Rev. 1 - April 18th, 2024

CAENWaveDemo_x743

Multiboard Software Application for 743 Digitizer Series

PRELIMINARY

CAEN
Tools for Discovery

User Manual

UM8789

Purpose of this Document

This document contains the description of the CAENWaveDemo_x743 software for the x743 Digitizers and a guide to the multi-board synchronization.

Change Document Record

Date	Revision	Changes
April 4th, 2022	00	Initial release.
April 4th, 2022	01	Updated binary output file description.

Symbols, Abbreviated Terms, and Notations

ADC	Analog to Digital Converter
DAQ	Data Acquisition
DAW	Dynamic Acquisition Window
GPO	General Purpose Output
LVDS	Low-voltage Differential Signaling
TTT	Trigger Time Tag

Reference Documents

[RD1] UM2750 – V1743 & VX1743 User Manual

[RD2] UM2748 – DT5743 User Manual

[RD3] UM2749 – N6743 User Manual

[RD4] UM1935 – CAENDigitizer Library User & Reference Manual

[RD5] UM2754 – CAEN WaveCatcher User Manual

https://www.caen.it/support-services/documentation-area/

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Limitation of Responsibility

If the warnings contained in this manual are not followed, Caen will not be responsible for damage caused by improper use of the device. The manufacturer declines all responsibility for damage resulting from failure to comply with the instructions for use of the product. The equipment must be used as described in the user manual, with particular regard to the intended use, using only accessories as specified by the manufacturer. No modification or repair can be performed.

Disclaimer

The information contained herein has been carefully checked and is believed to be accurate; however, no responsibility is assumed for inaccuracies. CAEN spa reserves the right to modify its products specifications without giving any notice; for up to date information please visit www.caen.it.

MADE IN ITALY: We remark that all our boards have been designed and assembled in Italy. In a challenging environment where a competitive edge is often obtained at the cost of lower wages and declining working conditions, we proudly acknowledge that all those who participated in the production and distribution process of our devices were reasonably paid and worked in a safe environment (this is true for the boards marked "MADE IN ITALY", while we cannot guarantee for third-party manufactures).

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Figures

1 Introduction

The CAENWaveDemo_x743 is a C-based console application for the specific support of the x743 CAEN digitizers basing on the CAENDigitizer library **[RD4]**.

This software can control multiple digitizers and, particularly, it can be used as a demonstrator of the synchronization of the V1743/ VX1743 digitzers.

Specifically, CAENWaveDemo_x743 can perform the following operations:

- Connect one or more digitizers through a physical communication interface (USB, Optical Link or VME).
- Program the digitizer according to parameters written in a configuration file (text file).
- Perform SAMLONG chips calibration.
- Start and stop the acquisition (run on/off).
- Configure the Trigger mode (software, external or on channel self-trigger).
- Read the event data and display the acquisition statistics.
- Perform some simple data analysis (post-processing) such as the histograms of energy and time of the events.
- Save the waveforms samples to ASCII or binary output files, as well as the histograms and the run information.
- Plot and process the acquired waveforms.
- Manage the configuration and acquisition of multiple boards in synchronized mode.

Besides being a ready-to-use software, CAENWaveDemo_x743 is provided with C source files to let the users customize the code for personalized solutions.

The program core is a C application that configures the digitizer, starts/stops the acquisition, and manages the data readout according to a set of parameters as reported in the configuration text file. Data (waveforms or histograms) are plotted using Gnuplot, an external plotting tool, or saved to output text files. The configuration text file can be found in the installation folder, inside the *bin* folder.

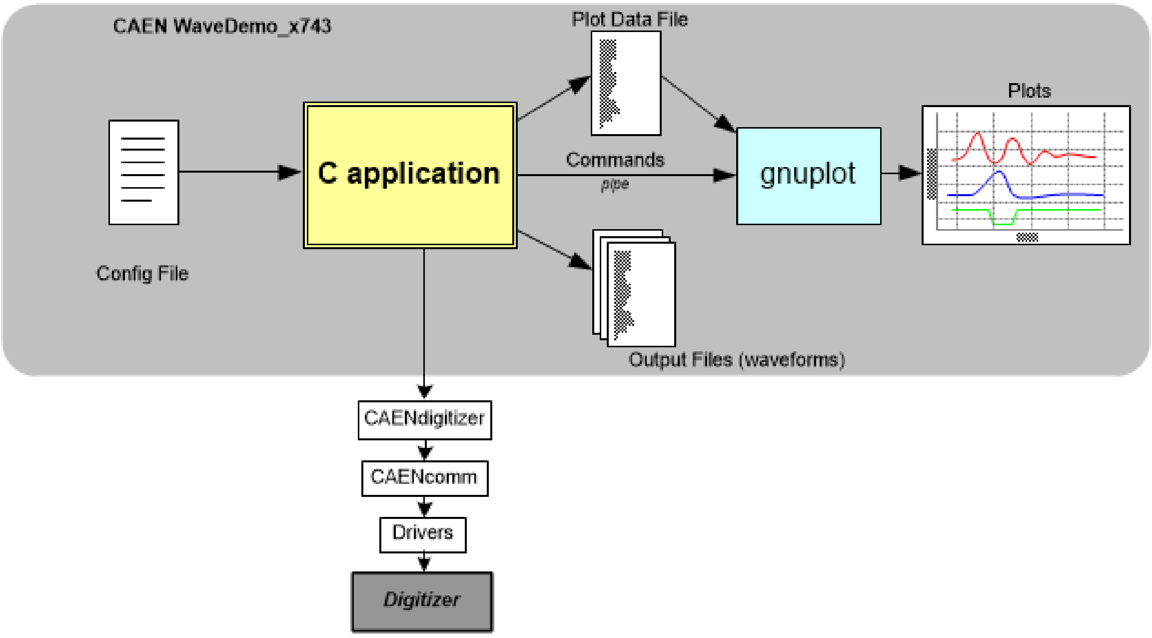


Fig. 1.1: CAENWaveDemo_x743 block diagram

2 Installation

2.1 System Requirements

2.1.1 Drivers

To deal with the hardware, CAEN provides the drivers for all the different types of physical communication interfaces featured by the specific digitizer and compliant with Windows and Linux OS:

- **USB-2.0 Drivers for NIM/Desktop boards** are downloadable on CAEN website (www.caen.it) at the digitizer web page (**login required**) in:

  "Downloads" page -> "Software" tab

- **USB-2.0 Drivers for V1718/VX1718** (obsolete) **and V3718/VX3718** CAEN Bridges, required for VME boards interface, are downloadable on CAEN website (www.caen.it) at the V1718/VX1718 and V3718/VX3718 web pages (**login required**) in:

  "Downloads" page -> "Software" tab

- **USB-3.0 Driver for the A4818 Adapter** (CONET to USB3) is required only for Windows OS, and downloadable on CAEN website (www.caen.it) at the adapter web page (**login required**) in:

  "Downloads" page -> "Software" tab

- **Optical Link** Drivers are managed by the A2818 PCI card or the A3818 PCIe card. The driver installation packages are available on the CAEN website at the A2818 or A3818 page (**login required**) in:

  "Downloads" page -> "Software" tab

- **USB-3.0 Driver for the V4718/VX4718** CAEN Bridges, required only for Linux OS and downloadable on CAEN website at the V4718/VX4718 web page (**login required**) in:

  "Downloads" page -> "Software" tab

2.1.2 Libraries

CAEN libraries are a set of middleware software required by CAEN software tools (including CAENWaveDemo_x743) for a correct functioning. These libraries, including also demo and example programs, represent a powerful base for users who want to develop customized applications for the digitizer control (communication, configuration, readout, etc.):

- **CAENVMELib library:** it is a set of ANSI C functions helpful for a user software development to configure and control CAEN Bridges V1718/VX1718 (obsolete), V2718/VX2718 (obsolete), V3718/VX3718, and V4718/VX4718. The library is available on the CAEN web site.

- **CAENComm library:** it manages the communication at low level (read and write access). The purpose of the CAENComm is to implement a common interface to the higher software layers, masking the details of the physical channel and its protocol, thus making the libraries and applications that rely on the CAENComm independent from the physical layer. Moreover, the CAENComm requires the CAENVMELib library (access to the VME bus) even in the cases where the VME is not used. This is the reason why **CAENVMELib has to be already installed on your PC before installing the CAENComm.** The library is available on the CAEN web site.

- **CAENDigitizer library:** it is a library of functions designed specifically for the Digitizer family, and it supports also the boards running the DPP firmware. The CAENDigitizer library is based on the CAENComm library. For this reason, the **CAENComm libraries must be already installed on the host PC before installing the CAENDigitizer.** The library is available on the CAEN web site.

- **Gnuplot:** it is a command-line and GUI program that can generate two-and three-dimensional plots of functions, data, and data fits.

2.2 Installation Procedure

Before installing WaveDemo_x743 make sure to have all system requirements up to date on your PC, and check if your x743 digitizer is properly installed (refer to the digitizer User Manual for details **[RD1][RD2][RD3]**).

The WaveDemo_x743 package is downloadable on the CAEN site for Linux and Windows OS.

2.2.1 Windows Users

The Windows installation package is standalone: it installs all the binary files required to directly use the software (i.e. no need to install the required CAEN libraries in advance).

- Download the Windows installation package from CAEN website.
- Extract the file to your host.
- Run the installer and complete.
- The installation procedure will ask if the Program should be for all the Users or only for the selected one (recommended).

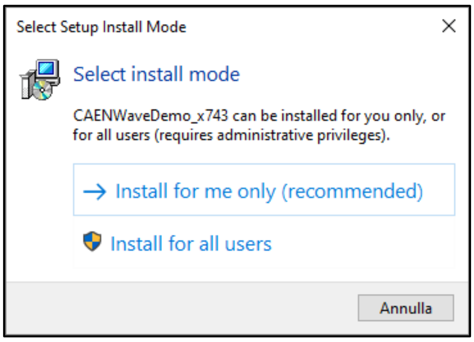


Fig. 2.1: Install mode of WaveDemo_x743

WaveDemo_x743 is installed at the default path: *C:\Program Files\CAEN\Digitizers\WaveDemo_x743*, in case of installation for all the Users, or in: *C:\Users\user\AppData\Local\Programs\CAEN\Digitizers\WaveDemo_x743*, otherwise.

