CAEN
Tools for Discovery

Electronic Instrumentation

User Manual UM3147

N6730/N6725

8-Channel 14-bit 500/250 MS/s Waveform Digitizer

Rev. 2 - 10 June 2016

Purpose of this Manual

This document contains the full hardware description of the N6730 and N6725 digitizers and the principle of operating as Waveform Digitizer (based on the hereafter called *default firmware*).

Firmware version of reference: rel. 4.8_0.5

For any reference to registers in this user manual, please refer to document [RD2] at the digitizer web page.

Change Document Record

Date	Revision	Changes
25 November 2013	00	Initial release
15 December 2014	01	Added new § **6** on temperature protection. Updated § **Trigger Management**. General revision.
10 June 2016	02	Fully reviewed to the new N6725 digitizer (250 MS/s). Updated § **1**, § **3**, § **7**, § **Clock Distribution**, § **PLL Mode**, § **Trigger Clock**, § **Channel Calibration**, § **Custom Sized Events**, § **Event Structure** § **Trigger Distribution**, § **12**. Added § **Changing the ADC Frequency**, § **CAENScope**, § **MC²Analyzer (MC²A)**

Symbols, abbreviated terms and notation

GUI	Graphical User Interface
DPP	Digital Pulse Processing
OS	Operating System
PSD	Pulse Shape Discrimination
TTT	Trigger Time Tag

Reference Documents

[RD1] GD2512 – CAENUpgrader QuickStart Guide

[RD2] UM5118 – 730-725 Families Default Firmware Registers

[RD3] GD2783 – First Installation Guide to Desktop Digitizers & MCA

[RD4] UM1934 - CAENComm User & Reference Manual

[RD5] UM1935 - CAENDigitizer User & Reference Manual

[RD6] UM2091 - CAEN WaveDump User Manual

[RD7] GD2483 - WaveDump QuickStart Guide

[RD8] UM2092 - CAENSCOPE User Manual

[RD9] UM2580 - Digital Pulse Shape Discriminator (DPP-PSD) User Manual

[RD10] UM3182 - DPP-PHA and MC²Analyzer User Manual

[RD11] GD2728 – How to make Coincidences with CAEN Digitizers

All documents can be downloaded at: http://www.caen.it/csite/LibrarySearch.jsp

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Safety Notices

CAUTION: this product needs proper cooling.

USE ONLY CRATES WITH FORCED COOLING AIR FLOW SINCE OVERHEATING MAY DEGRADE THE MODULE PERFORMANCES!

CAEN HEARTLY RECOMMENDS TO MONITOR THE TEMPERATURE OF THE ADC CHIPS DURING THE BOARD OPERATION BY READING AT REGISTER ADDRESS 0x1nA8 (SEE **[RD2]** FOR DETAILS)

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ALL CABLES MUST BE REMOVED FROM THE FRONT PANEL BEFORE EXTRACTING THE BOARD FROM THE CRATE!

1 Introduction

The N6730 is a NIM module housing a 8-channel 14-bit 500 MS/s FLASH ADC Waveform Digitizer with software selectable 2 V_{pp} or 0.5 V_{pp} input dynamic range on single ended MCX coaxial connectors. The DC offset is adjustable in the ±1 V (@ 2 V_{pp}) or ±0.25 (@ 0.5 V_{pp}) range via a 16-bit DAC on each channel (see § **Analog Input Stage**).

Operationally, the N6725 differs from the N6730 for working at 250 MS/s sampling frequency.

The ADC resolution and the sampling frequency make these digitizers well suited for mid-fast signal detection systems (e.g. liquid or inorganic scintillators coupled to PMTs or Silicon Photomultipliers).

Each channel has a SRAM Multi-Event Buffer divisible into 1 ÷ 1024 buffers of programmable size. Two sizes of the channel digital memory are available by ordering options (see **Tab. 1.1**).

N6730 and N6725 digitizers are provided with FPGAs that can run special DPP firmware for Physics Applications (see § **12**).

A common acquisition trigger signal can be fed externally via the front panel TRG-IN input connector or via software. Alternatively, each channel is able to generate a self-trigger when the input signal goes under/over a programmable threshold. For each couple of adjacent channels, the relevant self-triggers are then processed to provide out a single trigger request. In the DPP firmware, the trigger requests can be used at channel level for the event acquisition (independent triggering), while in the default firmware they can be processed by the board to generate a common trigger causing all the channels to acquire an event simultaneously. The trigger from one board can be propagated to the other boards through the front panel GPO output connector.

During the acquisition, the data stream is continuously written in a circular memory buffer. When the trigger occurs, the digitizer writes further samples for the post trigger and freezes the buffer that can be read by one of the provided readout links. The acquisition can continue without any dead time in a new buffer.

N6730 and N6725 feature front panel CLK-IN connector as well as an internal PLL for clock synthesis from internal/external references. Multi-board synchronization is supported, so all N6730 or all N6725 can be synchronized to a common clock source and ensuring Trigger time stamps alignment. The fan-in of an external clock signal to each CLK-IN is required. Once synchronized, all data will be aligned and coherent across multi-board system.

Each module houses USB 2.0 and Optical Link interfaces. USB 2.0 allows data transfers up to 30 MB/s. The Optical Link supports transfer rate of 80 MB/s and offers Daisy chain capability. Therefore, it is possible to connect up to 8 ADC modules to a single A2818 Optical Link Controller, or up to 32 using a A3818 (4-link version). Optical Link and USB accesses are internally arbitrated.

