Berlin, 9th April 2024

BH-QC 008

8 Channel Event Counter with Software Correlation Options

USER GUIDE

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Thank you…

… for choosing a quality product from Becker&Hickl. This guide will lead you through the installation process of the BH-QC008 application and some simple operating commands to get even more out of your hardware.

Use QC008 if you…

… have purchased a B&H SPC-QC-008 event recording card and want to control its hardware parameters, perform time measurements and do correlation or MCS analysis on the acquired data and display it to your PC's screen.

Recorded events can be electric impulses created by a wide range of devices like photomultipliers or pulse generators. The maximum time resolution of events lies below 1 ps.

Each of the 8 input channels can be configured to be analyzed in correlation to any of the other input channels or to be displayed in a binned timeline MCS trace.

The software offers three standard analysis options:

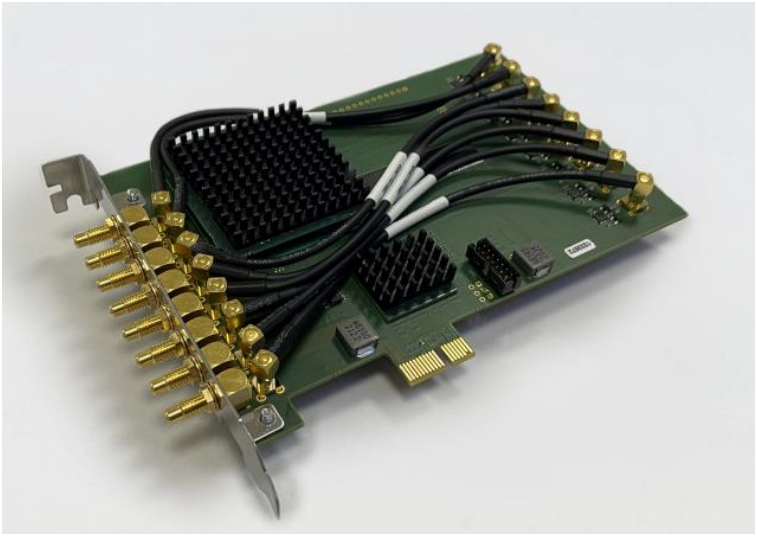
1. **Delta T** displays the accumulated time differences between two successive events in different channels.
   - typical scenario: Lifetime decay curves with photon events vs laser sync pulses
2. **MCS** displays the accumulated events of one channel over time.
   -typical scenario: Observe fluorescence molecules passing the detection area in bursts
3. **Correlation** displays the accumulated time differences between one event and all other events in a certain correlation time.
   - typical scenario: i) Fluorescence Correlation Spectroscopy in auto- or cross-correlation
     ii) Bunching / Antibunching experiments

Pre-Requisites

A PC running Windows 10 or newer, 32 GB RAM, 10 Core.

An installed Becker&Hickl SPC-QC-008 event recording card.

1 to 8 connected SMC cables connected to electric event producing signal sources.

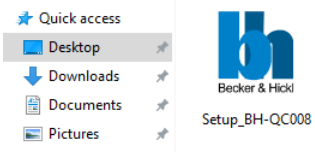


Software Installation

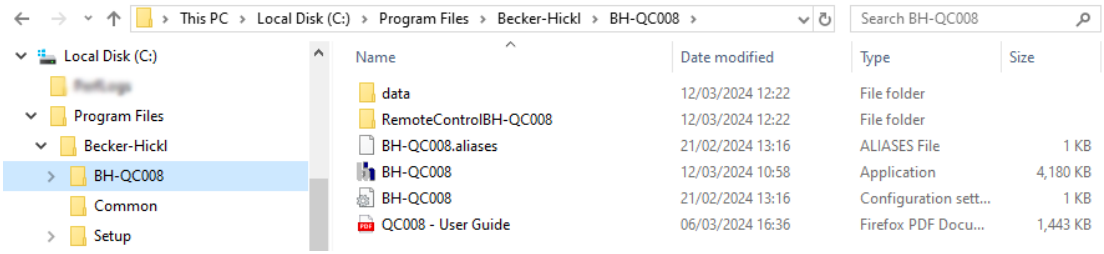
The BH-QC008 application installer comes with your SPC-QC-008 card or can be downloaded from www.becker-hickl.com.

Run Installer

- Execute the Setup_BH-QC008.exe to run the installer.

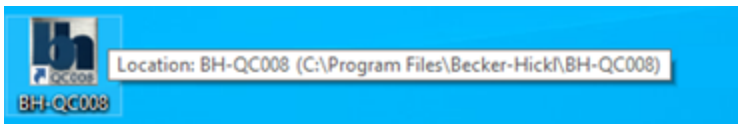


- The default installation path is C:\Program Files\Becker-Hickl\BH-QC008.

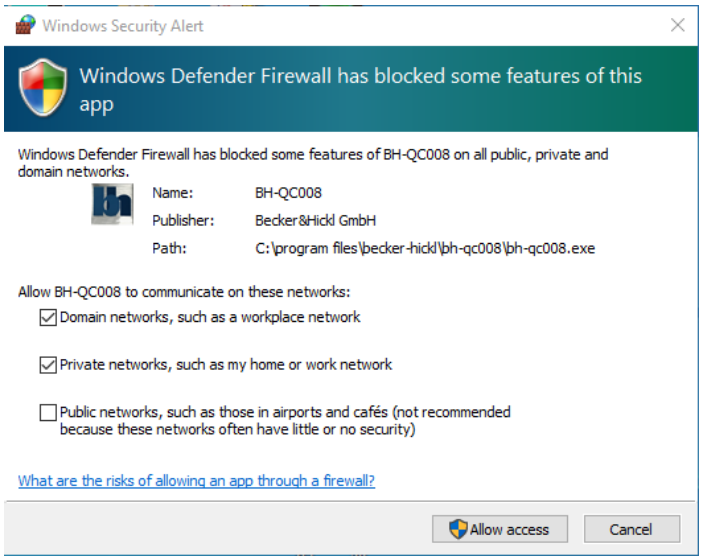


The required **LabView Runtime Engine 2017 SP1** is also installed. The runtime can be used to operate software written with LabVIEW without needing a LabVIEW license. It can also be downloaded from www.ni.com.
The default destination is C:\Program Files\National Instruments\

- The BH-QC008 software shortcut is now available on your desktop. Another link can be found in the start menu.



- Upon the first start Windows will ask you to allow BH-QC008.exe to access your network. This is not necessary for the operation of the app or its communication with SPC-QC-008 card, but important if you plan to remotly control the app through a self-written script in the future.
Leave the "Public networks"-option unchecked.

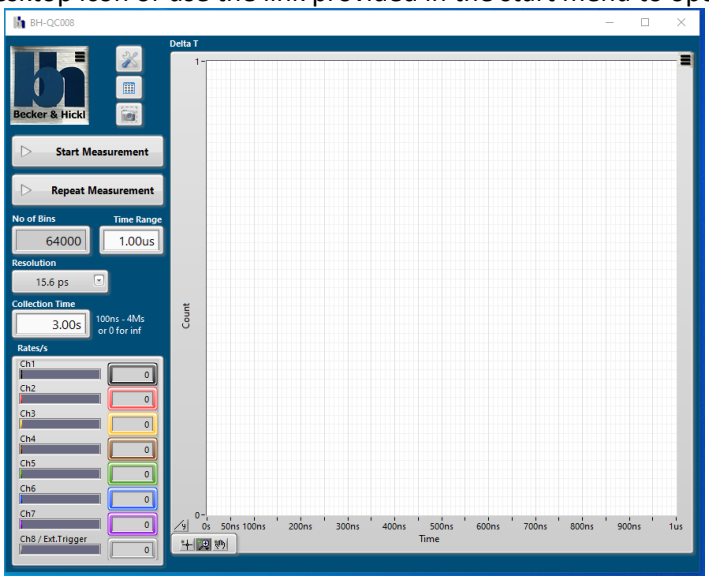


Using the BH-QC008 Application

BH-QC008.exe allows you to configure the B&H SPC-QC-008 event recording card, initiate a measurement and analyse the collected data in three different styles. The raw event data can be exported to file as well as the processed data in the graphs, allowing you to read a previous measurement back into the application or to do a post-analysis in your personal software.
The application's window is resizable in a Windows standard fashion and can be configured to display a desired amount of information at the same time.
BH-QC008 was developed to handle a high amount of data in high resolution making use of at least 32 GB of RAM and using up to 16 logical processors in parallel. Nevertheless, disabling unused features of the analysis can speed up processing time significantly. In other words: Turn off what you don't need.

Starting BH-QC008

Double-click the desktop icon or use the link provided in the start menu to open the application.



