

# Time-to-Digital Converters (TDCs)

The Surface Concept Time-to-Digital Converters (TDCs) are compact time measurement systems that provide time resolutions as low as 27ps\*. These systems are available in a variety of layouts and performance characteristics. All devices are equipped with a high-speed USB 2.0 interface that enables measurement rates up to 8 million results per second\*\*.

Different operating modes enable measurement time ranges up to 44ms. Each stop channel is capable of measuring multiple stops correlated to one start signal (min. pulse pair time distance 5.5ns). Hits at different stop channels are measured without any dead time.



SC-TDC-1000/04 D combining 1 start and 4 stop channels at a time bin resolution of 27.4ps.

\*The time resolution depends on the TDC type and can even reach values below 27ps (see Burst Mode Operation for SC-TDC-1000/02 D and SC-TDC-1000/04 D).

\*\*can be increased to 80 million results per second by optional FPGA features.



SC-TDC-1000/08 S equipped with 1 start and 8 stop channels with a time bin resolution of 82.2ps.



Customized TDC type 03-06-27 (3 start and 6 stop channels at time bin resolution of 27.4ps) housed in a 2/12 unit NIM-module.

## Layouts

The Surface Concept TDCs are available as stand-alone devices (SC-TDC-1000 Series) and NIM (2/12) modules with customized design. The standard layouts are

- **SC-TDC-1000/08 S** 1 start, 8 stop channels at a time resolution of 82.2ps
- **SC-TDC-1000/16 S** 1 start, 16 stop channels at a time resolution of 82.2ps
- **SC-TDC-1000/02 D** 1 start, 2 stop channels at a time resolution of 27.4ps
- **SC-TDC-1000/04 D** 1 start, 4 stop channels at a time resolution of 27.4ps

Customized TDC combining 1 start and 4 stop channels at 27.4ps time resolution (2/12 NIM-module).



# Performance

In their basic configuration all devices can cover measurement times\* up to 10.7 $\mu$ s (for devices with 82.2ps time resolution) and 40 $\mu$ s (for devices with 27.4ps time resolution), respectively.

Longer measurement times can be covered by an optional measurement time extension that is available for all TDCs. This extension contains two additional operating modes:

- Start Counter Mode** This mode provides information on the number of starts that occurred since the start of the current measurement. Depending on the application, this mode allows for time measurements beyond the standard range (10.7 $\mu$ s/40 $\mu$ s).
- Extended Time Mode** Using this mode the user has to apply a start signal (<10MHz) to one of the stop channels that is used as time reference signal. In this way measurement times up to 44.2ms (for devices with 82.2ps time resolution) and 14.7ms (for devices with 27.4ps time resolution) are reached. An additional feature of this mode is the referencing between arbitrary channels which allows for the use of more than one channel as start.

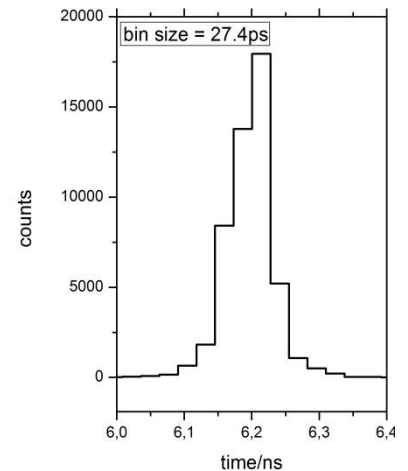
In combination with the measurement time extension layout, another device option is available for the high resolution models (SC-TDC-1000/02 D and SC-TDC-1000/04 D):

- Burst Option** In order to increase the time resolution each event is multiplied internally by means of hardware and is measured multiple times. Theoretically, the time resolution of such a measurement is improved by a factor of SQRT(N) where N is the number of multiple time measurements of the same event. The burst mode can be used in combination with all modes described earlier with the restriction of an appropriately extended dead time (Burst Pulse Option will restrict the min. pulse pair time distance of the device to about 8ns).

