

quTAG MC

Time-to-Digital Converter

Manual V1.0



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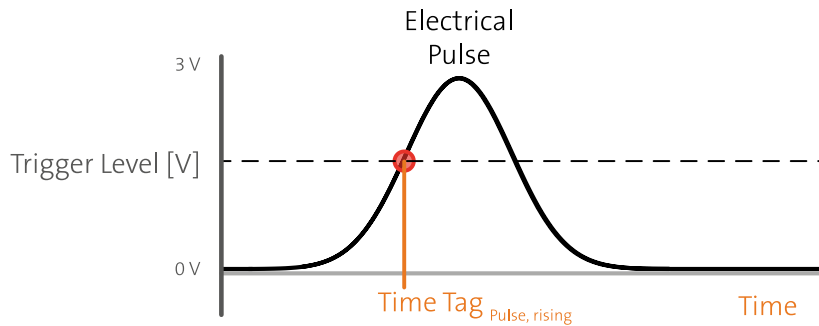
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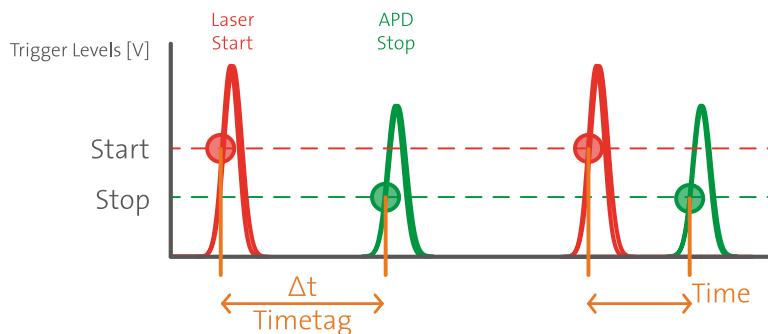
1. Introduction

1.1 quTAG MC – state of the art time-to-digital converter

The quTAG MC – Multi Channel – is a time-to-digital converter that measures electric signals and marks them with time tags. This stream of time tags can be used in various and versatile applications – from measurements in the picosecond range up to an hour.



The universal time tagging method allows correlation measurements (cross-correlation, auto-correlation), lifetime measurements (start-(multi)stop) and many more possibilities within one measurement. The saved stream of time tags contains all information needed to reconstruct every measurement and analysis performed.



1.2 Technical overview

The key features of the quTAG device are:

- High timing resolution (bin size 1 ps)
- High event rates
- USB3.0 interface
- Easy-to-use

The device can be used for a variety of Applications:

- Time correlated single photon counting (TCSPC)
- Fluorescence lifetime imaging
- Quantum information experiments
- LIDAR

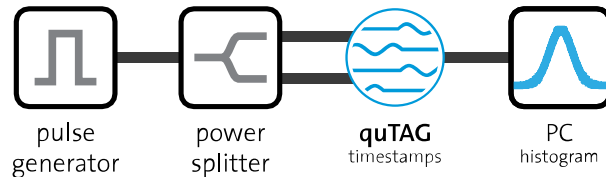
- High energy/accelerator physics
- High precision time measurements

Channels input	1 Start / 8, 16, 32 Stop
Bin width	1 ps
Timing jitter – RMS, FWHM	20 ps, 50 ps
Input pulse high level	-5.0 V ... + 3.5 V
Input Impedance	50 Ohm

1.3 Jitter Measurement

In order to measure the jitter, we generate an electrical pulse with steep edges. This pulse gets split into two by a power splitter and sent into two different inputs of the quTAG (i.e. start and stop-X or stop-X and stop-Y). Then we use the quTAG software to generate a start-stop-histogram.

We fit a Gaussian function to this histogram and determine RMS and FWHM. The single channel jitter corresponds to $\sigma / \sqrt{2}$ from this two-channel measurement, assuming equal Gaussian contributions from both signals. The FWHM can be obtained by the standard deviation with the relation $FWHM = 2 \sqrt{2 \ln 2} \sigma \approx 2.35 \sigma$.



2. Safety and Maintenance

2.1 Legend



Caution

General risk of danger.



Warning

An instruction which draws attention to the risk of injury or death.



Warning

Risk of electric shock. High voltages present.

2.2 General Instructions



The equipment, as described herein, is designed for use by personnel properly trained in the use and handling of mains powered electrical equipment. Only personnel trained in the servicing and maintenance of this equipment should remove its covers or attempt any repairs or adjustments. If malfunction is suspected, immediately return the part to the vendor for repair or replacement. There are no user-serviceable parts inside the electronics. Modified or opened electronics cannot be covered by the warranty anymore. Take special care if connecting products from other manufacturers. Follow the General Accident Prevention Rules.



If this equipment is used in a manner not specified by the manufacturer, the protection provided by the equipment may be impaired. Do not operate the instrument outside its rated supply voltages or environmental range. In particular, excessive moisture may impair safety.



For laboratory use only. This unit is intended for operation from a normal, single phase supply, in the temperature range 5° to 40°C, 20% to 80% RH.

2.3 Environmental Conditions



Warning. Operation outside the following environmental limits may adversely affect operator safety:

- Indoor use only
- Maximum altitude 2000 m
- Temperature range 5°C to 40°C
- Maximum humidity less than 80% RH (non-condensing) at 31°C
- To ensure reliable operation the unit should not be exposed to corrosive agents or excessive moisture, heat or dust. If the unit has been stored at a low temperature or in an environment of high humidity, it must be allowed to reach ambient conditions before being powered up.

2.4 Electrical Installation



The unit must be connected only to an earthed fused supply of 100 to 240V (Japan, USA and Europe).

Use only power supply cables supplied by the manufacturer, other cables may not be rated to the same current. The unit is shipped with appropriate power cables for use in Europe. When shipped to other territories the appropriate power plug must be fitted by the user.



Never connect any cabling to the electronics when contacts are exposed!

Avoid short-cuts.



Prevent electrical shock from electronic. To prevent electrical shock do not remove the cover of the control unit. Unplug power cord and all other electrical connections and consult qualified service personnel when servicing or cleaning. Operate only under dry conditions and at room temperature conditions.

2.5 Preventive Maintenance



The equipment contains no user serviceable parts. There is a risk of severe electrical shock if the equipment is operated with the covers removed. Only personnel authorized by the vendor and trained in the maintenance of this equipment should remove its covers or attempt any repairs or adjustments. Maintenance is limited to safety testing and cleaning as described in the following sections.

2.6 Safety Testing



Safety testing in accordance with local regulations, should be performed on a regular basis, (typically once per year for an instrument in daily use).

Caution. The instrument contains a power supply filter. Insulation testing of the power supply connector should be performed using a DC voltage.

2.7 Cleaning



Disconnect the power supply before cleaning the unit. Never attempt to clean the quTAG by immersion into any liquid. Never allow water to get inside the case. The quTAG parts are sensitive to any kind of liquid. Do not use any type of abrasive pad, scouring powder, or solvent, e.g. alcohol or benzene. Please note that all parts of quTAG are cleaned in our production facility.

