



Gasific 7.0 Manual

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This document provides a brief description of Gasific 7.0, the latest version of the digital data acquisition system developed for nuclear spectroscopy experiments at IFIC-Valencia. It gives a general overview of the system and its main features and describes summarily how to configure and run it.

1. General description

Gasific 7.0 is the latest version of the digital data acquisition system (DDACQ) developed by the Gamma and Neutron Spectroscopy group at IFIC-Valencia [1] for nuclear spectroscopy experiments. The system is based on VME digitizers from Struck Innovative Systeme [2]. The system can be configured to run with an external hardware trigger defining an event, but most often it is used in a self-triggered mode where the event definition is done via software *a posteriori*. Currently SIS3302 (100 MS/s, 16 bits, 8 channels) and SIS3316 (250 MS/s, 14 bits, 16 channels) digitizers can be employed. With some restrictions, also SIS3350 (500 MS/s, 12bits, 4 channels) digitizers can be used.

Every two (SIS3302) or four (SIS3316) input channels in the digitizer share a Field Programmable Gate Array (FPGA) that stores the firmware to process the digitized pulse. We use the standard *Gamma Firmware* from the manufacturer, which matches our requirements, for on-board data processing. A trapezoidal Finite Impulse Response (FIR) filter produces a short waveform for discrimination purposes (fast filter). Signals out of the fast filter that are larger than a given threshold generate an internal trigger for processing the input pulse with a second FIR filter for precise amplitude determination (slow filter). At the same time the crossing of the threshold by the rising flank of the fast filter signal retrieves the content of a sample counter with 48 bit capacity. This provides an absolute time stamp with 10 ns (SIS3302) or 4 ns (SIS3316) resolution (at the respective maximum sampling rate). The firmware includes also a Constant Fraction Discrimination (CFD) algorithm, which can provide sub-nanosecond time resolution. When activated, the timestamp mark is obtained when the falling flank crosses a value equal to 50% of the signal height. The slow filter is of trapezoidal type with compensation. The latter term refers to a correction for preamplifier signal exponential fall time, which the firmware presumes is the shape of the input signal. The parameters for both filters can be adjusted independently, according to the characteristics of the input signal.

Each acquisition channel has a 64 Mbyte (SIS3302) or 128Mbyte (SIS3316) on-board memory, where the result of the digital processing of the signal is stored. Typically the pulse information stored is reduced to the minimum, which includes the time stamp and the amplitude of the slow filter output. This requires 24 bytes of space per pulse for the SIS3302 including the header and information on pulse pile-up generated when a second pulse within the processing time produces an internal trigger. The minimum size per event is reduced to 16 bytes for the SIS3316, which excludes pile-up information. Other event data output options are available including the input pulse waveform, the output of the slow filter or the integral of the pulse waveform in specified intervals (only for SIS3316). Each channel memory buffer is divided into two banks. This allows one to accumulate data in one bank and at the same time retrieve the stored data from the second bank into the computer. This arrangement contributes to a reduction of the DDACQ overall dead time. The communication with the computer occurs typically via an optical link, which connects the SIS1100 PCI card with the SIS3100 VME interface card (both from Struck). Several PCI cards can be used to connect several VME crates, to increase the total number of acquisition channels. The SIS3316

digitizers can communicate directly with the computer via Ethernet. If only this type of digitizer is used then the use of SIS1100/3100 cards can be avoided. In addition a single SIS3820 clock distributor can be used to provide common sampling times for up to 32 digitizers.

The DDACQ software runs on a PC with a Linux Operating System. The software is organized into four parallel processes which are responsible for (1) hardware configuration and control, (2) block data read-out, (3) data storage on permanent media, and (4) on-line analysis. A fifth process, the Graphical User Interface (GUI), facilitates the control of these tasks. The GUI is built using Qt software [3]. For the communication and synchronization of the different processes Inter Process Communication (IPC) libraries available in POSIX [4] are used. Data is shared between processes through memory-mapped files. The use of semaphores regulates the traffic of data and resolves conflicts between processes. Data storage on disk has priority over the other processes. Read-out from a data bank, and accumulation on the alternative bank, is started by a Look At Me (LAM) signal generated when any channel memory content reaches a predefined value or after a predetermined time. On-line analysis can be very demanding, in particular the reconstruction of events and time correlations. The software uses parallel processing to speed it up. Nevertheless, typically only a fraction of the stored data is analyzed on-line. For construction, visualization and manipulation of histograms the DDACQ relies on the ROOT data analysis framework [5]. The DDACQ software uses a custom library which provides services as input/output abstraction, allowing to process data from hardware, file-system or network indistinctly, management of DDACQ configuration and setup, time stamp sorting, event windowing for classification and packaging, and data transformation for second level analysis. The library is written in C++11 using the standard template library, which provides genericity, predictable behavior in memory management and a well-known algorithm cost.

References:

- [1] J. Agramunt, et al., in: La Rabida 2012 International Meeting on Nuclear Physics; AIP Conference Proceedings 1541 (2013) 165.
- [2] Struck Innovative Systeme (<http://www.struck.de/>).
- [3] The Qt company (<https://www.qt.io/>).
- [4] POSIX Standard (<http://standards.ieee.org/develop/wg/POSIX.html>).
- [5] R. Brum, F.Rademakers, *ROOT: An object oriented data analysis framework*, Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment 389 (1997) 81.