Note: In case of installation for all the Users, WaveDemo_x743 must be run as administrator.

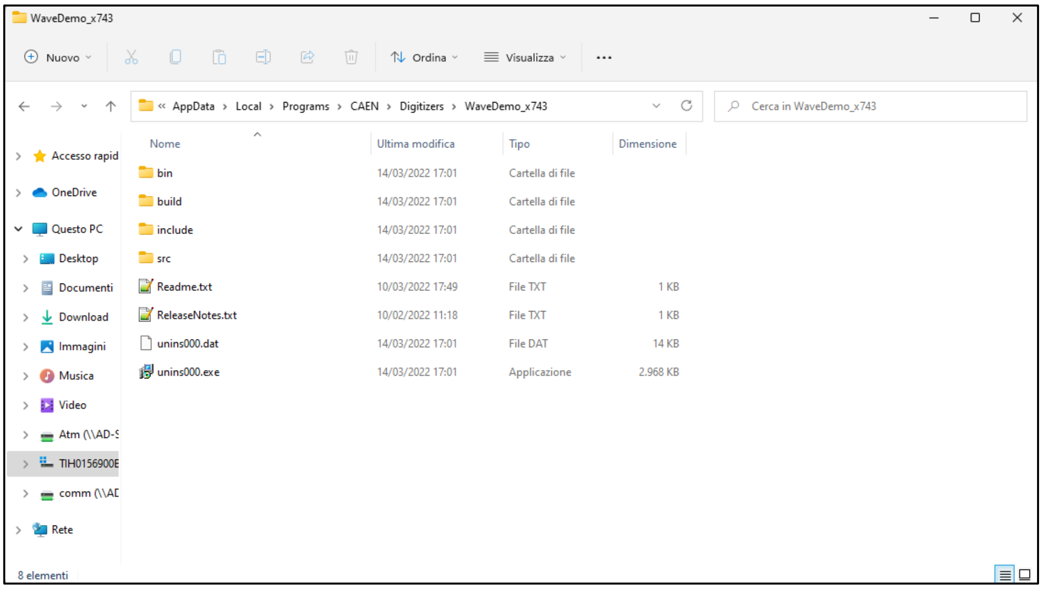


Fig. 2.2: Content of the installation folder of WaveDemo_x743 in Windows OS

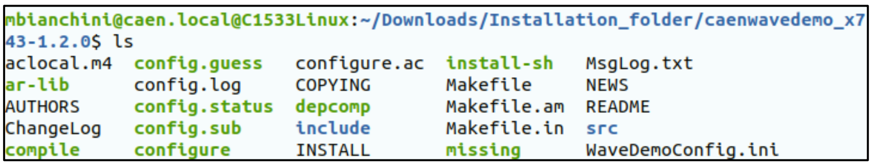
The "*bin*" subfolder contains the executable file (*WaveDemo_x743.exe*), the config file (*WaveDemoConfig.ini*), and the "*data_output"* folder, where the software saves the data (see **Fig. 2.2**).

The header and the source code of CAENWaveDemo_x743 are in the "*include*" and "*src*" folders, respectively.

2.2.2 Linux

Linux users must additionally install third-party Gnuplot graphical tool and the required CAEN Libraries: CAENVMElib, CAENComm, and CAENDigitizer.

- Download the Linux installation package from CAEN website.
- Unpack the installation package.
- Follow the instruction in the INSTALL file.
- Open the terminal and go in the WaveDemo_x743 folder.
- Type *./configure*
- Type *make*
- Type *sudo make install*
- The installation is complete.



```
mbianchini@caen.local@C1533Linux:~/Downloads/Installation_folder/caenwavedemo_x7
43-1.2.0$ ls
aclocal.m4   config.guess   configure.ac  install-sh   MsgLog.txt
ar-lib       config.log     COPYING       Makefile     NEWS
AUTHORS      config.status  depcomp       Makefile.am  README
ChangeLog    config.sub     include       Makefile.in  src
compile      configure      INSTALL       missing      WaveDemoConfig.ini
```

Fig. 2.3: Content of the installation folder of WaveDemo_x743 in Linux OS

The header and the source code of CAENWaveDemo_x743 are in the "*include*" and "*src*" folders, respectively.

3 Configuration File

This paragraph describes the structure of the CAENWaveDemo_x743 configuration file (*WaveDemoConfig.ini*) and the syntax of all the defined settings.

The configuration file is divided into four parts:

- Boards connection parameters
- Program options
- Common settings (applied to all channels as default value)
- Individual settings (applied channel by channel)

The Individual settings are applied after the Common settings, so, in case of conflicts, they have priority.

Note: The configuration file can be found in the installation folder, inside the *bin* folder for Windows users, and in the */usr/local/etc* folder for Linux users.

3.1 Board Connection Parameters

3.1.1 OPEN <N> LinkType LinkNumber NodeNumber BaseAddress

Description: opens the <N> digitizer.

<N>: is the incremental index of the board. Basically, in a synchronized multi-board system, 0 identifies the Master (see chapter **6**).

LynkType:

USB	Connection through USB
PCI	Connection through CONET
USB_A4818	Connection through CONET→A4818→USB
USB_A4818_V2718	VME Digitizer through V2718→A4818→USB
USB_A4818_V3718	VME Digitizer through V3718(CONET) →A4818→USB
USB_A4818_V4718	VME Digitizer through V4718 (CONET) →A4818→USB
ETH_V4718	VME Digitizer through V4718(ETHERNET)
USB_V4718	VME Digitizer through V4718(USB)

LinkNumber: it dipends by the *LinkType*, for*:*

USB	Number of the connection. 0 if it is only 1 board. For multiple boards indicates which board are you opening
PCI	Number of the connection. 0 if it is only 1 board. For multiple boards indicates which board are you opening
USB_A4818	PID of the A4818
USB_A4818_V2718	PID of the A4818
USB_A4818_V3718	PID of the A4818
USB_A4818_V4718	PID of the A4818

ETH_V4718	IP address of the V4718
USB_V4718	PID of the V4718

NodeNumber: this parameter must be specified only when connected via optical link (PCI) and indicates the node number in the daisy chain. Typically, it is 0 (only one digitizer in the optical chain), it may be different if more than one Slave board is connected in a daisy chain.

BaseAddress: address of the VME board, written as 32 bits hexadecimal.

Example:

OPEN 0 = USB 0 32110000 *#open the Master board connected via V1718*

OPEN 1 = PCI 0 0 0 *#direct optical link (CONET) connection*

3.2 Program Options

3.2.1 GNUPLOT_PATH *Path*

Description: path to Gnuplot executable file (optional if it is already in an environment variable).

Path: ../gnuplot (path)

3.2.2 DATAFILE_PATH *Path*

Description: path to save output file (the folder must already exist).

Path: ./data_output/ (path)

3.2.3 SAVE_RAW_DATA *Option*

Description: enables/disables raw data file saving.

Options:

YES
NO

3.2.4 SAVE_TDC_LIST *Option*

Description: enables/disables saving the Trigger Time Tag List.

Options:

YES
NO

3.2.5 SAVE_WAVEFORM *Option*

Description: enables/disables waveform file saving (of filtered events).

Options:

YES
NO

3.2.6 SAVE_ENERGY_HISTOGRAM *Option*

Description: enables/disables file saving with energy histogram.

Options:

YES
NO

3.2.7 SAVE_TIME_HISTOGRAMS *Option*

Description: enables/disables file saving with time histogram.

Options:

YES
NO

3.2.8 SAVE_LISTS *Option*

Description: enables/disables list file saving (of filtered events).

Options:

YES
NO

3.2.9 SAVE_RUN_INFO *Option*

Description: enables/disables run info file saving

Options:

YES
NO

3.2.10OUTPUT_FILE_FORMAT *Option*

Description: the output file can be either ASCII or binary (raw data files are always binary).

Options:

BINARY	The output file will be saved in binary
ASCII	The output file will be saved in ASCII (except for raw data)

3.2.1 OUTPUT_FILE_HEADER *Option*

Description: if enabled, the header is included in the output file data.

Options:

YES
NO

3.2.2 OUTPUT_FILE_TIMESTAMP_UNIT *Option*

Description: unit for the timestamps in the output list files.

Options:

0	ps
1	ns
2	µs
3	ms
4	S

3.2.1 STATS_ENABLE *Option*

Description: enables/disables updating and printing statistics while acquisition.

Options:

YES
NO

3.2.1 PLOT_RUN_ENABLE *Option*

Description: enables/disables waveform plotting when the run starts.

Options:

YES
NO

3.2.2 DGTZ_RESET *Option*

Description: specifies if the boards are reset before their programming.

Options:

YES
NO

3.2.3 SYNC_ENABLE *Option*

Description: enable for working with multiple boards synchronized. When this parameter is set as YES the software configure the boards as explained in **Chapter 6**. **If it's enabled the TRIGGER_TYPE must be set on EXTERNAL.**

Options:

YES
NO

3.2.1 TRIGGER_FIXED *Value*

Description: Program option to visually align the signals from different boards in the “Processed Waveforms” tab of the gnuplot window. The disalignment is due to the signals jitter as a consequence of the clock sampling. The "aligned" trigger of the reference channel is then fixed in percent of the whole acquisition window.

Values: from 10 to 90% (default= 20%).

3.2.2 BOARD_REF *Value*

Description: board to which the reference channel belongs.

Values: Number of the board.

3.2.3 CHANNEL_REF *Value*

Description: reference channel.

Values: Number of the channel.

3.2.4 ENERGY_H_NBIN *Option*

Description: number of bins in the energy histogram.

Options:

1K	1000 bins
2K	2000 bins
4K	4000 bins
8K	8000 bins
16K	16000 bins

3.2.5 TIME_H_NBIN *Option*

Description: number of bins in the time histogram.

Options:

256	256 bins
512	512 bins
1K	1000 bins
2K	2000 bins
4K	4000 bins
8K	8000 bins
16K	16000 bins

3.2.6 TIME_H_MIN *Value*

Description: lower time value used for time histograms.

Values: time in ns.