First appearance of the BH-QC008 application

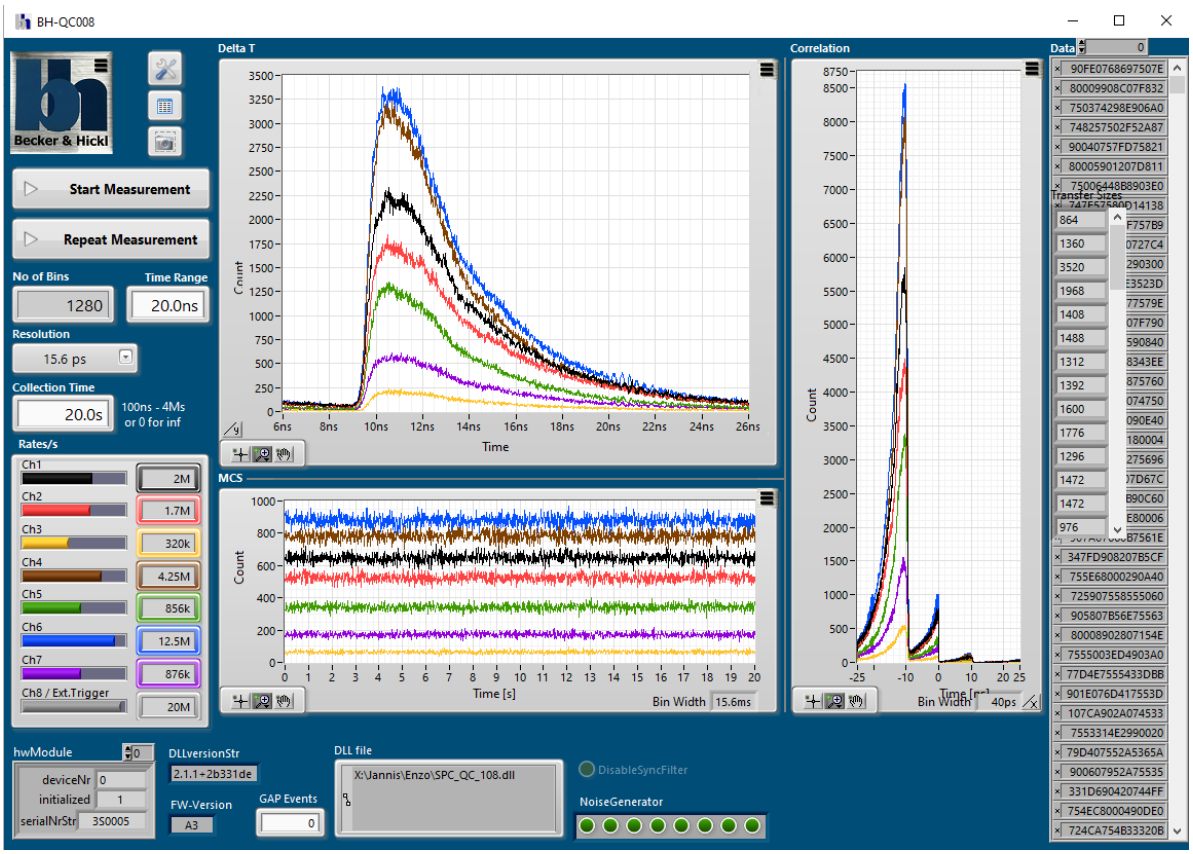
The BH-QC008 window first starts in the default configuration, but will remember all configuration changes (including window size and position) when you close the application and start with its last configuration when opened again.

GUI Components

Positioned in the top left corner is the B&H company logo acting as **main menu** button.
To the right of it you'll find two buttons to open panels with **card settings** or basic **analysis**, and a **screen print** button. Below that the single **Start Measurement** button and the **Repeat Measurement** button. Followed by the **measurement timing** settings.
The **Rates** display shows the currently detected events averaged per second. The colouring of the channels matches the plot colours in all graphs.
Initially only the **Delta T** graph is visible. The graphs for the **MCS** and **Correlation** analysis can be added through the main menu.
All three graphs possess a **private menu** button in their top right corner. There you can configure the correlation of the channels or other private settings related to the measurement mode.
In the lower left corner of the graphs are three **tool buttons** to zoom and scroll the plots in the graphs.
The axis range can also be adjusted by modifying the minimum or maximum tick-labels respectively. The y-axis will automatically be adjusted to new data range when performing a measurement – unless you right-click on the scale and un-check AutoScale.

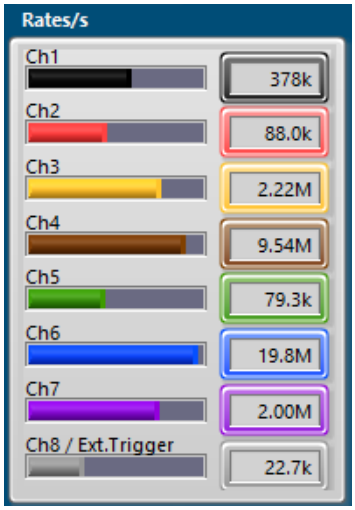
The Delta T graph possesses a button to change the Y-axis to **logarithmic scale** and back.
The Correlation graph possesses a button to change the X-axis to **logarithmic scale** and back.
In multi-graph view, the size of the graphs can be adjusted by dragging the splitter bars between them.

In the main menu you will find an item named **Show Debug Info**. By selecting it the application window size increases and makes space for more information about the internal workings.
Use this information to track errors or provide hardware information to Becker&Hickl when requesting support.
The **Data** column on the right shows the raw data as received from the SPC-QC-008 card prior to processing through the BH-QC008 application. The raw data is not easily interpreted by the human eye, unless you live in the Matrix.
Transfer Sizes shows the number of events received from the card per DMA transfer.
hwModules, **DLLversionStr** and **FW-Version** refer to the SPC-QC-008 card. **DLL file** shows the path to the dynamic link library used to communicate with the card.
For test purposes you can use the **Pulse Generator** to create an internal signal on each channel with ca. 1.72 M events per second.
In Delta T mode, when using one particular channel as reference for all other active channels, events on that reference channel that are not followed by an event on another channel are filtered to increase bandwidth over the PCIexpress slot. Use **Disable Sync Filter** when you are interested in all reference events received in this case.
GAP Events should always be zero unless the event rate becomes so high, that the data transfer over the PCIexpress slot cannot keep up.

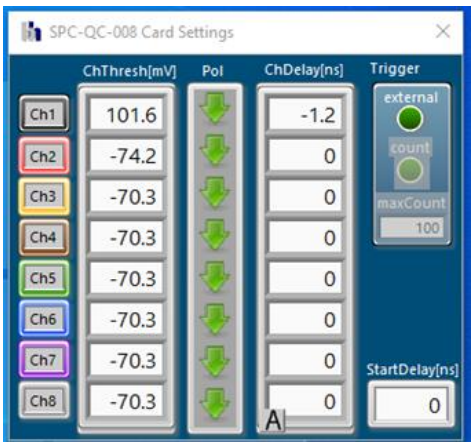


BH-QC008 application with maximum information depth

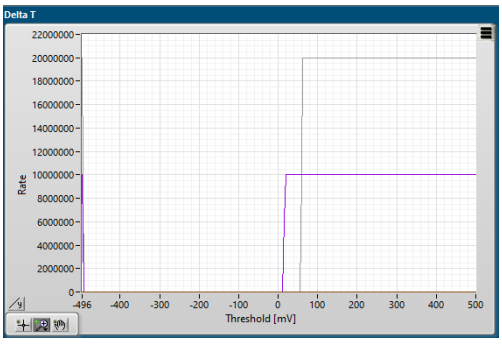
Setting Up a Measurement



Start all event sources and make sure that you see the expected event rate in the Rates display. This display samples all channels every second and is continuously updated regardless of a running measurement.
Rates can vary due to signal polarization and threshold level of the inputs.
Use the card settings window to adjust those parameters for each channel individually. Click on the button to bring up the card settings window.



The **ChThresh** can be adjusted in the range of -500 mV to +500 mV.
Note that the values are adjusted to the next granularity step of the DAC.
If you cannot decide on a channel threshold you could use the wizard provided by the BH-QC008 application. Click the main menu tag **Scan Threshold** and the application will scan through all possible threshold values between -500 mV and +500 mV and display the corresponding rates in the **Threshold Scan** window. This should allow you to choose the best threshold value for the channels.



Hint: You can stop a running threshold scan by clicking the item **Scan Threshold** in the main menu again.

Choose the measurement mode in the main menu. Select **Delta T**, **MCS** or **Correlation** or any combination of those.

In **Delta T** mode click on the private menu button to bring up the Delta T graph settings window. Here you can click on the coloured number boxes on the right to select which channel should be used as a reference (usually a sync signal) for each channel. You can also choose to disable any channel to reduce bandwidth and increase performance.

Using the channel itself as a reference will analyse the time difference between two successive events on that channel.
The sync channel itself should be disabled, unless you are especially interested in the timing of each event there. If all not disabled channels are referenced to the same (sync-) channel the application will automatically reduce bandwidth be filtering sync events that are not directly followed by an event in another channel.
Note: Should the sync channel appear in any of the other graphs, filtering is disabled.

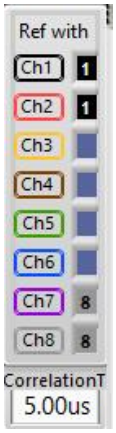
The time axis of the Delta T graph ranges from 0 s to the selected **Time Range** maximum.

In **MCS** mode click on the private menu button to bring up the MCS graph settings window.

Here you can click on the green buttons to dis- or enable single channels in the graph.
Note: Should you enable the channel that has been chosen as sync for the Delta T mode, sync filtering is disabled and all sync events will be registered.

The time axis of the MCS graph ranges from 0 s to the selected **Collection Time** maximum.

In **Correlation** mode click on the private menu button to bring up the Correlation graph settings window. You can choose a reference for each channel, similar to the Delta T settings. Additionally you choose a **Correlation Time** for FCS or Bunching / Antibunching measurements.
Selecting for a channel the same channel as reference will procduce an auto-correlation, a different channel procduces a cross-correlation.



The ranges of the time axis of the Correlation graph is set symmetrically around 0 s to minus half the selected **Correlation Time**. If desired, use the **Start Delay** in the card settings window to shift the time axis to start with zero.

Set the **Collection Time** to a desired value between 100 ns and 4 Ms (roughly 46 days). You could also set the Collection Time to zero causing an infinite measurement that you could stop manually by pressing the **Stop Measurement** button. When choosing a Collection Time of 2 s or longer a dial will appear informing you about the time in seconds that have already past.
In Delta T mode set the **Resolution** to a desired value between 0.976 ps and 64 ns. This will determine the time width of the bins used to accumulate events.
In Delta T mode you can set either **Time Range** or **No of Bins**. Both values are connected via the Resolution value. In both other modes only No of Bins is available since the **Resolution** is not applicable – instead the **Collection Time** (MCS mode) or **Correlation Time** (Correlation mode) determine the bin width (and therefore the resolution).
Note: You will receive a warning when choosing more the 10 million bins. You can still continue on the risk of an application shut down.