2. Hardware configuration

The basic hardware configuration of the DDACQ includes a VME crate with a SIS3100 VME controller connected via optical fiber with a SIS1100 PCI card hosted in the acquisition computer and at least one digitizer module of the type SIS3302 or SIS3316. The number of digitizers that can be fitted in a VME crate depends essentially on power consumption. If more than one digitizer is used in one crate, each one must be identified with a unique hardware address, which is selected by the on board address selection wheel. Several VME crates can be used if each one is equipped with a SIS3100 card and the corresponding SIS1100 PCI card is installed on the PC. Alternatively the SIS3316 digitizers can be accessed directly through Ethernet. The internal sampling-clock from one digitizer unit (CO output in SIS3316) can be distributed to few other digitizers (CI input in SIS3316, input #4 in SIS3302) as an external clock, for synchronization. Alternatively a SIS3820 clock module can generate (or distribute from an input clock signal) a common sampling frequency for up to 32 digitizer modules. In addition to this a signal distributed to a predefined input in all digitizers (UI input in SIS3316, input #2 in SIS3302) can be used to reset simultaneously (and thus synchronize) all the time stamp counters.

References:

- [1] SIS1100/3100 PCI to VME interface User Manual
- [2] SIS3302 8 channel 100 MHz 16-bit Gamma FADC User Manual
- [3] SIS3316 16 channel 250 MHz 14-bit FADC User Manual
- [2] SIS3820-CLOCK clock/start/stop distributor for SIS33xx ADCs User Manual

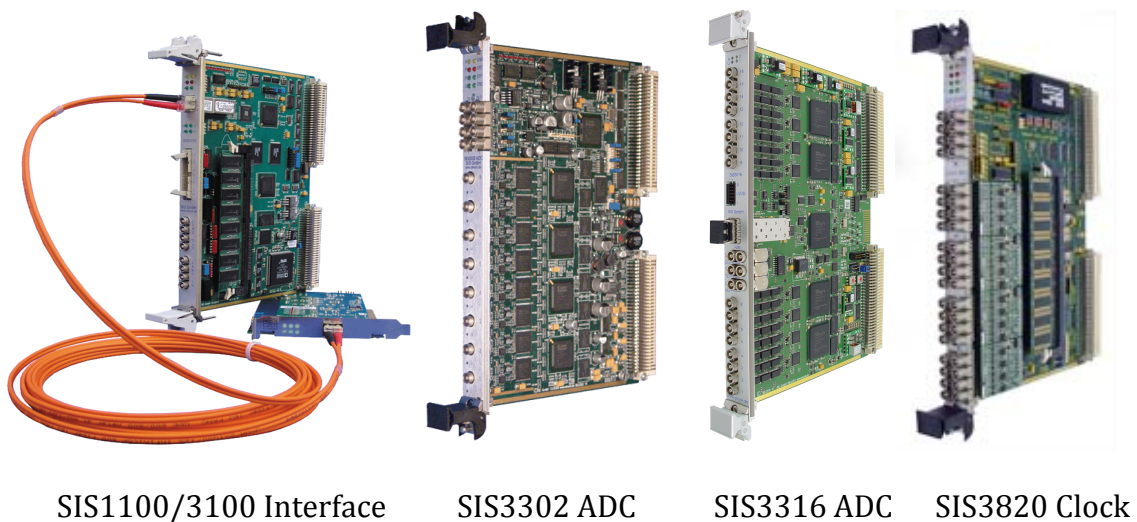


Figure 1. Electronic modules used by the DDACQ.

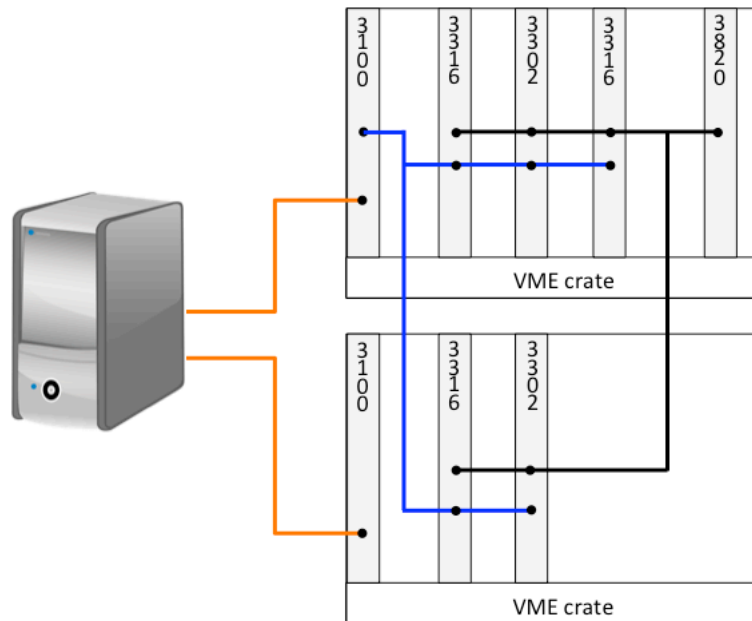


Figure 2. Example of connections for a system with 2 VME crates. Optical fibers (orange) connect the SIS1100 PCI cards in the PC to the 3100 interface/controller card in each crate. The SIS3820 distributes the clock signal (black) to all the digitizers SIS3302 and SIS3316. A signal generated in one 3100 module is distributed (blue) to all digitizers in order to reset simultaneously the time stamp.

