200 k Ω
- Signal Bandwidth: 250 kHz
- Equivalent Noise BW: 400 kHz



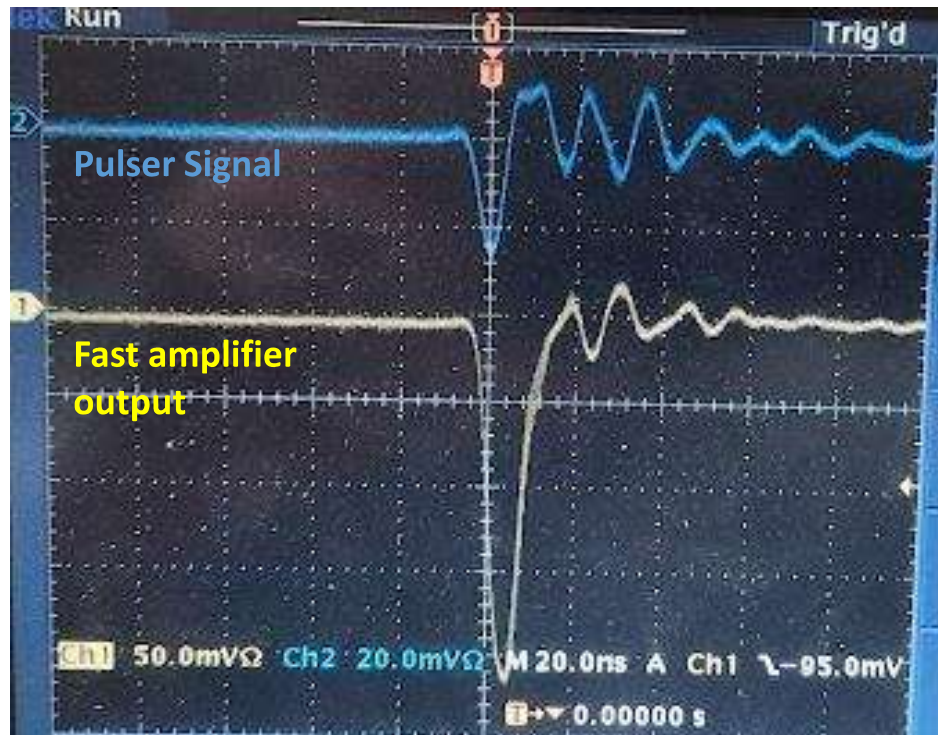
Response to Current Source Signal



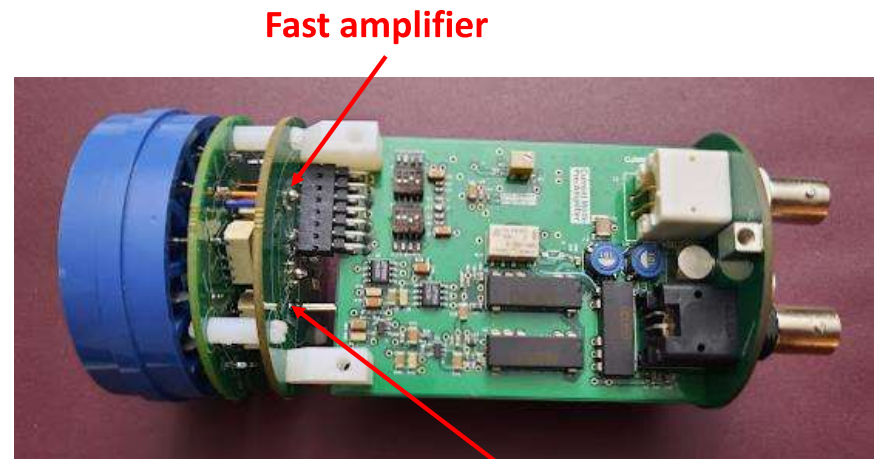
Test conditions:

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Pulse Mode Fast Amplifier – First Test