3 Technical Specifications

Time to digital converters

Digital resolution	1 ps
Timing jitter – RMS, FWHM	20 ps, 50 ps
Max. event rate per channel	100 Mcps
Sustained throughput rate	100 Mcps (USB3.0)
Delay range	-50 ... +50 ns
Delay resolution	1 ps
Min. pulse to pulse separation	10 ns
Differential non-linearity	<1%
Max. acquisition time without overflow	1.25 h

Input Channels

Number of channels	1 start / 8, 16, 32 stop
Connector	SMA
Signal level range	-5.0 V ... + 3.5 V, e.g. LVTTTL, NIM
Offset voltage max.	± 10 mV
Min. input level	± 50 mV
Threshold level resolution	0.15 mV
Threshold voltage range	- 3.0 V... + 3.0 V
Threshold voltage offset max.	± 25 mV
Edge	Rising, falling
Min. input pulse width	1 ns
Termination	50 Ohm

Output Channels

Number of channels	2
Connector	D-Sub, Pins 3 & 1
Signal levels	LVTTTL
Delay range	-100... 100 ns
Delay resolution	10 ps
Impedance	50 Ohm

Clock Input

Frequency	1 – 100 MHz
Signal levels (threshold)	-5 V ... +5 V
Signal form	Sinusoidal, square wave
Termination	50 Ohms
Input connector	SMA

Marker Inputs

Marker Inputs	4
Input pulse width minimum	10 ns
Input pulse level	Low -0.5 ... 0.8 V High 2.0 ... 5.5 V
Input Impedance	470 Ohm
Digital resolution	5 ns
Timing Jitter	2 – 5 ns
Connector	D-Sub, Pins 7, 6, 20, 19

Sync Output

Signal type	Square wave
Frequency	10 MHz
Signal level	LVTTL
Output impedance	50 Ohms
Connector	SMA

Operation

Interface	USB3.0
Operating system	Windows, Linux
Power consumption	< 50W at 100 to 230 VAC, 50-60 Hz

4 Variants and Options

The quTAG MC can be upgraded with the following features. The optional features that can also be installed individually. The basic variant does not include any of the options listed below. For the procedure of installation refer to section 6.4 .

Option	Meaning
Cross-correlation	Enables correlation measurement software, see section 7.4 for details.
Lifetime	Enables lifetime measurement software, see section 7.5 for details.
Markers	4 GPIO-Inputs can be used as data markers. The markers are included in the timeline to help sorting timestamps. See sections 5.4 and 7.6 .
Device Synchronization	Devices can be synchronized by the Sync-Out SMA connector via 10 MHz. If an external clock is connected, the Sync-Out signal is phase locked to the input.
External Clock	The device may be synchronized to an external clock signal 10 MHz.
User defined External Clock	The external clock frequency can be changed from 1 – 100 MHz.
Filters	Filters timestamp events that are not needed for the application. This filtering happens inside the device and therefore saves bandwidth on the USB connection. See section 7.7 for more details.
Channel Output	The two programmable outputs enable conditional measurements, state preparation, gating of detectors, control of shutters and more to synchronize events. An adjustable delay can be added on the output signal by software.

5 Hardware Description

5.1 Front side

The quTAG MC comes in different variants with 8, 16 or 32 stop input channels.

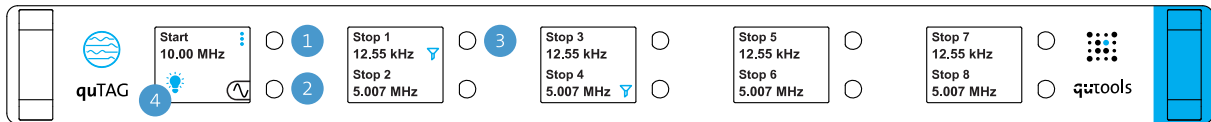


Figure 1: Front side of the quTAG MC - 8 stop input channels

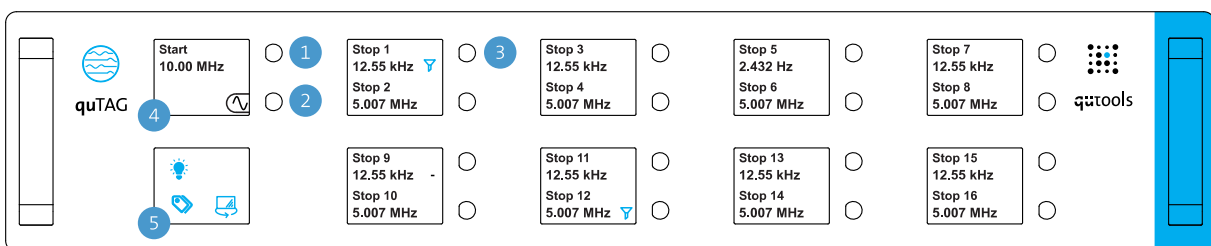
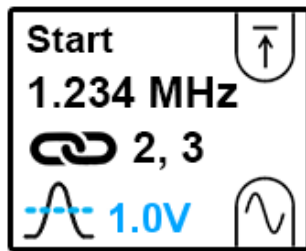







Figure 2: Front side of the quTAG MC - 16, 32 stop input channels

- 1 SMA start input connector
- 2 SMA clock input connector
- 3 One of 8 or 16 SMA stop input connectors on the front side, see rear side 5.3 for channels 17-32
- 4 Start channel display
- 5 Menu display for options, see detailed description 5.2
 - Switching the stop input channels to the SMA stop input connectors of the rear side, only at 32 channel devices
 - showing information about markers on the front displays
 - switching the displays off/on

5.2 Displays on the front panel



Single tap on the left display to toggle on and off the illumination of all displays within the device.

Start	Channel mode (start/stop) and channel number.
1.234 MHz	Displaying the counts per second.
 	Threshold with rising / falling edge. The threshold level is displayed next to it.
 	External Clock connected / Clock not connected
	Filter (see section 7.7 for details) active on that channel

5.3 Rear side

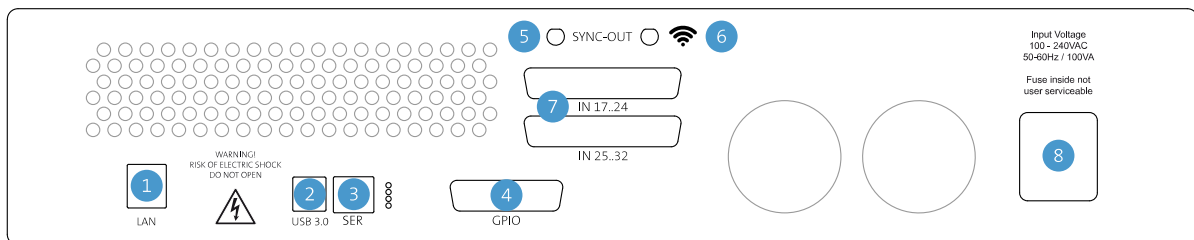


Figure 3: Rear side of the quTAG MC 32 channels



Make sure the cooling fans are not obstructed. Otherwise, the quTAG may be damaged due to overheating.

- 1 LAN port
- 2 USB3.0 connection
- 3 Service port
- 4 GPIO port: marker inputs, channel outputs and general purpose IOs
- 5 Synchronization output
- 6 WIFI antenna

- 7 Stop input channels 17-32, device dependent
- 8 AC power input and power switch

5.4 Marker Inputs

In addition to the channel inputs, the device features marker inputs that insert marker timestamps in the timeline. They can be connected e.g., to some pixel clock or line clock in order to help sorting the timestamps. The GPIO Connector is used for those inputs:

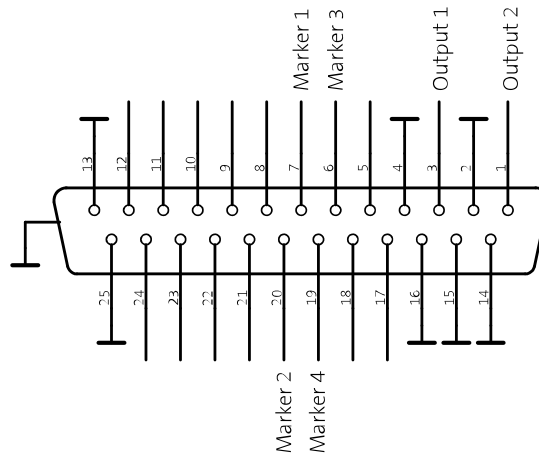


Figure 4: D-Sub connector at the back panel

Marker inputs 1...4 reside on pins 7, 6, 20, 19. Use the additionally shipped breakout cable.

If configured by software, Marker events are saved within the data stream as timestamps. Channel numbers 100-103 are the Markers 1-4 with rising edge and 105-108 with falling edge.