3. Starting Gasific 7.0

To launch the DDACQ program one must start three independent processes: *AcqRead*, *RootDisplay*, and *GUI_DAQ*

AcqRead: establishes the connection between computer, via the SIS1100 PCI card, and the VME controller/interface SIS3100

RootDisplay: opens a Root display window for displaying on-line histograms

GUI_DAQ: opens the DDACQ control GUI window, the *MainWindow*

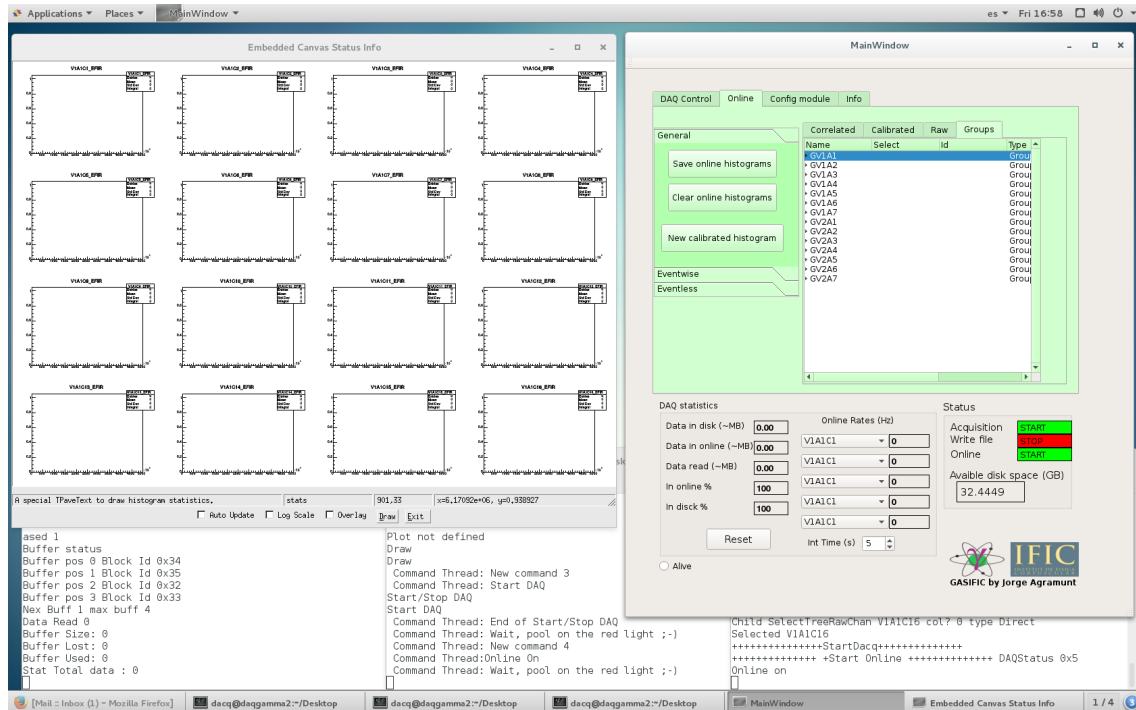


Figure 3. Screenshot of the PC display showing three terminals running the three Gasific 7.0 processes, the *MainWindow* and the *Root canvas*.

4. Gasific 7.0 configuration and control

The configuration of the DDACQ and the control of the acquisition are performed using the GUI. The **MainWindow** of the GUI includes four tabs/panels: *DAQ control*, *Online*, *Config module* and *Info* (not used at the moment)

4.1. DAQ control

See Fig. 4. Allows to start-stop the data transfer to the computer (*Start DAQ/Stop DAQ* button); to start-stop data writing onto disk (*Start File/Stop File* button: it prompts for a */path/filename* with default extension **.dlt*); and to start-stop the on-line analysis (*Start Online/Stop Online* button). In the lower part of the panel there are a few display boxes with useful information about the acquisition statistics: amount of data read from VME (in MByte), amount of data transferred to disk (both in MByte and as a percentage of data read), and amount of data analyzed online (both in MByte and as a percentage of data read). These values can be reset at any moment with an ad-hoc button (*Reset*). There are also up to five user defined on-line analysis ratemeters for individual acquisition channels. The rate is averaged over a user defined integration time *Int time (s)*. The total *Available disk space (GB)* is also displayed. The panel contains also a *Send Sync pulse* button, which generates a signal available at the LEMO output #2 of the SIS3100 module and can be sent to all digitizers in order to reset (and thus synchronize) the time stamp counters.