3.2.7 TIME_H_MAX *Value*

Description: upper time value used for time histograms.

Values: time in ns.

3.2.8 TIME_H_MODE *Option*

Description: time histogram mode.

Options:

START_STOP	Time from a reference common channel
INTERVALS	Time between consecutive events

3.3 Common Settings

3.3.1 INPUT_ENABLE *Option*

Description: all the channels are enabled/disabled by default (can be individually enabled/disabled in [BOARD x – CHANNEL n] sections).

Options:

YES	All channels enable
NO	All channels disable

3.3.2 SAMPLING_FREQUENCY *Option*

Description: Select the sampling frequency.

Options:

0	3.2 GHz
1	1.6 GHz
2	800 MHz
3	400 MHz

3.3.3 INL_CORRECTION_ENABLE *Option*

Description: enables the Integral Non Linearity correction for the acquired data.

Options:

YES
NO

3.3.4 TRIGGER_TYPE *Option*

Description: Select the trigger type.

Options:

SOFTWARE	The trigger command is generated by the software
NORMAL	The signal will be recorded in the enabled channels upon the channel self-trigger capability
EXTERNAL	Trigger only on signals received from TRG-IN input (they can be NIM or TTL)
ADVANCED	Allows separate settings, see EXTERNAL_TRIGGER, SOFTWARE_TRIGGER, and CHANNEL_SELF_TRIGGER

3.3.5 EXTERNAL_TRIGGER *Option*

Description: external trigger input settings. The setting works only if TRIGGER_TYPE = ADVANCED.

Options:

DISABLED	The external trigger is disabled
ACQUISITION_ONLY	The external trigger is not propagated through the TRG-OUT
TRGOUT_ONLY	The external trigger is only propagated (doesn't trigger the board)
ACQUISITION_AND_TRGOUT	The external trigger is propagated through the TRG-OUT and causes the acquisition for the board

3.3.6 SOFTWARE_TRIGGER *Option*

Description: software trigger settings. The setting works only if TRIGGER_TYPE = ADVANCED.

Options:

DISABLED	The software trigger is disabled
ACQUISITION_ONLY	The software trigger is not propagated through the TRG-OUT
TRGOUT_ONLY	The software trigger is only propagated (doesn't trigger the board)
ACQUISITION_AND_TRGOUT	The software trigger is propagated through the TRG-OUT and causes the acquisition for the board

3.3.7 CHANNEL_SELF_TRIGGER *Option*

Description: channel auto-trigger settings. The setting works only if TRIGGER_TYPE = ADVANCED.

Options:

DISABLED	The channel self trigger is disabled
ACQUISITION_ONLY	The channel self trigger is not propagated through the TRG-OUT
TRGOUT_ONLY	The channel self trigger is only propagated (doesn't trigger the board)
ACQUISITION_AND_TRGOUT	The channel self trigger is propagated through the TRG-OUT and causes the acquisition for the board

3.3.8 CHANNEL_TRIGGER_ENABLE *Option*

Description: channel auto-trigger enabling (they can be individually enabled/disabled in [BOARD x – CHANNEL n] sections).

Options:

YES
NO

3.3.9 RECORD_LENGHT *Value*

Description: number of samples in the acquisition window.

Values: multiple of 16 (min 16, max 1024).

3.3.10POST_TRIGGER *Value*

Description: post trigger size in percent of the whole acquisition window.

Values: from 0 to 100%.

3.3.11TRIGGER_EDGE *Option*

Description: decides whether the trigger occurs on the rising or falling edge of the signal.

Options:

RISING	The trigger occurs on the rising edge of the signal
FALLING	The trigger occurs on the falling edge of the signal

3.3.12TRIGGER_THRESHOLD *Value*

Description: threshold for the channel auto-trigger.

Values: between -1.25 V and 1.25 V.

3.3.13PULSE_POLARITY *Option*

Description: selects the input signal polarity.

Options:

POSITIVE
NEGATIVE

3.3.14FPIO_LEVEL *Option*

Description: type of signal accepted by the front panel I/O LEMO connectors.

Options:

NIM
TTL

3.3.15DC_OFFSET *Value*

Description: DC offset adjust (DAC channel settings).

Values: between -1.25 V and 1.25 V.

3.3.16GATE_WIDTH *Value*

Description: allows the user to select the width of the gate window, used for the calculation of the energy of the signal.

Values: in ns.

3.3.17PRE_GATE *Value*

Description: portion of the gate before the trigger.

Values: in ns.

3.3.18NS_BASELINE *Value*

Description: number of samples for the input baseline calculation.

Values: any value.

3.3.19DISC_MODE *Option*

Description: Discriminator mode.

Options:

LED	Leading edge
CFD	Constant fraction discriminator

3.3.20CFD_DELAY *Value*

Description: CFD delay. This parameter works only with DISC_MODE = CFD.

Values: in ns.

3.3.21CFD_ATTEN *Value*

Description: CFD attenuation. This parameter works only with DISC_MODE = CFD.

Values: between 0.0 and 1.0.

3.3.22TTF_SMOOTHING *Option*

Description: smoothing of the input signal.

Options:

0	Disabled
1	2 samples
2	4 samples
3	8 samples
4	16 samples

3.3.23 WRITE_REGISTER *Address Data*

Description: generic write register access. This command allows the user to have direct write access to the register of the board. NOTE: all the direct write accesses are executed before the other setting, thus one specific setting might overwrite the register content.

Syntax:

WRITE_REGISTER ADDRESS DATA

ADDRESS	Address offset of the register
DATA	Value being written (32 bit hex)

Example:

WRITE REGISTER 1080 00000010 #Set the threshold of channel 0 to 16 ADC counts (hex 10)

3.4 Individual Settings

The following settings are usually applied on a channel-by-channel basis; however, if moved in the Common Settings section, the settings are applied to all channels.

3.4.1 INPUT_ENABLE *Option*

Description: enables/disables one channel.

Options:

YES
NO

3.4.2 CHANNEL_TRIGGER_ENABLE *Option*

Description: channel auto trigger settings.

Options:

YES
NO

3.4.3 DC_OFFSET *Value*

Description: DC offset adjust.

Values: between -1.25 V and 1.25 V.

3.4.4 TRIGGER_EDGE *Option*

Description: decides whether the trigger occurs on the rising or falling edge of the signal.

Options:

RISING	The trigger occurs on the rising of the signal
FALLING	The trigger occurs on the falling of the signal

3.4.5 PULSE_POLARITY *Option*

Description: input signal polarity.

Options:

POSITIVE
NEGATIVE

3.4.6 TRIGGER_THRESHOLD *Value*

Description: threshold for the channel auto-trigger.

Value: between -1.25 V and 1.25 V.

Example:

```
[BOARD 0]
INPUT_ENABLE = NO
TRIGGER_THRESHOLD = 0.05
[BOARD 0 – CHANNEL 0]
INPUT_ENABLE = YES
DC_OFFSET = 0
TRIGGER_EDGE = RISING
PULSE_POLARITY = POSITIVE
TRIGGER_THRESHOLD = 0.15
```

4 Online Commands

Once the WaveDemo_x743 has been run the console will appear on the prompt.

The console has different commands that could be used. The commands are key-sensitive.

A full list is reported here and shown in **Fig. 4.1**:

- [?]: Opens the “Keyboard shortcut help”, where all the command-keys are listed.
- [q]: Quits the program.
- [i]: Get info on the digitizers.
- [r]: Enters in Reading/Writing register mode.
- [R]: Reloads the configuration file and restarts the program.
- [s]: Starts/Stops the acquisition.
- [T]: Enables/Disables continues software trigger.
- [t]: Forces the software trigger (only a single shot).
- [W]: Enables/Disables continuos writing to the output file.
- [w]: Records one event to the output file.
- [e]: Resets the histograms statistics.
- [f]/[F]: Enables/Disables automatic statistics refresh.
- [o]: One shot statistic refresh.
- [m]: Toggles between the statistics mode (integral/istantaneous).
- [a]/[d]: Adds/Deletes channel to the plot.
- [c]: Switches to “channel selector mode” in the waveform plot.
- [b]: Switches to board selector mode or changes the board to plot (only one board plot mode).
- [z]: Switches to traces selector mode. List of commands:
    - [1]: Adds/Removes “Discriminator” trace from the plot.
    - [2]: Adds/Removes “Smoothing” trace from the plot.
    - [3]: Adds/Removes “Trigger Threshold” trace from the plot.
    - [4]: Adds/Removes “Trigger” trace from the plot.
    - [5]: Adds/Removes “Gate” trace from the plot.
    - [6]: Adds/Removes “Baseline Calc” trace from the plot.
    - [7]: Adds/Removes “Baseline” trace from the plot.
- [*]: Enables all channels on the plot.
- [/]: Enables only one channel on the plot.
- [+]/[-]: Adds/Substacts 10 on the digits entered.
- [0-9]: Enables/Disables selected trace on the plot. The list of the available traces is at the [z] command (traces selector mode).
- [P]: Enables/Disables the continuos waveform plot.
- [p]: Plots one event at the time (stops if the plot is continuous).
- [g]: Toggles between waveform plot modes.
- [h]/[H]: Enables/Disables histogram plot.
- [h]: Toggles between histogram plot types.
- [x]: Toggles between channels and units in histogram plots.

```
****************************************************************
INFO: Opening Configuration File -> WaveDemoConfig.ini
*** Loading...
INFO: Configuration file parsed
Initialization board 0...
Loading SAM Correction Data from board. Please wait a few seconds...
--------------------------------------------------------------------------------
# 0 - Model: V1743 (S/N 20) - Rel.: ROC 04.17 - Build 2110, AMC 1.02.22
--------------------------------------------------------------------------------
*** Digitizers configuring...
Configuring board # 0...
INFO: Board # 0 configured.
*** Allocating buffers...
INFO: Ready.

[s] start/stop the acquisition, [q] quit, [?] help

                         Keyboard shortcut help
----------------------------------------------------------------------------
   [?]   This help
   [q]   Quit
   [i]   Get info on the digitizers
   [r]   Enter in Read/Write register mode
   [R]   Reload configuration file and restart
   [s]   Toggle Start/Stop acquisition
   [T]   Toggle Enable/Disable continuous software trigger
   [t]   Force software trigger (single shot)
   [W]   Toggle Enable/Disable continuous writing to output file
   [w]   Write one event to output file
   [e]   Reset Histograms and Statistics
 [f]/[F] Enable/Disable automatic statistics refresh
   [o]   One shot statistics refresh
   [m]   Toggle statistics mode (integral/istantaneous)
 [a]/[d] Add/Delete channel to the plot
   [c]   Switch to channel selector mode
   [b]   Switch to board selector mode or change the board to plot (only one board plot mode)
   [z]   Switch to traces selector mode
   [*]   Enable all channels on the plot
   [/]   Enable only one channel on the plot
 [+]/[-] Add/Subtract 10 on the digits entered
  [0-9]  Enable/Disable selected channel on the plot
   [P]   Toggle Enable/Disable continuous Waveform plot
   [p]   Plot one event at a time (stops if plot is continuous)
   [g]   Toggle between Waveform plot modes
 [h]/[H] Enable/Disable Histogram plot
   [h]   Toggle between Histogram plot types
   [x]   Toggle between Channels and Units in the Histogram plot
----------------------------------------------------------------------------
        Press a key to continue
```

