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Design Note TRI-EDEV-DN-00 NuPRISM MAX10 PMT Verification

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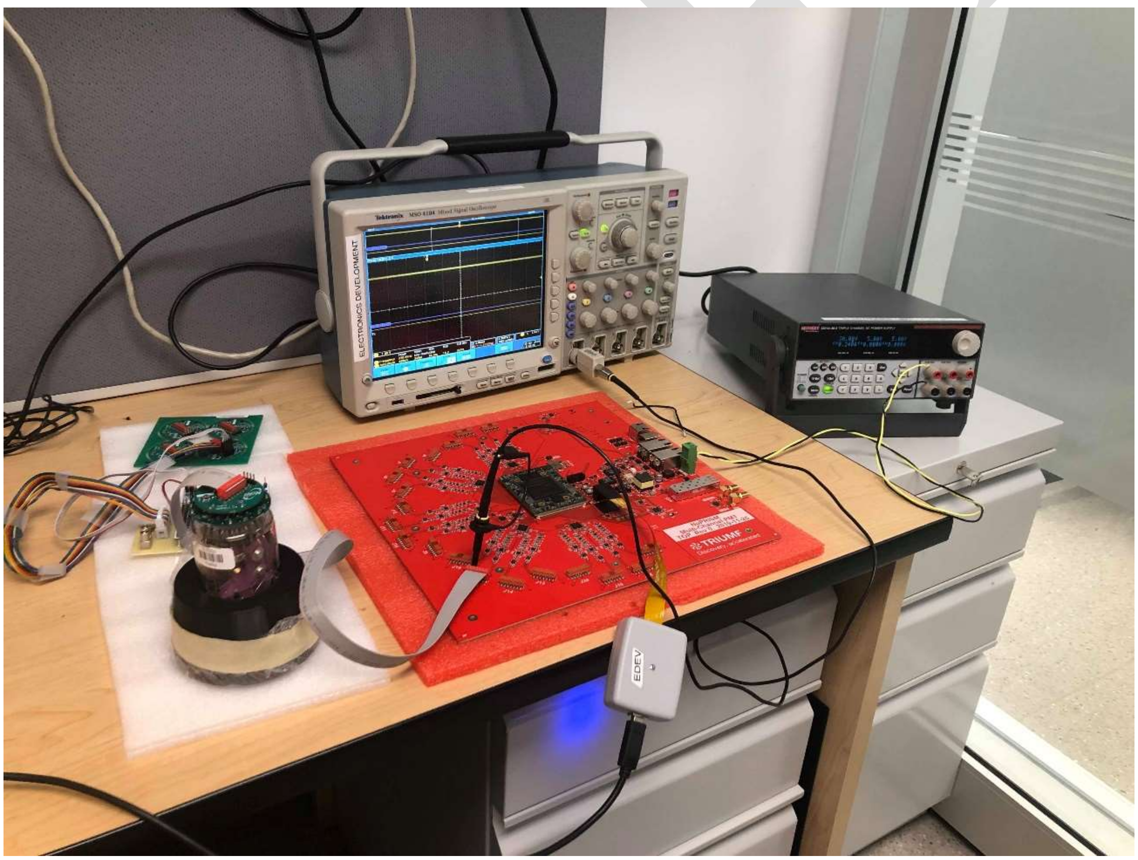
History of Changes

Release Number	Date	Description of Changes	Author(s)
1	2020-01-20	First draft	Ryan Payne



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1 Abstract

This report documents the work done by Ryan Payne to verify hardware for the NuPRISM Multi-Channel PMT Rev. 0. The verification found the following:

- Altera MAX10 FPGA powers on and is programmable
- UART connections from PMT connectors to MAX10 are correct
- The MAX10 can communicate through UART to the PMT bases
- The PMT bases receives specified commands
- High voltage on the PMT is operational

2 Introduction

This report documents the work done by Ryan Payne to verify hardware for the NuPRISM Multi-Channel PMT Rev. 0. The verification found the following:

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- UART connections from PMT connectors to MAX10 are correct
- The MAX10 can communicate through UART to the PMT bases
- The PMT bases receives specified commands
- High voltage on the PMT is operational

Additionally, this document details some bugs found with the PMT base controller.

Further steps in development include determining the role of the MAX10 and developing the firmware for it.

2.1 Purpose

The intent of this document is to act as a reference for the functionality of the MAX10 on the NuPRISM Multi-Channel PMT Rev. 0. Information is also included regarding the assembly and testing of the PMT.

2.2 Scope

This document mainly covers functionality of the MAX10 on the NuPRISM Multi-Channel PMT Rev. 0 and the PMT UART interface. Additionally, some details are provided about the fixing of the PMT controller to the PMT and notable bugs found in the PMT controller. Information on the firmware used to test is include in the apendicies.

2.3 Definitions and Abbreviations

HW – Hardware
HV – High Voltage
PMT – Photo-multiplier Tube
RX – Receiver
TX – Transmitter
UART – Universal Asynchronous Receiver Transmitter

3 MAX10

3.1 Programming

The MAX10 enumerates and is programmable through the JTAG interface seen in figure 3.1.

