Time-to-Digital-Converter (TDC) with USB 2.0 interface

The Fourfold Quad Channel USB2.0-TDC consists of 4 independly working TDC/ FPGA units, each including the high performance of the TDC-GPX. Communication and data handling is realized via a high speed USB 2.0 interface. Optional, a programmable logic unit (PLUs) enable comfortable data preconditioning and a variable data stream handling via USB 2.0.

Fig. 1: Customer specific layout of Fourfold Quad Channel USB2.0-TDC operating in R mode with 16 stop channels on 4 HDMI connectors.

TDC basic device features

- LVTTL or PECL inputs, common start input usable as reset of the internal clock
- Internal clock quartz-accurate, resolution adjust PLL, i.e. self correcting temperature / voltage variations (no calibration necessary)
- 64 stop channels at a digital bin size of 82.2 ps, measurement range 0 ns – 9.8 µs in start-stop operation (endless measurement range by internal retriggering available)
- 16 stop channels at a digital bin size of 27.4 ps, measurement range 0 ns – 40 µs in start-stop operation
- Higher number of stop channels available on request
- Minimum time between start and stop 0 ns
- Pulse pair resolution 5.5 ns, min. 32 multi-hits per channel
- No minimum time limit for hits at different channels
- Event memory space for up to 30 million events (4 x 32 MByte memory)
- Equivalent count rates of > 280 million counts per second for bursts into the internal memory (only if events are distributed homogeneously to all stop channels)
- Permanent event streaming of 30 million bytes per second via USB 2.0 (corresponds to 7.5 million results per second when full time range dynamic is used, higher event rates possible for reduced dynamics range)
- Programmable logic unit (PLUs) available on request for a comfortable data preconditioning and a variable data stream handling via USB 2.0

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Fourfold Quad Channel USB2.0-TDC

Technical data of basic operational mode

The fourfold Quad Channel USB2.0-TDC is available in 2 different operation modes.

I-Mode
- Time bin resolution of 82.2 ps per channel ($\sigma \cong 1$ BIN)
- 64 stop channels referring to 1 start channel (8 groups of 8 stop channels possible, using 8 separated start inputs)
- Measurement range 0 ns – 10.7 µs
- Endless measurement range by internal retrigger of START
- 5.5 ns pulse-pair resolution with 32-fold multi-hit capability for each channel, 0 ns between channels
- Start-retrigger frequency (min./max.): 100 kHz/ 7 MHz
- Trigger to rising or falling edge

R-Mode
- Time bin resolution of 27.4 ps per channel ($\sigma \cong 2$ BIN for a small measurement range)
- 16 stop channels referring to 1 start channel (8 groups of 2 stop channels possible, using 8 separated start inputs)
- Measurement range 0 ns - 40 µs
- 5.5 ns pulse-pair resolution with 32-fold multi-hit capabilityfor each channel, 0 ns between channels
- Start-retrigger frequency (min./max.): 25 kHz/ 9 MHz
- Trigger to rising or falling edge