Fig. 4.1: Full list of the online commands of the WaveDemo_x743 demo console

4.1 Statistics Table

When running the acquisition, the statistics table in the home of WaveDemo_x743 includes:

- "*Throughput*": evaluation of the rate of the events in the channel.
- "*Match*": percentage of events processed in comparison to the read ones.
- "*Queue%*": percentage of the buffer in the program busy (for every board WaveDemo_x743 creates a 2000 events buffer, used to store events to be processed).
- "*TotCnt*": number of total events read in the channel.
- "*DeltaCnt*": the difference between two consecutive "*TotCnt*".

```
        --- WaveDemo for x743 Digitizer Family  (version: 1.2.0) ---
Press [?] for help

Acquisition started at 2022-03-15 12:04:03
All Data Corrections are enabled
Enabled Output Files: Raw TDCList Lists Waveforms Histograms (ET) Info
Enabled Waveform plot: only output data of board 0 [continuous plot  << - >>]
Enabled Histogram plot: ENERGY board 0 - channel 00
Statistics Mode: Istantaneous
Total processed events = 11565
Total bytes = 48.1757 MB
RealTime (from boards) = 199.97 s
Readout Rate = 0.23 MB/s

Brd  Ch |   Throughput   Match%  Queue%    TotCnt   DeltaCnt
-----------------------------------------------------------------------
 0  0  |    59.18 Hz  100.00%   0.00%      11565         29
-----------------------------------------------------------------------


INFO: Stop Acquisition at 2022-03-15 12:07:23

[s] start/stop the acquisition, [q] quit, [?] help
```

Fig. 4.2: WaveDemo_x743 acquisition statistics

5 Getting Started

This section is intended to describe how to acquire data with WaveDemo_x743. In the following example, exponential pulses are created with a DT5810 Fast Digital Detector Emulator and fed into a V1743 module via Optical Link. The signals present an amplitude of -500 mV, a rise time of 10 ns, and a decay time of 50 ns, as shown in **Fig. 5.1**, and are sent frequency of 100 Hz.

In the following sections, it is described how to get the energy estimation and the timestamp measurement of the events using WaveDemo_x743 software.

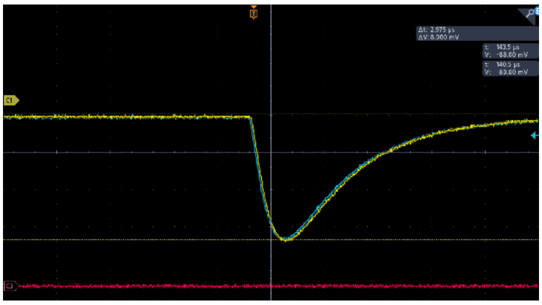


Fig. 5.1: Signals generated with the DT5810 Fast Digital Emulator feed to a V1743

5.1 WaveDemo_x743 Configuration File Overview

- First, turn on the crate and connect your pulse generator to channels 0 and 1 respectively.
- Go in the installation folder and enter in *bin*.
- Open *WaveDemoConfig.ini* file.
- Set the “Boards connection parameters” as follow:

```
# ----------------------------------------------------------------
# Board Connection Parameters
# ----------------------------------------------------------------
[CONNECTIONS]

# OPEN <N>: open the digitizer
# options: USB 0 0                 Desktop/NIM digitizer through USB (direct to USB)
#          USB 0 BA                VME digitizer through USB-V1718/V3718 (BA = BaseAddress of the VME board, 32 bit hex)
#          PCI 0 0 0               Desktop/NIM/VME through CONET (optical link)
#          PCI 0 0 BA              VME digitizer through V2718/V3718 (BA = BaseAddress of the VME board, 32 bit hex)
#          USB_A4818 X 0 0         Desktop/NIM digitizer through USB->A4818->CONET (X is the PID (product id) of A4818)
#          USB_A4818_V2718 X 0 BA  VME digitizer through USB-A4818-V2718 (BA = BaseAddress of the VME board, 32 bit hex) (X is the PID (product id) of A4818)
#          USB_A4818_V3718 X 0 BA  VME digitizer through USB-A4818-V3718 (BA = BaseAddress of the VME board, 32 bit hex) (X is the PID (product id) of A4818)
#          USB_A4818_V4718 X 0 BA  VME digitizer through USB-A4818-V4718 (BA = BaseAddress of the VME board, 32 bit hex) (X is the PID (product id) of A4818)
#          ETH_V4718 IP 0 BA       VME digitizer through ETH-V4718 (BA = BaseAddress of the VME board, 32 bit hex) (IP is the IP Address of the V4718)
#          USB_V4718 X 0 BA        VME digitizer through USB-V4718 (BA = BaseAddress of the VME board, 32 bit hex) (X is the PID (product id) of V4718)
#
# for multiple boards, OPEN 0 indicates the master board

# example for using two VME digitizer through USB-V1718 (uncomment the two lines below)
OPEN 0 = PCI 0 0 0
#OPEN 1 = USB 0 32100000

# example for using two VME digitizer through ETH-V4718 (uncomment the two lines below)
#OPEN 0 = ETH_V4718 192.168.1.254 0 32110000
#OPEN 1 = ETH_V4718 192.168.1.254 0 32100000

# examples for using one digitizer (uncomment just one of the lines below)
#OPEN 0 = USB 0 32110000
#OPEN 0 = USB 0 32100000
#OPEN 0 = PCI 0 0 0
#OPEN 0 = PCI 0 0 32100000
#OPEN 0 = ETH_V4718 192.168.1.254 0 32100000
#OPEN 0 = USB_V4718 12345 0 32100000
#OPEN 0 = USB_A4818 12345 0 0
#OPEN 0 = USB_A4818_V2718 12345 0 32100000
```

- In “Program options” section set:

```
# STATS_ENABLE: enable/disable updating and printing statistics while acquisition
# options: YES, NO
STATS_RUN_ENABLE = YES
# PLOT_ENABLE: enable/disable waveform plotting when the run starts
# options: YES, NO
PLOT_RUN_ENABLE = YES

# DGTZ_RESET: specify if the boards are reset before their programming
# options: YES, NO
DGTZ_RESET = YES

# SYNC_ENABLE: enable for working with multiple boards synchronized
# options: YES, NO (N.B.: if enabled you must use TRIGGER_TYPE = EXTERN)
SYNC_ENABLE = NO

# TRIGGER_FIXED: fix the trigger of the reference channel in percent of the whole acquisition window
# values: 10 to 90 (%) (default = 20)
TRIGGER_FIXED = 20

# BOARD_REF: Board to which the CHANNEL_REF belongs
BOARD_REF = 0
# CHANNEL_REF: Channel used as a start in the TOF measurements
CHANNEL_REF = 0
```

- In “Common settings” section set:

```
[COMMON]

# INPUT_ENABLE: all channels can be enable/disable by default (can be individually enable/disable in [BOARD x - CHANNEL n] sections)
# options: YES, NO
INPUT_ENABLE = NO

# SAMPLING_FREQUENCY
# options: 0 = 3.2 GHz, 1 = 1.6 GHz, 2 = 800 MHz, 3 = 400 MHz
SAMPLING_FREQUENCY = 0

# INL_CORRECTION_ENABLE: enable the Integral Non Linearity correction for the acquired data
# options: YES, NO
INL_CORRECTION_ENABLE = YES

# TRIGGER_TYPE
# options: SOFTWARE (trigger  command  is generated  by  the  software),
#          NORMAL (the signals will be recorded in the enabled channels upon the channel self trigger capability),
#          EXTERNAL (trigger only on signals received from TRG-IN input),
#          ADVANCED (allows separate settings, see EXTERNAL_TRIGGER, SOFTWARE_TRIGGER and CHANNEL_SELF_TRIGGER)
#TRIGGER_TYPE = EXTERNAL
TRIGGER_TYPE = NORMAL

# EXTERNAL_TRIGGER: external trigger input settings.
# SOFTWARE_TRIGGER: software trigger settings.
# CHANNEL_SELF_TRIGGER: channel auto trigger settings.
# When enabled, the specific trigger can be either propagated (ACQUISITION_AND_TRGOUT / TRGOUT_ONLY) or not (ACQUISITION_ONLY) through the TRGOUT
# options: DISABLED, ACQUISITION_ONLY, ACQUISITION_AND_TRGOUT, TRGOUT_ONLY
# These settings work if TRIGGER_TYPE is set on ADVANCED.
#EXTERNAL_TRIGGER = ACQUISITION_ONLY
#SOFTWARE_TRIGGER = ACQUISITION_ONLY
#CHANNEL_SELF_TRIGGER = ACQUISITION_ONLY

# CHANNEL_TRIGGER_ENABLE: channel auto trigger settings. (can be individually enable/disable in [BOARD x - CHANNEL n] sections)
# options: YES, NO
CHANNEL_TRIGGER_ENABLE = YES

# RECORD_LENGTH = number of samples in the acquisition window
# values: multiple of 16 (min = 16, max = 1024)
RECORD_LENGTH = 1024

# POST_TRIGGER: delay added to the trigger in the front-end FPGA before the acquisition is stopped. Units are in periods of the SAMLONG chips write clock (see V1743 userl Manual).
# values: 1 to 255
POST_TRIGGER = 20

# TRIGGER_EDGE: decides whether the trigger occurs on the rising or falling edge of the signal
# options: RISING, FALLING
TRIGGER_EDGE = FALLING

# TRIGGER_THRESHOLD: threshold for the channel auto trigger
# value: between -1.25 V and 1.25 V
TRIGGER_THRESHOLD = -0.10

# PULSE_POLARITY: input signal polarity
# options: POSITIVE, NEGATIVE
PULSE_POLARITY = NEGATIVE

# FPIO_LEVEL: type of the front panel I/O LEMO connectors
# options: NIM, TTL
FPIO_LEVEL =  NIM
```