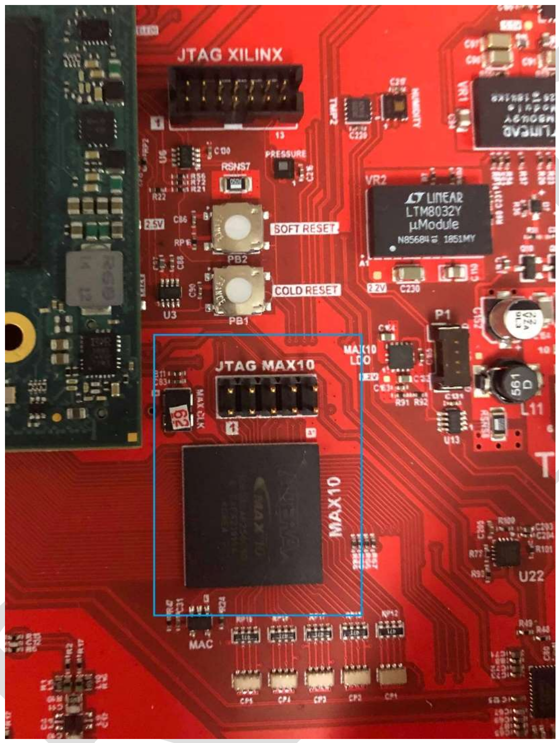

Figure 3.1: MAX10 and JTAG connector

The board was powered by a Keithly 2231A-3003 Triple Channel DC Power Supply. Before being programmed, the board consumed 239mA off of a 30V supply. When programmed to run a soft processor to communicate with PMT bases, the MAX10 uses and additional 7-8 mA. These conditions are summarized in table 3.1. information on the firmware is located in Appendix A.

Table 3.1: Operating conditions, (Auxiliary power, Keithly 2231A-3003 Triple Channel DC Power Supply, Vin = 30V, Imax = 0.5A)

Condition	Voltage (V)	Current (mA)	Power (W)
No code running on the MAX10 or Enclustra module	30	239	7.17
MAX10 programmed, no code running on the Enclustra module	30	247	7.41

Given a known clock source, the MAX10 can successfully generate 9600 baud for UART communications. This indicates that the 62.5 MHz clock input was correct.

3.2 Hardware Connections

The MAX10 was found to be successfully connected to the 20 PMT connectors and soft reset connector shown in figure 3.2. Figure 3.3 shows the pinout of the 20 connectors. The mating connector used was a TE Connectivity AMP Connectors 8-215083-4.