Clear the message by clicking on the **Messages** text.

Now you are ready to press the **Start Measurement** button. A measurement will continue until the selected Collection Time has passed, or you press manually the **Stop Measurement** button.

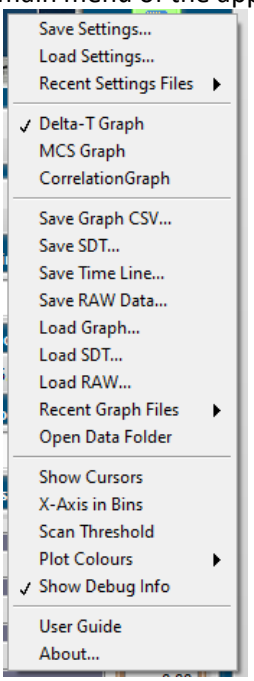
Note: You might perceive some delay before the application becomes responsive after stopping a measurement. This can happen when there is still data in memory that needs to be processed.

Alternatively, you could press the **Repeat Measurement** button that will run a measurement for the selected Collection Time and after data processing start a new measurement immediately. This feature is handy when using short collection times and adjustments on the measurement probe might still be necessary.
Stop a repeating measurement by either clicking on Repeat Measurement again or on Stop Measurement.

Use the **Screen Print** button to conveniently archive your measurement to a PNG-file.
Use the main menu item **Save Graph CSV** to save the data from the graphs to a comma separated value file.

The BH-QC008 Main Menu

Clicking on the B&H company logo in the top-left corner will bring up the main menu of the application.



The About Box

By selecting **About** you can open the about box window.

The Becker&Hickl company logo and the copyright information is displayed, alongside with contact details, the version and build date of the application and the open VI Server port for remote controlling the application from other customer apps.
Dismiss this window by clicking into it.

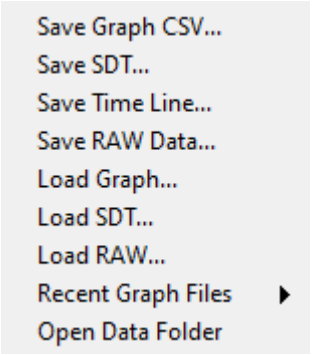
User Guide

Selecting **User Guide** will bring up this document.

Handling Data

The Becker&Hickl SPC-QC-008 event recording card uses a highly compressed event data format to achieve its performance of high count rates and high resolution. This means that sometimes the analysis of the raw data might be quite time consuming. To avoid having to do this for the same data over again the BH-QC008 application offers several export and re-import functions of the raw data as well as of the processed data.

Export Options



The main menu (accessible by clicking on the B&H company logo) offers options to save the processed data as comma separated value files (CSV) or in the B&H standard data container file (SDT).

Use **Save Graph CSV** if you want to further process the data plotted in graphs, e.g. do custom fits.

Use **Save SDT** to create files readable by application like B&H's SPCImage to do elaborate decay curve analysis.

Note: The **No of Bins** needs to be 2 exponential in order to be able to write to a SDT-file. Right click on No of Bins to **Adjust for SDT-format**, rounding to a nearest value of 2, 4, 8, 16, 32, 64, 128, 512, 1024, 2048, 4096, 8192, 16384.

The complete event data can be saved to time line files in CSV format or in compressed raw format as BIN-files.

Use **Save Time Line** if you need information about each recorded event and want to further process them in applications capable of reading ASCII-format.

Use **Save RAW Data** if you want to save information about each recorded event so you can read them back into BH-QC008 at a later time and do new analysis under different conditions, e.g. different reference channels or delays.

Note: Save Graph CSV, Save Time Line and Save RAW Data are automatically saving an additional settings file in CFG format. They are needed when importing the data back into BH-QC008.

Note: Save Graph CSV and Save SDT are storing processed data, meaning absolute timing information of single events are not retrievable from these formats.

Note: The menu items Save Time Line and Save RAW Data are simply arming the saving process for the following measurement – indicated by a check mark next to the menu item. You have to manually start a new measurement and will be asked for a filename after completion. This saves Memory space when saving is not needed.

You can disarm saving time lines or raw data by selecting the corresponding menu items again.

The Analysis window possesses a **Save Analysis Data** button. This exports a CSV-file with the data in that window.

The CSV format is an ASCII coded comma separated value format. You can open and read those files in any text editor, but note, that German based Excel versions get confused with the comma as separator.

Import Options

Processed graph and SDT data as well as SPC-QC008 raw data can be read back from file.

Load Graph will read previously saved graph data back into the application. To succesfully set the time axis a matching CFG-file at the same location is needed.

Load SDT will read a previously saved decay curve back into the Delta T graph. All measurement parameters are loaded from the SDT-file itself.

For Graph or SDT data only the view scope of the data can be modified. A re-analysis is not possible.

Load RAW will read a previously saved measurement fully back into the application. To succesfully set the time axis a matching CFG-file at the same location is needed. Once raw data is loaded into the application measurement parameters can be changed and a new analysis is performed.

Convenience Options

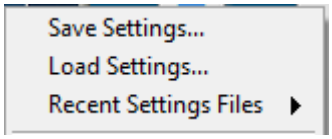
The main menu offers a memory of the last 10 used data files. Use **Recent Graph Files** to quickly manoeuvre through your file history.
Open Data Folder will open the location of the last handled data file in your standard file browser.

Creating a Screen Print

Use the **Screen Print** button to conveniently archive your measurement to a PNG- file.

Measurement Settings

While the data export options **Save Graph CSV**, **Save Time Line** and **Save RAW** Data automatically create a settings file (the SDT-format includes the setting in the file itself), you might want to save the current measurment parameters so you can quickly return to those parameters at a later stage for new measurements.

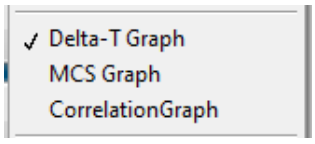


Use the **Save Settings** item in the main menu to save all current parameters to a CFG-file in ASCII format. If desired you can edit this file in Notepad or similar app without harm. The default location for settings files is *C:\Users\<username>\AppData\Local\BH* but you can choose any location on your file system.
Use the main menu item **Load Settings** to read a previously saved CFG parameter file back into the application. This could be a manually saved file, the BH-QC008.cfg auto-save file or any CFG-file saved as pair when saving measurement data.
The menu item **Recent Settings Files** gives you quick access to load any of the last 10 used settings files.
Any time a parameter is changed the BH-QC008 application updates a settings file named BH-QC008.cfg so that at a restart of the application you can continue with the last used parameters.
The menu item **Auto Saved Settings** under **Recent Settings Files** will load this setting file. This comes in handy when a previous measurement data file loaded back in has changed your setting parameters.
Note: in the unlikely event of a corrupted settings file it is save to completely delete the *C:\Users\<username>\AppData\Local\BH\BH-QC008.cfg* file. All measurement parameters will be returned to their default values and you will have to set them again to your requirement.

Display Settings

The BH-QC008 application offers several options to customize its front end to give you the best possible feedback of your measurement. Take some time and choose the settings that will display just the right amount of information you need.

The Measurement Graphs

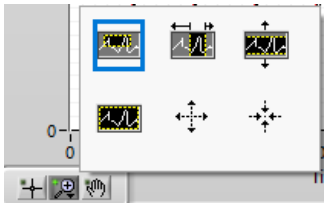


In the main menu (accessible by clicking on the B&H company logo) you can choose your measurement mode. A single selection is possible or any combination of two or three modes. Every mode has its own graph that will open when selected.
Should you have more than one graph selected they will appear next to each other with grey splitter bars between them.

When you come close to the splitter bars the mouse pointer is changing and you can click and drag the bars, causing a resize of the graphs next to it.

The Delta T graph possesses a button to change the Y-Axis to **logarithmic scale** and back.
The Correlation Graph possesses a button to change the X-Axis to **logarithmic scale** and back.

Zoom and Pan Tools

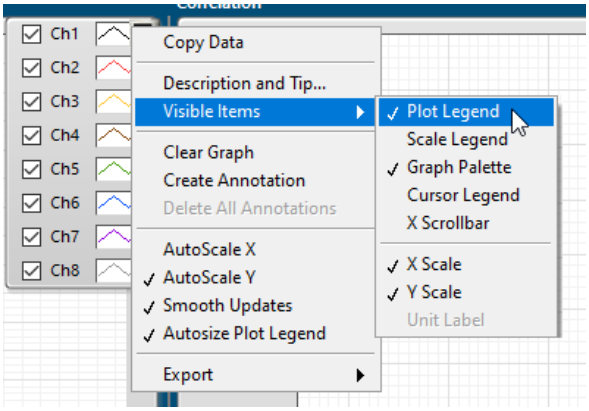


The magnifying glass button in the lower left corner of the graph brings up the zoom tools. Use the top 3 tools for zooming in on a range, only x-axis or only y-axis. Clicking the bottom left tool zooms fully out. Stepwise zoom in or out with the arrow tools.
The hand tool allows panning of the graph.

Autoscale

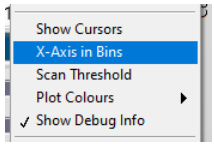
By right-clicking on any scale you can toggle between autoscale and static scale. The default is autoscale, but you might want to switch to static when trying to observe signal changes in **Repeat Measurement** mode.

The Plot Legend



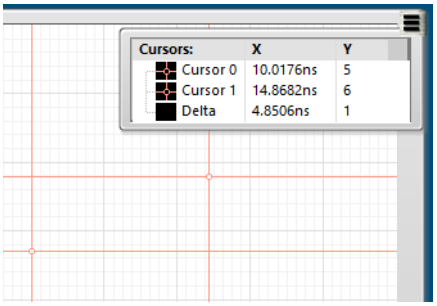
Right-clicking in a graph will bring up a context menu where you can select **Plot Legend** in the **Visible Items** section. This brings up the plot legend where you can change settings like plot visibility, plot colour or line- or point-style.
Note: Changes to these settings are temporary and are not stored in the settings file. An application restart will set the default values again.