Board Models	Description	Product Code
N6730	N6730 - 8 ch. 14bit 500 MS/s Digitizer: 640kS/ch,CE30, SE	WN6730XAAAAA
N6730B	N6730B - 8 ch. 14bit 500 MS/s Digitizer: 5.12MS/ch,CE30, SE	WN6730BXAAAA
N6725	N6725 - 8 ch. 14bit 250 MS/s Digitizer: 640kS/ch,CE30, SE	WN6725XAAAAA
N6725B	N6725B - 8 ch. 14bit 250 MS/s Digitizer: 5.12MS /ch,CE30, SE	WN6725BXAAAA
DPP Firmware	**Description**	**Product Code**
DPP-PSD (730 family)	DPP-PSD - Digital Pulse Processing for Pulse Shape Discrimination (x730)	WFWDPPNGAA30
DPP-PSD (725 family)	DPP-PSD - Digital Pulse Processing for Pulse Shape Discrimination (x725)	WFWDPPNGAA25
DPP-PHA (730 family)	DPP-PHA - Digital Pulse Processing for Pulse Height Analysis (x730)	WFWDPPTFAA30
DPP-PHA (725 family)	DPP-PHA - Digital Pulse Processing for Pulse Height Analysis (x725)	WFWDPPTFAA25
Related Products	**Description**	**Product Code**
A2818	A2818 – PCI Optical Link (Rhos compliant)	WA2818XAAAAA
A3818A	A3818A – PCIe 1 Optical Link	WA3818AXAAAA
A3818B	A3818B – PCIe 2 Optical Link	WA3818BXAAAA
A3818C	A3818C – PCIe 4 Optical Link	WA3818CXAAAA
Accessories	**Description**	**Product Code**
A318	SE to Differential Clock Adapter	WA318XAAAAAA
A654	Single Channel MCX to LEMO Cable Adapter	WA654XAAAAAA
A654 KIT4	4 MCX TO LEMO Cable Adapter	WA654K4AAAAA
A654 KIT8	8 MCX TO LEMO Cable Adapter	WA654K8AAAAA
A659	A659 - Single Channel MCX to BNC Cable Adapter	WA659XAAAAAA
A659 KIT4	4 MCX TO BNC Cable Adapter	WA659K4AAAAA
A659 KIT8	8 MCX TO BNC Cable Adapter	WA659K8AAAAA
AI2730	Optical Fibre 30 m simplex	WAI2730XAAAA
AI2720	Optical Fibre 20 m simplex	WAI2720XAAAA
AI2705	Optical Fibre 5 m simplex	WAI2705XAAAA
AI2703	Optical Fibre 30 cm simplex	WAI2703XAAAA
AY2730	Optical Fibre 30 m duplex	WAY2730XAAAA
AY2720	Optical Fibre 20 m duplex	WAY2720XAAAA
AY2705	Optical Fibre 5 m duplex	WAY2705XAAAA

Tab. 1.1: Table of models and related items

(*) Multi-license packs are also available. Please, refer to the Digitizer web page for the relevant ordering options.