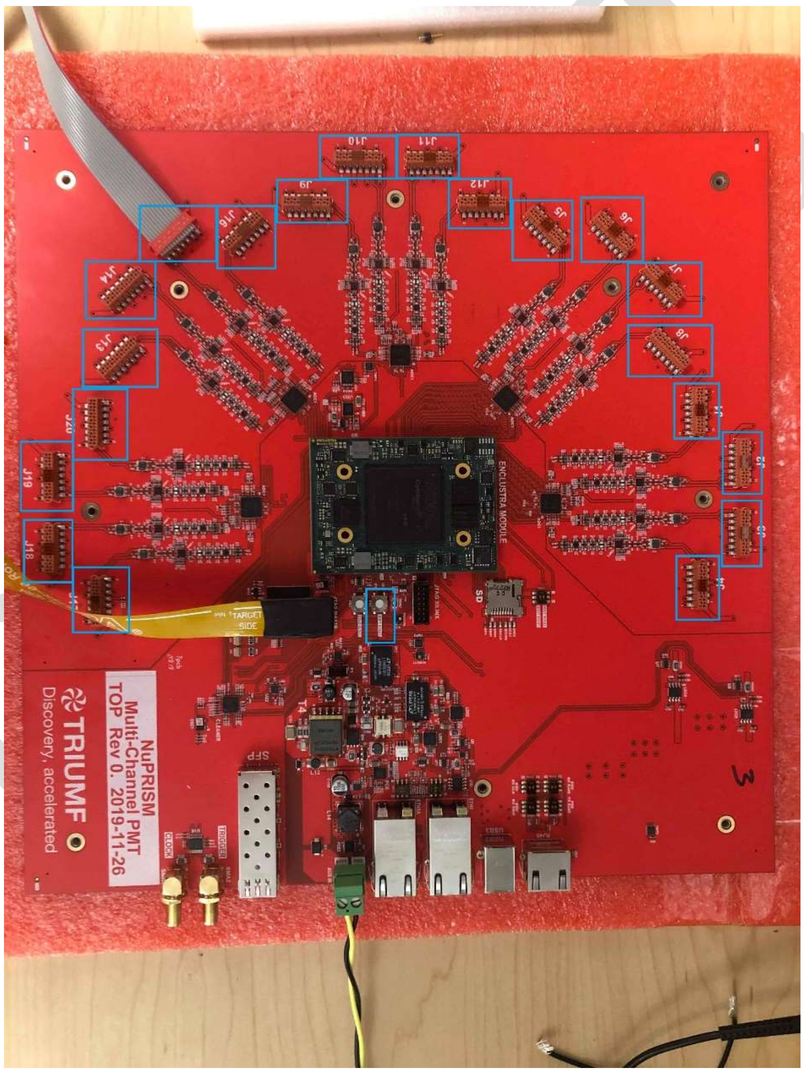

Figure 3.2: MAX10 hardware peripheral connections

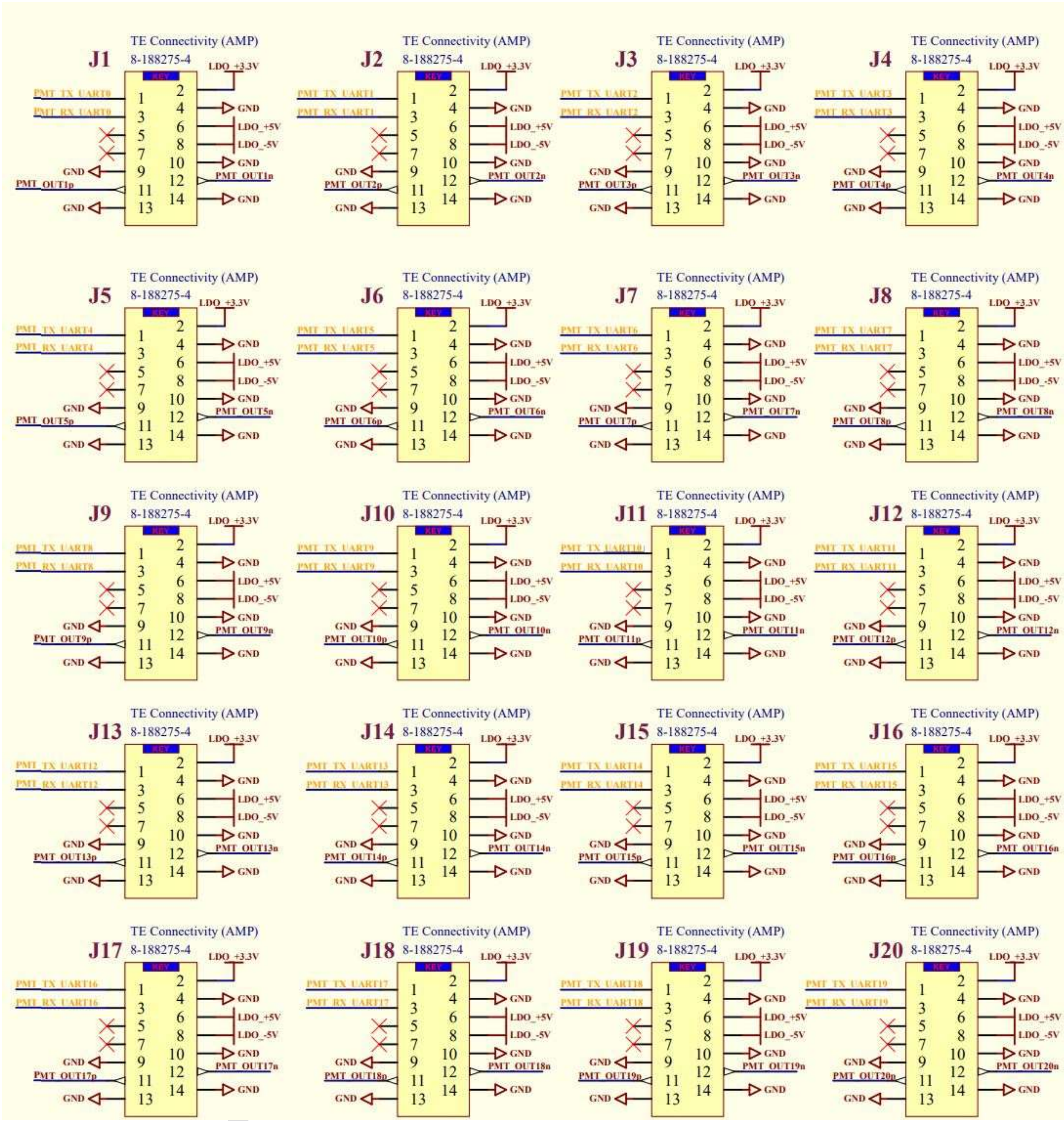

Figure 3.3: Schematic of the pinout of the 20 PMT connectors.

The UART bypass circuit successfully passes a 9600 baud signal.