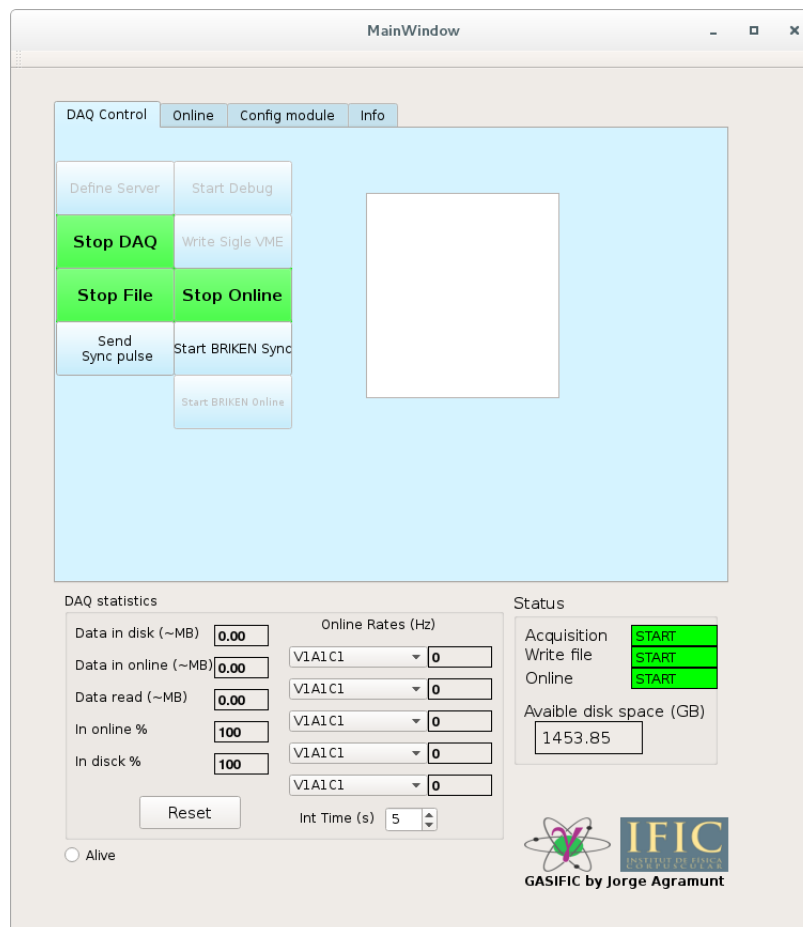


Figure 4. Gasific 7.0 DAQ Control panel.

4.2. Online

Allows to define, display, erase and save histograms used for the on-line analysis. See Fig. 5. There are four subpanels (*Raw*, *Calibrated*, *Correlated*, *Groups*) with different types of histograms:

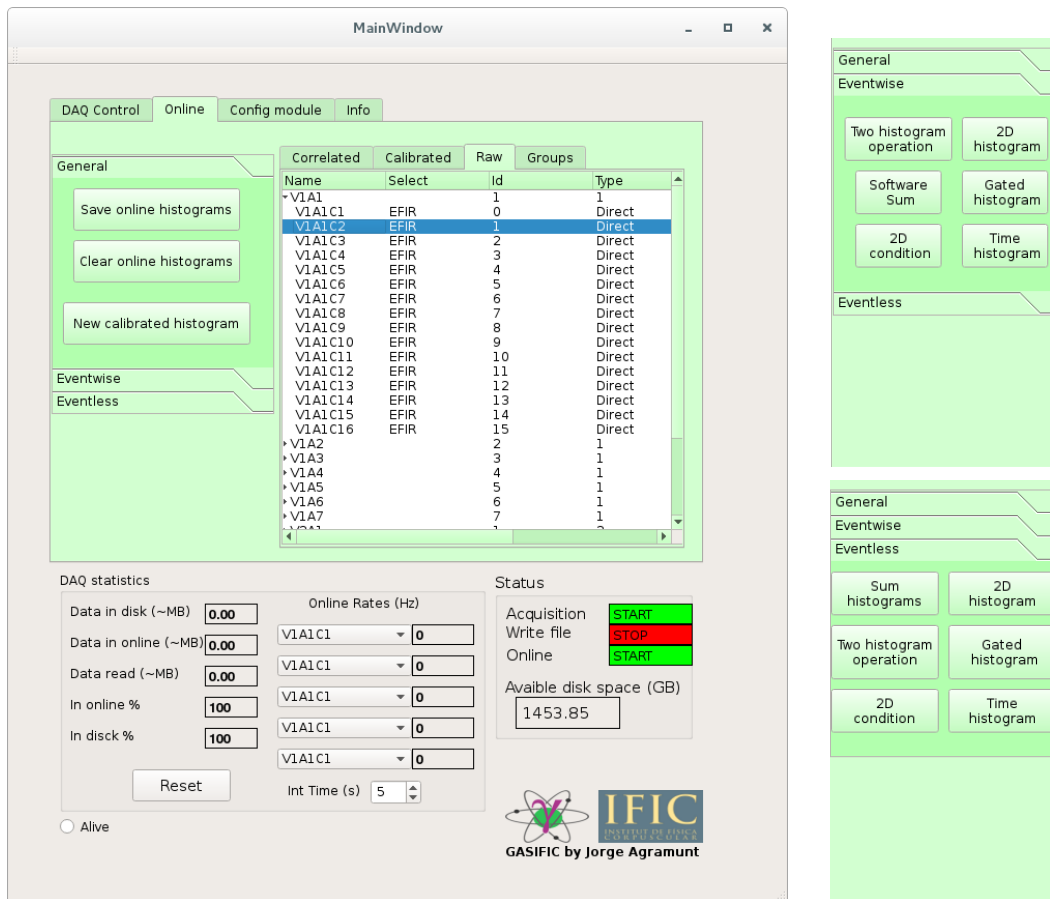


Figure 5. Gasific 7.0 Online panel showing the *General* tab. The *Eventwise* and *Eventless* tabs are shown on the side.

Raw: Contains raw uncalibrated unconditioned histograms. For every DDACQ channel defined in the configuration file and depending on the channel configuration (see below) one or more histograms can be displayed: *EFIR*, *Pulse height*, *Time stamp*, *CFD time*, *Samples*, *MAW samples*, They can be selected from a pick-up list after clicking the channel name with the mouse left button.

Calibrated: Contains calibrated unconditioned histograms. For every raw histogram one (or more) calibrated histogram can be defined. The calibrated histogram and the calibration parameters are defined using the *New calibrated histogram* button.

Correlated: Contains the histograms with conditions or correlations. For every calibrated histogram one or more gated or correlated histograms can be defined.

Groups: Contains groups of histograms for simultaneous visualization. Groups can be defined from histograms in previous tabs by selection with the mouse (left button to select histograms, right button to define the group).