- In “Individual settings” section set:

```
[BOARD 0]
INPUT_ENABLE = NO
[BOARD 0 - CHANNEL 0]
INPUT_ENABLE = YES
DC_OFFSET = 0
TRIGGER_EDGE = FALLING
[BOARD 0 - CHANNEL 1]
INPUT_ENABLE = NO
DC_OFFSET = 0
[BOARD 0 - CHANNEL 2]
INPUT_ENABLE = NO
[BOARD 0 - CHANNEL 3]
INPUT_ENABLE = NO
```

5.2 Data Acquisition with WaveDemo_x743

At this point, you can start the acquisition. To do that, open the Terminal, go into the installation folder, and enter in *bin*.

- Launch the program using the command *WaveDemo_x743.exe* (for Windows users) or *WaveDemo_x743* (for Linux users).

Note: The configuration file for Linux users is in */usr/local/etc/*.

- A command shell will appear (see **Fig. 5.2**). Press [Space] to visualize all the available commands.
- Start the acquisition pressing [s].
- Once the acquisition has started the console will show a table containing the statistics of the run and the Gnuplot window containing the waveform plot will be open (see **Fig. 5.3**).
- Pressing [g] it is possible to change the waveform plot, where only the input trace is visualized, to the Processed Waveform plot where all the traces are available (see **Fig. 5.4**). To add/remove some traces read command [z] in Chap. **4.**

```
**************************************************************
        WaveDemo for x743 Digitizer Family  (version: 1.2.0)
**************************************************************
INFO: Opening Configuration File -> WaveDemoConfig.ini
*** Loading...
INFO: Configuration file parsed
Initialization board 0...
Loading SAM Correction Data from board. Please wait a few seconds...
------------------------------------------------------------------------
# 0 - Model: V1743 (S/N 20) - Rel.: ROC 04.17 - Build 2110, AMC 1.02.22
------------------------------------------------------------------------
*** Digitizers configuring...
Configuring board # 0...
INFO: Board # 0 configured.
*** Allocating buffers...
INFO: Ready.

[s] start/stop the acquisition, [q] quit, [?] help
```

Fig. 5.2: WaveDemo_x743 home

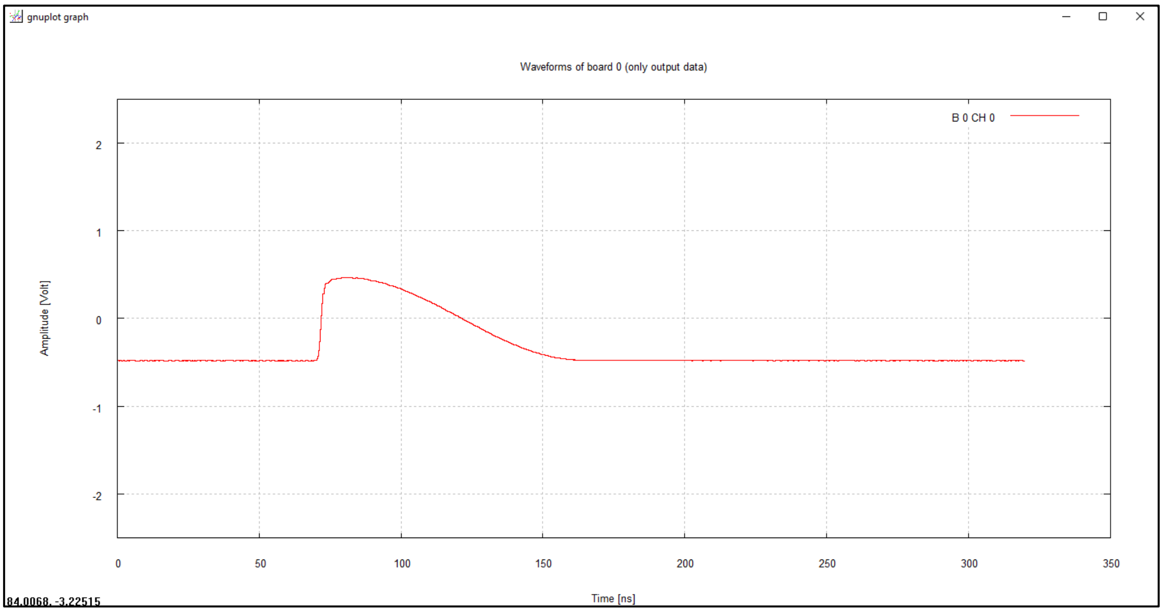


Fig. 5.3: Waveform plot

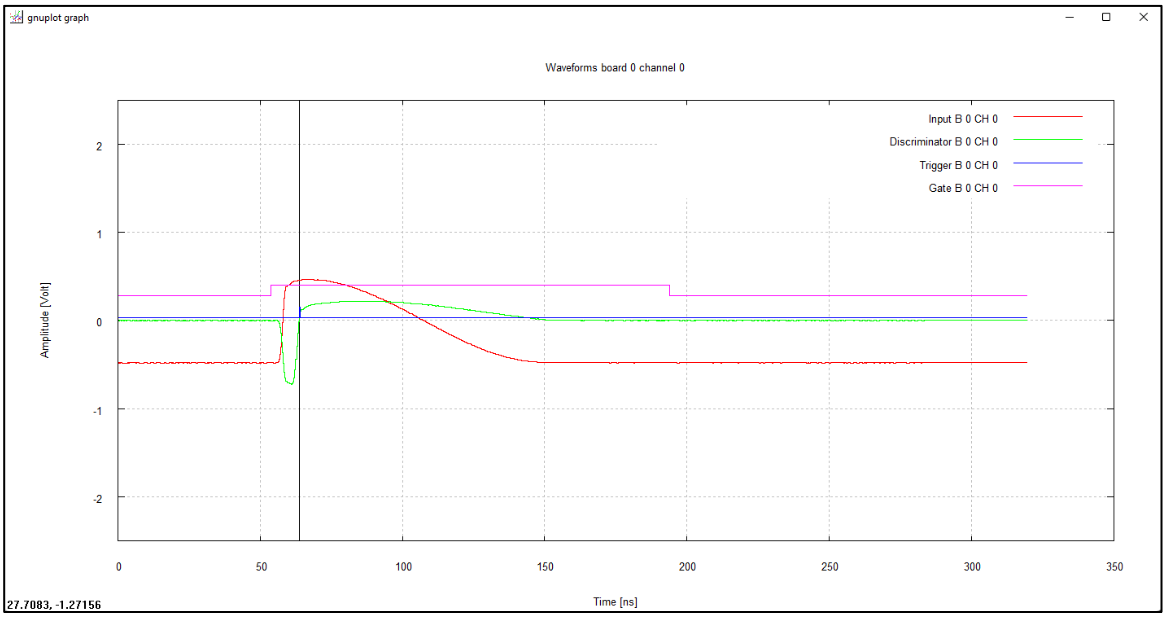


Fig. 5.4: Processed waveform plot

- Pressing [h] will show the time histogram selected in the configuration file ("START_STOP" or "INTERVAL" mode).
- Pressing [h] again will show the energy histogram (see **Fig. 5.5**).

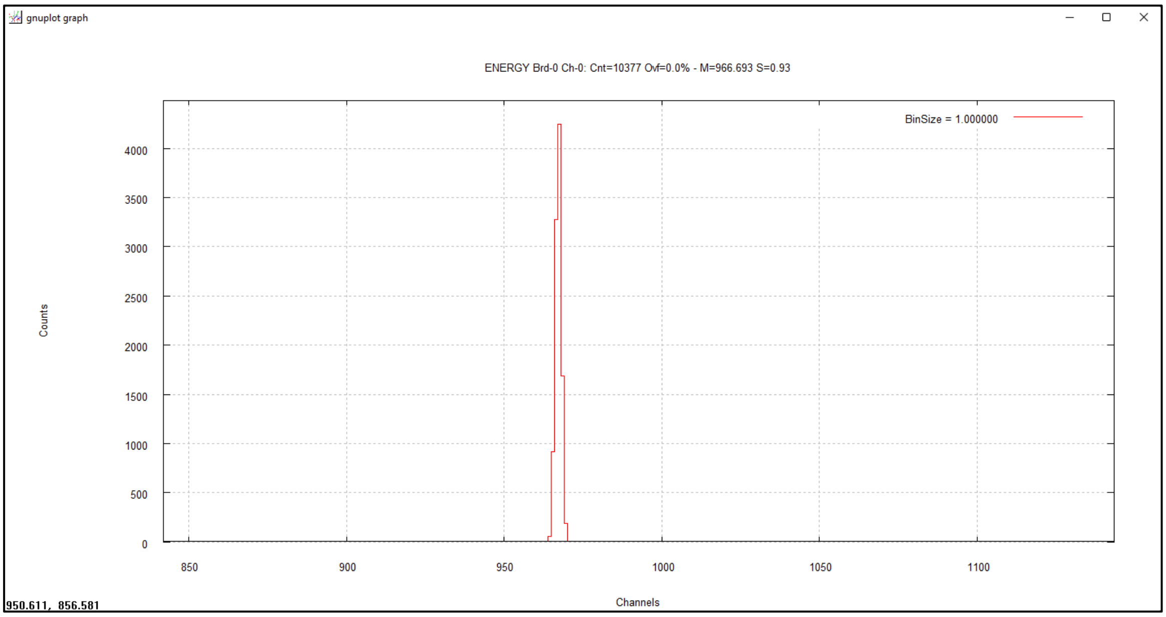
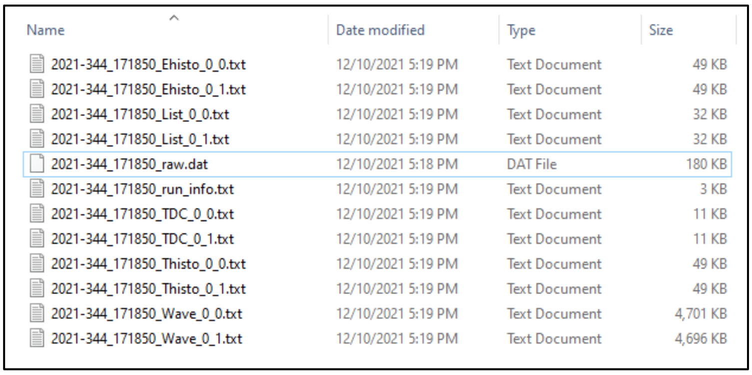


Fig. 5.5: Energy histogram

5.3 Save Data to File

The record of the data to file can be enabled in the configuration file (see Sec. **5.1**) or in the console, by pressing [w] or [W]. The data will be saved in the format defined in the configuration file, ASCII in this example. The option OUTPUT_FILE_HEADER in the configuration file allows to include, in the output file, a header for each acquired event.

