TDC mezzanines on SVEC carriers Long Runs

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The purpose of the tests is the confirmation of the performance of the TDC mezzanine board with SVEC as carrier. Similar tests with the SPEC carrier board are available in [1,2].

Test Setup 1 | Pulse Pairs

Figure 1 shows the test setup. We use four calibrated TDC v3 boards housed on two SVEC boards. Both SVEC boards are plugged in the same ELMA crate.

As pulse generator we use a Fine Delay mezzanine board housed on a third SVEC board, inside the same ELMA crate. The Fine Delay pulses enter the pulse distributor from where they arrive properly terminated to the four different TDC channels.

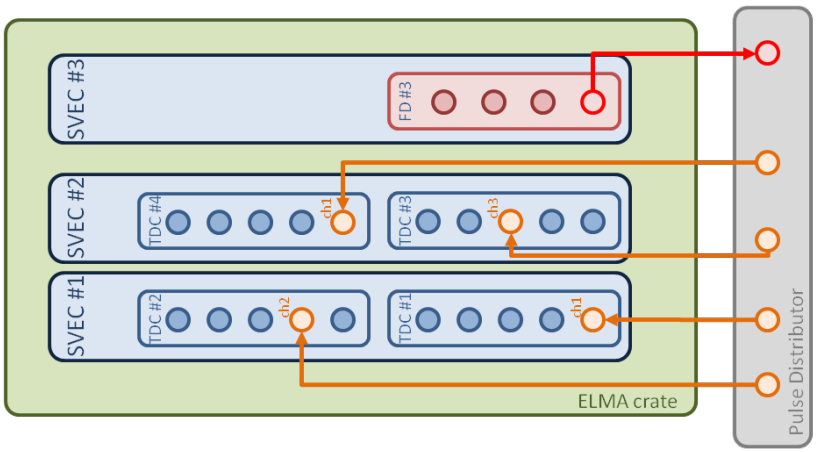

Figure 1: Test Setup 1

The Fine Delay is providing pulse pairs of 500 ns. The pairs are separated between them by a random amount of time.

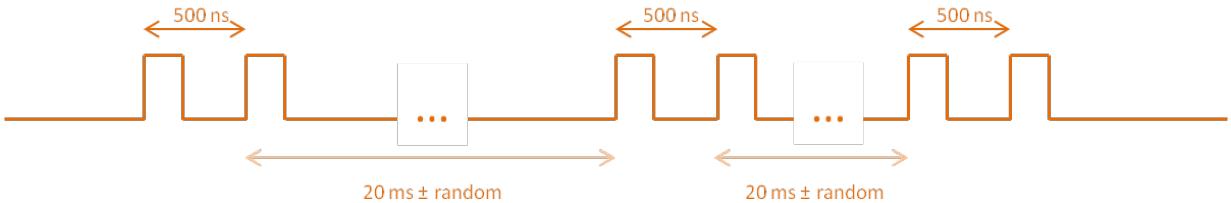

Figure 2: Pulses fed to the TDC boards

The test extended over around three days. We retrieved the timestamps of each channel and subtracted consecutive timestamps by pairs. The SVEC driver developed by Tomasz Wlostowski is used for the retrieval of the TDC timestamps.

Figure 3 shows the results from 10M data from each channel and Table 1 presents the main statistics. The average column of Table 1 illustrates the consistency of the measurements of the different boards.