The selected histogram, or group is displayed in the ROOT canvas. See Fig. 6. Selecting the *Update* button in the canvas shows “live” the accumulation of statistics in the histograms. Selecting the *Log scale* button defines a logarithmic scale for all histograms in the canvas. Selecting the *Overlay* button allows to superimpose several histograms in the same frame. The usual interactive ROOT functionalities (like histogram fitting) are available in this canvas.

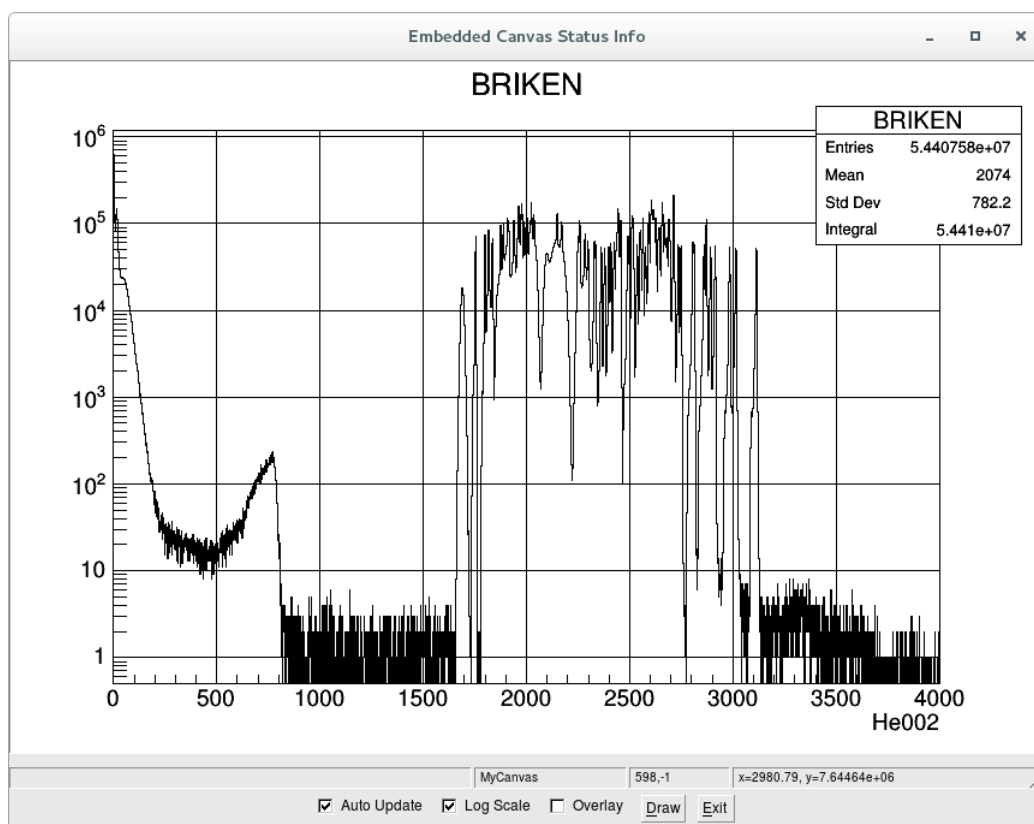


Figure 6. Example of ROOT display.

There are three additional subpanels *General*, *Eventless* and *Eventwise* that are used to perform or define additional operations with the histograms

General: Apart from the button to define a *New calibrated histogram*, it contains a button *Clear online histograms* to erase the content of all defined histograms (it asks for confirmation), and a button *Save online histograms* to save them in a **.root* file (it asks for a filename).

Eventless: Allows defining a number of operations and correlations between channel data of eventless (self-triggered) type. The channel data must be calibrated (the corresponding calibrated histogram must exist). There are six buttons (*Sum histograms*, *Gated histogram*, *Time histogram*, *Two parameter operation*, *2D histogram*, *2D Condition*). Clicking on each opens a pop-up panel.

Sum histograms: It is used to add the statistics of several histograms. No correlation is required in this case. See Fig. 7.

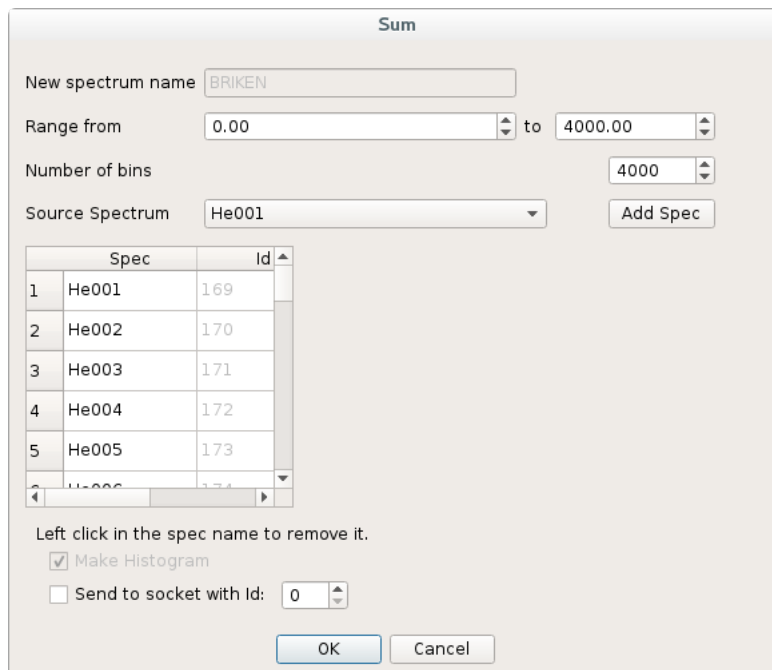


Figure 7. The *Sum histograms* popup panel.