X-Axis in Bins



By selecting the **X-Axis in Bins** menu item, the x-axis of all graphs will change from time scale to bin number.
Use this option if you want to get information about the actual data resolution of your measurement.

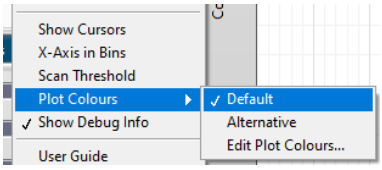
Show Cursors



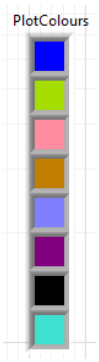
The application offers the option to display two crosshair cursors in each graph. Selecting **Show Cursors** in the main menu will bring up the pink cursors with a small circle at their hotspots. Their positions are listed in the cursor legend. The cursors distance is listed as **Delta**.
Use the graph tool to move the cursors around. The listed position will be updated in real time. When releasing the cursor it will attempt to snap to the closest plot and the listed Delta will be updated.

The cursor legend X values are displayed in time units or bin units according to the setting of **X-Axis in Bins**.
Dismiss the cursors and legend by selecting **Hide Cursors** in the main menu.

Plot Colours

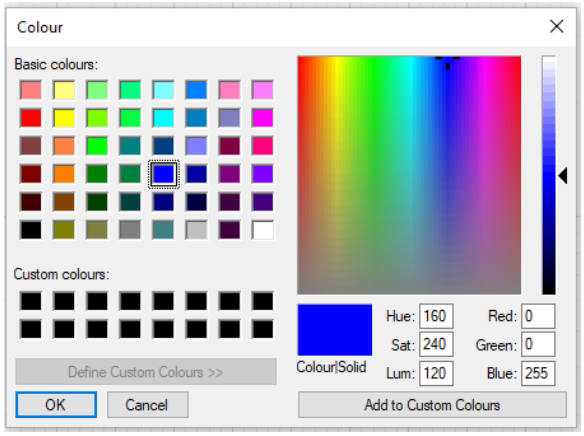


Sometimes it might be difficult to distinguish between plots when their colours don't show a sufficient contrast. To help in these conditions BH-QC008 offers the option to choose between the default colours set, an alternative colour set and one custom editable colour set. Between the **Default** and **Alternative** colour set you can switch by simply selecting the corresponding menu tag. When selecting **Edit Plot Colours** a colour array appears allowing you to change the colour of any plot by clicking into it an choose your colour in the colour select box. You can even refine your choice by clicking the button to bring up the full colour box.



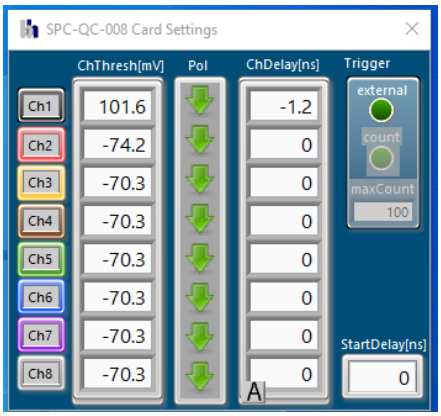
After choosing a colour set all plots and corresponding menus will reflect the changes. The selected colour set will be saved in the auto saved settings and, in the settings file created when saving measurement data.

Note, that the custom colour set can't be saved separately. Use **Save Settings** to be able to return to a created custom colour set



The SPC-QC-008 Card Settings

Use the card settings window to adjust card parameters for each channel individually.
Click on the button to bring up the card settings window.

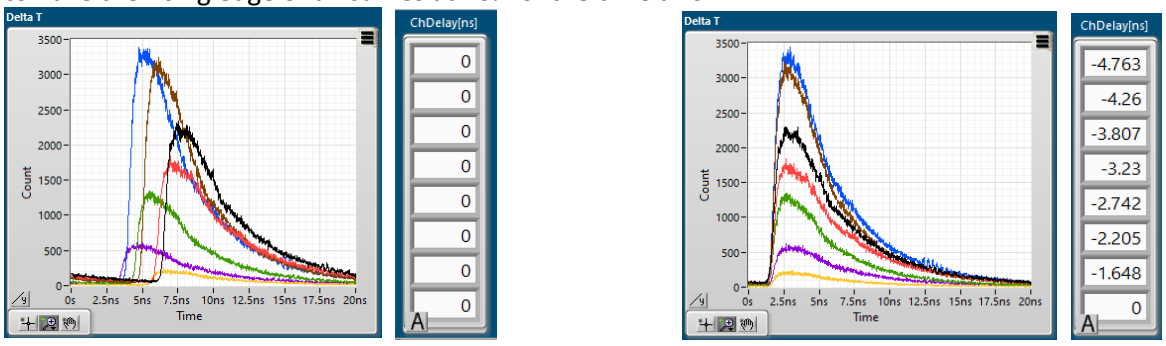


Each of the 8 input channels has an individual comparator circuit. Only level changes that cross the adjustable threshold are considered valid events and recorded.
The **ChThreshold** can be adjusted to values between -500 mV and +500 mV. You must manually set the threshold level to an appropriate value, but you can use the Scan Threshold wizard for support.
Note that the values are adjusted to the next granularity step of the DAC.

The inputs can detect a rising or falling edge in the electric signal. Use the **Pol**arity setting to fit your setup. Registering the wrong edge of a pulse can change the timing result.

A given measurement setup might induce unwanted timing offsets between channels; typically, through different cable lengths. If you are sure, that certain events should occur at the same time (e.g. after a sync pulse), but the plots show them at different locations you could adjust one channel delay by adjusting the input cable length. Or use the **ChDelay** setting and correct the delay mathematically.

BH-QC008 offers a wizard to automatically move the rising edges of decay curves to the same position in the Delta T graph. When clicking the **auto adjust** button all ChDelays are calculated to have the rising edge of all curves at 10% of the time axis.



Using the ChDelays to adjust the position of the plots

Right clicking on any field in the **ChThresh**, **Pol** or **ChDelay** list offers the "**same all**" option to use this value for all other channels.

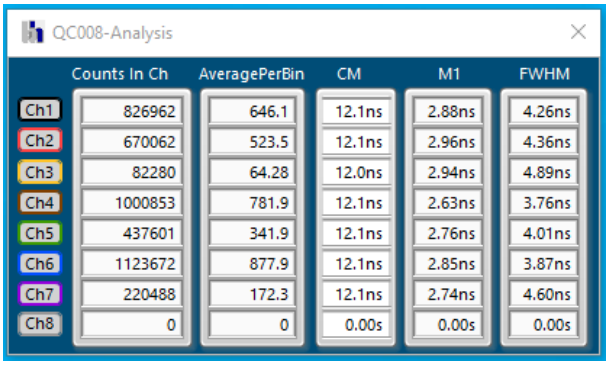
It is possible to enter a value for **Start Delay**. This will shift the visible time window. Use this, when you expect signal far away from zero, but do not want to compromise on the actual resolution. All plots will be shifted by the same amount.

It is possible to have the SPC-QC-008 card waiting for a measurement trigger on channel 8. Press the **external Trigger** button to have it turn bright green. After arming a measurement by pressing Start Measurement the card will start acquisition with the first detected edge on channel 8. Should there be no signal on channel 8 within 5 seconds a timeout will occur.

A measurement that has started because of an external trigger can be automatically stopped after a set number of events on channel 8. Press the **count** button to have it turn bright green and set the value of **max Count**.

The Analysis Window

Use the button to bring up the Analysis Window. Currently the displayed values refer mostly to the Delta T graph. Further analytics catering the MCS and Correlation graphs is in planning, e.g. FCS fit.



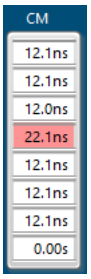
Here the analysis of all 8 card channels are displayed in parallel. The colours of the labels are identical to the plots colour in the graphs. Customization is not possible.

Counts in Ch is the total number of events collected in each channel.

Note: Is one particular channel used as sync for all other channels and not selected in any graph to be displayed, its **Counts in Ch** will be indicated as zero. This is forced because the actual rate is filtered by the SPC-QC-008 card to only transfer sync events that are actually followed by events on other channels to reduce data volume.

Average Per Bin is the Counts in Ch divided by the currently selected number of bins. Use the information to get a quick overview about the distribution of your signal.

CM stands for centre-of-mass. All events collected during a measurement are weighted with their occurrence and divided by the number of events. This is an indicator of where a signal peak might be found.



Sometimes this might be outside the scope of the selected **Time Range**. In that case, the corresponding field will be coloured red. To get the signal into view you could either increase the **Time Range** to beyond the **CM** position, but this might increase the **No of Bins** above the capacity of the PC; which in turn you could compensate by decreasing the **Resolution**. Alternatively, you could use **Channel Delay** and/or **Start Delay** to bring the signal into view, which has the advantage of keeping the Resolution at the desired value.

A wizard is available by right clicking a red coloured field. The options are **Extend Time Range**, **Shift Time Range** and **Adjust ChDelay**.

M1 stands for First Moment. The underlying algorithm can give you a first estimate on the tau value of a decay curve. The scope of the algorithm is just the selected **Time Range**.

FWHM stands for Full-Width-Half-Maximum and is relevant only if a clear peak is visible in the signal.