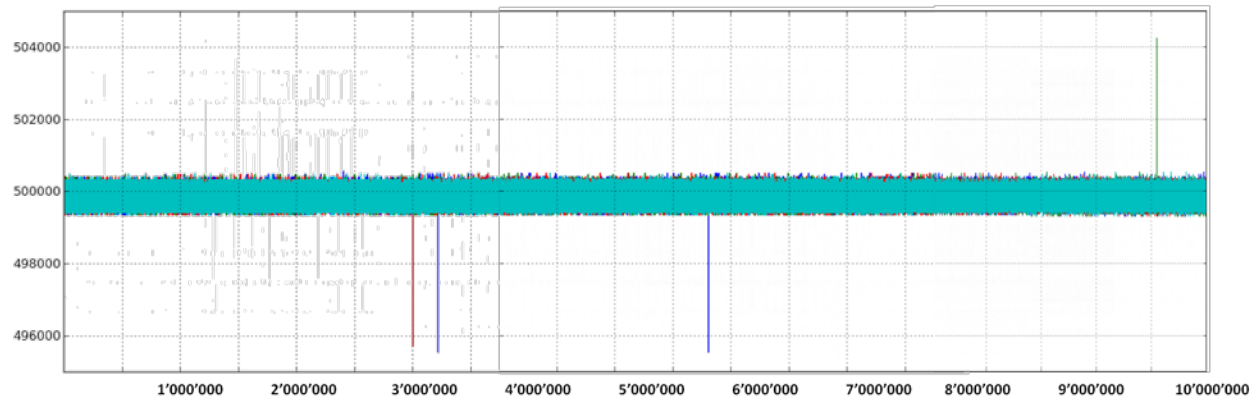

Figure 3: 10M data per channel

As expected, from previous tests, outliers of ±4ns appear. In total four outliers appear in 40 M data, which agrees with the 1 outlier/10M that has been previously observed [1].

	number of pulse pairs	average (ps)	max (ps)	min (ps)	span (ps)
TDC #1 Channel #1	10'000'000	499'956	500'576	495'552	5'024
TDC #2 Channel #2	10'000'000	499'958	504'256	499'328	4'928
TDC #3 Channel #3	10'000'000	499'952	500'512	495'712	4'800
TDC #4 Channel #1	10'000'000	499'957	500'544	499'328	1'216

Table 1: Statistics from the measurements from the four channels

Removing the four outliers gives the statistics of Table 2 and the histogram of Figure 4. The spanning of the measurements is within the ±700 ps of the TDC specifications.

	number of pulse pairs	average (ps)	max (ps)	min (ps)	span (ps)
TDC #1 Channel #1	9'999'998	499'956	500'576	499'328	1'248
TDC #2 Channel #2	9'999'999	499'958	500'544	499'328	1'216
TDC #3 Channel #3	9'999'999	499'952	500'512	499'328	1'184
TDC #4 Channel #1	10'000'000	499'957	500'544	499'328	1'216

Table 2: Statistics from the measurements from the four channels, without the ±4ns outliers

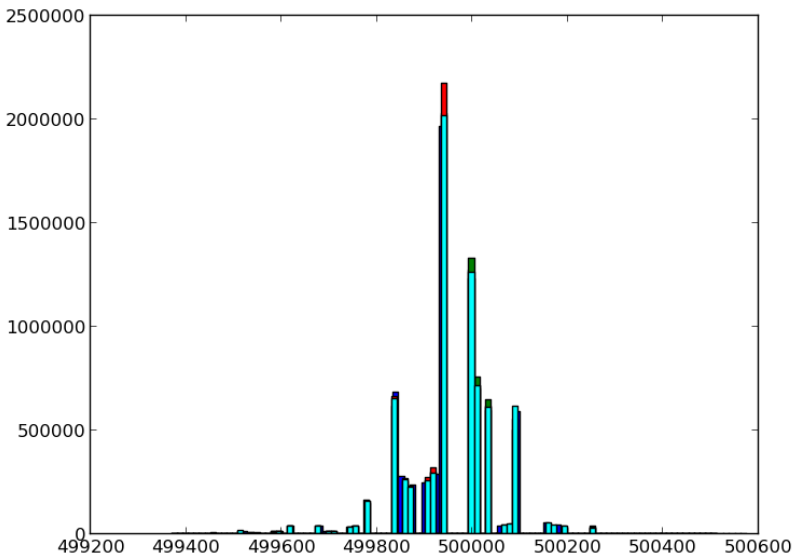

Figure 4: Histograms of the measurements from the four channels.
Note that because of computation resources issues the graph contains 6M data per channel, rather than 10M.

Test Setup 2 | Pulses of constant period

The setup is very similar to the one of Figure 1. We used the same four calibrated TDC v3 boards.