The remaining functions require the definition of a time correlation window for application.

Gated histogram: Histograms calibrated channel data with a condition (gate) on another parameter (calibrated channel data). See Fig. 8.

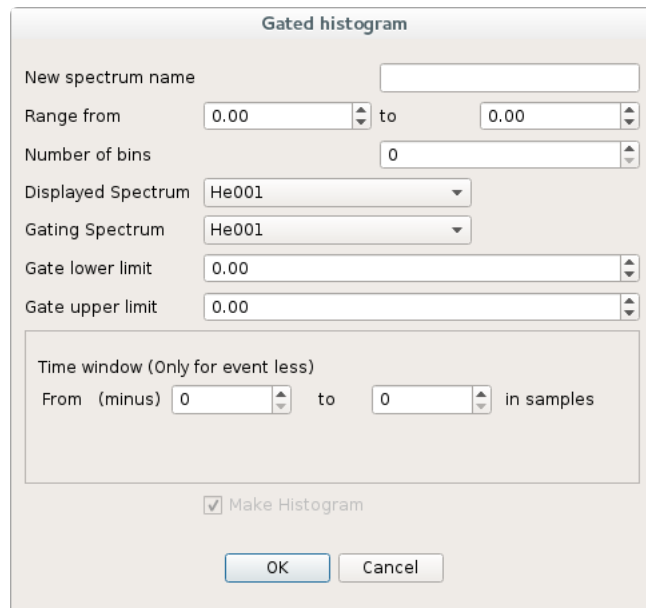


Figure 8. The Gated histogram popup panel.

Time histogram: Defines for one input channel a calibrated time stamp histogram (eventually with CFD correction) with an energy (amplitude) window selection (gate). See Fig. 9. Needed to construct time correlations between different channels. Useful also for cyclic type measurements.

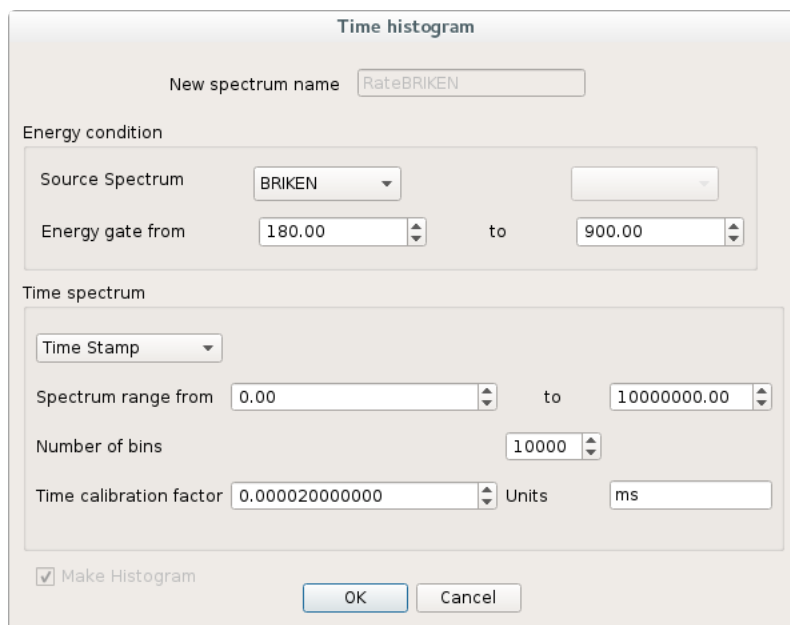


Figure 9. The Time histogram popup panel.

Two parameter operation: Performs operations (+,-,*,/) between two parameters (calibrated channel data). See Fig. 10. Can be used to define time correlations between two data channels, for example.

Figure 10. The *Two parameter operation* popup panel.

2D histogram: constructs a bi-dimensional plot between two correlated channel data. See Fig. 11.

Figure 11. The *2D histogram* popup panel.

2D condition: defines a bi-dimensional condition (banana) on a 2D histogram to apply to a given data channel. NOT WORKING CURRENTLY.

Eventwise: In this mode of operation, events are defined from the stream of data. An *OR* of all channels is used as “event trigger”. The first channel arriving opens an event time window whose length is currently set internally (10 microseconds). All channel data arriving within this window are grouped as one event. The first channel data after the window opens a new event window. There are six buttons (*Software Sum, Gated histogram, Time histogram, Two parameter operation, 2D histogram, 2D Condition*) to define similar conditions and operations between parameters as in the *Eventless* case using popup menus, but in this case no time correlation window need to be defined. The only difference is that a *Software Sum* button replaces the *Sum histograms* button, which allows defining the sum of the values of several calibrated channel data. This is useful to sum-up all the energy released in a multi-detector system.

4.3. Config module

Allows defining the configuration of the channels in each digitizer module to be included in the DDACQ. The *Add Module* button opens a *Dialog* window for setting the module and channel parameter data. See Fig. 12.

Figure 12. The *Dialog* popup panel for channel configuration.

Module data:

VME ID: enter the module VME address as defined by the address wheel on the digitizer board.

Name: enter a name to identify the digitizer module

Type: select SIS3302 or SIS3316

Memory length for LAM (kw): give the amount of buffer occupation (value in kwords) that signals the swap of memory bank. In any case the memory is swapped after 2 seconds.