Closing the BH-QC008 Application

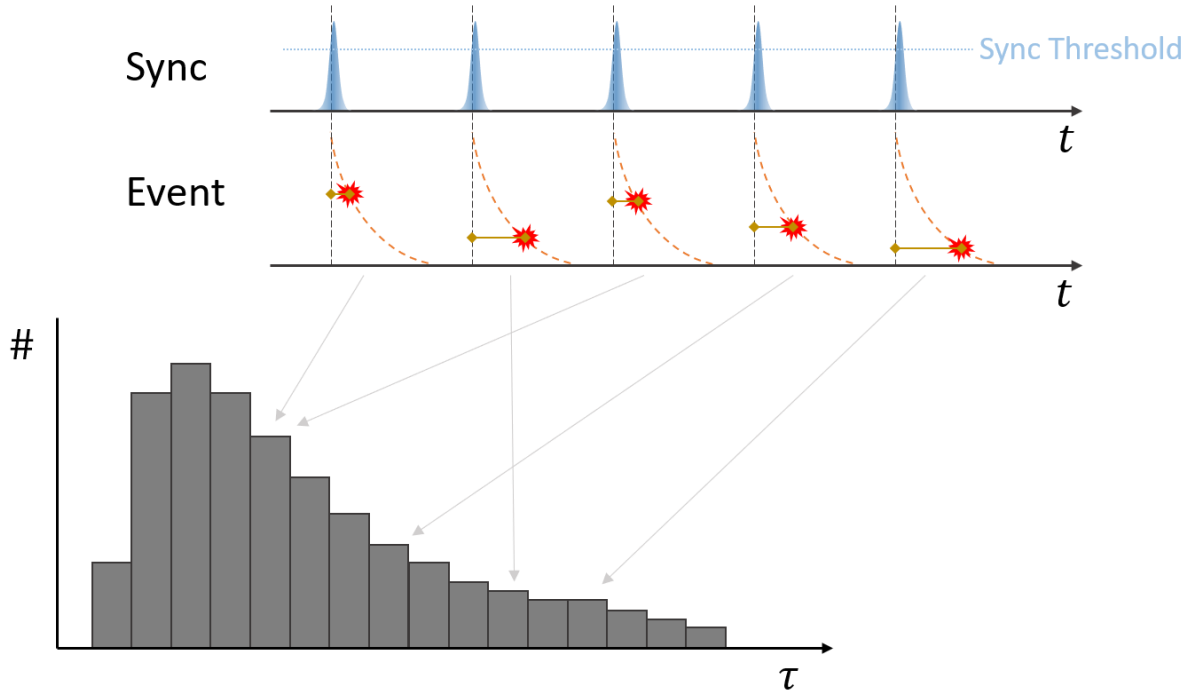
You can terminate the BH-QC008 application, as you are used to from any other Windows application, by clicking on the red X in the top right corner. The current settings will be stored to disk and reloaded when you start BH-QC008 again.

The Measurement Modes

Currently BH-QC008 offers three main measurement modes, all with their private graph panels. Since the Becker&Hickl SP-QC-008 is a pure event recording card, all data analysis is performed in the Windows-PC. With 8 channels and the knowledge of the precise timing of each event a multitude of relations can be observed, created or filtered. We are certain, that you can come up with even more possibilities of what to do with your data, nevertheless here are three ways already implemented that might get you started on your job.
While more than two channels referencing is technically possible, it is currently not available.

Use the main menu to choose which mode graph to display.

Delta T mode

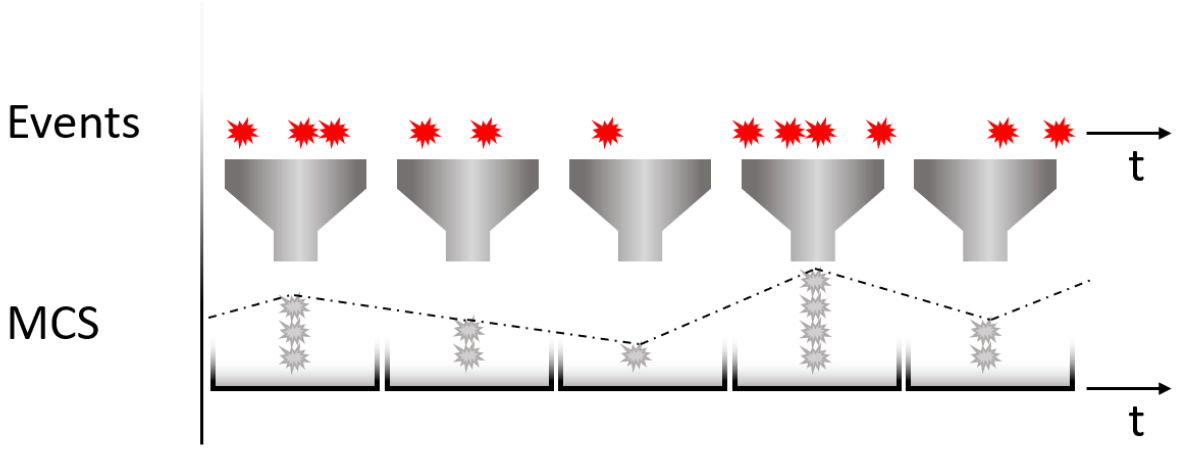


Schematic of the Delta T measuring mode

The Delta T mode is aimed at decay curve recording. In one channel you will record repeating events that are triggering events on another channel. Typically, the first is something like a sync signal from a laser source and the second could be a photomultiplier signal. The time difference between Sync and Event is calculated and stored in a histogram where all dT with similar length get accumulated in one bin.
Important parameters are the **Resolution**, the **Time Range** and the **Collection Time**, where the last is the overall time in which events are recorded. You should compromise between longer times to create higher event rates and better statistics and processing time due to large amounts of data. The **Time Range** is the length of the histogram and should match the period of your repeating sync signal The **Resolution** describes the bin width of the histogram. In BH-QC008 the highest resolution is 0.976 ps which is the maximum resolution of the card. The lowest resolution is software limited to 64 ns.
The **No of Bins** of the histogram is connected to the **Time Range** via the **Resolution**. It is suggested not to go over 10 million bins for most “normal” PCs.

There is no limitation to which channel should be used as sync or event input. Just make sure you have selected the right channels in the Delta T graphs private menu . Disable all unused channels to save bandwidth.

MCS mode

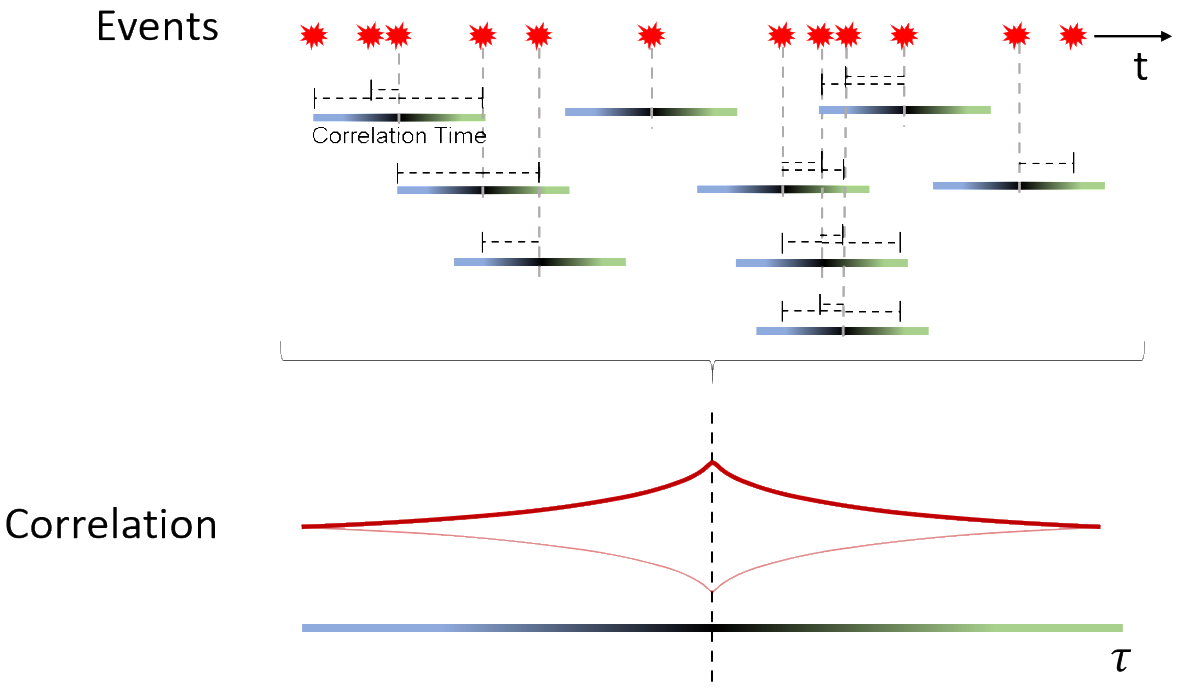


Schematic of the MCS measuring mode

In MCS mode events are recorded over a longer time period. The **Collection Time** sets the length of the time axis of the graph. Theoretically up to 46 days. The setting of **No of Bins** determines the resolution in which the recorded events are stored in the graph. The resulting **Bin Width** is displayed in the lower right corner of the graph.

Since there is no channel referencing in this mode, the private menu only offers to dis-or enable single channels. Disable all unused channels to save bandwidth.

Correlation mode



Schematic of the Correlation measuring mode

The Correlation Mode is aimed at FCS or bunching/anti-bunching measurements. By default, the x-axis of the graph is set up symmetrical around tau zero, but can be shifted to start anywhere using the **Start Delay** in the card settings. For FCS measurements you might choose to have the time axis displayed logarithmically by clicking the button in the bottom right corner.

The correlation algorithm takes every event in the selected channel and computes the time differences to all events in the reference channel that lay within the correlation time. Use the private menu to set the **Correlation T** and choose which channel to display and to correlate

with which second channel. Both, auto-correlation and cross-correlation are possible. Disable all unused channels to save bandwidth.