2 Block Diagram

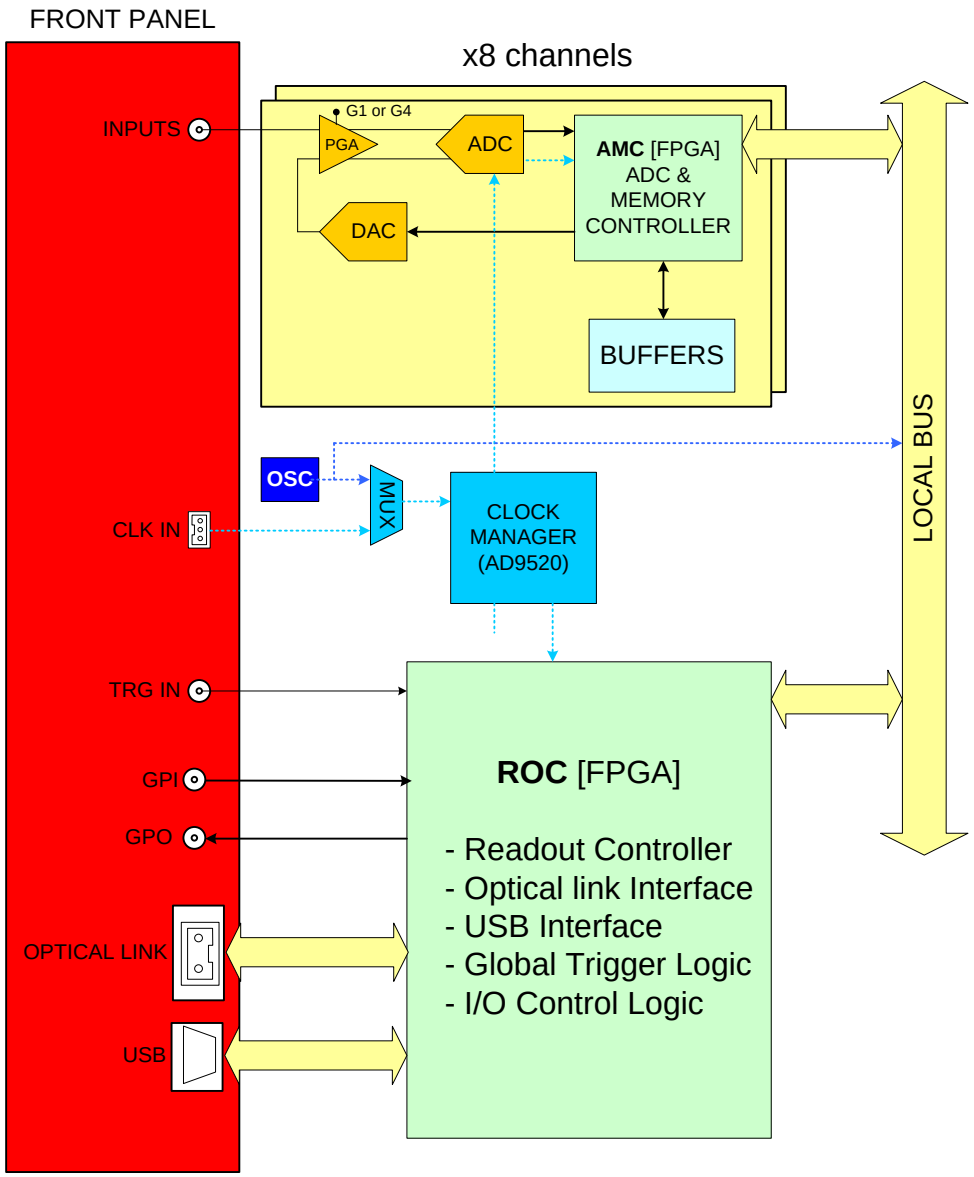

Fig. 2.1: Block Diagram

3 Technical Specifications

GENERAL	**Form Factor** 1-unit wide NIM		
ANALOG INPUT	**Channels** 8 channels Single ended **Impedance** Z_{in} = 50 Ω	**Connector** MCX **Full Scale Range** 0.5 or 2 V_{pp} (default) SW selectable	**Bandwidth** 250 MHz (N6730) 125 MHz (N6725) **Offset** Programmable 16-bit DAC for DC offset adjustment on each channel. Range: ±1 V (@2V_{pp}); ±0.25 V (@0.5V_{pp})
DIGITAL CONVERSION	**Resolution** 14 bits	**Sampling Rate** 500 MS/s Simultaneously on each channel (N6730 250 MS/s Simultaneously on each channel (N6725)	
ADC CLOCK GENERATION	Clock source: internal/external On-board PLL provides generation of the main board clocks from an internal (50 MHz local Oscillator) or external (front panel CLK-IN connector) reference		
DIGITAL I/O	**CLK-IN (AMP Modu II)** AC coupled differential input clock LVDS, ECL, PECL, LVPECL, CML (single ended NIM/TTL available by CAEN adapter) Jitter<100ppm requested **TRG-IN (LEMO)** External trigger digital input NIM/TTL, Z_{in} = 50 Ω	**GPO (LEMO)** General purpose digital output NIM/TTL, R_t = 50 Ω **GPI (LEMO)** General purpose digital input NIM/TTL, Z_{in} = 50 Ω	
MEMORY	640 kS/ch or 5.12 MS/s Multi-Event Buffer divisible into 1 ÷ 1024 buffers Independent read and write access; programmable event size and pre-post trigger		
TRIGGER	**Trigger Source** *Self-trigger*: channel over/under-threshold for Common or Individual (DPP firmware only) Trigger generation *External-trigger*: Common trigger by TRG-IN connector *Software-trigger*: Common by software command	**Trigger Propagation** GPO programmable digital output **Trigger Time Stamp** *Default FW*: 31-bit counter, 16 ns resolution, 17 s range; 48-bit extension available by firmware *DPP-PHA/DPP-PSD FW (N6730)*: 31-bit counter, 2 ns resolution, 4 s range; 47-bit extension available by firmware; 10-bit and 2 ps fine time stamp by digital CFD (DPP-PSD FW only); 64-bit extension available by software *DPP-PHA/DPP-PSD FW (N6725)*: 31-bit counter, 4 ns resolution, 8 s range; 47-bit extension available by firmware; 10-bit and 4 ps fine time stamp by digital CFD (DPP-PSD FW only); 64-bit extension available by software	
SYNCHRONIZATION	**Clock Propagation** *One-to-many*: clock distribution from an external clock source on CLK-IN connector	**Acquisition Synchronization** Sync, Start/Stop through digital I/O (TRG-IN or GPI input, GPO output) **Trigger Time Stamps Alignment** By GPI input connector	
ADC & MEM.CONTROLLER	Altera Cyclone EP4CE30 (one FPGA serves 4 channels)		
COMMUNICATION INTERFACE	**Optical Link** CAEN CONET proprietary protocol Up to 80 MB/s transfer rate Daisy chainable: it is possible to connect up to 8 or 32 ADC modules to a single Optical Link Controller (respectively A2818 or A3818)	**USB** USB 2.0 compliant Up to 30 MB/s transfer rate	
DPP FW SUPPORTED	DPP-PSD for the Pulse Shape Discrimination (e.g. Neutron-Gamma discrimination) DPP-PHA for the Pulse Height Analysis		
FIRMWARE UPGRADE	Firmware can be upgraded via USB/Optical Link		
SOFTWARE	General purpose C libraries, configuration tools, readout software (Windows and Linux support)		
POWER CONSUMPTIONS	**N6730**	4.9 A @ +6V; 250mA @ -6 V	
	N6725	*t.b.d.*	

Tab. 3.1: Specifications table

4 Packaging and Compliancy

The module is housed in a single-width NIM unit.

Fig. 4.1: Front view

Fig. 4.2: Side view

CAUTION: to manage the product, consult the operating instructions provided.

A POTENTIAL RISK EXISTS IF THE OPERATING INSTRUCTIONS ARE NOT FOLLOWED!

CAUTION: this product needs proper cooling.

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CAEN provides the specific document "Precautions for Handling, Storage and Installation" available in the documentation tab of the product web page that the user is mandatory to read before to operate with CAEN equipment.

5 Power Requirements

The table below resumes the N6730 power consumptions per relevant power supply rail.

MODULE	SUPPLY VOLTAGE	
	+6V	-6V
N6730	4.9 A	250 mA
N6725	*t.b.d.*	*t.b.d.*

Tab. 5.1: Power requirements table

6 Temperature Protection

TEMPERATURE PROTECTION IS NOT AVAILABLE FOR DEFAULT FIRMWARE RELEASES < 4.5_0.3 (REFER TO § 12)

To preserve hardware damages, the N6730 and N6725 implement an automatic turning off of the board channels in event of internal over-temperature. Internal temperature can be monitored at register address 0x1nA8.

The over-temperature limit is fixed at 70°C. As soon as the internal temperature exceeds 70°C, the board enters the temperature protection condition and the firmware automatically performs the following actions:

- turns off all the channel ADCs;
- stops the acquisition, if running (data possibly stored at that moment can be readout in any case).

This status is valid as long as the internal temperature remains over 62°C. Starting from 61°C, the user is allowed to turn on the channel ADCs again and restart the acquisition, if necessary.

The temperature protection can be controlled by register addresses 0x8104 and 0x810C.

7 Panel Description

Fig. 7.1: Front panel view

Front Panel

ANALOG INPUT

FUNCTION

Input connectors (CH0 to CH7) receiving the input analog signals.