Marker Inputs	4
Input pulse width min.	10 ns
Input pulse level	Low -0.5 ... 0.8 V High 2.0 ... 5.5 V
Input Impedance	470 Ohm
Digital resolution	5 ns
Timing Jitter	2 – 5 ns

5.5 Output Channels

In addition to the channel inputs, the device features 2 output channels. The two programmable outputs enable conditional measurements, state preparation, gating of detectors, control of shutters and more to synchronize events. An adjustable delay can be added on the output signal by software. The GPIO Connector is used for those outputs:

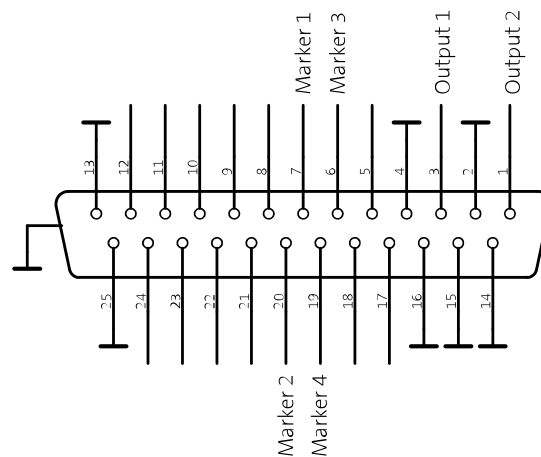


Figure 5: D-Sub connector at the back panel

The output channels 1 and 2 reside on pins 3 and 1. Use the additionally shipped breakout cable.

Output channels	2
Connector	D-Sub, Pin 3 and 1
Signal levels	LVTTL
Delay range	-100... 100 ns
Delay resolution	10 ps
Impedance	50 Ohm

5.6 Synchronization

Multiple quTAGs can be synchronized – provided the "Sync" option (see section 4) is activated. To synchronize devices, connect the Sync-Out from your master device to the clock input of the next quTAG. The Sync-Out synchronizes the internal clock via 10 MHz of both devices. Additional devices can be connected by the same principle.

Multiple instances of Daisy can be run to work with different synchronized devices. The usage of multiple devices by the DLL is described in a Python software example.

5.7 First Setup

- Install the USB driver included in the software package, downloaded from the homepage.
- Supply power to the quTAG via the AC power input and turn it on using the power switch.
- Connect the quTAG to a PC using the USB 3.0 connector. An USB 2.0 can be used, but limits the transfer rate.
- The clock input hasn't to be connected in most cases. It is used only to synchronize the device with an external clock source.
- "Payload" signals are connected to the start and the stop input connectors, see input channel specifications.

6 Software Installation and Configuration

6.1 Software Installation

The quTAG software can be installed on Windows 7, 8, 8.1, and 10, 32- and 64 Bit. The Linux version requires a x86-64 Bit distribution with libc 2.19 or newer.

On **Windows**, using the **installer**

Daisy@QUTAG-MC-
Vx.y.z.exe

Start the installer program and follow the instructions. Drivers and necessary libraries will be installed automatically.

On **Windows**, using the **zip archive** QUTAG-MC-
Vx.y.z.zip

Extract the zip archive to a directory of your choice.
Install the device driver in the usbdriver directory using dpinst32.exe or dpinst64.exe, whatever conforms to your Windows version.

On **Linux**, using the **tgz archive** QUTAG-MC-
Vx.y.z.tgz

1. The software is built for x86 systems; builds for 32 bit and 64 bit (AMD architecture) systems are available. It is linked against libc 2.19; binary compatibility has been verified with different distributions / distribution families.
2. Besides the standard installation, the following software is required:
 - a) Qt4 Core, GUI, and OpenGL libraries
(Ubuntu: packets libqtcore4, libqtgui4 libqt4-opengl:
e.g. add the repository:
sudo add-apt-repository ppa:rock-core/qt4)
 - b) libusb 1.0 (don't confuse with libusb 0.1)
(Ubuntu: libusb-1.0-0)
3. Extract the directory tree to a place of your choice. E.g. /home/me/daisy .
4. Add nhands.rules from /home/me/daisy/install to the udev rules. (Ubuntu: copy to /etc/udev/rules.d, requires root privileges).
The file installs a rule that grants access to nhands USB devices to every user.
5. Daisy et al. require a couple of shared libraries that reside in the program folder. The program loader must be enabled to find those libs. Using the start scripts "rundaisy" and "runflasher" instead of "daisy" and "nhflash" will do the job.

To call the programs (or userlib applications) directly, the library path has to be published. This may be achieved

a) temporarily: add the extra search path to your shell:
export
LD_LIBRARY_PATH=\$LD_LIBRARY_PATH:/home/me/daisy

Daisy only can be started by command from that shell window:

```
/home/me/daisy/daisy &
```

b) permanently: add the extra search path to the loader config. Ubuntu: create a file "daisy.conf" that contains just one line /home/me/daisy .

Copy that file to /etc/ld.so.conf.d and call ldconfig for cache generation. Root privileges required.

Daisy now can be started by command or file manager click. Note that daisy versions can't be installed in parallel this way because daisy's shared libs don't have real version management.

The following software is packed in the zip/tgz archive:

daisy	"Data Analysis and Imaging System" – the main control software for the quTAG. See chapter 7 .
nhflash	The firmware update tool. See section 6.2 .
tarec	A record & merge tool for synchronized devices. See section 8.1 .
tdccli	A command line tool for simple tasks. See section 8.3 .
userlib	The directory contains the custom programming library, with HTML documentation and LabView wrapper VIs. See section 8.1 .
usbdriver	USB driver packet for Windows 32 and 64 Bit.
firmware	Firmware for the device.

When using the Windows installer, also start menu entries for the programs are created.

6.2 Firmware Update



Attention: Naturally, firmware updates are a delicate process and can potentially harm the device if done incorrectly. Please read and follow the instructions carefully.

A firmware update is generally necessary when a new software version is installed. If the control software is warning about an outdated firmware or if you are unsure if the firmware currently running is up to date, execute the following procedure:

1. Turn on the device. If any quTAG software is still running, close it.

2. Start nhflash(.exe). After some time, the indicator turns green. Proceed only if the tool display "Firmware: outdated".
3. Press "Flash". **Make absolutely sure the device is not shut down or disconnected during this step!** The flash process takes several minutes and may seem to hang without progress for up to 3 minutes. After the update is completed successfully, the indicator stops flashing and the text next to it shows "Update complete".
4. Close the firmware update utility.
5. Turn the quTAG device off and on again.

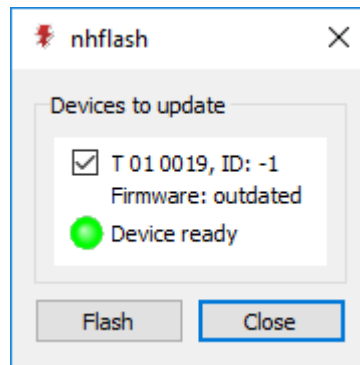


Figure 6: The firmware update tool nhflash

6.3 Hardware ID

The Hardware ID is a (positive) number stored in the device so that it can be used to distinguish between multiple quTAG that are connected to the same PC. If the Daisy software detects more than one device, it asks the user to select a device using the Hardware IDs and serial numbers. Also, the DLL uses the ID to identify a device. If device discrimination is an issue, individual IDs should be programmed.

To assign a device ID start Daisy.exe, locate "id.ngc" in the installation folder with the file manager and drag it into the program window (or open the program menu using ctrl+F9 and select file/load panel). Enter an individual ID and press "Save". Close the program window and restart the device.

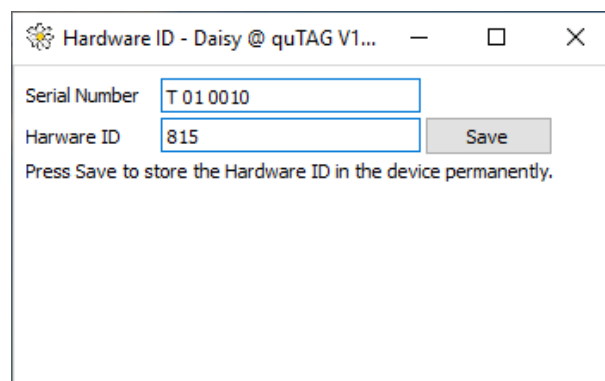


Figure 7: Programming the Hardware ID

6.4 Option Upgrade

As stated in chapter 4 the number of axes and some features of quTAG are optional. Options and axes may be upgraded (or downgraded) on-site by entering a device specific key. The serial number of the quTAG is required when ordering an upgrade key.