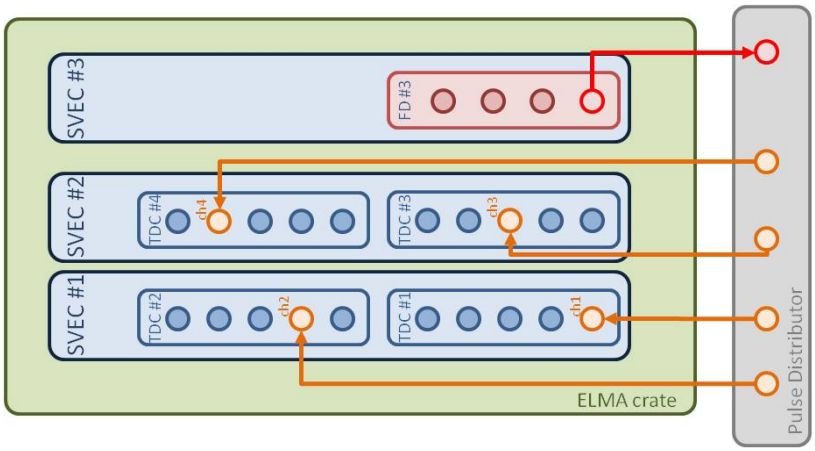

Figure 5: Test Setup 2

The pulses sent by the Fine Delay are of constant period of 20 ms.

Figure 6: Pulses fed to the TDC boards

Figure 7 shows 20M data per channel and Table 3 presents the main statistics. The test extended over around five days. The jump on all the channels after around 11M data is because the acquisition was stopped and then restarted. Note the seven ±4ns outliers throughout the 80M data that are again in accordance with previous observations [1]. The outliers in this graph appear both as +4ns and -4 ns; here we calculate the difference between consecutive pulses (rather than pulse pairs) and one wrong timestamp gives two wrong measurements.

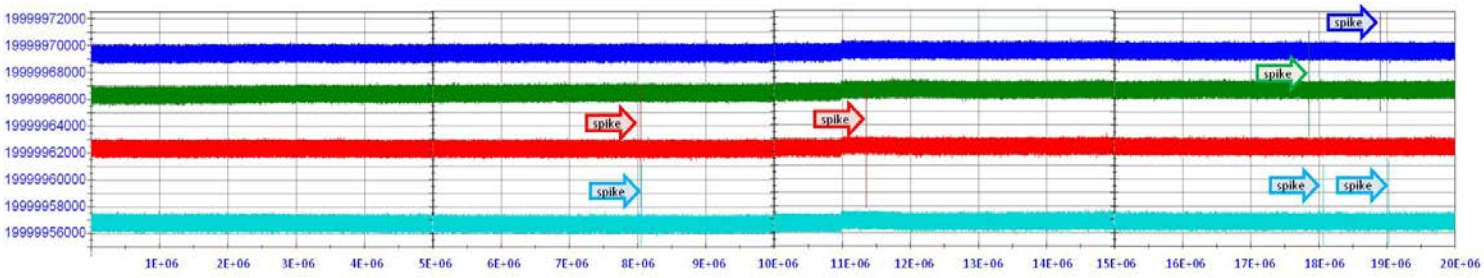

Figure 7: 20M data per channel

	number of pulse pairs	average (ps)	max (ps)	min (ps)	span (ps)
TDC #1 Channel #1	20'000'000	19'999'969'497	19'999'974'144	19'999'965'056	9'088
TDC #2 Channel #2	20'000'000	19'999'966'548	19'999'971'072	19'999'962'176	8'896
TDC #3 Channel #3	20'000'000	19'999'962'385	19'999'967'008	19'999'957'824	9'184
TDC #4 Channel #4	20'000'000	19'999'956'801	19'999'961'344	19'999'952'256	9'088

Table 3: Statistics from the measurements from the four channels

Figure 8 zooms into one of the outliers.