ELECTRICAL SPECS

Input dynamics: 2 or 0.5 V_{pp} (SW selectable)

Input impedance (Z_{in}): 50 Ω.

MECHANICAL SPECS

Series: MCX connectors.

Type: CS 85MCX-50-0-16.

Manufacturer: SUHNER

Suggested plug: MCX-50-2-16 type.

Suggested cable: RG174 type.

CLOCK IN

FUNCTION

Input connector for the external clock.

ELECTRICAL SPECS

Sign. type: differential (LVDS, ECL, PECL, LVPECL, CML). CAEN provides single-ended to differential A318 cable adapter (see **Tab. 1.1**) for CLK-IN.

Coupling: AC.

Z_{diff}: 100 Ω.

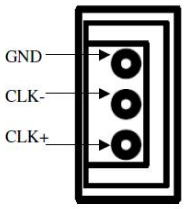
MECHANICAL SPECS

Series: AMPMODU connectors.

Type: 3-102203-4 (3-pin).

Manufacturer: AMP Inc.

PINOUT



CLK IN LED (GREEN): indicates the external clock is enabled.

GPO

FUNCTION

General purpose programmable digital output connector to propagate:

- the internal trigger sources;
- the channel probes (i.e. signals from the mezzanines);
- GPI signal

according to register addresses 0x8110 and 0x811C, or

- the motherboard probes (i.e. signals from the motherboard), like the Run signal, ClkOut signal, ClockPhase signal, PLL_Unlock signal or Busy signal

according to register address 0x811C.

ELECTRICAL SPECS

Signal level: NIM or TTL.

Requires 50 Ω termination.

MECHANICAL SPECS

Series: 101 A 004 connectors.

Type: DLP 101 A 004-28.

Manufacturer: FISCHER.

Alternatively:

Type: EPL 00 250 NTN.

Manufacturer: LEMO.

TRG IN

FUNCTION

Digital input connector for the external trigger.

ELECTRICAL SPECS

Signal level: NIM or TTL.

Input impedance (Z_{in}): 50 Ω.

MECHANICAL SPECS

Series: 101 A 004 connectors.

Type: DLP 101 A 004-28.

Manufacturer: FISCHER.

Alternatively:

Type: EPL 00 250 NTN.

Manufacturer: LEMO.

GPI

FUNCTION

General purpose programmable input connector.

Can be used to reset the time stamp (see § **Timer Reset**)or to start/stop the acquisition.

ELECTRICAL SPECS

Signal level: NIM or TTL.

Input impedance (Z_{in}): 50 Ω.

MECHANICAL SPECS

Series: 101 A 004 connectors.

Type: DLP 101 A 004-28.

Manufacturer: FISCHER.

Alternatively:

Type: EPL 00 250 NTN.

Manufacturer: LEMO.

OPTICAL LINK PORT

FUNCTION

Optical LINK connector for data readout and flow control. Daisy chainable. Compliant to Multimode 62.5/125µm cable featuring LC connectors on both sides.

ELECTRICAL SPECS

Transfer rate: up to 80 MB/s.

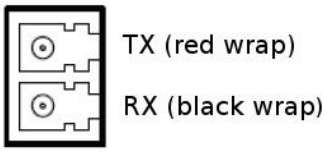
MECHANICAL SPECS

Series: SFF Transceivers.

Type: FTLF8519F-2KNL (LC connectors).

Manufacturer: FINISAR.

PINOUT



LINK LEDs (GREEN/YELLOW): right LED (GREEN) indicates the network presence, while left LED (YELLOW) signals the data transfer activity.

USB PORT

FUNCTION

USB connector for data readout and flow control.

ELECTRICAL SPECS

Standard: compliant to USB 2.0 and USB 1.0.

Transfer rate: up to 30 MB/s.

MECHANICAL SPECS

Series: USB connectors.

Type: 787780-2 (B-Type).

Manufacturer: AMP Inc.

USB LINK LED (GREEN): indicates the USB communication is active.

DIAGNOSTICS LEDs

TTL (GREEN): indicates the standard TTL is set for GPO, TRG IN, GPI;

NIM (GREEN): indicates the standard NIM is set for GPO, TRG IN, GPI;

PLL LOCK (GREEN): indicates the PLL is locked to the reference clock;

PLL BYPS (GREEN): indicates the PLL drives directly the ADCs. PLL circuit is switched off and PLL LOCK LED is turned off;

RUN (GREEN): indicates the acquisition is running (data taking). See § **Acquisition Run/Stop**;

TRG (GREEN): indicates the trigger is accepted.

DRDY (GREEN): indicates the event/data is present in the Output Buffer.

BUSY (RED): indicates all the buffers are full for at least one channel.

LABELS	
	A blue label on top of the NIM front panel indicates: – Manufacturer name and functional name – Module name and the input range information
	A little silver label on the bottom of the NIM front panel reports: – Serial Number (S/N)

8 Functional Description

Analog Input Stage

Input dynamics can be 2 V_{pp} (default) or 0.5 V_{pp}, by software selection (basing on the Programmable Gain Amplifier in the scheme of **Fig. 8.1**), on single ended MCX coaxial connectors (see § **7**). A 16-bit DAC allows to add a DC offset in order to preserve the full dynamic range also in the extreme case of unipolar positive or negative input signal. The input bandwidth ranges from DC to 250 MHz (@3dB) for N6730, to 125 MHz (@3dB) for N6725, by 2nd order linear phase anti-aliasing low-pass filter.