To inspect the active options or to install a new one start Daisy. In the file manager, locate "feature.ngc" in the installation folder and drag it into the program window (or open the program menu using ctrl+F9 and select file/load panel). Enter the key obtained from the vendor and press Enter. Close the program window and restart the device.

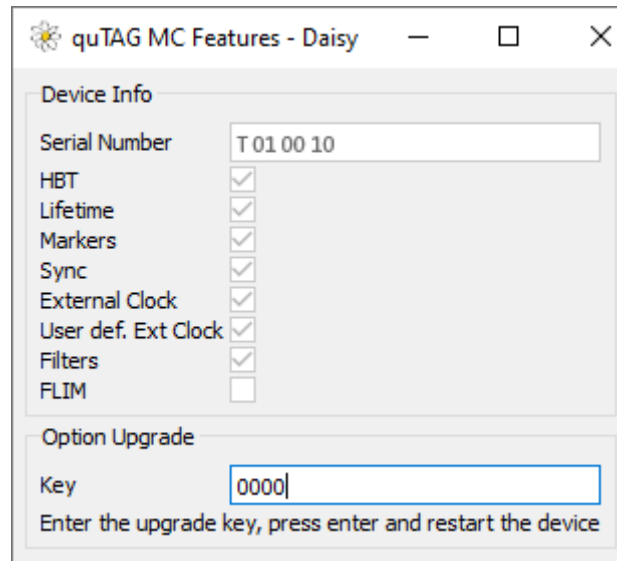


Figure 8: Option upgrade

7 Daisy Software

The Daisy GUI is started by daisy.exe. It provides several functions which allow the full control of the device. The user interface consists of several tabs for different tasks. All tabs and all graphs can be decoupled from the main window by double-clicking it.

Note that some features depend on installed options (see chapter 4). If they are not available for your device, they are typically invisible in the software.

7.1 Counting

All single counting rates for each channel individually are displayed in the "Counts" Tab shown in the following figure.



Figure 9: Counters tab of Daisy

The integration (or "exposure") time can be set to any ms value between 1 ms and $2^{16} - 1$ ms \approx 65.5 s.

The count rates can be saved to a text file by pressing on the button next to "Save Counts". The button with two red dots will save the count rates continuously after every exposure time.

The raw time tags can be saved with the buttons next to "Save Time Tags" at the bottom of the Tab. The used file format is determined by the file name and its suffix. "Textfiles" save the timetags in ASCII format which is easy to read and process, but also needs more hard disk space. "Binary" saves the time tags in a simple binary format with a header of 40 bytes (containing some information about the device, please ignore that in our own processing routine) and a 10 byte timestamp event, containing 8 bytes for the timestamp and 2 bytes for the channel number, stored in little endian (Intel) byte order. The binary format can be read back with functions of the custom programming library.

If configured, Marker events and time ticks are saved within the data stream as timestamps. Channel numbers 100-103 are the Markers 1-4 with rising edge, 105-108 with falling edge and 104 is the millisecond time tick.

7.2 Coincidences

The input channels 1-5 participate to the internal calculations of coincidences. That gives a total of 26 different coincidental possibilities between the input stop-channels.

The coincidence time window can be set to any value between 0 ps and $2^{32}-1$ ps \approx 4.3 ms. The exposure time will be used from the Counts tab.

Two (or more) detection events will be counted as a coincident event if the difference of their time stamps is less or equal than the specified time window. The trend of a selected count rates can be displayed in the line graphs.

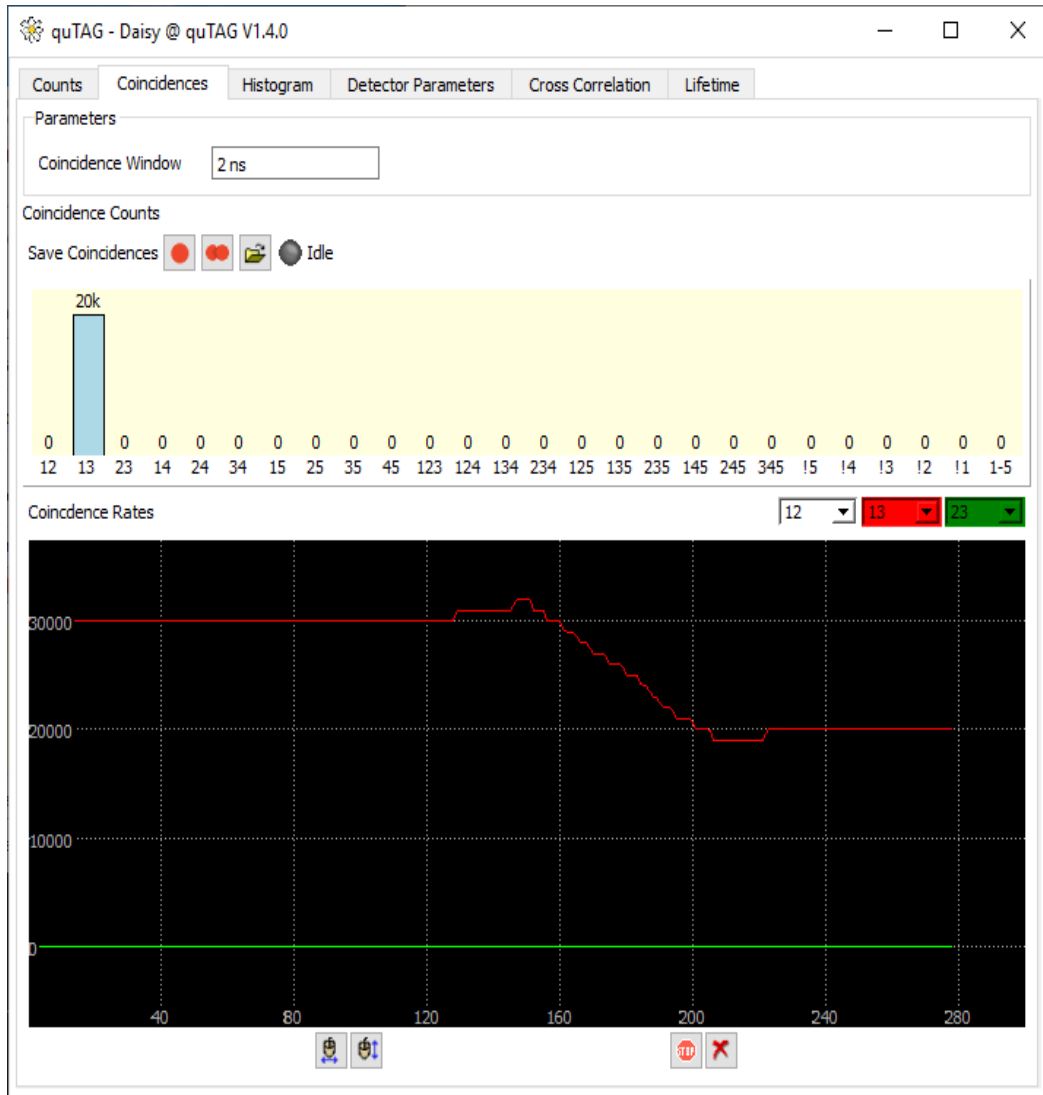


Figure 10: Coincidence counting tab of Daisy

7.3 Histograms

Timestamps histograms accessible in the "Time diffs" tab shown in the following figure. The histogram is calculated in the PC, therefore only timestamps transferred to the PC contribute to it. Timestamps filtered out or suppressed by the "single stop" feature don't show up here.