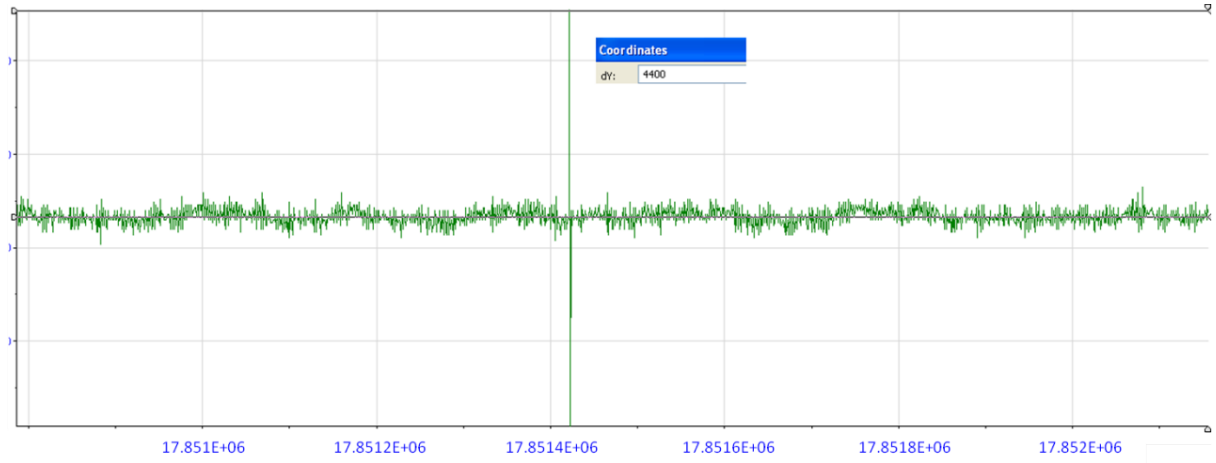

Figure 8: Zoom into an outlier on TDC #2 Channel #2 after around 17M measurements

Removing the seven outliers gives the statistics of Table 4 and the histogram of Figure 9.

Note that the measurements of each channel are consistent, but between channels the measurements have clear offsets. The maximum offset, between the average of the blue and the average of the cyan measurements of Figure 9, is 12'696 ps, which for a 20 ms measurement translates to < 1ppm. Also the maximum offset between the average of the cyan measurements and the expected value 20 ms is 43'199 ps which translate to ~2ppm. The offsets come from the fact that for a measurement of 20 ms, a board heavily depends on its local oscillator; despite the fact that the boards are calibrated, differences in temperature and on the oscillators' quality cause these offsets. Remark here that both the TDC as well as the Fine Delay oscillators contribute to the offsets.

	number of pulse pairs	average (ps)	max (ps)	min (ps)	span (ps)
TDC #1 Channel #1	19'999'998	19'999'969'497	19'999'974'144	19'999'968'608	1'824
TDC #2 Channel #2	19'999'998	19'999'966'548	19'999'967'552	199'99'965'535	2'017
TDC #3 Channel #3	19'999'996	19'999'962'385	19'999'963'296	19'999'961'472	1'824
TDC #4 Channel #4	19'999'994	19'999'956'801	19'999'957'760	19'999'955'872	1'888

Table 4: Statistics from the measurements from the four channels, without the ±4ns outliers

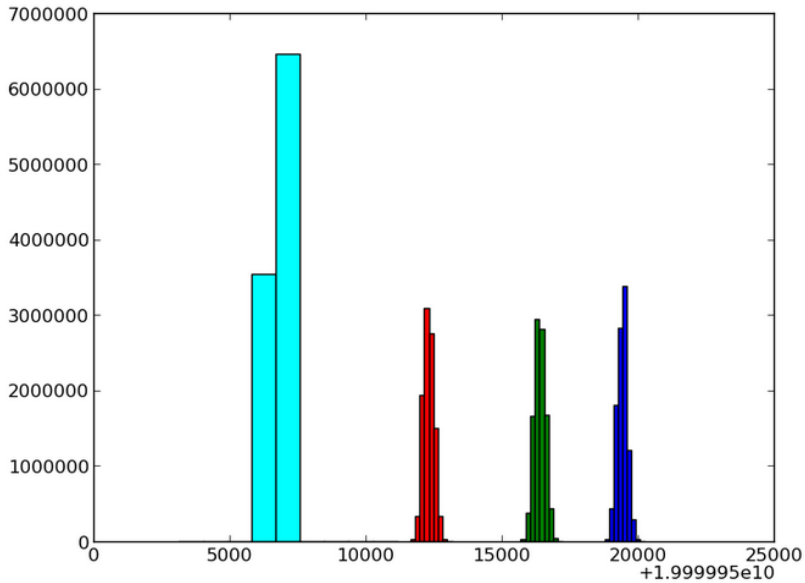

Figure 9: Histograms of the measurements from the four channels without outliers. The same number of bins has been used; cyan measurements are concentrated into fewer bins. Note that because of computation resources issues the graph contains 6M data per channel, rather than 20M.

Figure 10 focuses on the first 5M data from each channel and Figure 11 shows the corresponding rough temperature measurements from the One-Wire thermometers on the boards. The figures clarify that the dependence on the temperature is not the only parameter for the offsets (otherwise we would be expecting the red temperature graph to be at lower temperature than the green one).

Note also that the calibration of a TDC board takes place on a SPEC board at a temperature of ~50oC.