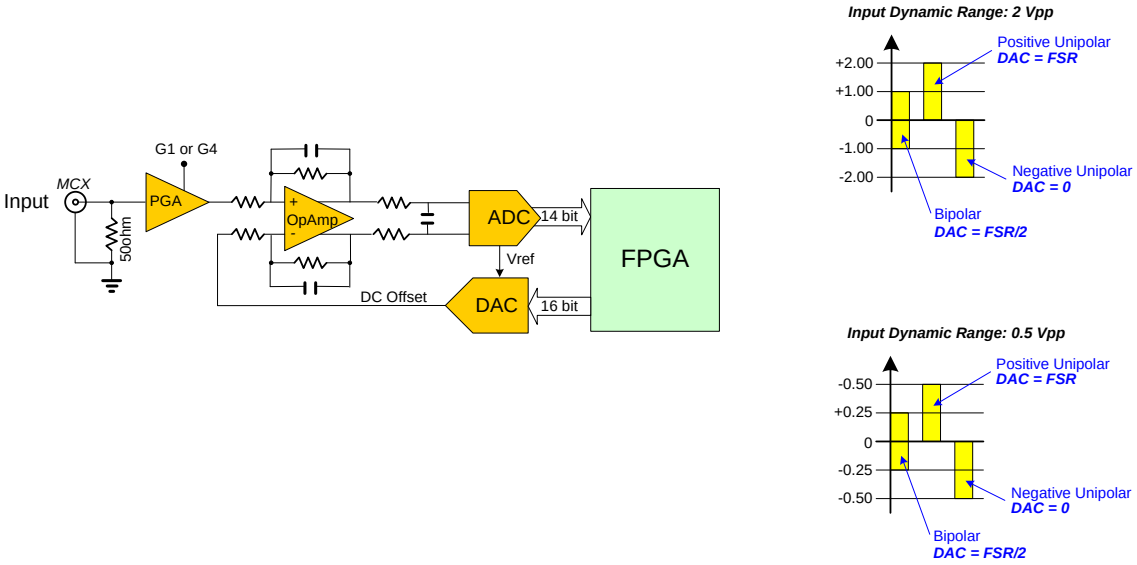


Fig. 8.1: Analog Input Diagram

Setting the input range requires a write access at register address 0x1n28, while at register address 0x1n98 it is possible to configure the DC offset level.

Clock Distribution

The module clock distribution takes place on two domains: OSC-CLK and REF-CLK; the former is a fixed 50MHz clock provided by an on- board oscillator, the latter provides the ADC sampling clock.

OSC-CLK handles Local Bus (communication between motherboard and mezzanine boards; see red traces in **Fig. 8.2**).

REF-CLK handles ADC sampling, trigger logic, acquisition logic (samples storage into RAM, buffer freezing on trigger) through a clock chain. Such domain can use either an external (via front panel signal on CLK-IN) or an internal (via local oscillator) source, in the latter case OSC-CLK and REF-CLK will be synchronous (the operation mode remains the same anyway).

N6730 and N6725 use an integrated phase-locked-loop (PLL) and clock distribution device, AD9520. It is used to generate the sampling clock for ADCs and the mezzanine FPGA (SAMP-CLK0/SAMP-CLK1), as well as the trigger logic synchronization clock (TRG-CLK).

Both clocks can be generated from the internal oscillator or from external clock input. By default, the board uses the internal clock as PLL reference (REF-CLK).

The external clock can be selected by write access at register address 0x8100 (refer to **[RD2]**). The external clock signal must be differential (LVDS, ECL, PECL, LVPECL, CML) with a jitter lower than 100ppm (see **Tab. 3.1**).

AD9520 configuration can be changed and stored into non-volatile memory. AD9520 configuration change is primarily intended to be used for external PLL reference clock frequency change:

N6730 and N6725 lock to an external 50 MHz clock with default AD9520 configuration (see § **PLL Mode**).

Refer to the AD9520 datasheet for more details:

http://www.analog.com/static/imported-files/data_sheets/AD9520-3.pdf

(in case the active link above doesn't work, copy and paste it on the internet browser)

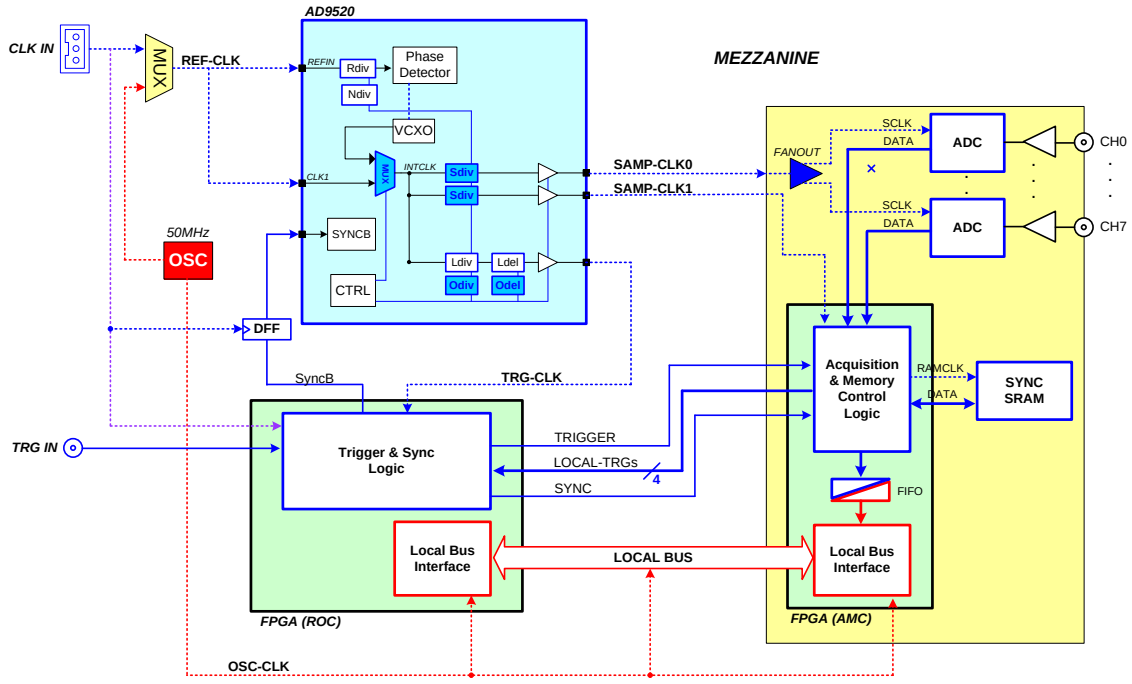


Fig. 8.2: Clock Distribution Diagram

PLL Mode

The Phase Detector within the AD9520 device allows to couple REF-CLK with a VCXO (500 MHz frequency) providing out the nominal ADCs frequency (500 MHz sampling frequency); for this purpose, it is necessary that REF-CLK is a submultiple of the VCXO frequency.