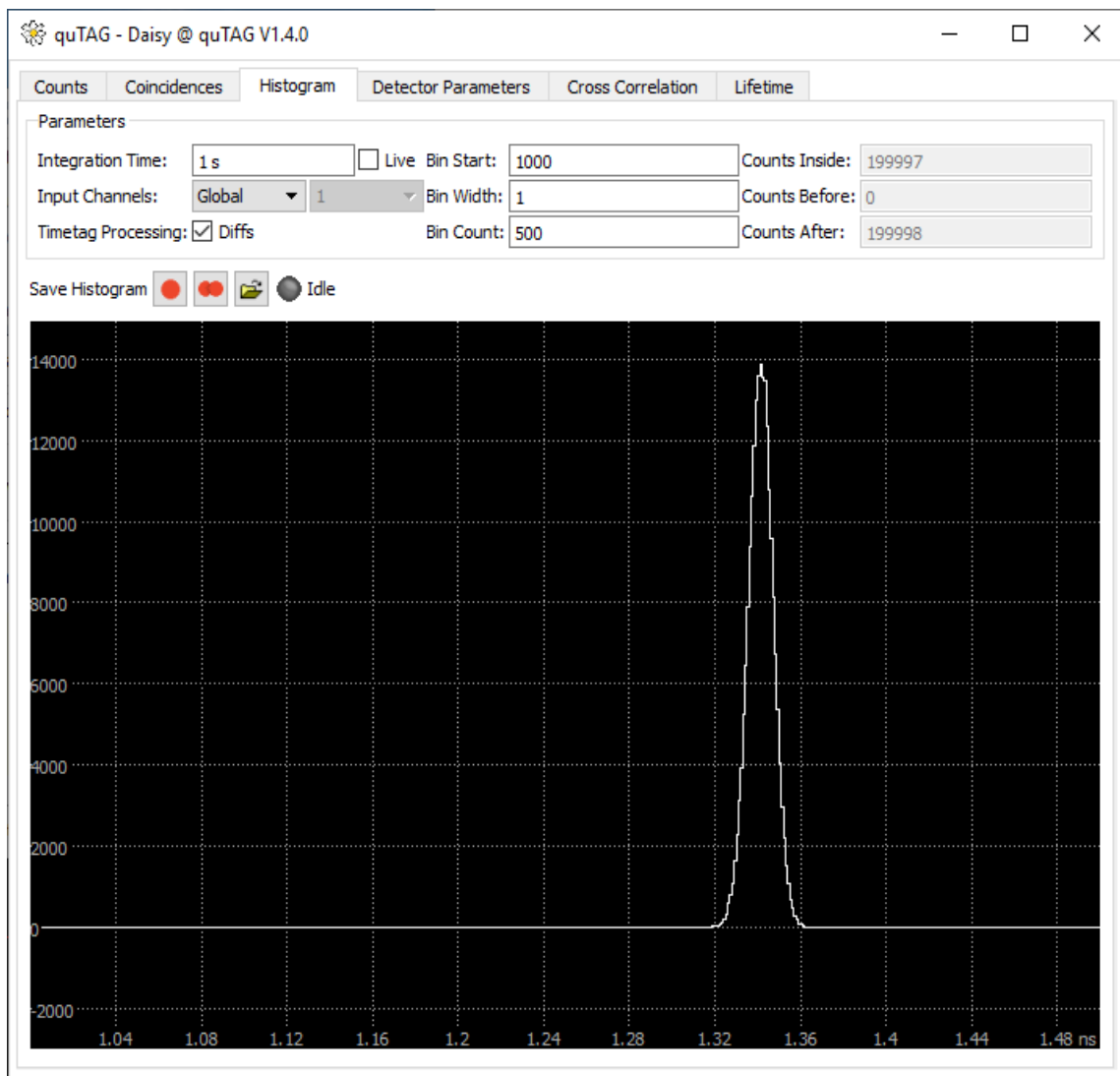


Figure 11: Histogram tab of Daisy

To configure the histogram measurement, the bin width, bin count and the value of the first bin can be configured under "Histogram Window". Note that negative values are not allowed for these settings. Which channels contribute to the measurement can be chosen in the "Histogram" drop-down menu. If "Global" is selected all Timestamps from all channels used are used as start and stop events. If a histogram from one channel using the start-stop mode is desired, use the same channel name for both inputs and deselect "diffs".

The integration time of each measurement is set at "Exp. Time". If "Live" is not selected, the finished histogram is displayed after every measurement (equals the exposure time), otherwise a "live view" of the running measurement is shown.

If "Diffs" is selected, the differences of consecutive Timestamps are added to the histogram. Use this setting if the time differences between events on different stop inputs are of interest. If "Diffs" is not selected the absolute value of individual timestamps are added to the histogram. Use this setting if the time between events on the start input and a stop input is of interest.

The data of the currently displayed histogram or of every finished measurement can be saved using the buttons next to "Save histogram".

7.4 Correlation Measurement: HBT

The HBT measurement and fit feature is accessible in the "Cross Correlation". This tab will only be visible if the "HBT" option (see chapter 4) is activated.

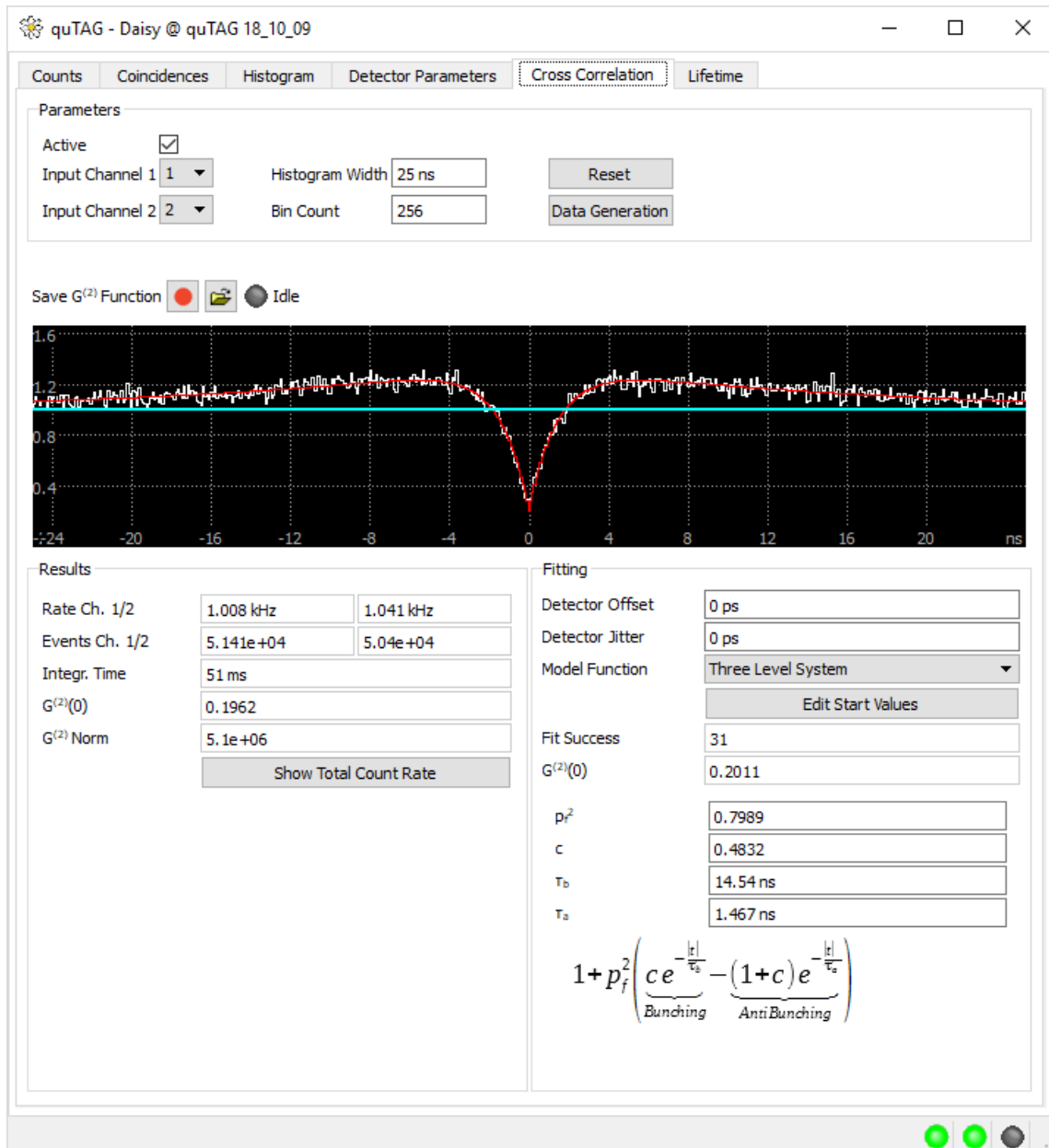


Figure 12: HBT measurement and fit tab of Daisy

The measurement is configured in the "Parameters" field. Here the histogram width, a bin count as well as the two input channels are selected. Select "active" to start collecting the correlation data.

