

#### Canadian Electronics Status

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#### **mPMT Electronics Overview**

- PMT signal digitization using 125MHz ADC, with pulse finding and feature extraction in FPGA.
- PMT power generated on PMT base with Cockroft-Walton circuit.
- Single cat-5 network cable connected to mPMT mainboard, provides power/communication/clock/trigger.





#### **Timing Resolution Measurement**

- Restarted measurements of timing resolution to help finalize shaping circuit design and dynamic range choice.
- Measuring timing resolution for different PMT gain and amplifier gain.
- Want to disentangle intrinsic PMT dependence of TTS on gain vs worsening TTS because of lower signal to noise.
- Need to finalize choice of PMT gain and shaping circuit within next 2-3 months



Plot of Timing Resolution versus PMT Gain

#### **TRIUMF Test Stand**

- Have a 2D gantry system at TRIUMF for scanning pulsed LED across photosensor. Test stand being commissioned.
- Plan to use it for both individual PMTs and assembled mPMT
- So far have made scans with two PMTs.



#### Integration mPMT Tests

- Now starting tests with an assembled mPMT (16 PMTs) in test stand.
- First step is just turning all PMTs and equalizing gain.
- Have found two worrisome problems so far
  - 1. One of the PMTs has 'gone bad'
    - symptoms of 'bad 'PMT are
      - High current: ~16uA of HV
      - Measured voltage doesn't match setpoint voltage
      - No PMT pulses seen
    - This is third PMT PMT that has gone bad. Have send two of the bad PMTs to Poland for testing
  - 2. Bad PMT seems to be causing the mainboard itself to turn off. Don't understand why yet. To be investigated more.

- Most of the tests at TRIUMF have been done using mPMT mainboards with Altera FPGA.
- But we are switching to Xilinx FPGAs for the production WCTE mPMTs.
- Between WUT and TRIUMF have solved last problems with the communication between Xilinx FPGAs and the PMT microcontrollers.
- Priority now is doing extensive tests now with mPMTs + PMTs with Xilinx FPGAs.
  - This will be final key tests before we are ready for the mainboard mass production
- The 100 production Xilinx FPGAs have arrived at TRIUMF and WUT.

#### Status of Mainboard Component Purchase and Delivery

- We are purchasing and receiving components for a pre-production of mPMT mainboards (QTY=4) and production mainboards (QTY=102).
- Obviously, has been difficult to purchase components.
- TRIUMF engineer has replaced most of the unavailable components.
- We have 11 components which we have ordered, but haven't been delivered yet and a couple components we haven't ordered at all (and all the analog shaping passives)
- Latest stated delivery date for some of the components is Oct 2022.
- R&D needs to finish on several items in order to make final purchases:
  - Analog shaping
  - Finalize light pulser scheme
  - Firmware backup scheme
  - MCC-mPMT Interfaces (clock, trigger, etc)

#### **Mainboard Electronics Schedule**

- Need to finish all mainboard R&D in next 3 months
- want to be ready for pre-production mainboard manufacture in Nov 2022 once last components arrive.
- Main production of mainboards in Jan-Apr 2023.

	2022					2023	1		
Task	March	May	July	Sept	Nov	Jan	March	May	July
mPMT Electronics									
Develop ADC Xilinx firmware (with linux) [WUT/TRIUMF] (COMPLETE)									
Test rev 1 board [everyone]									
Develop modbus communication with PMT [Romina/Yair]									
Test different analog shaping and fitting; finalize shaping [WUT/TRIUMF]									
Develop common Xilinx scheme for firmware/software [Yair/WUT]									
Start using eMMC in real firmware/software [Yair/Bryerton/WUT]									
Implement online pulse finding algorithm in firmware [WUT]									
Develop/Finalize Firmware update scheme [TRIUMF]									
Test Light Pulser Board [TRIUMF]									
Finalize cooling scheme and make final prototype [Miles/TRIUMF]									
Define MCC/mPMT Interface [Poland]									
Design/Build MCC prototype [Poland]									
Test Final Clock / Trigger distribution [Daryl, Yair, Thomas]									
test multiple module setup (synchronization) [TRIUMF]									
Final design and layout for WCTE mainboard [Daryl]									
Buy Components for rev-2 pre-production board [TRIUMF]									
Produce rev 2 board (pre-production) and test [TRIUMF]		$\leq$				$\geq$			
Purchase 100 SoM from Enclustra (COMPLETE)									
Buy and receive components for mainboard production [TRIUMF]									
Produce 101 rev 3 mainboard [TRIUMF]									
Develop mainboard testing jig [TRIUMF]									
Test production mainboards [TRIUMF]									
Produce and Test Mezzanine LED Card [Uvic/TRIUMF]									
Finalize PMT base design [WUT]									
Build 2000 PMT HV and FEB boards [WUT]									
Buy / Assemble Ribbon Cables [WUT]									

#### **Backup**

# **RIUMF**

#### **Timing Analysis**

PMT gain	Op-amp gain	1PE PH (mV)	Dynamic range	eTTS (FWHM)	Comments
1x10 <sup>7</sup>	4	25	0-40PE	1.727ns	Should be best S/N. Best eTTS? Same eTTS as 2x10 <sup>7</sup> . So no effect of electronics timing resolution? Ideal case?
1x10 <sup>7</sup>	2	13.9	0-72PE	1.817ns	eTTS is 5% larger than for op-amp=4 case (ideal?); implied electronics timing resolution: 0.56ns (FWHM)
1x10 <sup>7</sup>	1	7	0-142PE	1.992ns	eTTS is 15% larger than for op-amp=4 case; implied electronics timing resolution: 0.99ns (FWHM)
5x10 <sup>6</sup>	4	13	0-77PE	1.899ns	Same pulse height as $1 \times 10^7$ / op-amp=2 case. So could guess that this configuration has ~5% higher eTTS compared to ideal case.
5x10 <sup>6</sup>	2	6.5	0-155PE	2.184ns	Same pulse height as $1 \times 10^7$ / op-amp=1 case. 15% increase in eTTS compared to $5 \times 10^6$ / op-amp=4. Implied electronics timing resolution of 1.22ns (FWHM) Why worse than $1 \times 10^7$ / op-amp=1 case?

 Currently targeting a choice of PMT gain \* op-amp gain that gives 0-70PE of dynamic range. Electronics timing resolution seems acceptable at this S/N.

#### **Bad PMT killing mainboard**

- Have found that the bad PMT in integration mPMT is causing some failure that is causing mainboard to reboot.
- Slowed down PMT ramp rate and checked currents (in uA). Can see current steadily rising until mainboard reboots.
- Power measured by POE switch confirms that the mainboard reboots and then recovers.
- Daryl doesn't understand problem and is concerned; needs investigating!