As introduced in § **Clock Distribution**, the source of the REF-CLK signal can be external (see **Fig. 8.2**) on CLK-IN front panel connector or internal from the 50 MHz local oscillator. The following options are allowed:

1. 50 MHz internal clock source – It's the standard operating mode, where the default AD9520 configuration doesn't require to be changed. OSC-CLK = REF-CLK.
2. 50 MHz external clock source – In this case it is not required to reprogram the AD9520 dividers, as the external clock reference is identical to the frequency of the internal oscillator. CLK-IN = OSC-CLK = REF-CLK.

   Note that, In order the board to sense the external signal on CLK-IN and use it as new reference, bit[6] at register address 0x8100 must be set (see **[RD2]**).
3. External clock source different from 50 MHz – In this case, the user is required to program the AD9520 dividers in order to lock the VCXO to REF-CLK in order to provide out the 500 MHz (N6730) or 250 MHz (N6725) nominal sampling frequency. In principle, the allowed external frequencies are submultiples of the VCXO frequency (500 MHz). CLK-IN = REF-CLK.

Note: the user who wants to work as in point 3, please contact CAEN indicating the required reference clock frequency to check its feasibility and then receive the PLL programming file. The "Upgrade PLL" function in CAENUpgrader software tool can be used to update the digitizer PLL. See § **10** for the program description and refer to **[RD1]** for documentation. The programming file also takes care to set the board to sense the external signal on CLK-IN.

Changing the ADC Frequency

Please, contact CAEN (see § **13**) for information on how to operate the N6730/N6725 with a sampling frequency lower than the nominal.

Trigger Clock

TRG-CLK signal has a 125-MHz frequency, that is equal to 1/4 (N6730) or 1/2 (N6725) of SAMP-CLK. In consequence, a 4 samples (N6730) or 2 samples (Nn6725) "uncertainty" occurs over the acquisition window.

Acquisition Modes

Channel Calibration

The module performs a self-calibration of the ADCs at its power-on. Anyway, in order to achieve the best performance, the calibration procedure is recommended to be executed by the user, on command, after the ADCs have stabilized their operating temperature. The calibration will not need to be repeated at each run unless the operating temperature changes significantly, or clock settings are modified (e.g. switching from internal to external clock).

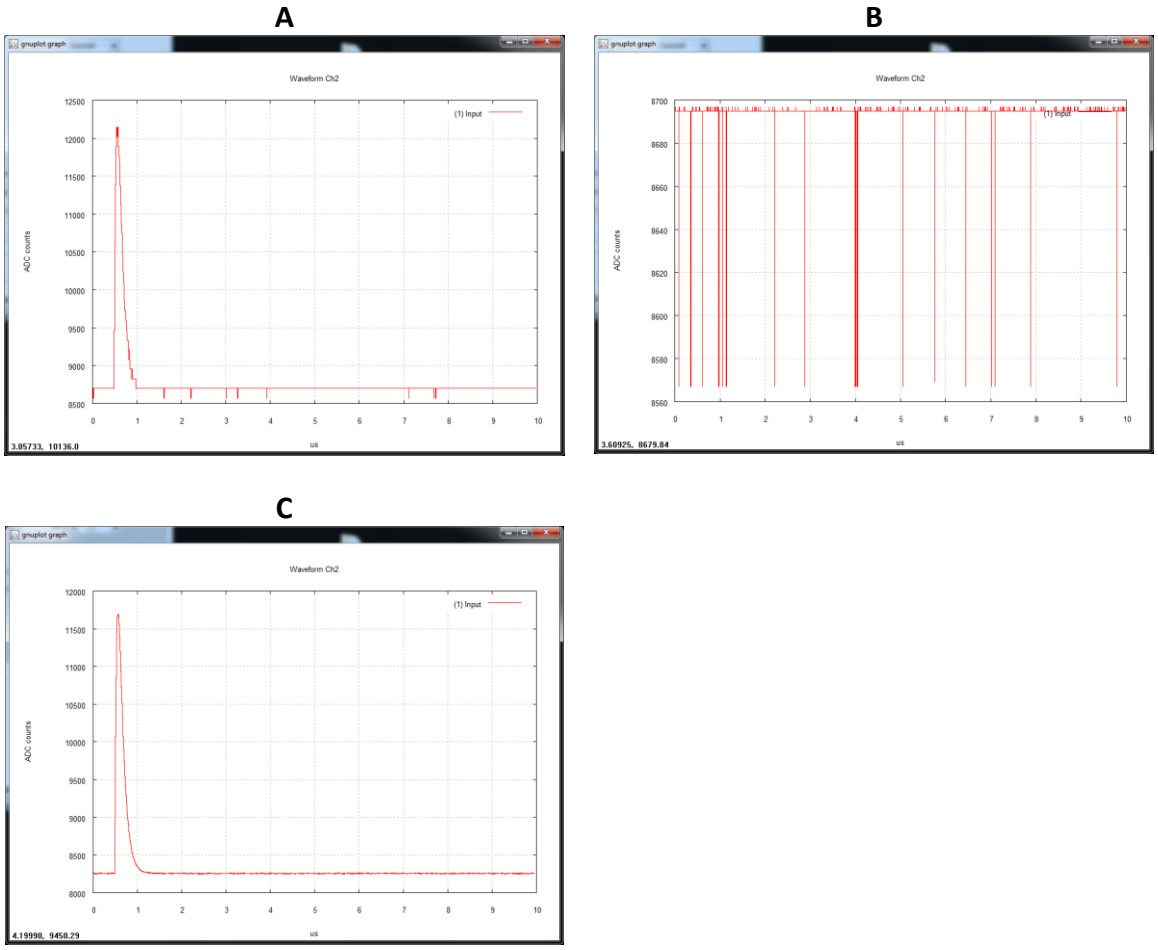
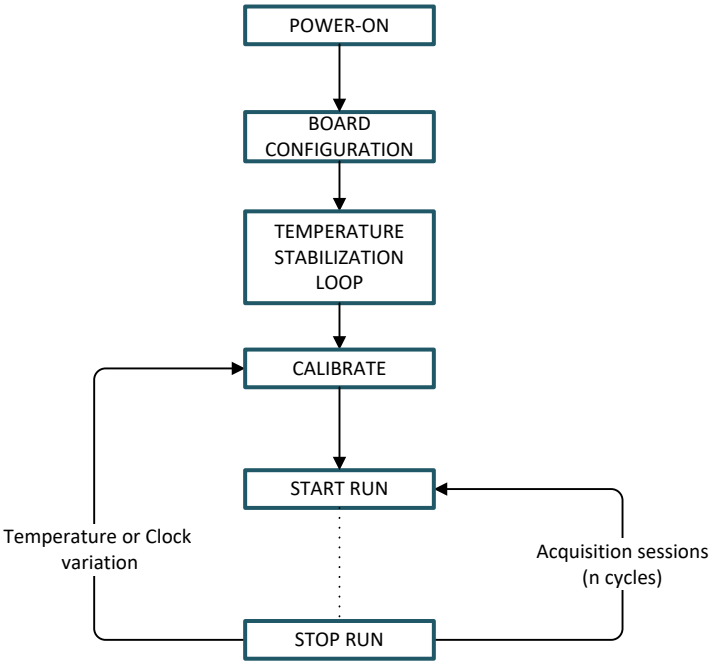