The 3.3V (pin 2), 5V (pin 6), and -5V (pin 8) signals of each PMT connector were measured to be correct within 10% of their specified value. The measurements taken are summarized in table 3.2

Table 3.2: PMT supply voltage measurements

	Voltage (V)		
Base	**Pin 2**	**Pin 6**	**Pin 8**
J1	3.29	4.98	-4.57
J2	3.29	4.98	-4.57
J3	3.29	4.98	-4.57
J4	3.29	4.98	-4.57
J5	3.29	4.98	-4.57
J6	3.29	4.98	-4.57
J7	3.29	4.98	-4.57
J8	3.29	4.98	-4.57
J9	3.29	4.98	-4.57
J10	3.29	4.98	-4.57
J11	3.29	4.98	-4.57
J12	3.29	4.98	-4.57
J13	3.29	4.98	-4.57
J14	3.29	4.98	-4.57
J15	3.29	4.98	-4.57
J16	3.29	4.98	-4.57
J17	3.29	4.98	-4.57
J18	3.29	4.98	-4.57
J19	3.29	4.98	-4.57
J20	3.29	4.98	-4.57

3.3 Notable Bugs

As of the moment, there are no notable bugs regarding the MAX10 hardware.

4 PMT Base

4.1 Programming

The PMT Bases can be flashed using the setup provided by INFN (figure 4.1). The STM32CubeProgrammer is used to read and write binary files into the memory of the STM32L011 on the PMT base controller.

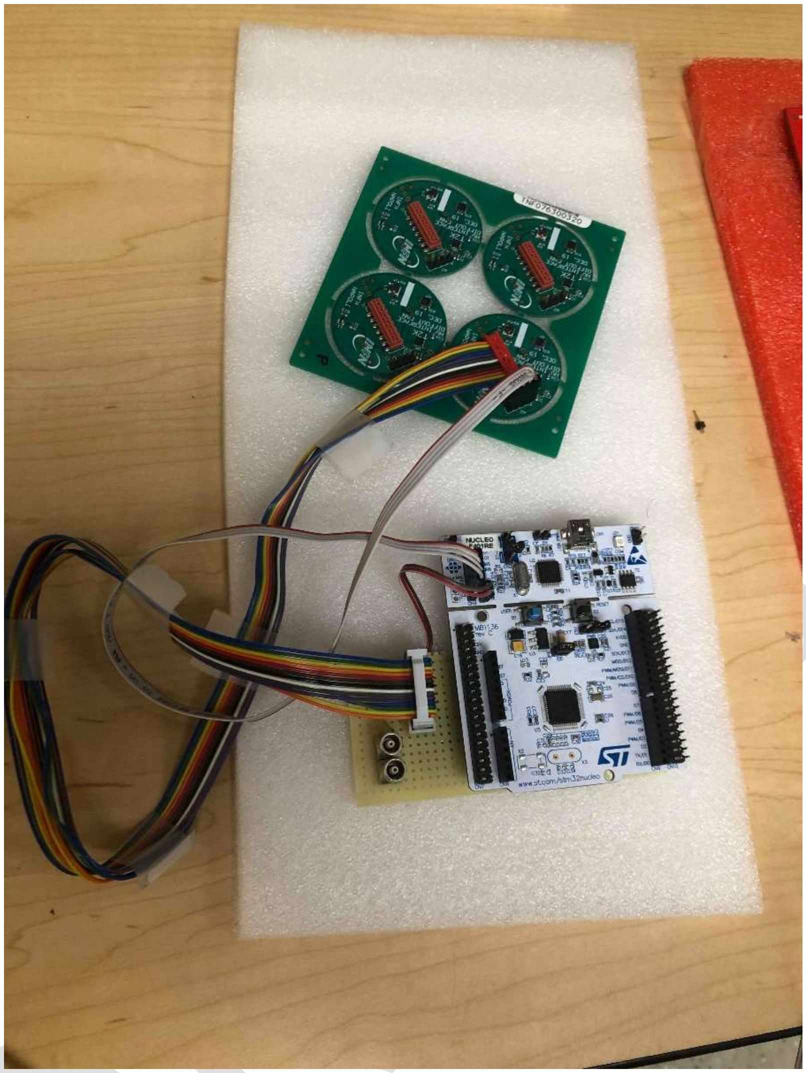

Figure 4.1: Programmer for PMT controller

4.2 Commands

The PMT bases successfully respond to all UART commands delivered by the MAX10. The commands are summarized in table 4.1 and the testing of the commands is summarized in table 4.2. All freshly flashed units respond to address 01. Figures 4.2 and 4.3 shows a waveform captured from the NuPRISM UART TX and RX. The waveform data is summarized in table 4.3

Table 4.1: Provided command list for the PMT controllers.