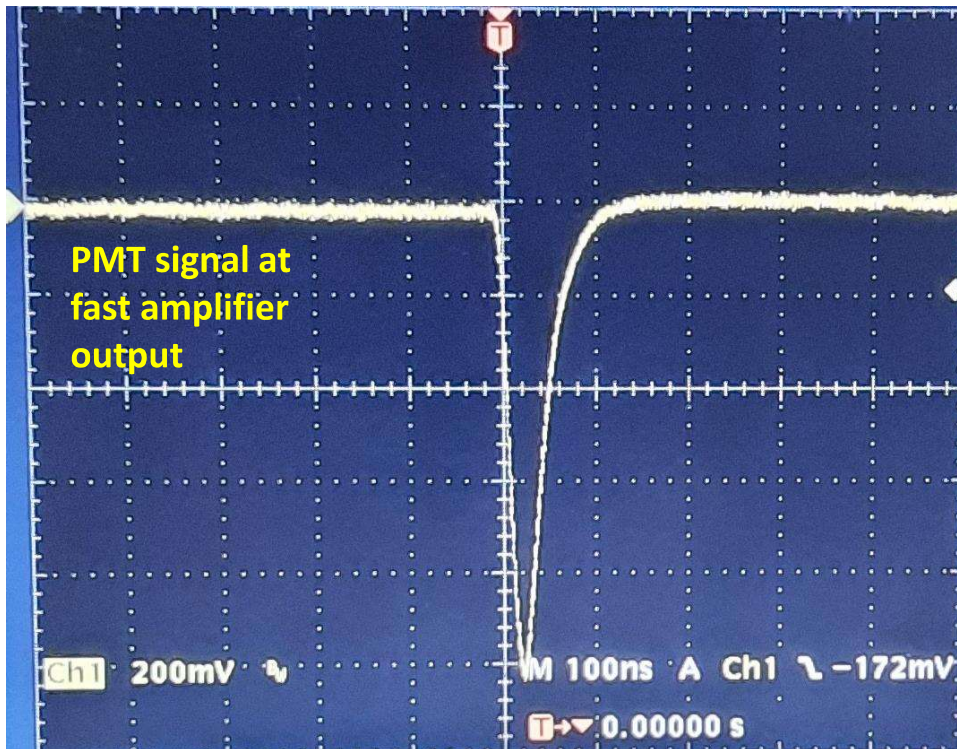
Tested with a pulse generator:
10 ns negative pulses, x10 gain



Fast amplifier

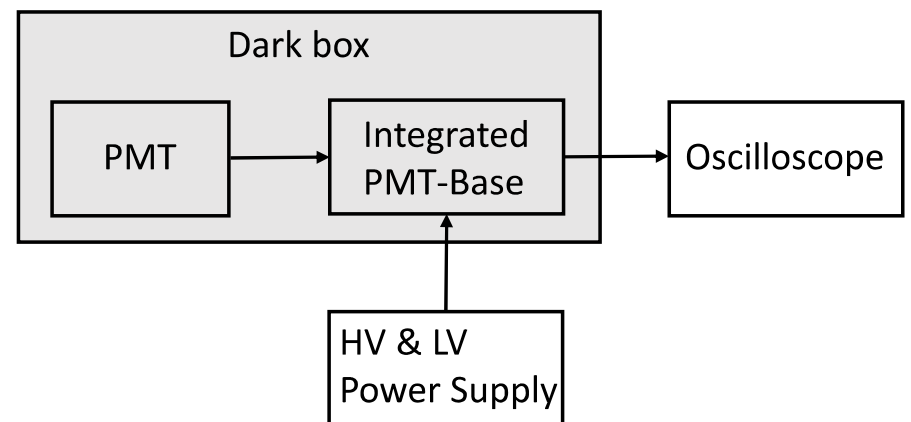
**A jumper is available to completely
bypass the fast amplifier**

Pulse Mode Fast Amplifier – Test with PMT



HV = -900 V

Test Setup:



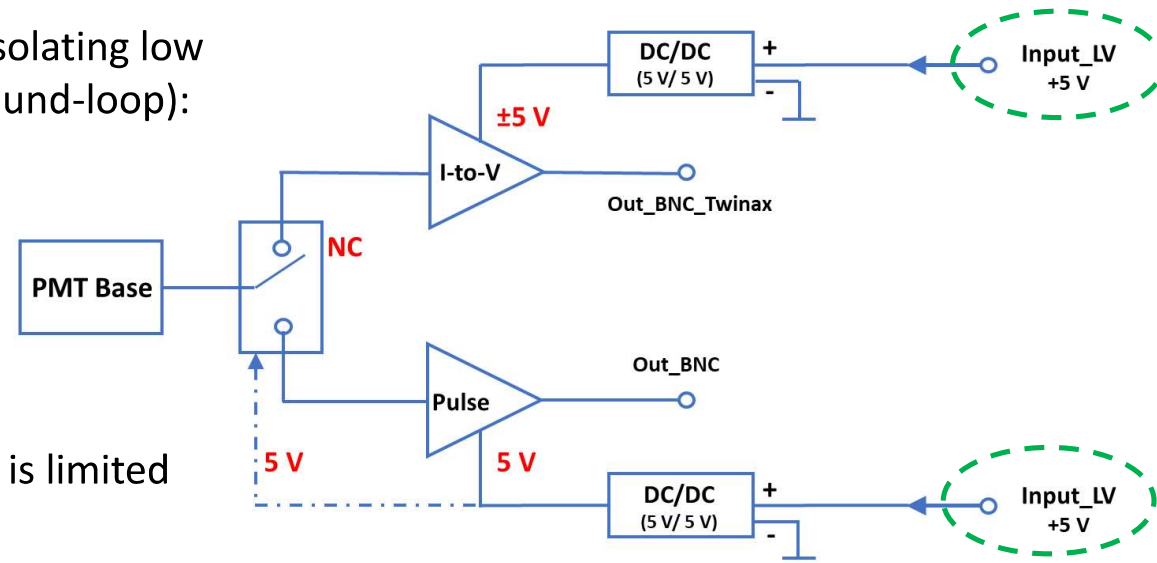
Observed ideal clean pulses, 40 ns width