Fig. 8.3: Typical channel before the calibration (A and B) and after the calibration (C)

The diagram below schematizes the flow for a proper calibration:



– At low level, the ADCs temperature can be read at the register address 0x1nA8, while the calibration must be performed through register address 0x809C. The following steps are required:

  - Write whatever value at register address 0x809C: the self-calibration process will start simultaneously on each channel of the board and the "Calibrating bit" flag of register address 0x1n88 will be set to 0.
  - Poll the "Calibrating bit" flag until it returns to 1.

Note: It is normally not required to calibrate after a board reset but, if a Reset command is intentionally issued to the digitizer (write access at register address 0xEF24) to be directly followed by a calibration procedure, it is recommended to wait for the board to reach stable conditions (indicatively 100 ms) before to start the calibration.

– At the library level, developers can exploit the CAENDigitizer library (see § **9**) dedicated routines like *ReadTemperature()* function for temperature readings, Set/GetChannelDCOffset for DC Offset management, *Reset()* function to reset the board, and the *Calibrate()* function which executes the channel calibration steps above described.

IMPORTANT NOTE: Starting from CAENDigitizer release 2.6.1, the *Reset()* function has been modified so that it no longer includes the channel calibration routine implemented in the code. This calibration must be performed on command by the dedicated *Calibrate()* function. Please, see the Library user manual for reference ([RD5]).

- At software level, CAEN manages the on command channel calibration in different readout software (please, refer the relevant software User Manual for details).

  - ***WaveDump***

    1. Lauch WaveDump. This software performs an automatic ADC calibration and displays a message when it is completed (see **Fig. 8.4**).

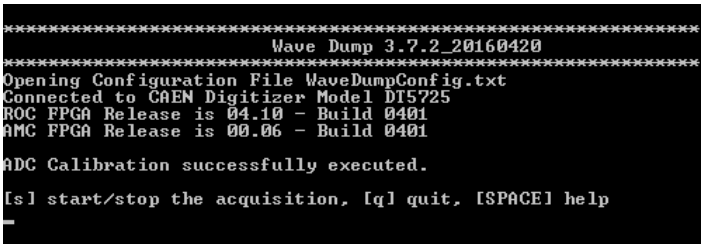


Fig. 8.4: Automatic calibration at WaveDump first run

This allows the user to start using the program sure that the digitizer has been calibrated at least once.

NOTE THAT: If SKIP_STARTUP_CALIBRATION parameter is set to YES in WaveDump configuration file, the automatic start-up calibration is not performed and no message is displayed

2. At any time, the user can check the channel temperatures (with the acquisition not running) by issuing multiple "m" commands from the keyboard.

3. In case of significant variations, issuing a "c" command provokes a manual channel calibration to be executed (see **Fig. 8.5**).

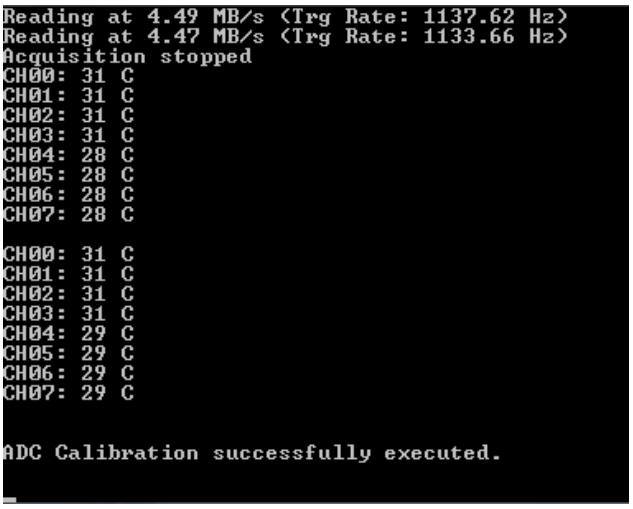


Fig. 8.5: Temperature monitoring with manual calibration in WaveDump software

4. A new acquisition can start.

Please, refer to WaveDump User Manual for complete software description (**[RD6]**).