The "Results" shows several parameters of the current measurement including the event rates, measurement time and the $g^{(2)}(0)$ value.

In the "Fitting" field a model function for the fit can be chosen. The result of the fit is displayed in the bottom field. The fit is only valid, if the number next to "Fit Success" is positive. If no fit can be found, please adjust the starting values using the "Edit Start Values" button.

The available models for the correlation function are shown below. With these, thermal photons, single photons (antibunching) and three-level-systems can be described.

Thermal
$$g_{th}^{(2)}(t) = Ae^{-\frac{t^2}{2c^2}} + B$$

Antibunching
$$g_{ab}^{(2)}(t) = 1 - e^{-\frac{|t|}{\tau_a}}$$

Three-Level-System
$$g_{tl}^{(2)}(t) = 1 + p_f^2 \left(ce^{-\frac{|t|}{\tau_b}} - (1 + c)e^{-\frac{|t|}{\tau_a}} \right)$$

Additional fit models which take detector offsets and jitter into account are available. If they are used, the appropriate values for the detectors have to be entered in the "Detector Parameters" field.

The "Data Generation" dialog allows to demonstrate the functions with data generated by one of the model functions.

7.5 Lifetime Measurement

The lifetime measurement and fit feature is accessible in the "Lifetime" tab in the daisy software. This tab will only be visible if the "Lifetime" option (see chapter 4) is activated.

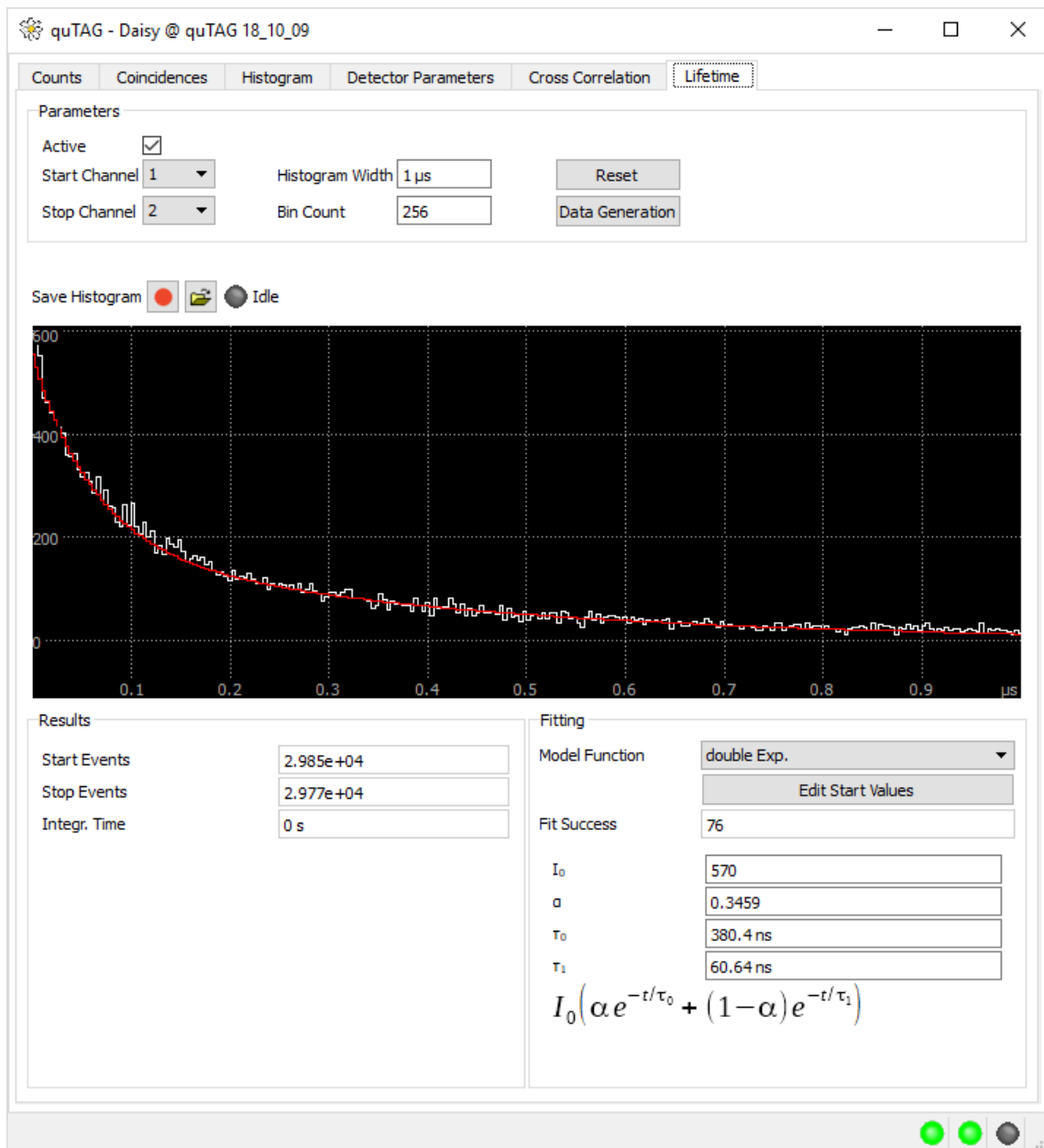


Figure 13: Lifetime measurement and fit tab in daisy software

The measurement is configured in the "Parameters" field. Here the histogram width, a bin count as well as the two input channels are selected. The lifetime histogram is calculated from the difference between the stop and the start channel. Select "active" to start collecting the lifetime data.

The "Results" shows several parameters of the current measurement, showing the event rates and the measurement time.

In the "Fitting" field a model function for the fit can be chosen. The result of the fit is displayed in the bottom field. The fit is only valid, if the number next to "Fit Success" is positive. If no fit can be found, please adjust the starting values using the "Edit Start Values" button.

The available models for the lifetime function are shown below:

Exponential fit
$$h_{exp}(t) = I_0 e^{-\frac{t}{\tau_0}}$$

Double exponential fit
$$h_{de}(t) = I_0 (\alpha e^{-t/\tau_0} + (1 - \alpha) e^{-t/\tau_1})$$

Kohlrausch fit
$$h_k(t) = I_0 e^{(-t/\tau_0)^\beta}$$

The "Data Generation" dialog allows to demonstrate the functions with data generated by one of the model functions.

7.6 Detector Parameter Settings

Input parameter settings like the trigger level and rising/falling edge detection can be configured in the "Detector Parameters". After a restart of the device, all channels are by default configured to detect the rising edge of input signals at a trigger level of 1 V, which is suitable for LVTTTL signals.