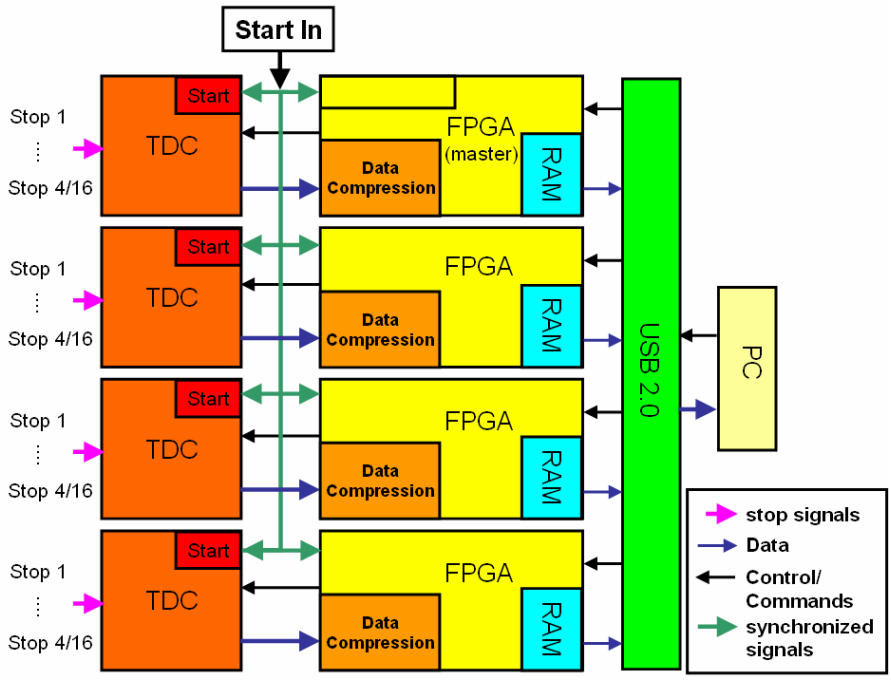

Fig. 2: Schematic Layout of Fourfold Quad Channel USB2.0-TDC with a FPGA assisted data compression.

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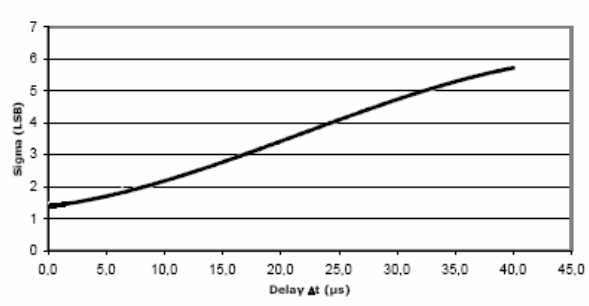


Fig. 3: R-Mode systematic walk of standard deviation: typ. 1.4*LSB + 2.8 ps * dt/µs

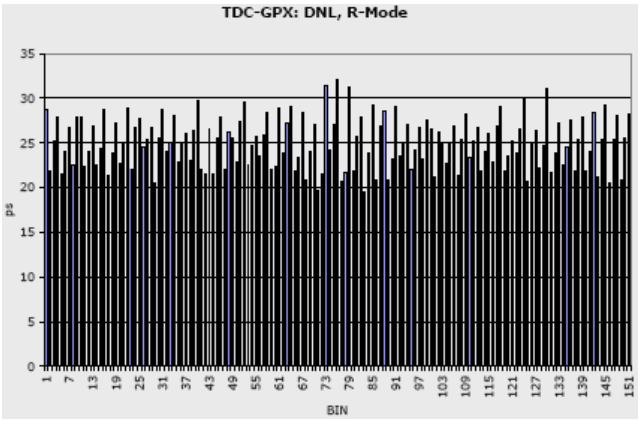


Fig. 4: typ. DNL (differential non-linearity) for R-Mode

Count Rate Limitations

Limitation by writing into internal memory

The maximum possible count rate which can be reached is limited by the writing speed into the internal memory. The Fourfold Quad Channel USB.2.0-TDC consists of 4 independent TDC units. Each TDC unit fullfills the following specifications:

- Maximum writing speed into memory: 73.6 MCPS distributable over 16/ 4 stop channels in I/ R mode
- Maximum writing speed per single stop channel: 9.2 MCPS/ 36.8 MCPS in I/ R mode

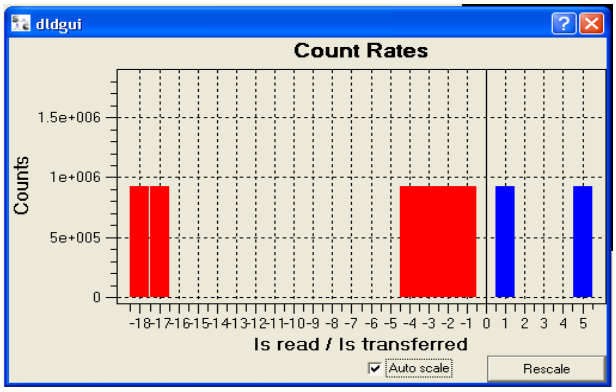
Thus, the entire Fourfold Quad Channel USB2.0-TDC with 4 TDC units enables the transfer of 294.4 million results into the internal memory space.
Typical test results at the transfer limits are shown in fig. 5, using a burst length of 50 ms.