The time differences are accumulated in their corresponding bin in the histogram of the graph. The **No of Bins** value serves as maximum number for the histogram, but will be typically slightly smaller to avoid rounding errors when binning. The actual resolution can be read from the **Bin Width** field in the lower right corner of the graph. Set the **Collection Time** to a convenient value for your measurement.

Note, with a correlation time equal or less than a period of a repeating signal on one channel the cross-correlation plot will be technically identical to a plot in Delta T mode, since there will be always only one pair within the correlation time. However, the plot will look reversed, since the referencing is swapped.

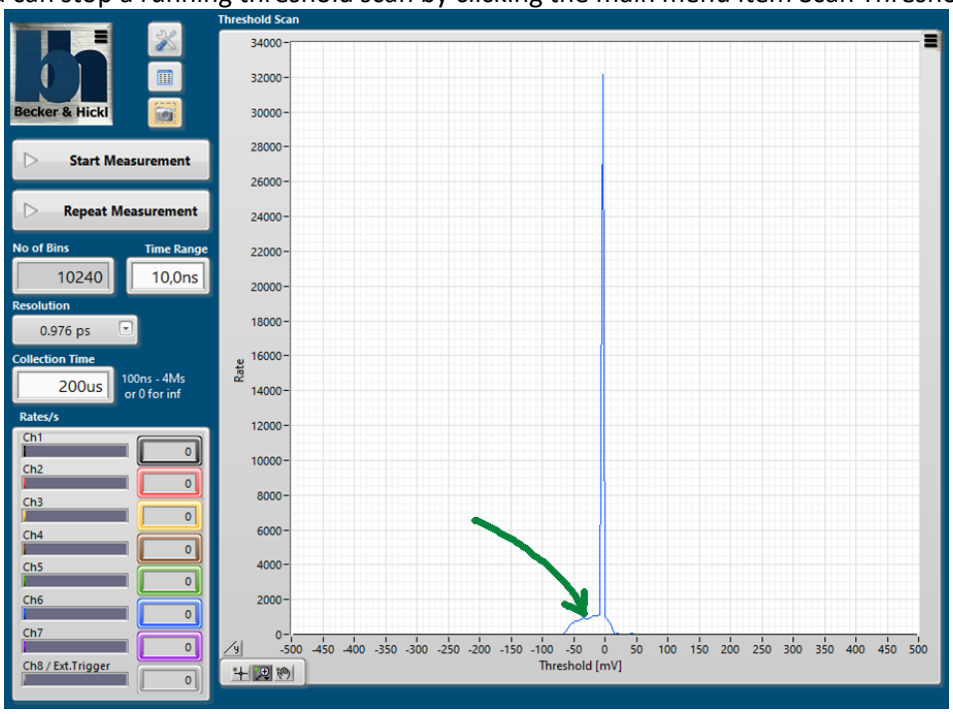
Wizards and Helpers

BH-QC008 offers two wizards helping you to set up your measurement. Basically, they are simple automation processes performing tasks you could also do by hand using the application.

Threshold Scan

The channel threshold in the card settings can be adjusted to values between -500 mV and +500 mV. Sometime it can be hard deciding on a **ChThreshold** without full knowledge of the incoming signals. The Scan Threshold wizard available through the main menu can assist you with that. The wizard will scan through all possible threshold values between -500 mV and +500 mV and display the corresponding rates in the Threshold Scan window. This should allow you to choose the best threshold value for each channel. Pick a threshold value where the rates are high enough to indicate a strong signal but not yet superimposed by noise.

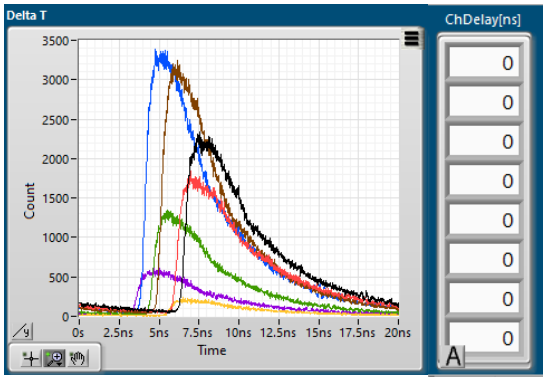
Hint: You can stop a running threshold scan by clicking the main menu item Scan Threshold again.

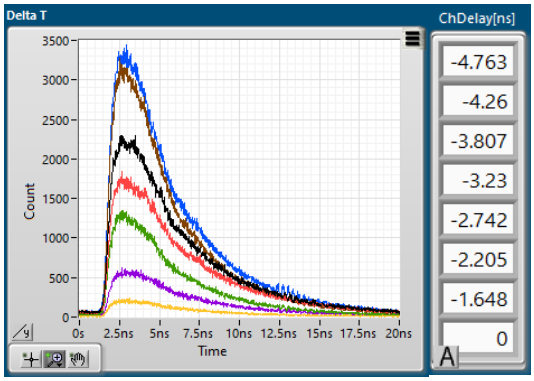


A performed Threshold Scan. Event Rates vs. Threshold Voltage.

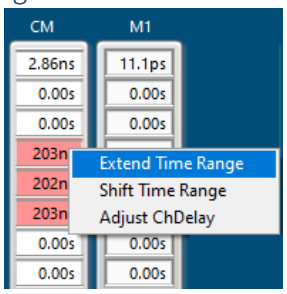
Channel Delay Auto Adjust

A measurement setup might induce unwanted timing offsets between channels; typically, through different cable lengths. You can set the **ChDelay** value for each channel in the Card Settings to compensate for this. Again, here the Auto Adjust wizard can do that for you with the press of a button in the **Card Settings**. All ChDelays are calculated to move the rising edge of all curves to 10% of the time axis.





Bring CM into View



It might happen, that a signal is out of the scope of a graph, for example when the selected **Time Range** does not cover the position of the signal. The centre of mass **CM** field in the Analysis Window will indicate that with red colouring. By right clicking a red coloured field the wizard options **Extend Time Range**, **Shift Time Range** and **Adjust ChDelay** come up.

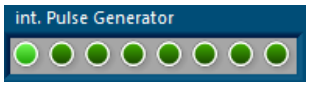
Use Extend Time Range to have the Time Range value be increased to just behind the centre of mass of the signal.

Use Shift Time Range to adjust the **StartDelay** to have the centre of mass of the signal be positioned in the middle of the graph, without changing the time range.

Use Adjust ChDelay to set the **ChDelay** of that particular channel to a value so that the centre of mass of the signal is positioned in the middle of the graph, without changing the time range.

Internal Pulse Generator Helper

Sometimes it can be hard to determine which part of an experiment does not work. Is it the signals, the hard- or software? Or sometimes there might be a sync signal missing during setup.



For test purposes you can use the **int. Pulse Generator** in the **Debug Info** section to have the SPC-QC-008 card creating an internal signal on each channel with 1.72 M events per second. This signal can be fed to the application and used and displayed like any life signal on the channel inputs.

When enabling a signal generator, the **Rates** display is automatically enabled for the corresponding channel.

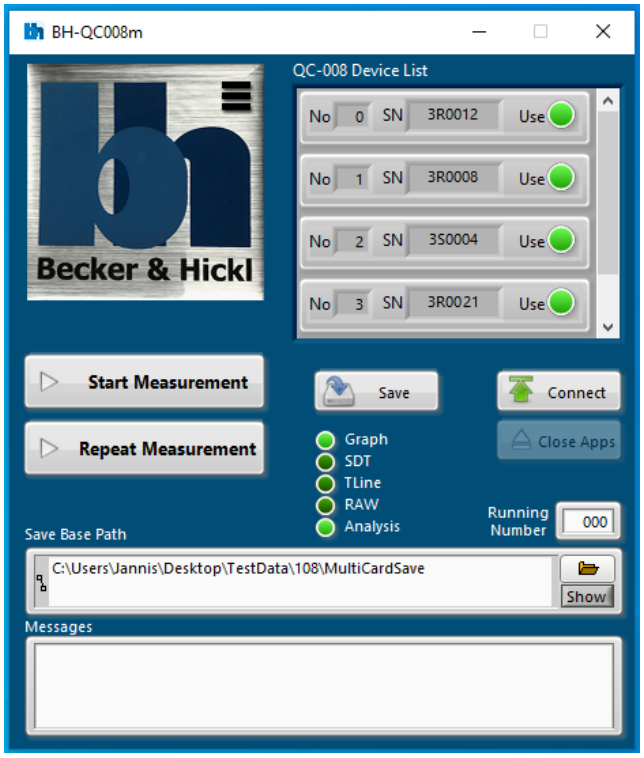
Multi Card Support

Provided you can find so many PCIe bus slots connected to your PC, you can run in parallel up to 32 Becker&Hickl SPC-QC-008 event recording cards. Simply start another instance of the BH-QC008 application and it will attach itself to the next available module. The serial number of the attached card is displayed in the windows title bar.

Note, that there is currently no common clock for all cards. So, you might have to connect a common sync signal to all cards effectively reducing the total possible number of channels to 224.

For easier access to so many cards a little helper program called BH-QC008m is provided in the same folder as your BH-QC008 application.

BH-QC008m Multi Card Application



When starting the application, it will scan the PC for all connected QC-008 cards and list them with their current device number and serial number.

With the green LED to the right you can select whether this module should be connected and a BH-QC008 application controlling it should be opened.

Once you made your decision press the **Connect** button and the corresponding BH-QC008 applications will be opened.

You can change the **Use** setting anytime, resulting to open another BH-QC008 application or disconnecting one from the remote control.

Once a connection is successful the **Start Measurement** and **Repeat Measurement** buttons are enabled. Using these buttons, you can start a measurement on all connected QC-008 cards nearly simultaneously.

Note, that the communication between the BH-QC008m multi card application and the connected BH-QC008 control application is implemented using the remote-control system. This means, that there is an unknown software and Windows operating system delay between the actual start time of each card.