Clock source: select internal or external (LEMO)

Clock frequency: select the sampling frequency for internal clock source

Communication: select the PCI sis1100 device (/dev/sis1100_XXremote) on the computer

Crate number: enter a number to identify different VME crates

Channel data:

Channel n°: select the channel to be configured

Name: enter a name to identify the channel

Enable: Click to include this channel in the DDACQ

Fast filter (trigger):

(Parameters of the trapezoidal filter or moving averaging window MAW)

Integration length: (or peaking time) of the filter in samples

Flat-top length: (or gap minus peaking time) of the filter in samples

Pre-trigger delay: enter a value, in samples, that allows seeing clearly the slow filter output baseline (around zero). The position of the trigger corresponds to the sample value after the rising flank of the fast filter output crosses the threshold, except if the CFD option is activated. In this case the trigger position corresponds to the sample value after the falling slope crosses half of the fast filter amplitude.

Threshold: for triggering, in trapezoidal filter units

Trigger gate length: length, in samples, of the input waveform for processing (identical to the energy gate length)

Slow filter (EFIR):

(Parameters of the trapezoidal filter with signal fall-time compensation)

Integration length: (or peaking time) of the filter in samples

Flat-top length: (or gap minus peaking time) of the filter in samples

Tau correction (ns): value in nanoseconds of the input signal mean decay time

Averaging/decimation: number of samples used for decimation (SIS3302) or averaging (SIS3316)

Energy pickup: enter the number of samples to skip in order to look for the maximum of the slow filter output

Input signal:

(Input channel parameters)

Input range: select 2V/5V for SIS3316, fixed 2V for SIS3302

Input impedance: select 50-Ohm/1-MOhm

Negative signal: select, if signal is negative (signal is inverted)

Signal offset: enter a value, in DAC units (16 bit), that maximizes the dynamical range. Depends on polarity, range and module type.

Configuration logic:

(Defines the trigger logic that fires the acquisition)

The following parameters can be selected: *External veto*, *External gate*, *Internal gate 1*, *External gate 1*, *External trigger*, *Internal trigger*, *Int sum trigger*. Refer to the *Gamma Firmware Manual* for further details.

To run in self-triggered mode select *Internal trigger* alone.

Accumulators:

(Define up to eight regions for input signal integration or QDC mode. Not available for SIS3302 modules.)

For *Accum 1* to *Accum 8* one can define

Start sample: first sample for the integration counted from the pre-trigger delay value

Length: number of samples for integration

Histogram range:

Define the range of values to be stored in the raw online histograms in the appropriate units. All raw histograms have a fixed number of channels (bins) of 16000. The range can be defined for *EFIR*, *Pulse height*, *CFD time*, *Time stamp* and *Accum 1* to *Accum 8*.

Signal sample range:

(Defines the range of the input signal waveform for storage and visualization)

Start sample: first sample for storage counted from the pre-trigger delay value

Length: number of samples to be stored

Output:

(Defines additional information to be stored on disk for every active channel)

Save energy (slow filter): stores the base line value and the maximum value of the slow filter output.

Save pulse height, Accum 1-6: stores the position and maximum value of the input signal and the content of Accumulators 1 to 6.

Save Accum 7-8: stores the content of Accumulators 7 and 8.

Save CFD values: stores the maximum value of the fast filter and the fast filter values at the sample before and the sample after the 50% of the maximum value. Currently valid only for SIS3316.

Save fast filter samples: not implemented at the moment.

Save slow filter samples: stores a portion of the slow filter output (fixed to 800 samples for SIS3316, and 510 for SIS3302).

Slow filter start sample: enter the beginning of the range to be stored

After completing a channel configuration clicking on *Set Channel* saves the information entered and allows the selection of a new channel for configuration. Beware that some of the parameters can only be configured for a group of channels and not for individual channels. In this case the program copies the value for the first channel in the group to the other channels. After entering the parameters for all required channels clicking *OK* closes the *Dialog* window and returns to the *Config module* panel. In the panel a list of all modules that have been configured will appear.

To load effectively this configuration into the appropriate registers of the digitizer modules one must press the *Send to Hard* button. The configuration can be saved also on disk as an *excel* file by pressing the *Save Conf* button (it prompts for a filename with **.xlsx* extension). A configuration stored on disk can be retrieved pressing the *Load Conf* button and then loaded into the modules with the *Send to Hard* button. A loaded configuration can be changed by double clicking on the

listed module names, which opens the *Dialog* window. It is also possible to edit and change directly the **.xlsx* configuration file. The configuration file will contain also all histogram information for the online analysis. This includes the definitions of raw, calibrated, and conditioned histograms as well as the groups.

For further information about the configuration of digitizer modules refer to the appropriate Gamma Firmware User Manual.

References:

- [1] SIS3302 14xx Firmware – Gamma User Manual
- [2] SIS3316 16 Channel VME Digitizer User Manual

5. Running Gasific 7.0

It is a good practice to create beforehand an independent directory for every experiment and define it as the default directory.

To run Gasific 7.0 open three independent terminal windows (shells) and launch in each one, the three processes *AcqRead*, *RootDisplay*, and *GUI_DAQ*. This will open the *MainWindow* and a ROOT canvas for displaying histograms. It is also a good practice to rename each of the terminals with the name of the process running in it. **Never close these windows while running.**

The next step will be either to define a new DDACQ configuration or to load an existing one. In the first case one uses the *Config module* panel. When finishing, remember to save the configuration file on disk (*Save Conf*). This writes an *excel* file with a given name containing all the information. The file can be edited directly to change the configuration parameters. You can use *Load Conf* to retrieve an existing configuration file. In both cases one must use *Send to Hard* to store the configuration in the appropriate registers of the modules.