COMMAND DESCRIPTION	COMMAND			MCU ANSWER		
ADDRESS XX						
SET ADDRESS	XX	SU	VALUE[00;99]	XX	SU	VALUE[00;99]
SET TRIP TIME	XX	ST	VALUE [0000 ; 9999] mS	XX	ST	VALUE [0000 ; 9999] mS
SET THRESHOLD	XX	SS	VALUE [0000 ; 2425] mV	XX	SS	VALUE [0000 ; 2425] mV
SET RUMP UP-DOWN	XX	SR	VALUEE [000 ; 999] V/S	XX	SR	VALUEE [000 ; 999] V/S
SET HV VALUE	XX	SH	VALUE [0000 ; 1500] V	XX	SH	VALUE [0000 ; 1500] V
SET TRIP CURRENT	XX	SA	VALUE [0000 ; 9999] *10nA	XX	SA	VALUE [0000 ; 9999] *10nA
RESET	XX	RR	XXRR	XX	RR	XXRR
HV OFF	XX	HV	0	XX	HV	0
HV ON	XX	HV	1	XX	HV	1
READ CATHODE VOLTAGE	XX	LV		XX	LV	VALORE [0000000 ; 1500000] mV
READ ADDRESS	XX	LU		XX	LU	VALUE[00;99]
READ TRIP TIME	XX	LT		XX	LT	VALUE [0000 ; 9999] mS
READ THRESHOLD	XX	LS		XX	LS	VALUE [0000 ; 2425] mV
READ RUMP UP-DOWN	XX	LR		XX	LR	VALUEE [000 ; 999] V/S
READ REFERENCE VOLTAGE	XX	LQ		XX	LQ	VALORE [0000000 ;0002524] mV
READ CATHODE CURRENT	XX	LI		XX	LI	VALORE [0000000 ; 0016500] nA
READ SETTED HV	XX	LH		XX	LH	VALUE [0000 ; 1500] V
READ HV STATE	XX	LG		XX	LG	VALUEE[0;1]
READ AND RESET STATUS REGISTER	XX	LD		XX	LD	RU/RD/WR | OC/OV/CV | 0/1/2
READ TRIP CURRENT	XX	LA		XX	LA	VALUE [0000 ; 9999] *10nA

Table 4.2: PMT controller command test summary.

Command Description	Command	Response	Working?
Read Commands			
Read Cathode Voltage	01LV	01LV0468485	y
Read Address	01LU	01LU01	y
Read Trip Time	01LT	01LT1000	y
Read Threshold	01LS	01LT1500	y
Read Rump Up-Down	01LR	01LR0070	y
Read Reference Voltage	01LQ	01LQ2436735	y
Read Cathode Current	01LI	01LI0001024	y
Read Setted HV	01LH	01LH0000	y
Read HV State	01LG	01LG0	y
Read and Reset Status Register	01LD	01LDWRXX0	y
Read Trip Current	01LA	01LA1000	y
Write Commands			
Set Address	01SU01	01SU01	y
Set Trip Time	01ST2000	01ST2000	y
Set Threshold	01SS1600	01SS1600	y
Set Rumf Up-Down	01SR200	01SR200	y
Set HV Value	01SH0001	01SH0001	y
Set Trip Current	01SH1100	01SH1100	y
Reset	01RR01RR	~	y
HV On	01HV1	01HV1	y
HV Off	01HV0	01HV0	y