PMT Base: Mode Control & Low Voltage Power Supplies

- PMT base needs inter-isolating and ground-isolating low voltage power supplies (to avoid possible ground-loop):

Current mode preamp: $\pm 5V$
Pulse mode fast amp: $+5V$
Mode switching control: $+5V$

- Normally need two LV connectors, but there is limited space on the PMT end-plate
- Connectors/cables are costly!



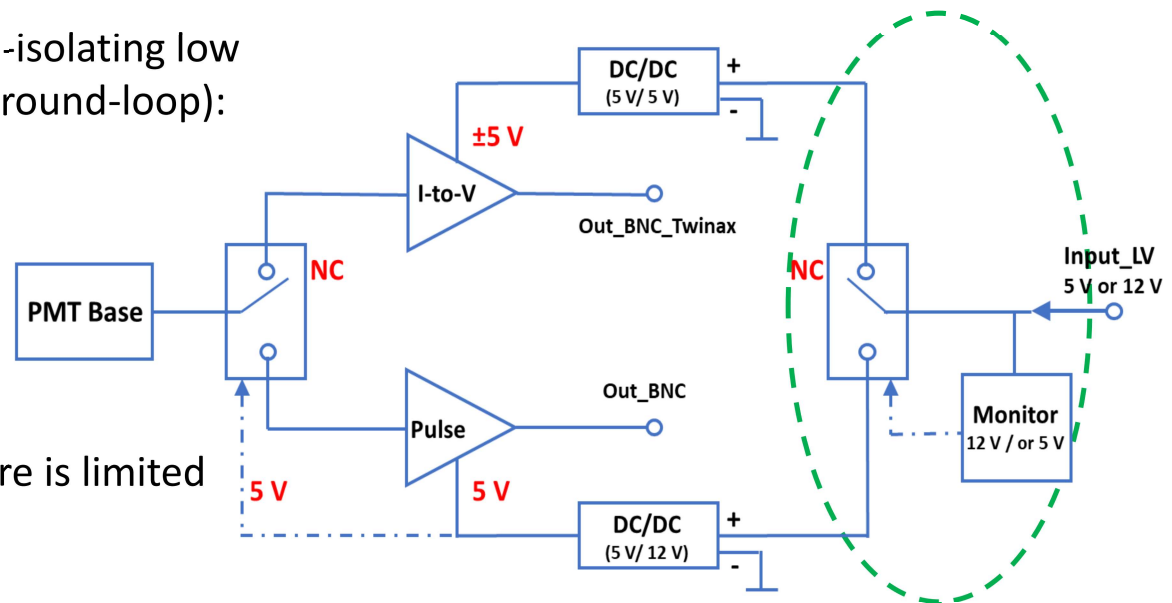
We need to find out a method on how to provide power supplies for the PMT base as well as mode switching control

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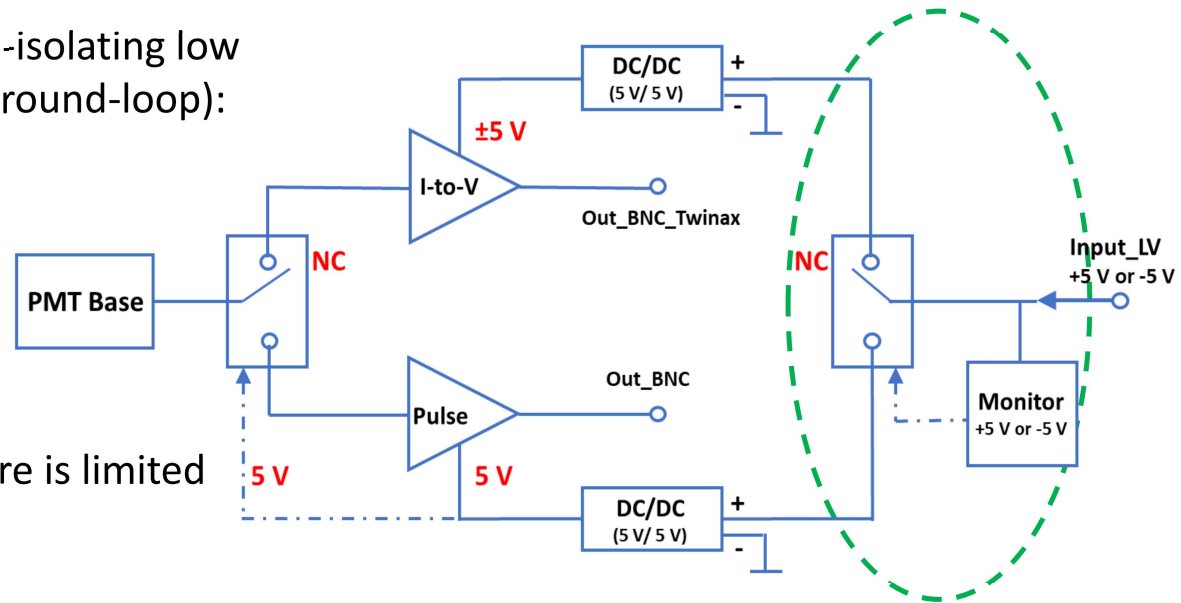
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PMT Base: Mode Control & Low Voltage Power Supplies