At this moment one can start the acquisition. In the *DAQ Control* panel use the *Start DAQ* button to start it. You must also press the *Start Online* button if you want to start filling the online histograms. You can verify in the *Online* panel the available histograms for display. If nothing else was defined you will see the *Raw* histograms for every channel enabled. By clicking on the channel name you will be able to select from a drop-down menu the parameter to display in the ROOT canvas (EFIR, Peak height, ...). In addition, or alternatively, one can start the data storage on disk (list mode) for offline processing using the *Start File* button and defining a filename (*/path/filename.dlt*). The three actions can be interrupted independently (*Stop DAQ*, *Stop Online*, *Stop File*).

Typically one may wish to define a *New calibrated histogram* (in the *General* subpanel of the *Online* panel), using calibration parameters obtained from the raw spectra. One may wish also to define histogram with conditions (requires the use of already calibrated histograms) using some of the possibilities of the *Eventless* (or *Eventwise*) subpanel. One can also define *Groups* for simultaneous visualization of a number of histograms. After defining the desired histograms and groups remember to save again the configuration file to store the new histogram definitions. The content of all histograms defined can be saved on disk at any moment as a *.root file (*Save online histograms*) with a given name, or erased (*Clear online histograms*)

Obtaining the appropriate parameters for the digital processing of input signals can be tricky. The optimum parameters depend on noise, rise-time, fall-time and amplitude of the signals (use an oscilloscope to verify them). Always use the *Signal samples* and *Save slow filter samples* features in the channel configuration to visualize the signal and the output of the filter (selecting *SamplesMAW* in the channel display, see Fig. 13). Choose the *Input range* (in Volts) appropriate to the amplitude of the signals. Choose values of *Integration length* and *Flat-top length* for the fast filter on the order of few hundreds of nanoseconds and a *Threshold* value

which can vary wildly depending on digitizer resolution, fast filter parameters and signal characteristics (values can change from 10 and 10000). Choose starting values for the slow filter *Integration length* and *Flat-top length* around 1-2 microseconds. The *Tau* parameter can be easily determined looking to the signal in an oscilloscope. Select the appropriate polarity and an appropriate value of the *Signal offset* to see the signal base line close (but not too close) to the bottom. If you don't see any signal you might need to adjust your threshold. Select the *Trigger gate length* (which is also the *Energy gate length*) and *Pre-trigger delay* in order to see clearly the base line (with a value around 0) and the flat top of the filter output signal. The *Pre-trigger delay* value depends on the parameters of the fast filter (*Integration length* and *Flat-top length*) and whether *CFD* is activated or not. Beware also that the actual start off the signal can vary considerably depending on shape, amplitude and noise of the signal. If you only see noise in the output of the filter you need to adjust your threshold.

Now one can optimize the shaping parameters of the slow filter. In general increasing the *Integration length* improves the energy resolution, but at the cost of an increased channel dead time thus a balance between the two could be needed. Check the resolution as a function of this parameter looking at the EFIR histogram and choose an appropriate value. Some detector types require values around 10 microseconds. The value of the *Flat-top length* can have also an impact but should not be made unnecessarily long. Remember to adjust the values of *Trigger gate length* (*Energy gate length*) accordingly. You might want at this point to optimize the parameters of the fast filter in order to improve the separation of low amplitude signals from noise and the time resolution. Again a compromise must be met as both requirements demand opposite variations of the *Integration length*. Adjust the threshold value to cut (most of) the small amplitude noise looking at the EFIR spectrum. Once you have finished, and unless you want explicitly to store this information, do not forget to switch-off the *Signal Samples* and *Slow filter samples* as this increases tremendously the amount of data written on disk.

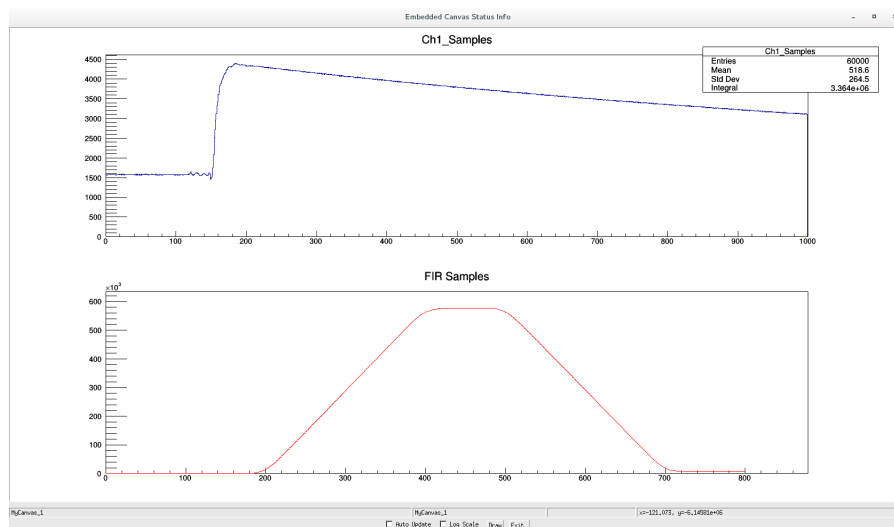


Figure 13. The *SamplesMAW* ROOT display showing the input signal (top) and the output of the slow filter (bottom).