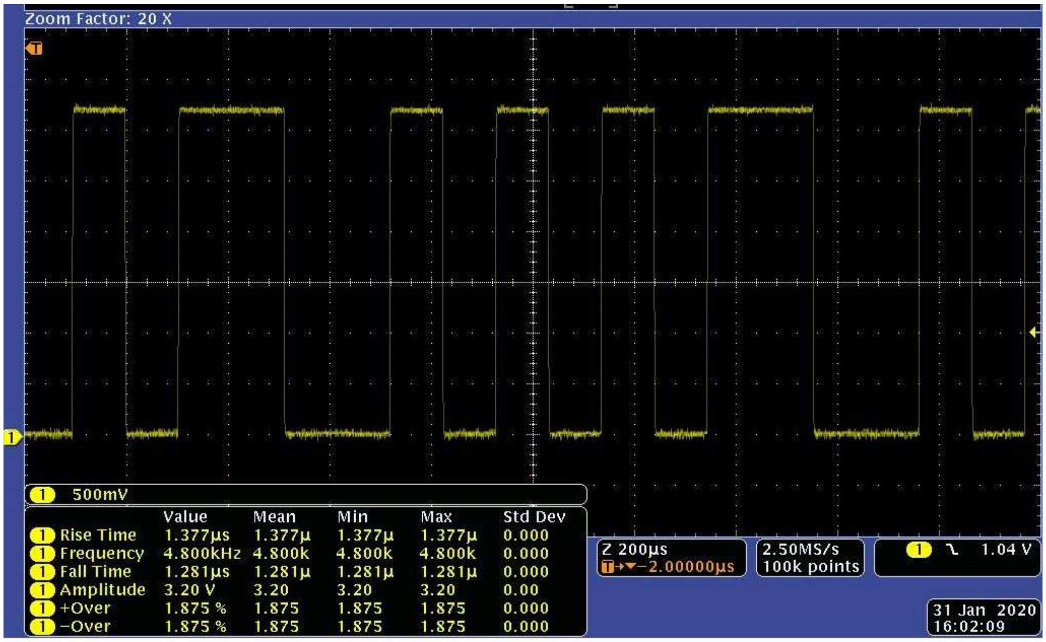

Figure 4.2: UART TX Waveform

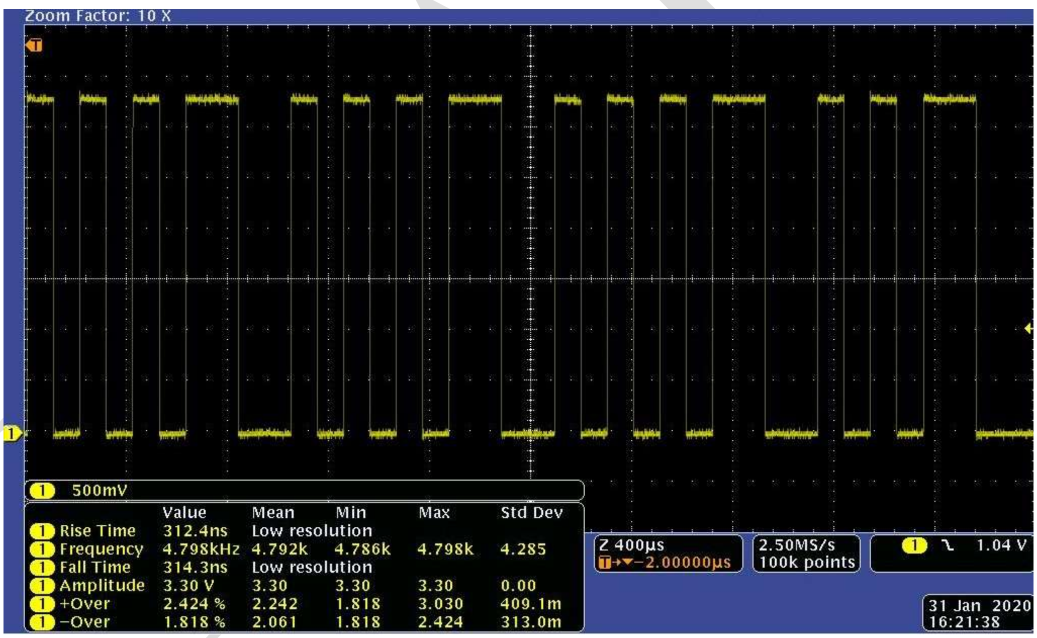

Figure 4.3: UART RX Waveform

Table 4.3: UART waveform performance (PMT connector J15)

UART	Rise Time (ns)	Fall Time (ns)	Amplitude (V)	Positive Overshoot	Negative Overshoot
TX	1377	1281	3.2	1.82%	1.82%
RX	340.6	314.3	3.3	1.82%	1.82%

4.3 Assembly

The PMT controller was soldered onto the PMT and Cockcroft–Walton circuit (figure 4.4. 4.5). To provide maximum clearance to the Cockcroft–Walton circuit, the pins connecting the controller board were given 2-3mm of clearance. To ensure the controller PCB was level the solder joints were added in a star pattern.

The PMT assembled was a Hamamatsu R14374-01, No. KM09823.