Extension of the TDC core with White Rabbit will provide sub-ns timebase accuracy and eliminate the offsets appearing on these long measurements.

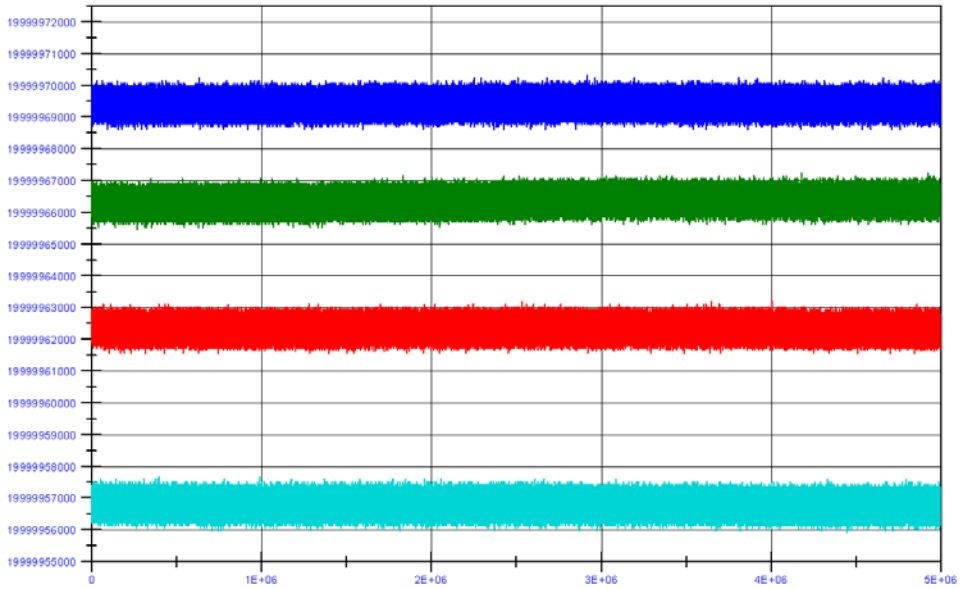

Figure 10: Focus on only 5M data per channel

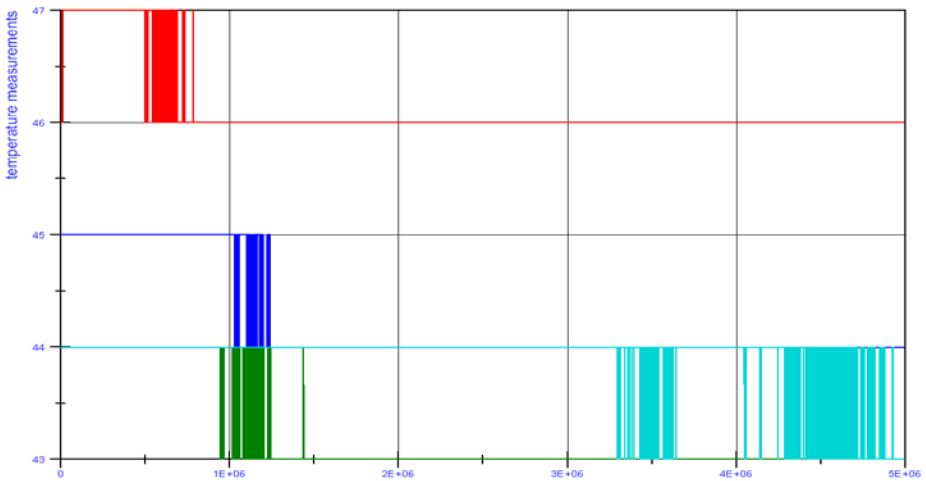

Figure 11: Rough temperature measurements from the One Wire thermometer on each board

Conclusions

- Confirmation of the ±700 ps precision of the TDC board
- Validation of the SVEC driver with multiple boards giving interrupts simultaneously
- Outliers of ±4 ns observed at the expected frequency of ~ 1 outlier/10M measurements.
- Confirmation of the TDC 4 ppm timebase accuracy; extension with WR will bring sub-ns levels

[1]: TDC mezzanine board Performance testing: ohwr.org/projects/fmc-tdc/repository/changes/board_testing/TDCperformance.pdf
[2]: Precision tests on the TDC mezzanine board: ohwr.org/projects/fmc-tdc/repository/changes/board_testing/TDCprecision.pdf