If your application requires an exact same starting time for all cards we recommend to put all connected cards in the external start trigger mode. Like this you can arm all connected cards for measurement with the BH-QC008m application, while the cards will start the actual measurement with the next trigger signal.

After a successful measurement you might want to save your data to disk. Choose a common **Save Base Path** for all connected devices and select one or several file types from the LED list. The actual filenames will be created by appending a “D” and the device No and the **Running Number** which is automatically incremented with every saving action.

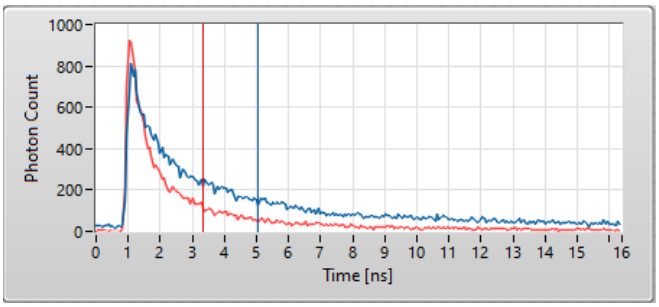
Note, that the analysis table gets appended as a new line to the previous file with the last two columns being the device No and the running number.

Use the **Close Apps** button to close all connected BH-QC008 applications with one click.

1st Moment Algorithm

The full analysis of a decay curve would need an exponential curve fit, folded with an instrument response function (IRF). Sometimes even multi-exponential curves are observed. Modern PCs are still not offering this sort of computational power for large data sets.
We at Becker&Hickl understand, that sometimes a quick and possibly not so accurate result is desired, especially when dealing with rapid changes or moving objects. To this end BH-QC008 offers some mathematical and computational simplification to present you with a first estimate of a simple exponential decay.

In the examples in the next image you see the red decay curve emitted from a molecule with a shorter lifetime while the blue curve has a longer lifetime (slower decay).



We assume, that the declining part of the curve can be characterized by an exponential decay curve.

$$N(t) = N_0 e^{-\frac{t}{\tau}}$$

Now, it is a characteristic of the exponential decay curve, that its lifetime value tau can be approximated in first order by the centre of mass of the curve. Also called the 1st moment.

$$R = \frac{1}{M}\sum_{i=1}^{n} m_i r_i \quad \text{with } M = \sum_{i=1}^{n} m_i$$

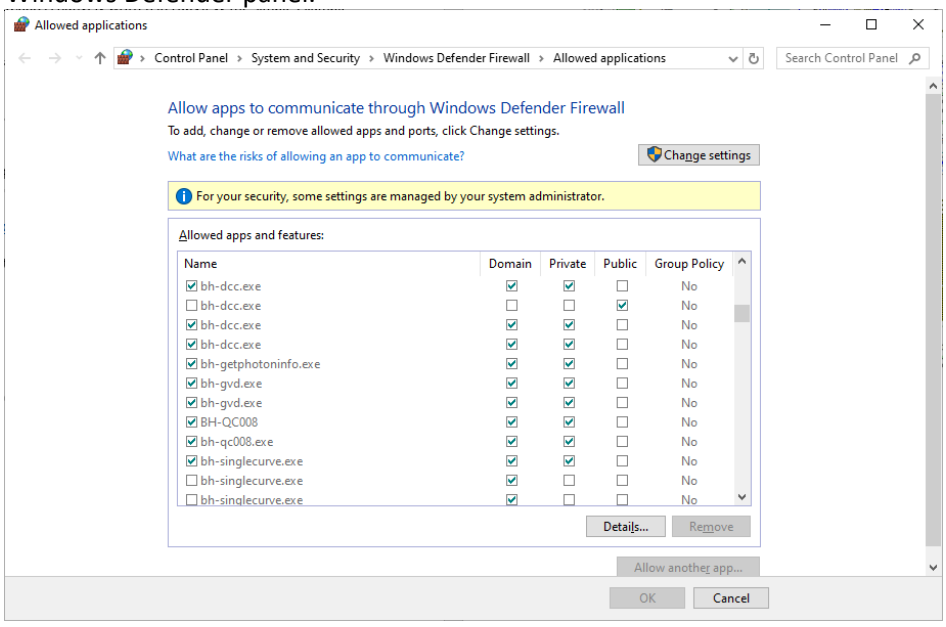
Of course, we still need to subtract the start position of the decay curve. BH-QC008 uses the maximum of the curve which can be only an approximation of a real IRF position.
Another uncertainty lays in the shape of the curve itself: The 1st moment algorithm cannot detect or compensate for multi-exponential decays.
For a more precise analysis of lifetimes you could export your measurement data as SDT-file and process it in specialized application like Becker&Hickl's SPCImage.

Remote Controlling BH-QC008

BH-QC008 offers an interface to other applications wanting to remotely control features and actions of BH-QC008. Experienced programmers can write their own script to automate processes. Three interfaces are provided. Since BH-QC008 is natively written in LabVIEW the simple example VI ControlQC008.vi using the VI-Server exists to allow other LabVIEW applications or code to connect to BH-QC008.
A Python wrapper is available via pip install bhpy.
Alternatively, the dynamic link library ControlQC008.dll can be used in all other computer languages.
You will find all three interface adapters in the *C:\Program Files\Becker-Hickl\BH-QC008\RemoteControlBH-QC008* folder.

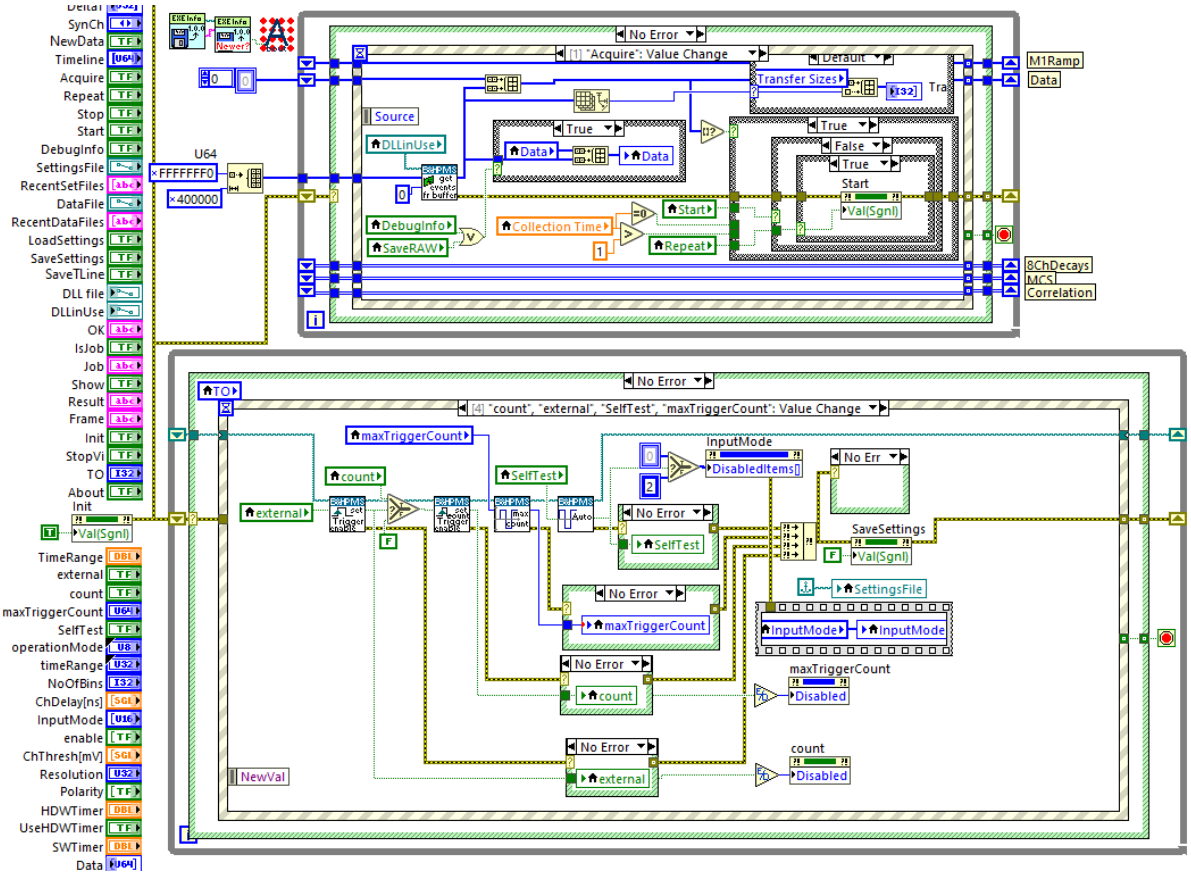
All available actions in the BH-QC008 application have their corresponding remote commands which can be sent by writing well defined strings to a control, while the result can be read from another string control.
Check the appendix for a list of all available remote commands.

Note: A connection with BH-QC008 is not possible if you have not set the check marks for “Allow BH-QC008 to communicate on networks” during the installation process. You can allow access later on in the Windows Defender panel.



Source Code Distribution

For developers the complete LabVIEW 2017 source code (Virtual Instruments) of the BH-QC008 application is available for your modification requirements. Please contact info@becker-hickl.com for pricing and licenses.



Where to go from here…

We at Becker&Hickl hope you will get the most out of your SPC-QC-008 card and the control application BH-QC008. A lot of analysis data and the graphs are readily available to be used in documentation or publications. You might use collected data saved to file for further specialized analysis specific to your setup.

But since we at B&H are continuously progressing our development of user inspired hard- and software, you can expect new features in the future. Some of which will cater to your needs. To do so we are thankful for your feedback about your expectations, workflow procedures and of course bug-reports.

Please feel free to contact us at info@becker-hickl.com with suggestions or collaboration offers.