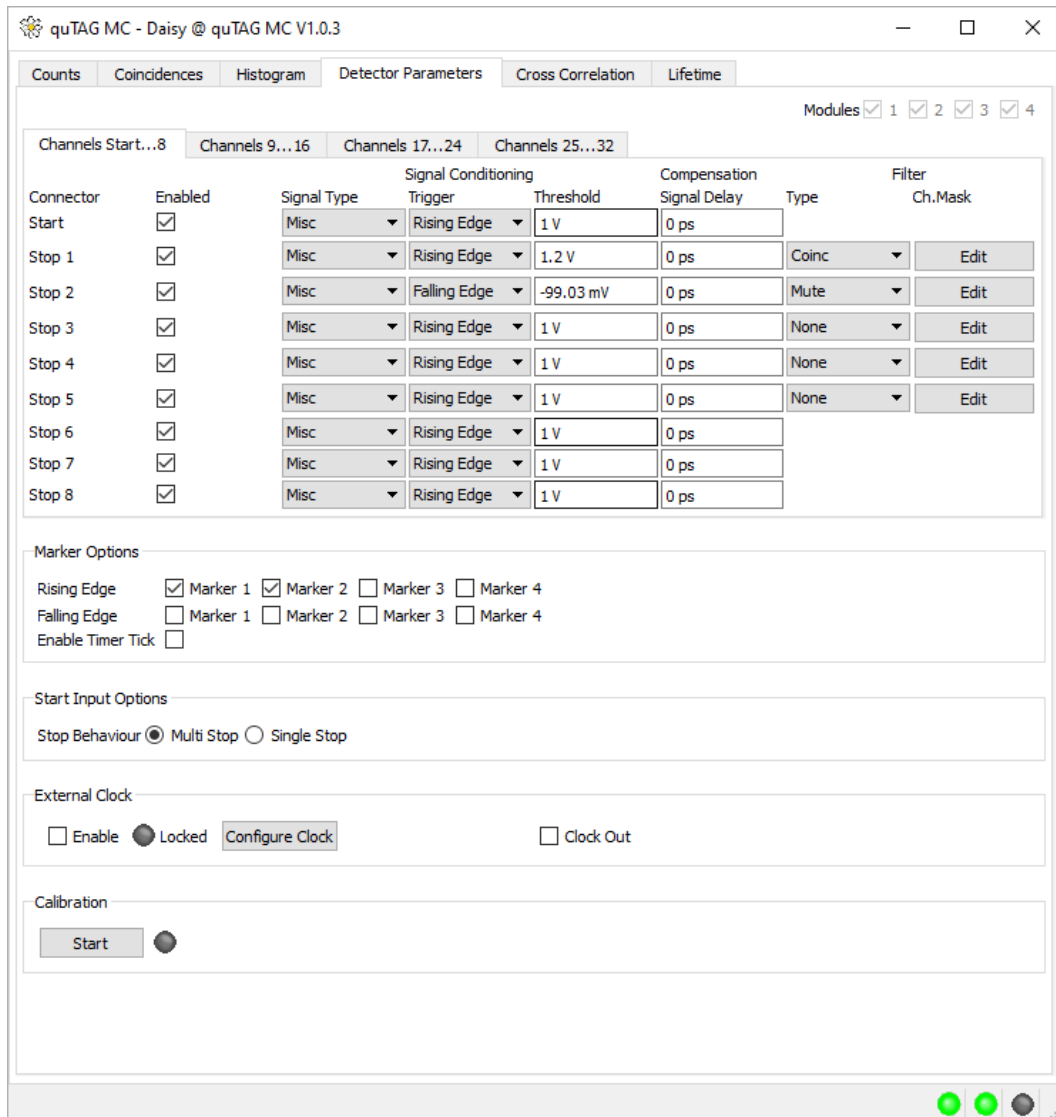


Figure 14: Input parameter settings in Daisy

Please note that these settings are saved in the device and therefore persistent between software restart. Only a restart of the device will reset all settings to their default values.

Connector	Enabled	Signal Conditioning		
		Signal Type	Trigger	Threshold
Start	<input checked="" type="checkbox"/>	Misc	Rising Edge	1 V
Stop 1	<input checked="" type="checkbox"/>	Misc	Rising Edge	1 V

The checkboxes next to "Enabled" can disable individual inputs. If a channel is disabled, no events will be detected on this channel and the events will not be processed.

The trigger level and rising/falling edge detection of each input can be configured with the inputs under "Signal Conditioning". Presets for the common LVTTTL and NIM signal standards can be chosen under "Signal Type".

The "Signal Delay" setting can be used to compensate runtime differences between -100 ns and 100 ns for each input.

In the filter section, different filters can be defined for channels 1-5. Events that are filtered will not be transferred to the PC but they will continue to contribute to count rates and correlations. "None" means that all events are processed and filtering is not active. There are three types of filter currently available (see section 7.7). The channel mask is a parameter of some filter types that can be edited by pressing "Edit".

Compensation		Filter	
Signal Delay	Type	Ch.Mask	
0 ps			
0 ps	None		Edit
0 ps	None		Edit
0 ps	None		Edit
0 ps	None		Edit
0 ps	None		Edit
0 ps			
0 ps			
0 ps			

Marker Options

Rising Edge Marker 1 Marker 2

Falling Edge Marker 1 Marker 2

Enable Timer Tick


The marker channels can be enabled globally and individually. The device internally generates a timer tick every millisecond for timing purposes. Markers and timer ticks can't be observed in the GUI itself but only in stored data. They show up as channels 100-103 (markers) and 104 (timer tick).

Start Input Options

Stop Behaviour Multi Stop Single Stop

In the next section, some options related to the start channel can be configured. When using the Single Stop mode, only the first event after one start channel event of each stop channel will be transferred to the PC, all others will be suppressed. The multi stop mode will process all events.

Calibration

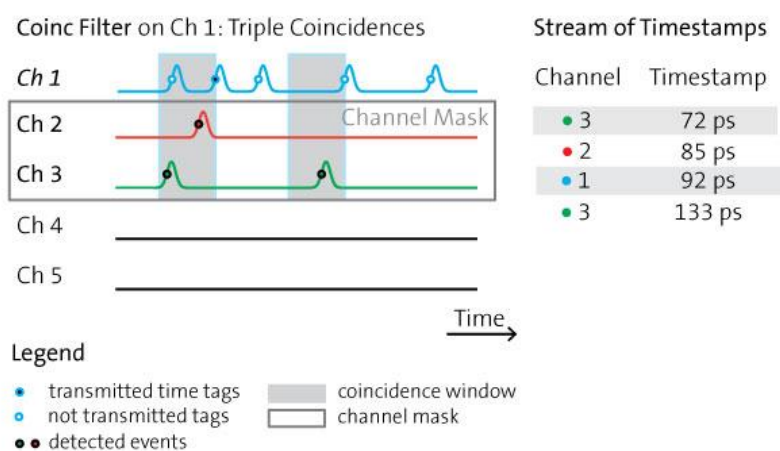


In order to achieve constant measurement resolution, an internal calibration process has to be performed from time to time. It may need to be redone when the temperature of the device or the environment have changed. The process doesn't require user support and is run each time Daisy is started. It can be retriggered by clicking "Start" in the calibration part.

7.7 Filters

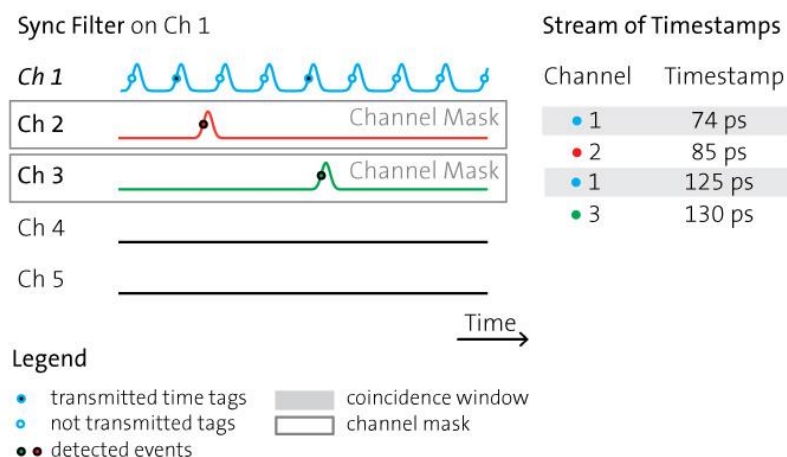
The following filters are applicable on input stop channels 1-5. A filter can be applied by choosing the filter type for the desired channel. After that, a channel mask for Coinc and Sync filters has to be applied on the related channels. The channels can be applied by pressing "Edit" and activating the desired checkboxes, see figure on page 31.

- Mute** This filter mutes the channel. This means that all events at this channel are processed internally and can be used for coincidence counting or other filters, but will not be transmitted to the PC.
- Coinc** The coincidence filter will only transmit the time tag to the PC if earlier events have been detected on each channel of the channel mask within the coincidence window (as defined in the "coincidence" tab).