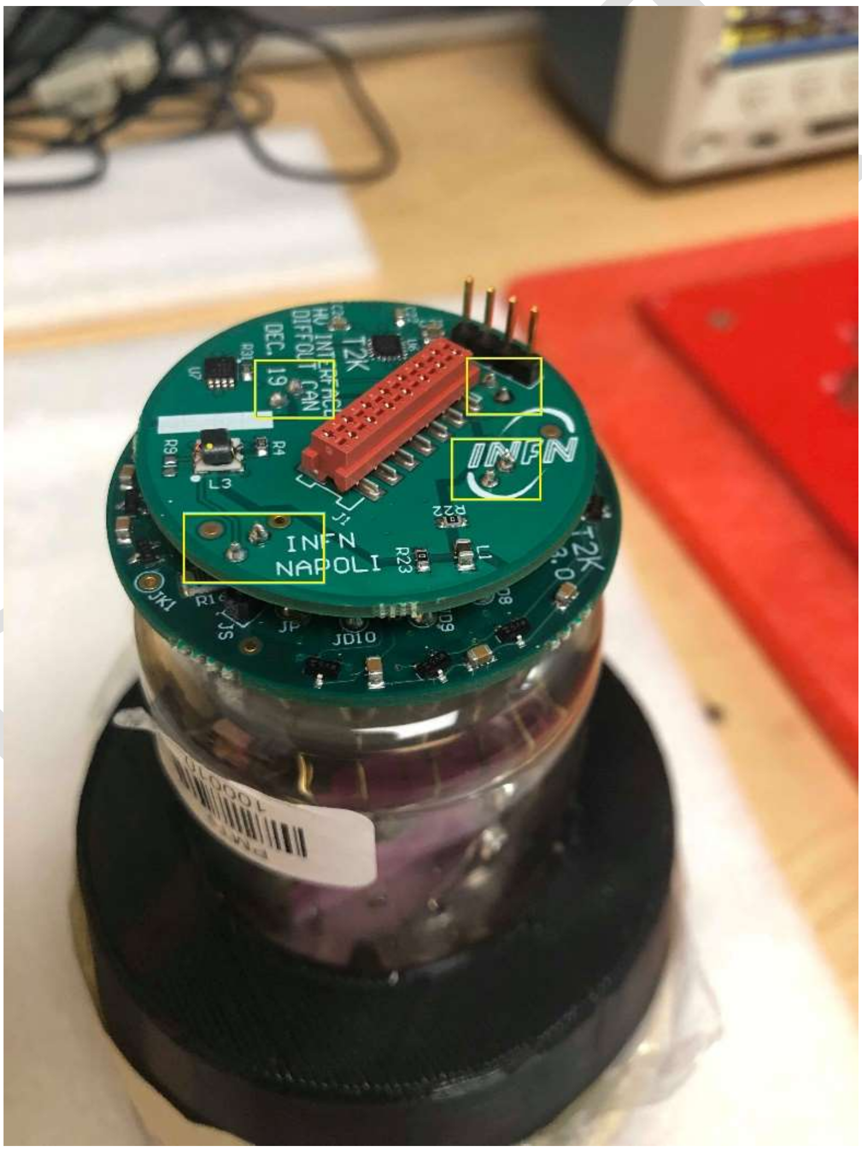

Figure 4.4: Solder joints on soldered on PMT controller

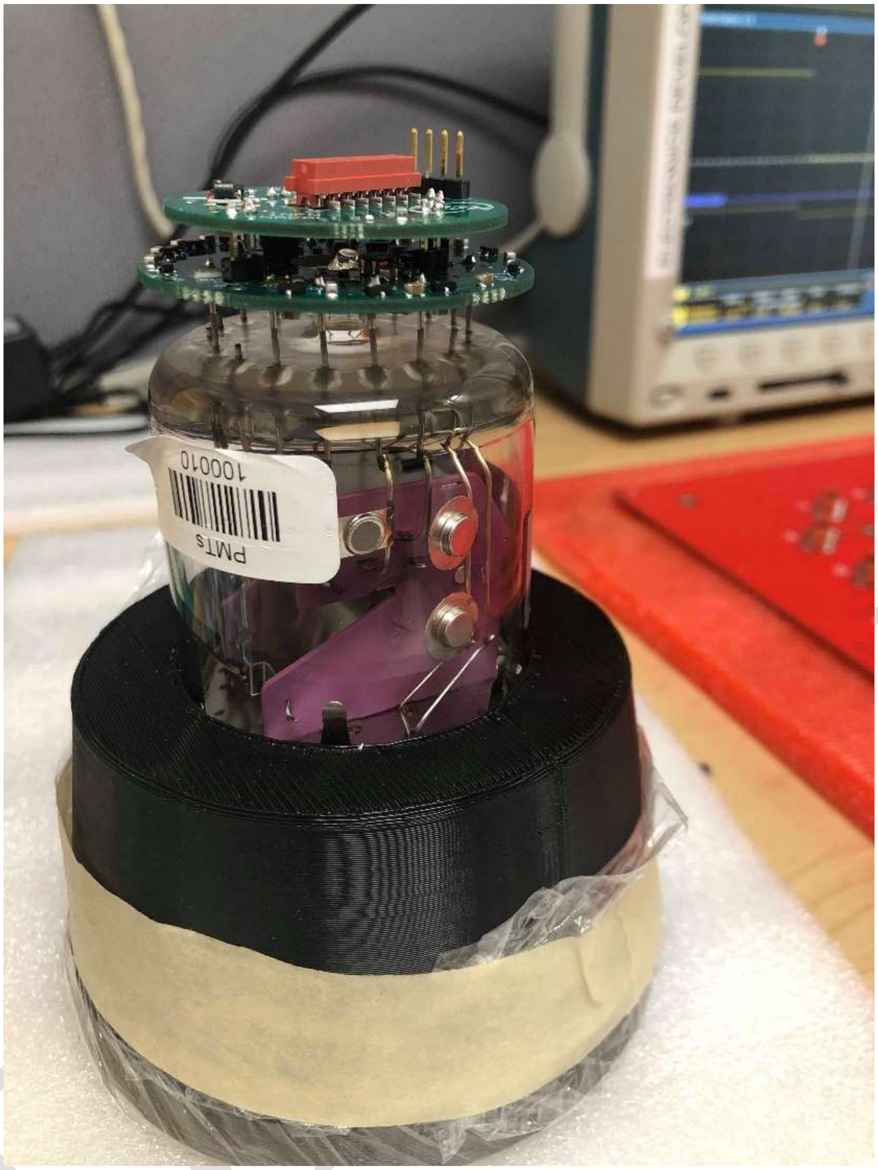

Figure 4.5: Image depicting clearance between controller and Cockcroft-Walton circuit

4.4 High Voltage

The device was set to several high voltage levels and the voltage was both measured directly and read out from the PMT commands. The results summarized in table 4.6 indicate that the PMT systems improves in accuracy as the set voltage increases. The difference between measured and ADC voltage is due to the loading effect of the multimeter.

