

# **Overview Of LabVIEW VI For Real-time Data Acquisition Incorporating High-speed Software Correlator For Single-molecule Spectroscopy**

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## **1. General Explanation**

### **1.1 Overview**

The running of the real-time correlator relies on four different units—data acquisition, data storage, data analysis, and data display—each embedded in a “timed loop” running in parallel with the other three.

### **1.2 Program Initialization**

The clock, which determines the temporal resolution of the ACF function, is either generated using the pulse generation function of the counter board or set as 20MHz or 80MHz based on the built-in time bases--dependent on the value set by the user. What follows is the initiation of computer resources, including the file creation, array and FIFO buffer allocation, and the initiation of the ACF dynamic link libraries. Next the counter board is configured in the desired acquisition mode and started. The data acquisition unit is next independently executed (before the other three units are started) for several loops to place some data into the FIFO buffer. The reasons this is necessary are two-fold. The first reason relates to data synchronization. If at the beginning the FIFO buffer is left empty, the data acquisition loop tries to write data into it while storage and analysis unit try to read data out. As the order of these actions is indefinite, asynchronization may result. This problem is likely to be more serious in the case where synchronization is important such as in cross-correlation. Placing data into the FIFO buffer ensures that there is data available for the storage and analysis units. In addition, as will be discussed later, the acquisition loop may fail to supply new data as a result of DAQ error. Second, the measure for excluding corrupted data, which will be discussed later, requires keeping certain amount of data in the buffer so as to discard them when an error occurs.

### 1.3 Acquisition Unit

In the acquisition unit, data is first read out from the counter board. Owing to the shallowness of the on-board FIFO buffer of the PCI-6602 card (National Instruments), occasionally error -200141 may result, suspending further acquisition before being cleared by restarting. However, our experience shows that the first few data right after the restart are incomplete and should be discarded. Thus, right after the data read-out, the error status is subsequently checked. In case that an error is detected, the DAQ task is restarted. Only if no errors are detected within the last few cycles is the newly acquired data written into the FIFO buffer. As the storage and real time analysis units run independently, they both require a copy of the data and so data is written into two FIFO buffers--one for each unit. In addition, as the size of the FIFO buffer is fixed while the acquired data number varies, another FIFO buffer is used to save the actual data number.

As we found that the data acquired right before this error is also incomplete, we designed another method to discard them. Briefly, a FIFO buffer is created to record whether there is an error occurring in the previous acquisition cycle. Then, at the end of the beginning acquisition loop it is read out a few times so that in the storage and analysis units its read-out always shows “whether there is an error a few cycles later”, and the data will be discarded if the answer is true. Except this feature, the storage and analysis unit also contain a mechanism to hold enough data in the FIFO buffer. After data are read out from the buffer, the amount of remaining data is reported. Once the amount is lower than certain value, the storage or analysis is suspended for a couple of loop cycle so as to accumulate enough data in the buffer.

### 1.4 Data Analysis Unit

The data analysis unit converts the raw data (the interphoton time) into the correlation function, histogram, and time trace by invoking the functions in the dynamic link libraries. The generated ACF is still unnormalized; the normalization is carried out in the display group to ensure the efficiency of the analysis unit. Notably, if there is a restart even before the current data, the ACF dll file will be reset (idelay=0) to ensure the accuracy of the results. The display unit simply normalizes the ACF, and send the data to the front panel on the host computer.

### 1.5 Shut-down

After the user presses the stop button, the data remaining in the FIFO buffer are processed in the post-storage and post-analysis unit. Afterwards, both the normalized and unnormalized ACF, as well as the histogram are all saved and the system resources such as the FIFO buffer are released. Finally parameters used in the measurement are saved as a log file before the program terminates.

## 2. Parameters and Information (User Interface)

There are a number of parameters on the user screen that can be adjusted from their default values by the user. These are divided into two categories: parameters which it is unlikely the user will want to adjust (already optimized), and parameters which the user might wish to adjust for a given experiment.

### 2.1 Adjustment not likely required

| Parameter          | Meaning  | Value Range  |
|--------------------|--|--|
| TimeBase           | The reciprocal of the temporal resolution of the ACF curve, namely, the time interval each ACF element correspond to. The data elements in the ACF equals the overall time window*Timebase | 80MHz<br>20MHz<br>Any value <20MHz<br>Don't set too large if not necessary<br>Be sure to calculate the number of elements in the ACF function. |
| Frequency          | The frequency of the deterministic pulse train. Only for record in the log file. No effect on the program running  | Any  |
| Time Duration      | How long does the measurement last. Only for record in the log file. No effect on the program running  | Any  |
| FIFOSize           | The number of the arrays in each FIFO buffer. Each array contains "Elements in ch1 array" elements.  | > PreAcq and >ArrInStock<br>Suggested >100   |
| ResetPosArrSize    | The number of the elements of the array used to record the position where the DAQ error occurs.  | Estimated maximum error number   |
| MeanCountRate(cps) | This value determines the number of elements of the delay array = $\text{MeanCountRate} * \text{ACFMaxtau} / 10E9$   | At least twice the average count rate  |
| HistoUBound(ns)    | Upper bound of the Interphoton time histogram  | Dependent on Experiment  |
| HistoLBound(ns)    | Lower bound of the Interphoton time histogram  | Dependent on Experiment  |
| HistoItv(ns)       | Binning time of the Interphoton time histogram   | Dependent on Experiment  |
| TT BinWidth(ns)    | Binning time of the Time trace   | Dependent on Experiment  |
| # to read(25~50)   | The number of the data to read from the DAQ read function  | Suggested -1 (read all data at once)   |
| Buffer(1000)       | The buffer used to temporarily store the data from counter board   | 10000000 should be large enough  |

### 2.2 May require optimization for a given experiment

| Parameter             | Meaning  | Value Range                         |
|-----------------------|--|-------------------------------------|
| Elements in ch1 array | Number of elements in the array used to store the data read out from DAQ read function in each loop cycle.             | maximum signal count rate*loop rate |
| LoopPeriod            | The loop period for the acquisition, storage and analysis loops  |                                     |
| ACFMaxtau(ns)         | Time window of ACF ie maximum delay time   | Dependent on Experiment             |
| PreAcq                | The number of turns of the independent acquisition loop before the parallel loops                                      | >1                                  |
| ArrInStock            | The minimum array numbers in the FIFO buffer   | >2                                  |
| DelayPeriod           | The number of loop cycles the storage or analysis loop should wait if the data amount in the FIFO buffer is not enough | Depends                             |

### **3. Running the program under Real-Time system**

- 3.1 Ensure Labview 8.5 is installed.
- 3.2 Set connection between remote and host computer
- 3.3 Run the program ACF.vi in the folder DAQmx\_ACF