The filter can also be applied symmetrically, e.g. to two channels, each one with the channel masks reversed. Hence, a huge variety of filtering options is available.

- Sync** The Sync filter will only transmit a time tag when a later event is detected at one of the channels of the "channel mask".



This filter is useful e.g., for a laser trigger signal when there is not a lot of detection signals. Trigger events not followed by a detection event are useless and will be suppressed.

- None** No filtering.

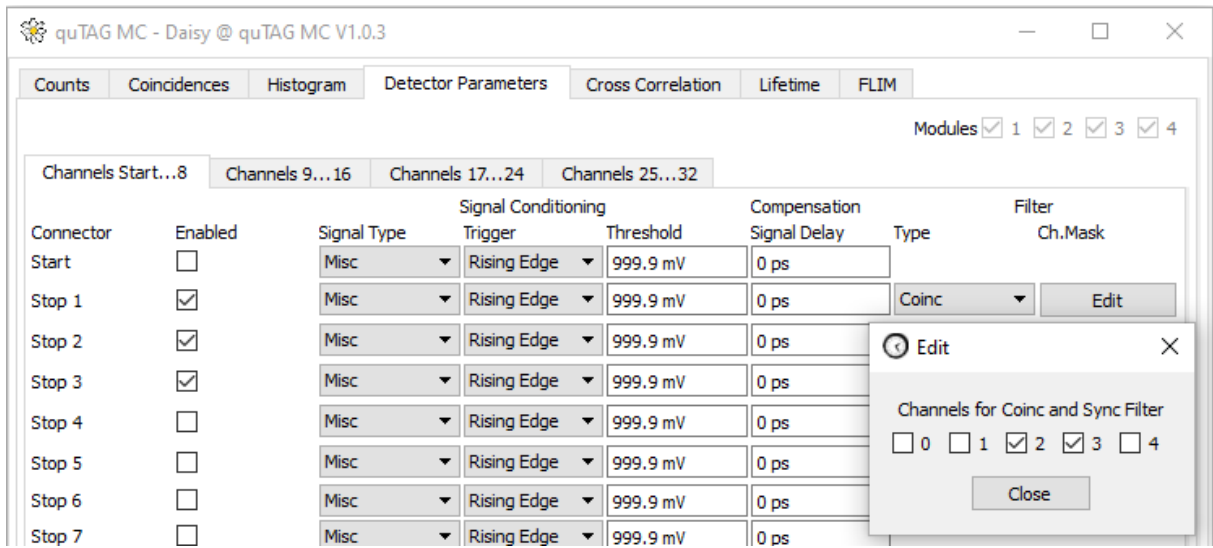


Figure 15: Filters can be applied in the Daisy software at the "Detector Parameters" tab.

8 Other Software Components

8.1 quTAG custom software ("DLL")

The software packet provides a shared library (DLL or shared object) that allows to access the quTAG from custom software. The development kit is located in the subdirectory userlib:

userlib\lib	All required shared libraries and a proxy lib (Windows only). The libs must be made available for the program loader when running an application.
userlib\inc	A couple of header files for custom programming of the lib.
userlib\doc	Documentation of the functions in HTML format. It can be opened by the link userlib\documentation.html .
userlib\src	A couple of example in C.
userlib\labview	LabView VIs that wrap every single function together with some simple examples (Windows only).

For further information using the DLL, see the software manual with Python examples.

8.2 Tarec

Tarec (quTag Record & Merge Tool) is a tool for use with synchronized devices (see section 5.6). It connects to all available devices at the same time, records their time tag streams and merges them into a single timeline. Tarec is able to handle more events per second than Daisy. Please close all instances of Daisy before starting Tarec. The Tarec GUI is shown in the following figure.

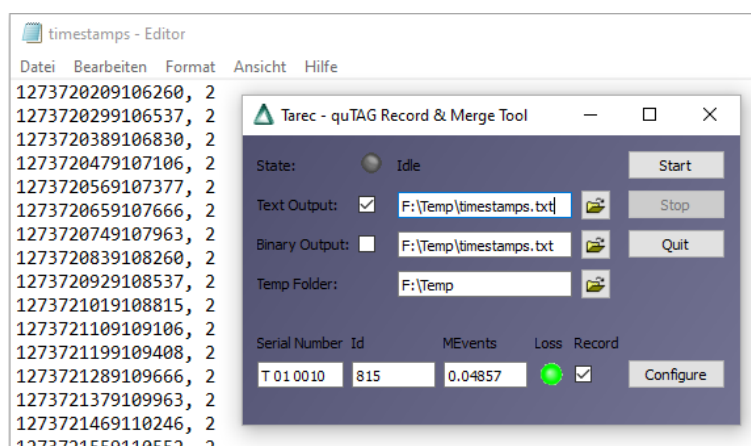


Figure 16: Tarec tool recording data and saving timestamps.

The serial number, hardware ID and an approximate number of recorded events are shown on the bottom for each connected device. The "Config" buttons on each line can be used to configure the inputs of the devices similar to the "Detector Parameters" tab in daisy introduced in section 7.6 .

Whether a text or a binary output file is created and their filenames can be chosen next to "Text Output" and "Binary Output". Recording data is controlled using the "Start" and "Stop" buttons.



For performance reasons, Tarec works in two steps: In the first step (after Start has been pressed), the time tags are stored in temporary files per device. In the second step (after Stop has been pressed), that files are read back and the timestamps are merged into the target file(s). The state indicator turns yellow and shows "Saving". If Tarec is closed in that state, the recorded data are lost.

8.3 Command Line Interface

The command line interface can be used for some simple tasks as a one-time readout of the count rates, writing time stamps to a file or saving histogram data. To use it, open a command prompt, go to the software directory and call `tdccli(.exe)`. Use the parameter `-h` for additional information.

The CLI program also serves as an example DLL application. The source code is available in `userlib\cli`.

9 FAQ / Trouble Shooting

9.1 USB Driver Version

Problem	Windows only: The software doesn't find any device. The software claims "Wrong version of USB Driver installed".
Cause	The quTAG is using an USB chip of FTDI. The Software works with FTDI's driver version 1.2. In the meantime, FTDI published version 1.3 which breaks the Software (we are convinced that the version is buggy but were not able to settle that with FTDI). The quTAG software installer is installing 1.2, but Windows sometimes updates to 1.3 autonomously. We don't know when and why that happens but it has sometimes been observed directly after installing the quTAG Software. This applies to Windows 7, 8, and 10.
Solution	The driver version 1.3 has to be removed and replaced by 1.2. To remove, open the device manager, click the device ("FTDI Bridge Device" or "quTAG R3") and disable the driver. Select the option "remove driver from PC" (or similar). Sometimes Windows offers an option "return to old driver version" (or similar) - that also works. Then install again the Software package, the previous installation hasn't to be removed.

9.2 Firmware Version

Problem	The Daisy software warns that the firmware version doesn't match the software version.
Cause	In many cases new software packages come along with new firmware files. The software can work correctly only if the matching firmware is installed.
Solution	Call the flasher tool "nhflash(.exe)" of the new software package and press "Flash" to update the firmware.

9.3 Unexpected Delays

Problem	The time differences between events happening on different input channels are systematically wrong by some nanoseconds.
Cause	quTAGs input signals have slightly different internal runtimes. The "signal delay" function is used to compensate that as well as external runtime differences. On delivery, the delays are not calibrated.
Solution	To remove the runtime difference between two channels, connect them with input signals of known pulse distance and adjust the signal runtime until the quTAG reproduces the known value.

9.4 Low Resolution

Problem	The quTAG MC has very low time resolution.
Cause	After starting the quTAG, the internal electronics are not in a thermal equilibrium. When the device temperature changes in the first minutes, the timing jitter degrades due to the different conditions at the startup calibration.
Solution	Perform the calibration procedure according to the handbook. At the Daisy start or restart, the calibration procedure is performed automatically.

10 Revision History

Revision	Date	Changes
1.0.0	2021-01-01	initial release