Limitation by data transfer via USB 2.0

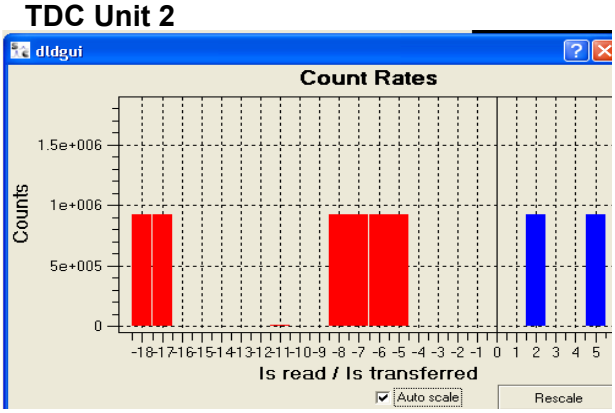
The maximum count rate for a permanent event streaming into the PC via USB2.0 is limited to 30 million bytes per second. This limit corresponds to a transfer rate of 7.5 million time results with full measurement dynamics, if data are send in raw data format without any FPGA-assisted data compression. Depending on the user application, data dynamics may be reduced or an appropriate data compression could increase the rate of streamed data.

Fourfold Quad Channel USB2.0-TDC

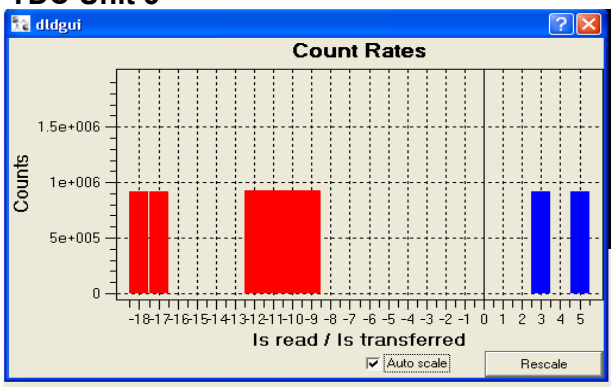
TDC Unit 1



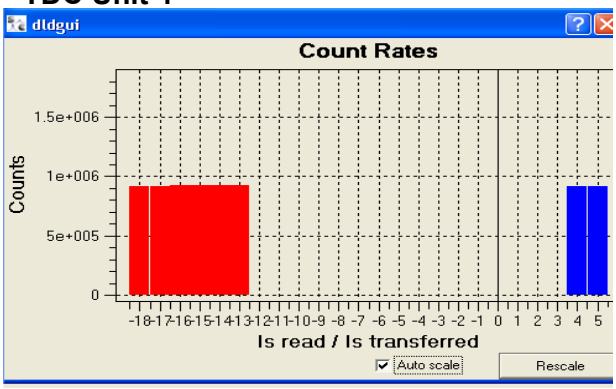
TDC Unit 2



TDC Unit 3



TDC Unit 4



	TDC Unit 1	TDC Unit 2	TDC Unit 3	TDC Unit 4
Counts per stop channel within 50 ms short burst	923.067 (coincident in all 4 channels)	921.862 (coincident in all 4 channels)	921.960 (coincident in all 4 channels)	920.214 (coincident in all 4 channels)
Equivalent Count Rate per stop channel in counts per sec.	18.461.340	18.437.240	18.439.200	18.404.280

Fig. 5: Burst rate limit measurements of all 16 stop channels of a Fourfold Quad Channel USB2.0-TDC operated in R Mode. TDC readout was made with the Surface Concept GUI Monitor Software. Bars at -17/ -18 represent the found coincidences and the blues bars represent how many coincidence results have been transferred via USB2.0 into the PC.

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