Customer specific layout of a fourfold quad-channel USB 2.0 TDC operating at a time resolution of 27.4ps with 16 stop channels on 4 HDMI connectors.



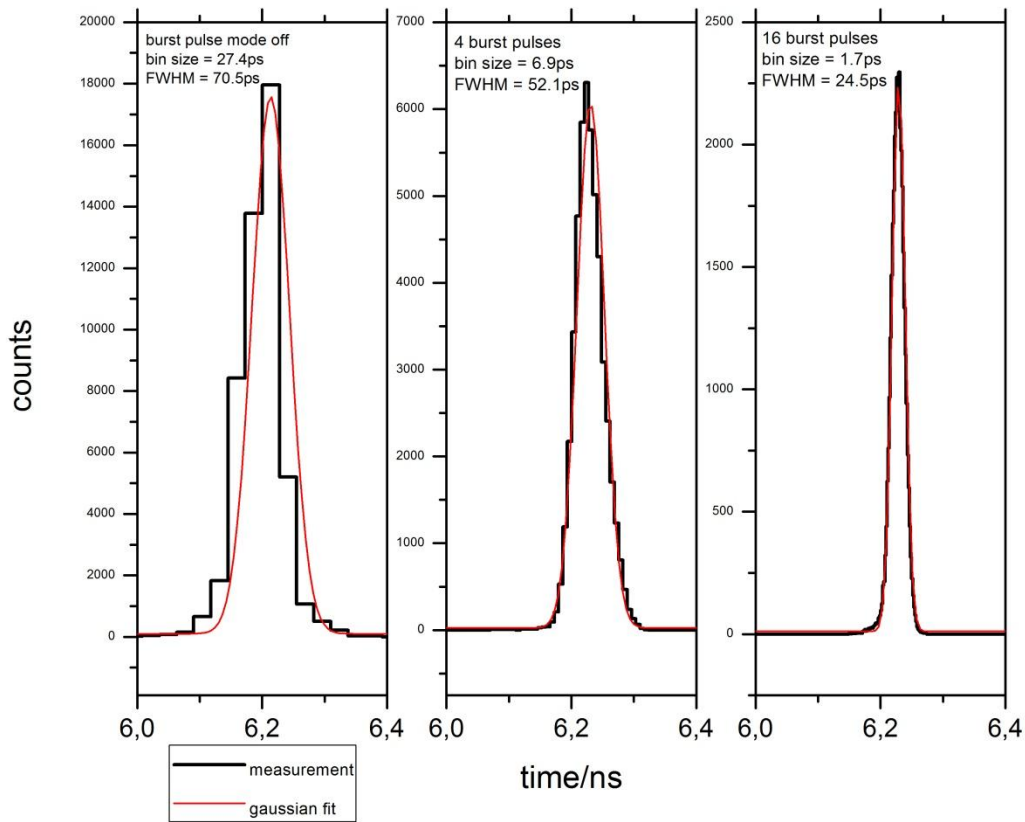
\*Within the measurement time the TDC is capable of detecting many stop signals in correlation to one start signal. Single hit applications can be covered by a customer specific layout.



Time measurement with a SC-TDC-1000/04 D at a time bin size of 27.4ps.

# Highest Precision Time Measurements

(available for SC-TDC-1000/02 D and SC-TDC-1000/04 D only)



Time measurement using a SC-TDC-1000/04 D in burst mode. Without multiple measurement of the same event (left) the standard time bin size of 27.4ps and a time resolution (FWHM) of 70.5ps is obtained. Using multiple measurements of the same event in burst mode enables an improved time resolution of FWHM=52.1ps (for 4 burst pulses, center) and 24.5ps (for 16 burst pulses, right). Further, for increased burst pulse number the time bin size is reduced by „27.4ps/burst pulse number“. If necessary the time bin size can be readjusted by means of software.

Demonstration of a reduced time bin size in burst mode using 16 burst pulses (right) and readjusted time bin size for the same measurement (left). A reduced time bin size enables highest precision in applications using fitting algorithms due to the increased number of data points.