The multimeter used was a Fluke 27 (10 MOhm input impedance)

Table 4.6: High voltage test summary

Set	Measured	ADC Read	% Error
20	25	33.306	66.53
50	47	62.586	25.172
100	84	111.996	11.996
150	121	161.04	7.36
500	380	505.812	1.1624

4.5 Notable Bugs

1. When an incorrect read statement is delivered (ex. "01Ls" vs "01LS"), the PMT controller exhibits erratic behaviour over UART and becomes unresponsive until power cycled.
2. The device will assign set point values to symbols (ex. "01LA))))" sets the trip current to "))))")
3. The PMT may not reach the expected HV when HV is set on until the HV is cycled (HV = 0, HV = 1)

5 Next Steps

The specific functionalities of the MAX10 must now be determined and implemented. Regarding UART communication to the PMT controllers, the MAX10 will likely act as a simple mux.

Appendix A: MAX10 Firmware

The firmware written for the purposes of testing the functionality of the MAX10 can be found on the TRIUMF Gitlab (https://edev-group.triumf.ca/fw/exp/nuprism/max10-testing/rev0). A diagram depicting the firmware is shown in figure A.1

The RTL developed for the MAX10 acts a simple mux for the UART connections from the Nios processor to the PMT bases. The select is controlled by the Nios soft processor.

The C code running on the Nios provides the user with a command server through JTAG. The commands allow the user to select a PMT base and send commands through UART to the selected base.

To run the firmware, first load the .sof file onto the MAX10 using the Quartus Programmer Tool. Then, run the Nios design using the Nios Eclipse IDE.

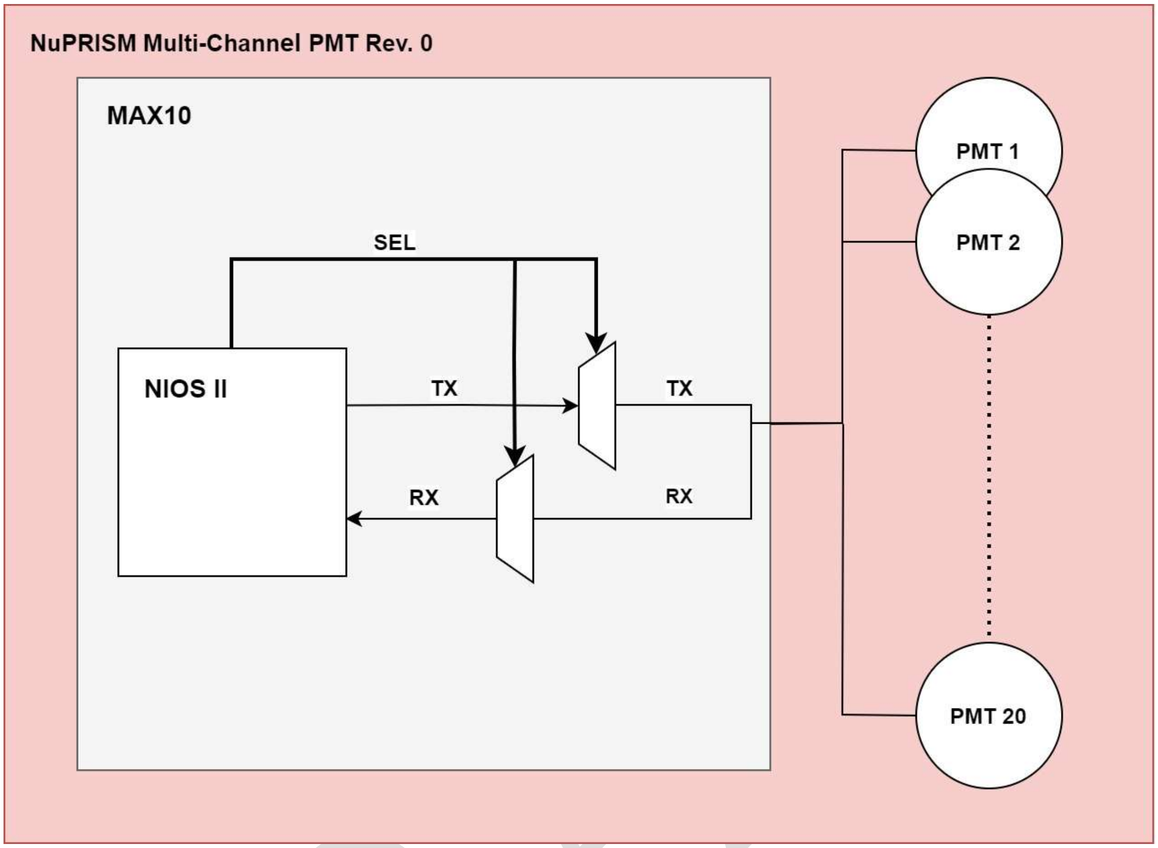

Figure A.1: MAX10 firmware diagram