The path to save the file can be selected in the configuration file. The default path is the installation folder, in *bin/data_output*. A screenshot of the files saved is shown in **Fig. 5.6**.



Name	Date modified	Type	Size
2021-344_171850_Ehisto_0_0.txt	12/10/2021 5:19 PM	Text Document	49 KB
2021-344_171850_Ehisto_0_1.txt	12/10/2021 5:19 PM	Text Document	49 KB
2021-344_171850_List_0_0.txt	12/10/2021 5:19 PM	Text Document	32 KB
2021-344_171850_List_0_1.txt	12/10/2021 5:19 PM	Text Document	32 KB
2021-344_171850_raw.dat	12/10/2021 5:18 PM	DAT File	180 KB
2021-344_171850_run_info.txt	12/10/2021 5:19 PM	Text Document	3 KB
2021-344_171850_TDC_0_0.txt	12/10/2021 5:19 PM	Text Document	11 KB
2021-344_171850_TDC_0_1.txt	12/10/2021 5:19 PM	Text Document	11 KB
2021-344_171850_Thisto_0_0.txt	12/10/2021 5:19 PM	Text Document	49 KB
2021-344_171850_Thisto_0_1.txt	12/10/2021 5:19 PM	Text Document	49 KB
2021-344_171850_Wave_0_0.txt	12/10/2021 5:19 PM	Text Document	4,701 KB
2021-344_171850_Wave_0_1.txt	12/10/2021 5:19 PM	Text Document	4,696 KB

Fig. 5.6: Folder with the output data files

5.4 Binary Output File Structure

Once the OUTPUT_FILE_FORMAT has been set to BINARY, the output file will be structured as follows:

- A file header composed by:
  - Testual Header: “"WaveDemo Raw Output FileFormat 0xX\n" (80 bytes max)
  - File Format (8 bit)
  - Header dimension = 8 (32 bit)
  - Record length (32 bit)
  - Reserved (64 bit)
  - Number of boards (32 bit)
  - Reserved (64 bit)
  - ADC Resolution = 12 bit (32 bit)
- For each event:
  - Board (int)
  - Event Counter (unsigned int 32 bit)
  - Trigger Time Tag (unsigned int 32 bit)
  - Enabled Group Mask (int)
  - Channel Enabled Mask (16 ch x 8 bit each)
- For each group:
  - Event ID (unsigned int 8 bit)
  - TDC (unsigned int 64 bit)
  - Start Index Cell (unsigned int 16 bit)
  - Channel Size (unsigned int 32 bit)
- For each channel:
  - Hit Counter (unsigned int 16 bit)
  - Time Counter (unsigned int 16 bit)
  - Data Channel (channel size x float 32 bit)

6 MultiBoard Synchronization

High-speed digitizers find applications in several fields ranging from the industry to the study of nuclear and particle properties. In many cases, complex measurement systems are implemented, which are composed of segmented or multiple detectors. These systems may require several acquisition channels and electronics to process the information.

Digitizers implement multiple input channels, but more boards may be needed to acquire all the information. The CAEN digitizers are designed also to have logic inputs and outputs which allow creating systems where boards operate as an all one board with synchronous signal sampling and same time reference. To obtain this, boards need to be "synchronized", that is board internal clocks are set synchronously and the time reference is set the same. The synchronization, in general, allows the user to acquire from N boards with Y channel each, like if they were just one board with (N x Y) channels.

This chapter introduces the main concepts on the synchronization of CAEN boards, describes a possible way to synchronize V1743/VX1743 digitizers, and demonstrates how this can be managed by the WaveDemo_X743 program. In the case of special setup needs different from the ones here presented, please contact CAEN for support (see Chap. **7**).

6.1 What does "Synchronize" Different Boards Mean?

It is possible to obtain the synchronization of a multi-board system with four main system settings.

a) Clock synchronization: same clock to all boards.

The clock synchronization is a basic requirement for the goal of a multi-board acquisition. All the channels of the system must have the same sampling clock (3.2 GS/s in case of x743 digitizers). While this is guaranteed by design on each board, it requires configuration steps when building up a multi-board system. With CAEN digitizers, this could be developed in two different ways:

- *Daisy chain:* The first one is to use the internal clock of one of the boards as Master and propagate it to the rest (the Slaves) by CLK-IN/CLK-OUT connectors.
- *One to many:* The signal generated by an external clock source can be split and provided to all the boards simultaneously (e.g. Fan-in) on CLK-IN connector.

Each board contains a Phase Lock Loop (PLL) which synthesizes the board clock either from an internal oscillator or from an external clock reference. Clock synchronization may then require the reprogramming of the PLL of the boards.

b) Time reference synchronization: same time reference for all boards.

In usual applications, all the boards belonging to an acquisition system have to start with the same time reference. For this reason, input and output connectors are used to synchronize the start of the data taking and the time reference. In principle, the start logic signal can be synchronized in different ways:

- *Daisy chain:* The run signal is propagated between all boards belonging to the acquisition system through the input/output front panel connectors (e.g. TRG-OUT / S-IN). This propagation of the start signal introduces a delay along the digitizer chain. This can be compensated by introducing time offsets in the data acquisition start.
- *One to many:* The signal generated by an external logic can be split and provided to all boards simultaneously (e.g. Fan-in) on the S-IN connector.

c) Trigger synchronization: same acquisition trigger for all the boards.

Each board has its own common acquisition trigger but, to have the same number of events on all the boards, we need to develop a common trigger system. The trigger source can generally be software, external (TRG-IN), upon the channel (channel self-trigger), even the output of an external combination logic. In principle, the common trigger system can be implemented in different way:

- *Daisy chain:* The trigger signal is propagated between all boards through the TRG-IN/TRG-OUT connectors
- *One to many:* The trigger signal from an external trigger logic is split and provided to all boards simultaneously (e.g. Fan-in) on the TRG-IN connector.

d) Readout synchronization and event alignment.

Each digitizer manages its own busy condition, that is no trigger is accepted while at least one channel memory is full. The event alignment is so guaranteed both at low and high rates. With a multiboard system, it must be implemented a mechanism that prevents asynchronous data taking in a way that all the boards do not accept triggers when at least one board is full. This mechanism needs a system busy signal to be used to veto the acquisition. The most common options are:

- *Internal logic:* The busy signal is propagated in daisy chain between all boards through the LVDS I/O connector properly configured as BUSY IN/OUT. For each board, the propagated signal is the OR between its own busy and the busy of the previous board. The last board in the chain will so provide the needed system busy conveniently on the TRG-OUT (single-ended TTL/NIM) or LVDS (differential) connector.
- *External logic:* Each board provides its own busy signal on TRG-OUT (or LVDS) to an external logic making the OR of the busy signals and providing the system busy as output.

Then, possible options for the veto could be:

- *Daisy chain:* The system busy is propagated between all boards through the LVDS I/O connector properly configured as VETO IN/OUT.
- *External veto:* The system busy is used to directly veto the common system trigger source. It can be used in case of a vetoable external trigger logic.

6.2 Synchronization Example

In this guide, we explain step by step one method of synchronization of two V1743 boards. In the following example, the solution implemented to have the same clock, the same reference time, and the common trigger is schematized in **Fig. 6.1**. The communication was by optical link to the PC through the V3718 Bridge and the A3818 controller.

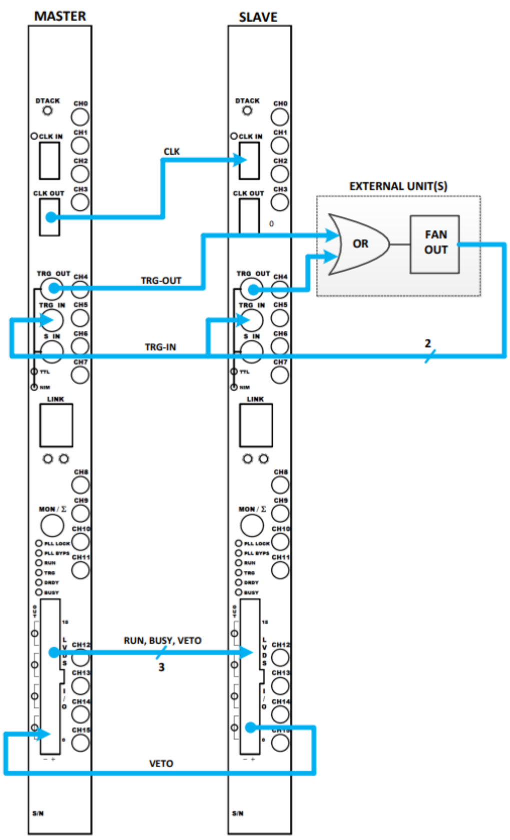


Fig. 6.1: Symplified synchronization scheme of two V1743 digitizers

> ***FOR ANY OTHER SYNCHRONIZATION SETUP REQUIREMENT DIFFERENT FROM WHAT DESCRIBED IN THIS EXAMPLE WE RECOMMEND USERS TO CONTACT CAEN FOR TECHNICAL SUPPORT (Chap. 7.)***

6.2.1 Clock Synchronization

The first step is to have the same sampling clock (e.g., 3.2 GS/s) in all channels and all the boards. The V1743/VX1743 features an on-board programmable PLL, locking either the internal oscillator (50 MHz) or an external frequency to generate clocks for the SAMLONG chips (200 MHz) and for the FPGAs (100 MHz). The 3.2 GS/s sampling frequency is obtained inside the SAMLONG chip from the 200 MHz reference clock.