Scheme	Description	Pros	Cons	Cost
A	One connector for low voltage power supply, another connector for mode switching control	Simple design Reliable	Extra cost on the 2nd Connector & cable	high
B	Combine LV power supply and the mode switching control into a single connector, 5V – low gain, 12V – high gain	One connector simple control	2 external power supplies	medium
C	Same with B but changing mode by flip the power supply polarity, +5V – low gain, -5V – high gain	One connector simple control		low
D	Use a single 4-pins LEMO push-pull	One connector	Multi-conductor cable, costly 4-pos LEMO	high



End-plate layout of scheme B & C

- Current prototype design: Scheme C (or B)
- Open to discussion for the scheme options

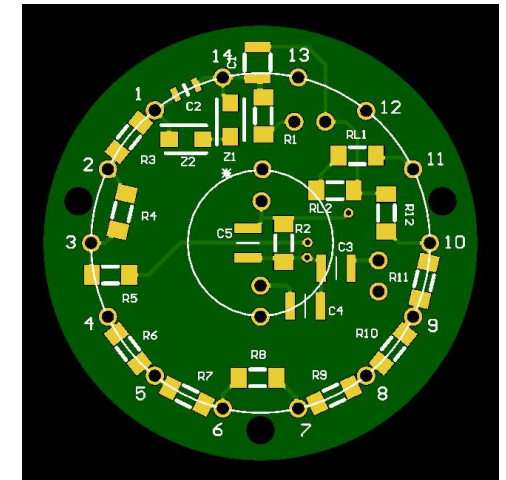
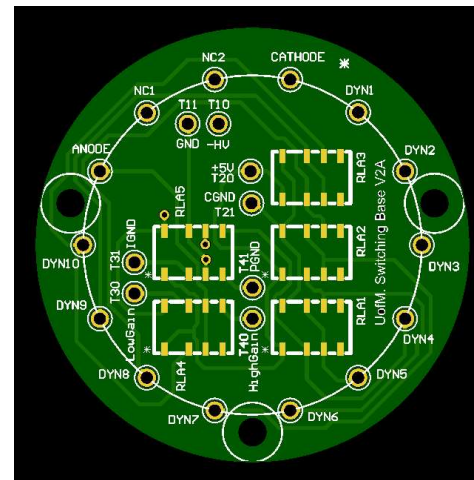
- Having 5 integration ADC boards
- A preliminary version of firmware has been developed and tested
- Currently working on trigger and TI programming (TRIUMF & JLab)
- Small modifications to hardware are still needed, but will ship out boards to JLab for tests soon



Integration ADC Board

Recent Production: Mode-Switchable PMT Voltage Divider

- Reproduction of the mode-switchable voltage dividers as per request by other groups
- Pulse mode gain $\sim 10^7$, Current mode gain ~ 500
- Recently received, 10 voltage dividers available for distribution
- Time for manufacturing: ~ 2 months from submitting design to receiving the assembled boards
- Cost per assembled board: \$55 USD without PMT socket



Mode-switchable voltage divider PCB top & Bottom

Status & Plan

- Beam tests of full electronics chain were conducted Nov. 2021 & May 2022
- 10 mode-switchable PMT voltage dividers (V3) are ready to distribute
- Designed a new version PMT base which integrated the PMT voltage divider, pulse mode fast amplifier and current mode preamp together
- Received 5 integrated PMT base prototypes, initial tests are underway
- Integration ADC boards with preliminary firmware are near ready to be sent out for tests
- New beam test is planned, the integrated base and full ADC board will be tested together with various detectors this fall.