Troubleshooting

The app's backdrop flashes red	Check the message window for error messages
I started a measurement but the graphs are not updating.	Too many events have been recorded for a speedy computation. Try reducing the event rate, Collection Time and/or No of Bins. A task kill in the task manager might be necessary.
I received an "Out of memory" error.	The histograms have become too large for your PC RAM. Try reducing Collection Time and/or No of Bins. A task kill in the task manager might be necessary.
Some Rates are dimmed and the values are not displayed.	Rates are only updated when the corresponding channel is enabled or referenced in at least one of the private menus in visible graphs.
I connected a signal to an input, but don't see any Rates displayed.	• Ensure to have the corresponding channel enabled or referenced in at least one of the visible graph's private menu. • Check the Threshold settings in the Card Settings. Positive and negative values are possible.
I do have Rates in a channel, but do not see the signal in the Delta T graph.	The signal might be outside the currently selected time range. Check the CM value in the Analysis window for a red warning.
The Rates panel is dimmed and the values are not updated.	You have loaded a previous measurement saved to file and the Rates panel shows the rates values when creating this file. Click on the Rates panel to turn it live again.
I have stopped a measurement by clicking on "Stop Measurement" and now a green lit "Start Measurement" is visible but the application is not responsive.	Patience!
I have an old measurement saved to file, but cannot reload it to the app because I lost the corresponding CFG-file.	It is possible to create a CFG file with matching parameters via Save Settings and name it corresponding to your measurement file.
I received and error: "Hardware did not report the beginning of the measurement".	Check the setting of external Trigger in the Card Settings and the Rates on channel 8.
I tried saving a measurement as SDT-file but receive "The SDT-format requires No of Bins to be 2 exponential up to 16384"	Right click on No of Bins and use Adjust for SDT-format
I cannot remotely connect to BH-QC008 but receive Error 56	A connection with BH-QC008 is not possible if you have not set the check marks for "Allow BH-QC008 to communicate on networks" during installation. Use the Windows Defender panel to allow the connection.
I tried everything but my problem persists.	Feel free to contact info@becker-hickl.com with a detailed description of your issue together with a screenshot of BH-QC008. Consider to email us in addition a copy of your BIN / CFG pair.

Appendix

SPC-QC-008 Datasheet

Photon Channels	
Principle	Threshold Discriminator
Discriminator Input Bandwidth	4 GHz
Min. Input Pulse Width	1 ns
Discriminator Threshold	-500 to 500 mV in Steps of 4 mV
Maximum Pulsed (<1 ms) Input Voltage Range	-5.5 V to +5.5 V
Maximum DC Input Voltage Range	-3.3 V to +3.3 V
Frequency Range	0 to 500 MHz
Input Connectors	SMC, 50 Ohm
Time-Measurement Circuitry	
Principle	Time-to-Digital Converter
IRF Width, FWHM	<40 ps
Typical RMS Timing Jitter	14 ps
Min. Time / Bin	1 ps
Timing Stability, Range 16 ns, over 10 Minutes	<5 ps RMS
Diff. Nonlinearity	<2 % RMS
Dead Time	2 ns
Data Acquisition (FIFO Mode)	
Method	Parameter-Tagging of Individual Photons, Continuous Writing to Disk
Peak Count Rate	500 MHz / Channel
Peak-Rate Buffer Capacity (Photons / Channel)	4,000
Sustained Count Rate (Bus-Transfer Limited)	140 MHz, All Channels Combined
On-Board FIFO Buffer Capacity (Photons Combined)	2,600,000
Data Acquisition GUI Software	
Online Display	Count Rates, Multiscaler, Delta-T Function, Threshold Scan, Auto-/Cross-Correlation
Delta-T Function	
No. of Time Bins	1 to 10 M
Time / Bin	1 ps to 65,536 ps
Time Range	1 ps to 640 ms
Selectable Sync Channel	1 to 8
Optional External Trigger	Channel 8
Threshold Scan	
Threshold Range	-500 mV to 500 mV
Stepsize	4 mV
Operation Environment	
Operating System	Windows 10, Windows 11
Bus Connector (Slot Type)	PCIe
Total Power Consumption	approx. 12 W from +3.3 V, 3 W from +12 V
Dimensions	205 mm x 120 mm x 18 mm

Data format in SPC-QC-008 RAW stream

Deeper understanding of the raw data format is not required for users of the BH-QC008 application. The information is included here for developers interested in interpreting the stream themselves for further analysis.

Fifo events will consist of 20 bits each. There will always be 3 events packaged into a 64bit vector with 4 empty header bits (63 .. 60). The first event in time will be placed in the most significant section (59 .. 40), the newest event will be placed in the least significant portion (19 .. 0).

The different FIFO events will be encoded in the following way:

Photons:

Bit	19	18	17	16	15 .. 11	10 .. 0
function	0	Ch[2]	Ch[1]	Ch[0]	Macrotime bits (2ns res.)	Microtime bits (1/1.024ps res.)
					dt_i time difference to Macrotime of last event	

Macrotime overflow - Main:

Bit	19	18	17	16	15 .. 13	12 .. 0
function	1	0	0	0	'000'	$dt_{i,mtof}$ Macro-Dt to Macrotime of last event (2ns res.)

Macrotime overflow - Subdivision:

Bit	19	18	17	16	15 .. 13	12 .. 0
function	1	0	0	1	'000'	$dt_{i,mtof}$ Macro-Dt to Macrotime of last event (2ns res.)

GAP:

Bit	19	18	17	16	15 .. 11	10 .. 0
function	1	1	0	0	Macrotime bits (2ns res.)	Microtime bits (1/1.024ps res.)
					dt_i time difference to Macrotime of last event	

It is important to know, that Macrotime overflows are never combined with photons. After a GAP event, only MTOFs are transferred. This allows to maintain an uninterrupted timing stream.

To calculate the actual event time in 1/1.024 ps steps, one can use the following equations. For the first event, we have the macro-time:

$$T_{macro,0} = dt_0[15..11] * 2^{11} \quad \text{(for photon, GAP)}$$
$$T_{macro,0} = dt_{0,mtof}[15..0] * 2^{11} \quad \text{(for MTOF)}$$

And the 1/1.024 ps timestamp:

$$T_0 = (dt_0[15..0])\frac{1}{1.024}ps$$

For all following events in the stream we calculate the Macro-time as:

$$T_{macro,i} = dt_i[15..11] * 2^{11} + T_{macro,i-1} \quad \text{(for photon, GAP)}$$
$$T_{macro,i} = dt_{i,mtof}[15..0] * 2^{11} + T_{macro,i-1} \quad \text{(for MTOF)}$$

The final time value can be calculated as:

$$T_i = \left(dt_i[15..0] + T_{macro,i-1}\right)\frac{1}{1.024}ps$$

Note, that the three most significant bits of the MTOF times are always zero. Only bits 12 .. 0 hold values.

Remote Control Commands

All remote commands are named similar to the corresponding button, input field or menu item in the application window, but do not include white spaces. Commands are not case sensitive.

Some commands are sent on their own, while others have an argument separated by a white space.

All successful set commands will reply with a string “OK” followed by a white space and a checksum. The chksum is calculated by adding the ASCII values of the complete sent string. This allows a remote application to confirm that a received OK is the actual response expected.

Sending a misspelt command will return an error message instead.

The get commands will return the requested values as strings. You should ignore the error status for get commands.

Note: Continuous polling of the interface might hinder the display of application errors.

Job-Command	**Argument**	**Result**
StartMeasurement	NA	
RepeatMeasurement	NA	
StopMeasurement	NA	
ScrPrt	filepath&name.png	
SaveAnalysis *	filepath&name.csv	
NoOfBins	integer	
TimeRange	seconds in E-9 notation	
Resolution	seconds in E-9 notation	
CollectionTime	seconds in E-9 notation	
ChDelays	ns,ns,ns,ns,ns,ns,ns,ns	
ChThresh	mV,mV,mV,mV,mV,mV,mV,mV	
StartDelay	ns	
maxCount	integer	
Polarity	one Byte binary	
external	0 or 1	
count	0 or 1	
AutoAdjust	NA	
PulseGenerator	one Byte binary	
DisableSyncFilter	0 or 1	
LoadSettings	filepath&name.cfg	
SaveSettings	filepath&name.cfg	
ShowDeltaT	NA	
HideDeltaT	NA	
ShowMCS	NA	
HideMCS	NA	
ShowCorrelation	NA	
HideCorrelation	NA	
ShowCardSettings	NA	
HideCardSettings	NA	
ShowAnalysis	NA	
HideAnalysis	NA	
DeltaTRef	ChN,ChN	
MCSRef	ChN,0 or 1	
CorrelationRef	ChN,ChN	

CorrelationT	seconds in E-9 notation	
SaveGraph	filepath&name.csv	
SaveSDT	filepath&name.sdt	
SaveTimeLine	filepath&name.csv	
SaveRAW	filepath&name.bin	
LoadGraph	filepath&name.csv	
LoadSDT	filepath&name.sdt	
LoadAutoSavedSettings	NA	
X-AxisInBins	0 or 1	
ExtendTimeRange	ChN	
AdjustChDelay	ChN	
ShiftTimeRange	ChN	
BunchingFit	ChN Modell[0/1]	
ScanThreshold	NA	
ShowDebugInfo	NA	
HideDebugInfo	NA	
GetRates	NA	%.4e,%.4e,%.4e,%.4e,%.4e,%.4e, %.4e,%.4e
GetGAPEvents	NA	%d
GetserialNrStr	NA	string
Getinitialized	NA	0 or 1
GetDLLversionStr	NA	string
GetFW-Version	NA	string
GetMeasurementStatus	NA	repeating/measuring/noData/ DataAvailable
AppStop	NA	

*The SaveAnalysis command expects the filename&name not to include any white spaces. A white space after the name can be followed by a user defined string including commas. Use this to add user information in trailing columns of the CSV-file, e.g. environment variables.

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