The V1743/VX1743 digitizers have front panel CLK-IN and CLK-OUT connectors (3-pin LVDS). The clock signal is propagated in Daisy chain between boards: the 1st board is the clock Master (using an internal clock), the 2nd board (clock Slave) takes the clock-out of the 1st one.

In the local "pll" repository of the CAENUpgrader tool, CAEN provides two programming files with predefined delay values, based on the use of CAEN A317 clock distribution cable for CLK-IN/CLK-OUT daisy chain, to minimize the difference in phase between clocks:

v1743_vcxo400_ref50_pll_out50_del5n.rbf

v1743_vcxo400_ref50_pll_out50_del7n5.rbf

where:

vcxo400 refers to the 400 MHz of the internal VCXO:

ref50 means 50 MHz as input reference clock (internal for the Master, external for the Slave/s);

out50 means the output frequency on CLK-OUT is 50 MHz (no matter if the last slave);

del5n / *del7n5* is the applied delay value in nanoseconds.

Note: Considering the Master and only one Slave, as in this example, the Salve board can be programmed with whichever of the two files; the delay will not be effective for this board if no other Slave is daisy chained. The delay is instead effective for the Master. By trying both files on the Master, then configuring Master and Slave to provide a copy of the reference clock on TRG-OUT connector (NIM by default), it is possible to see the two signals on an oscilloscope to establish which file for the Master minimizes the phase delay between the two clocks.

Note: A self-made clock cable can even be used, but it must have a Zdiff of 100 Ohm and twisted (recommended).

The whole procedure can be resumed in four points:

- The CLK-OUT of the Master is connected to the CLK-IN of the Slave by the A317 cable.
- By the CAENToolbox software, configure:
  - The Master PLL to work upon its own internal 50MHz oscillator as clock reference
  - The Master PLL to enable the output of the clock providing a copy of the 50MHz clock on CLK-OUT
  - The Master PLL to delay the CLK-OUT signal by 2.5 ns or 7.5 ns according to the selected file
  - The Slave PLL to accept the external clock on CLK-IN
  - The Slave PLL to provide a copy of the 50MHz clock on CLK-OUT (meaningful in case of multi-Slave systems).
- The TRG-OUT of both boards are programmed to deliver the clock signal.
- The clock signals are inspected on an oscilloscope to verify the synchronization and the phase skew.

Here follows the step-by-step procedure for clock synchronization:

1. Set the VME address of both the Master and the Slave (refer to the digitizer User Manual for details **[RD1]**).
2. Set the clock source to internal for the Master by the onboard slide switch (**Fig. 6.2**).
3. Set the clock source to external for the Slave by the onboard slide switch (**Fig. 6.2**).

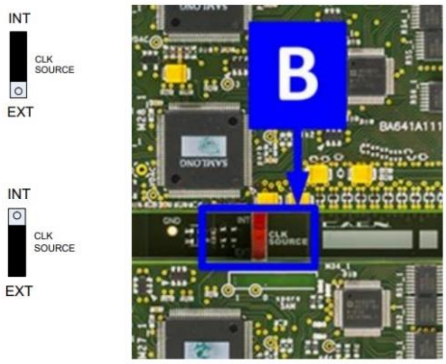


Fig. 6.2: The blue rectangle marked with "B" indicates the CLK switch, that can be set to INT (internal) as shown in the top figure on the left, or EXT (external), as in the bottom figure

4. Connect Master CLK-OUT to Slave CLK-IN using the A317 CAEN clock distribution cable.
5. Turn ON the crate.
6. Run CAEN Toolbox to program the Master PLL.
7. Select "*Digitizer 1.0*" and connect to the digitizer.

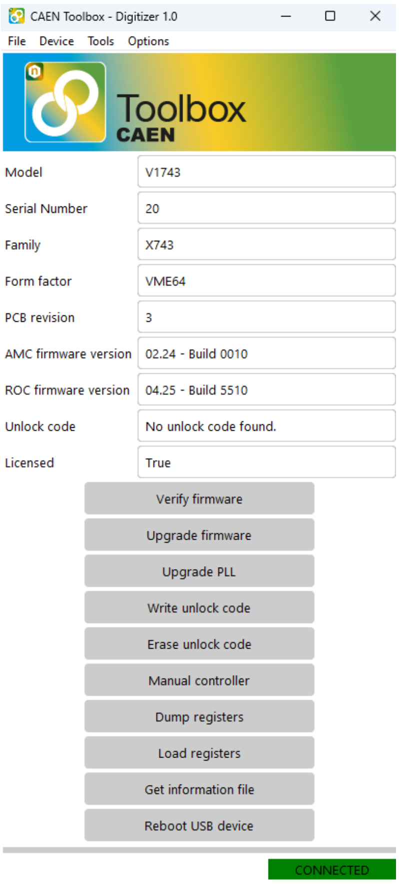
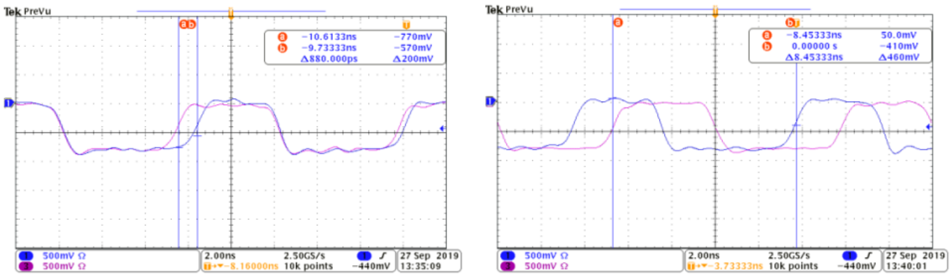


Fig. 6.3: CAEN Toolbox configuration for the upgrade of the PLL Master.

8. Select "*Upgrade PLL*" in the "*Digitizer 1.0*" section, then select one PLL file between *v1743_vcxo400_ref50_pll_out50_del5n.rbf* and *v1743_vcxo400_ref50_pll_out50_del7n5.rbf* in the PLL folder inside the CAEN Toolbox installation folder.
9. Repeat the steps to select the PLL of the Slave. Select the *v1743_vcxo400_ref50_pll_out50.rbf* in the PLL folder inside the CAEN Toolbox installation folder.
10. Reboot the boards to apply the new PLL configurations. Once programmed, the boards hold the last PLL configuration at any power-on or power cycle.

11. For Master and Slave, set Bit[19:18] = 01 and Bit[17:16] = 01 of 0x811C register to propagate the clock signal on TRG-OUT. This means to direct write 50000 (hex) at 0x811C. One of the provided CAEN Demos included in the VMELib or CAENComm library can be used.
12. Connect the TRG-OUT outputs of both the boards to an oscilloscope with cables of equal length (50 Ω termination required).
13. Check the clock synchronization and phase skew: the clock signals must not jitter between eachother and the phase difference between same fronts must be the minimum between the two predefined delays. Otherwise, change the PLL file of the Master and repeat the operations. Typical clock signals on the oscilloscope are shown in **Fig. 6.4**.



Delay_5ns: A(Slave) – B(Master) = 880 ps *Delay_7.5ns: A(Slave) – B(Master) = 8.45 ns*

Fig. 6.4: Clock signals of the Master and the Slave at the oscilloscope

Note: If using a clock cable different from A317, the needed delay to apply to the CLK-OUT of the Master could differ from the one implemented in the predefined PLL files. In this case, please contact CAEN for information (Chap. **7**).

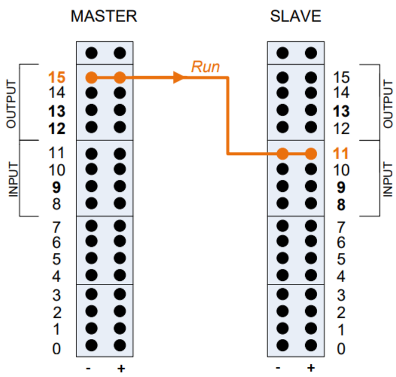
6.2.2 Timestamp Synchronization

The next step is to have the same zero for all the timestamps on all the boards. This means t=0 at the start of the run; the start of the Master in our example is given by software command. The run is propagated from the Master to the Slave by Daisy Chain of the LVDS I/O pins. The LVDS I/O connector manages 16 differential signals (each couple of pins corresponds to one signal) whose direction (input/output) and function can be programmed by groups of 4. The following pin configuration has been set:

- [15:12] configured as an output.
- [15:12] configured in nBusy/nVeto mode.
- [11:08] configured as an input.
- [11:08] configured in nBusy/nVeto mode.
- Run propagated through 15 (nRun) to 11 (nRunIn).

Running the WaveDemo_x743 with the "SYNC_ENABLE = YES" option will automatically set the pin as explained.

To propagate the start of the Run from the Master to the Slave, connect pin 15 to pin 11, as shown in **Fig. 6.5**.



Run: Master (pin 15) -> Slave (pin 11)

Fig. 6.5: LVDS I/O connection for the propagation of the start of the Run

Note: CAEN provides specific LVDS distribution cables A316.

6.2.3 Trigger Synchronization

According to **Fig. 6.6**, the trigger architecture has been implemented as follow:

- Both Master and Slave acquire an event only by an external trigger source on the TRG-IN input.
- The channel self-triggers of all the boards do not start the acquisition, but they are propagated in OR by TRG-OUT to an external logic.
- The exernal logic makes the OR of the TRG-OUT of all the boards to generate the common acquisition trigger.
- The external logic also makes a FAN-OUT of the common acquisition trigger that is so sent back to the TRG-IN input of each digitizer, as shown in **Fig. 6.6**.

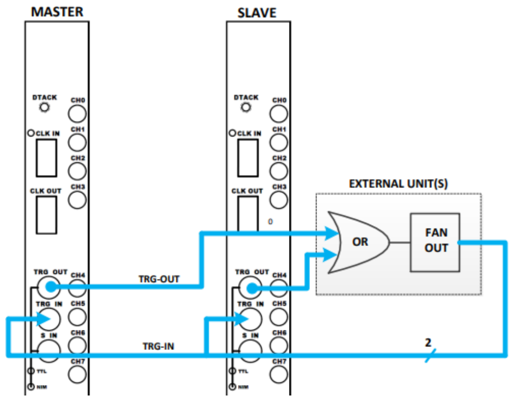


Fig. 6.6: Detail of the implemented Trigger scheme

By setting the "TRIGGER_TYPE" option to "EXTERNAL" in *WaveDemoConfig.ini*, the digitizers are configured to accept an external trigger sent to the TRG-IN input.

6.2.4 Event Data Synchronization

Event data are sycnhronized once a global Busy vetoes the acquisition of the entire system as soon as at least one board goes busy and as long as the system Busy is asserted.

The Busy signal is propagated in Daisy chain between the boards using the LVDS I/O connectors.

For a single board, the Busy signal is the OR of its own Busy and of the Busy signal coming from the other board. According to that, the Busy of the Slave is the desired global Busy (GBUSY). The global Busy is then fed back into the LVDS I/O of the first board as veto signal and propagated in Daisy chain along the boards to finally inhibit the entire system.

In this document, the pin settings are the same of the timestamp synchronization:

- [15:12] configured as output.
- [15:12] configured in nBusy/nVeto mode.
- [11:08] configured as input.
- [11:08] configured in nBusy/nVeto mode.

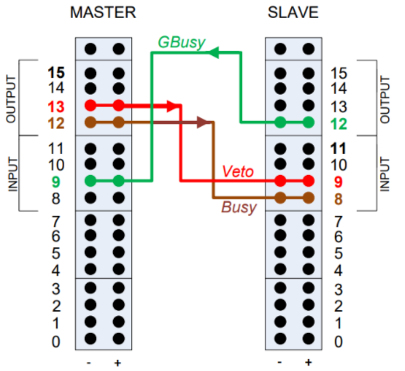
This time, the pins connect throght A316 cables (or compatible ones), as shown in **Fig. 6.7**, are:

- Pin 12 of the Master with pin 8 of the Slave.
- Pin 13 of the Master with pin 9 of the Slave.
- Pin 9 of the Master with pin 12 of the Slave.

Running the WaveDemo_x743 with the "SYNC_ENABLE = YES" option will automatically set the pin as explained.

To propagate the busy signal correctly connect the LVDS I/O connectors using A316 cables as shown in **Fig. 6.7**.

The boards are now synchronized.



Busy: Master (pin 12) -> Slave (pin 8)
Veto: Master (pin 13) -> Slave (pin 9)
GBusy: Slave (pin 12) -> Master (pin 9)

Fig. 6.7: LVDS I/O connections for the propagation of the Busy and Veto signals

6.2.5 Synchronization with WaveDemo_x743

This section will show how to test the synchronization of two V1743 with WaveDemo_x743 software. The digitizers have been synchronized as explained in the previous sections.

Two simultaneous pulses, generated with a Waveform Generator, of 1 V amplitude and 100 Hz frequency. The pulses are sent respectively to channel 0 of board 0 (the Master) and channel 0 of board 1 (the Slave). Same number of events is expected to be found on both boards. Furthermore, events with the same trigger ID must have the same timestamp on the two boards.

WaveDemo_x743 has been used to test the synchronization. In *WaveDemoConfig.ini* the folling configuration has been set: the *“SYNC_ENABLE”* option as *“YES”*, to have the boards set as explained in the previous sections, and the *“TRIGGER_TYPE”* as *“EXTERNAL”*. All parameters regarding the input shall be modified to fit with the signal (e.g. *“PULSE_POLARITY = POSITIVE”*, *“TRIGGER_EDGE = RISING”*, etc, etc..). Remember to set to *“YES”* the *“SAVE_TDC_LIST”* option.

```
# SYNC_ENABLE: enable for working with multiple boards synchronized
# options: YES, NO (N.B.: if enabled you must use TRIGGER_TYPE = EXTERN)
SYNC_ENABLE = YES
# TRIGGER_TYPE
# options: SOFTWARE (trigger  command  is generated  by  the  software),
#          NORMAL (the signals will be recorded in the enabled channels upon the channel self trigger capability),
#          EXTERNAL (trigger only on signals received from TRG-IN input),
#          ADVANCED (allows separate settings, see EXTERNAL_TRIGGER, SOFTWARE_TRIGGER and CHANNEL_SELF_TRIGGER)
#TRIGGER_TYPE = EXTERNAL
TRIGGER_TYPE = EXTERNAL
[BOARD 0]
INPUT_ENABLE = NO
[BOARD 0 - CHANNEL 0]
INPUT_ENABLE = YES
DC_OFFSET = 0
TRIGGER_EDGE = RISING
PULSE_POLARITY = POSITIVE
TRIGGER_THRESHOLD = +0.2
[BOARD 0 - CHANNEL 1]
INPUT_ENABLE = NO
DC_OFFSET = 0
TRIGGER_EDGE = RISING
PULSE_POLARITY = POSITIVE
TRIGGER_THRESHOLD = +0.2
[BOARD 0 - CHANNEL 2]
INPUT_ENABLE = NO
[BOARD 0 - CHANNEL 3]
INPUT_ENABLE = NO


[BOARD 1]
INPUT_ENABLE = NO
[BOARD 1 - CHANNEL 0]
INPUT_ENABLE = YES
DC_OFFSET = 0
TRIGGER_EDGE = RISING
PULSE_POLARITY = POSITIVE
TRIGGER_THRESHOLD = +0.2
```

Fig. 6.8: Example of settings for the synchronization of two V1743 in the *WaveDemoConfig.ini* file

Once run the software and started the acquisition, the alignment of the two signals has been checked in the Processed Waveform window, as shown in **Fig. 6.9**.

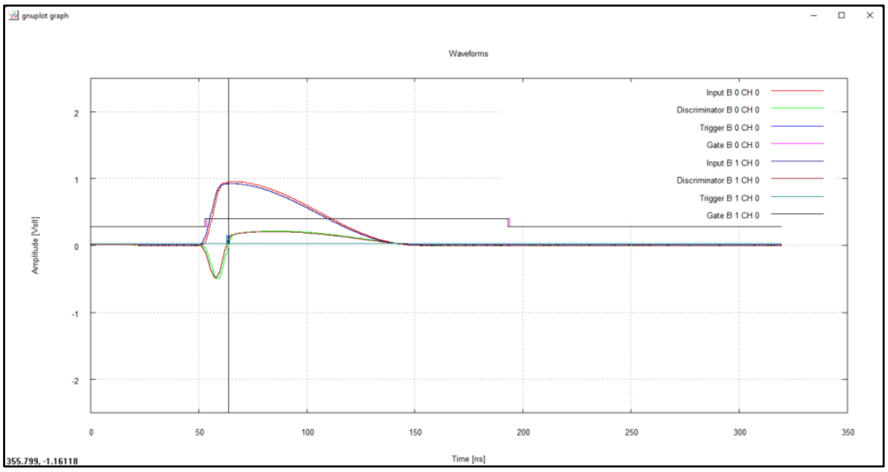


Fig. 6.9: Input pulses inspection in the Processed Waveform plot window

Aligned means the leading fronts of the two pulses are ideally overlapped and they do not jitter between each other within the acquisition window (they can anyway jitter together in the same direction)

Afte the visual check with the Processed Waveform plot, the signal alignment has been checked looking at the "*TotCnt*" and "*Match*" parameters given as output by the software. To have a good alignment, the "*TotCnt*" parameter is expected to be the same for the two boards and the *"Match"* parameter to be 100%.

```
        --- WaveDemo for x743 Digitizer Family  (version: 1.2.0) ---
Press [?] for help

Acquisition started at 2022-03-16 10:32:16
All Data Corrections are enabled
Enabled Output Files: Raw TDCList Lists Waveforms Histograms (ET) Info
Enabled Waveform plot: synchronous events [continuous plot  << - >>]
Histogram plot disabled.
Statistics Mode: Istantaneous
Total processed events = 650
Total bytes = 2.7077 MB
RealTime (from computer) = 2.00 s
Readout Rate = 0.60 MB/s

Brd  Ch |    Throughput   Match%  Queue%    TotCnt    DeltaCnt
-----------------------------------------------------------------
  0  0  |    72.00 Hz  100.00%   0.00%        325         72
  1  0  |    72.00 Hz  100.00%   0.00%        325         72
-----------------------------------------------------------------
```

Fig. 6.10: Example of acquisition with Wavedemo_x743 in synchronized mode: *"TotCnt"* has the same value for both the channels and *"Match"* is 100%, as expected

The final test involves the timestamp: events with the same trigger ID should have the same timestamp. This can be read in the TDC files.

100	315586023	100	315586023
101	317586021	101	317586021
102	319586021	102	319586021
103	321586021	103	321586021
104	323586019	104	323586019
105	325586019	105	325586019
106	327586019	106	327586019
107	329586019	107	329586019
108	331586017	108	331586017
109	333586017	109	333586017
110	335586017	110	335586017
111	337586017	111	337586017
112	339586015	112	339586015
113	341586015	113	341586015
114	343586015	114	343586015
115	345586013	115	345586013

Fig. 6.11: Timestamps for some events from Channel 0 of Board 0 and 1 respectively

As shown in figure **Fig. 6.11**,timestamps of events with the same trigger ID from different boards are the same. In addition to the other tests, this can guarantee that the synchronization of the boards has been correctly implemented.

7 Technical Support

CAEN makes available the technical support of its specialists for requests concerning the software and hardware. Use the support form available at the following link:

https://www.caen.it/support-services/support-form/

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