- ***DPP-PSD Control Software***

1. Launch DPP-PSD Control Software
2. Connect to the digitizer
3. Before to start the acquisition, go to the "Stats" tab and monitor the channel temperatures displayed in the relevant column until you see they don't vary significantly
4. Go to the "General" tab and press the "Calibrate" button
5. Start the acquisition

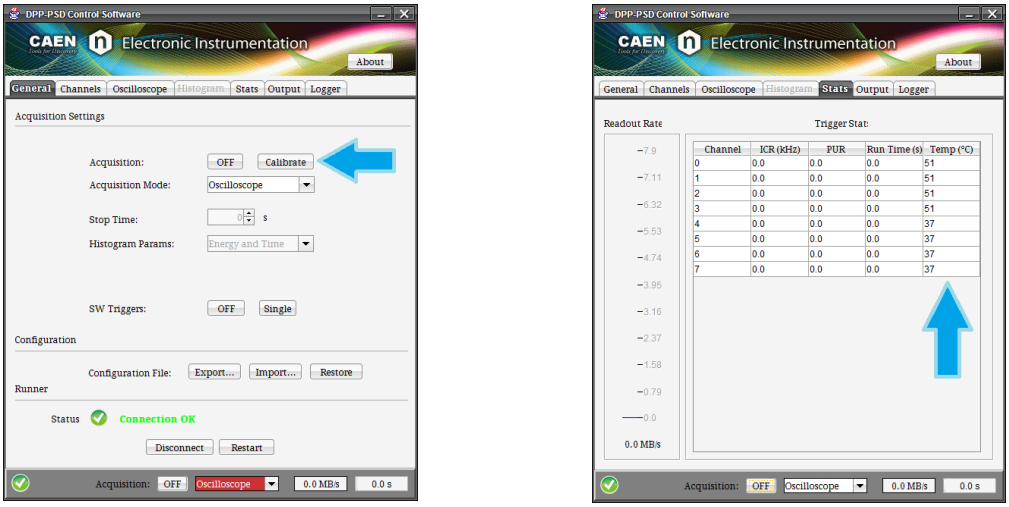


Fig. 8.6: Channel calibration in DPP-PSD Control Software

- ***MC²Analyzer***

1. Launch MC²A
2. Connect to the digitizer
3. Before to start the acquisition, monitor the channel temperatures in *Tools->ADC calibration*
4. Press "Calibrate" button to perform the calibration
5. Start the acquisition

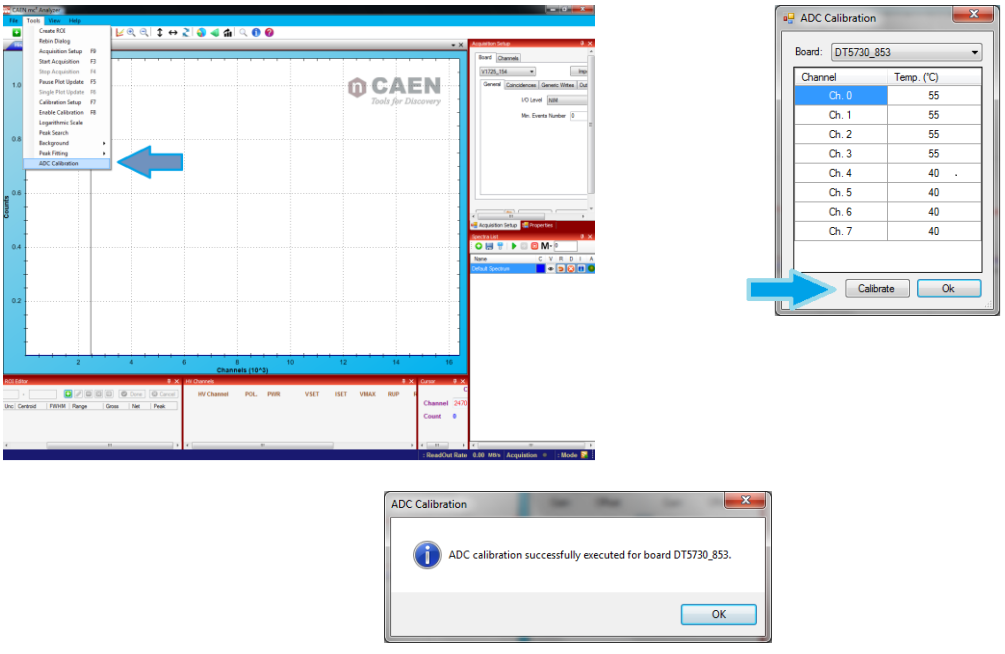


Fig. 8.7: Channel calibration in MC²Analyzer software

Acquisition Run/Stop

The acquisition can be started and stopped in different ways, according to bits[1:0] setting at register address 0x8100 and bit[2] of the same register:

- SW CONTROLLED (bits[1:0] = 00): Start and Stop take place by software command. Bit[2] = 0 means stopped, while bit[2] = 1 means running.

- GPI CONTROLLED MODE (bits[1:0] = 01): If the acquisition is armed (i.e. bit[2] = 1), then Run starts when GPI is asserted and stops when GPI returns inactive. If bit[2] = 0, the acquisition is always off.

- FIRST TRIGGER CONTROLLED (bits[1:0] = 10): bit[2] = 1 arms the acquisition and the Start is issued on the first trigger pulse (rising edge) on the TRG-IN connector. This pulse is not used as a trigger; actual triggers start from the second pulse on TRG-IN. The Stop acquisition must be SW controlled (i.e. reset of bit[2]).

Acquisition Triggering: Samples & Events

When the acquisition is running, a trigger signal allows to:

- Store the 31-bit counter value of the Trigger Time Tag (TTT).
  The counter (representing a time reference), like so the Trigger Logic Unit (see **Fig. 8.2**) operates at a frequency of 125 MHz (i.e. 8 ns, that is to say 4 ADC clock cycles). Due to the way the acquired data are written into the board internal memory (i.e. in 4-sample bunches), the TTT counter is read every 2 trigger logic clock cycles, which means the trigger time stamp resolution results in 16 ns (i.e. 62.5 MHz). Basing on that, the LSB of the TTT is always "0";
- Increment the EVENT COUNTER.
- Fill the active buffer with the pre/post-trigger samples, whose number is programmable (Acquisition window width), freezing then the buffer for readout purposes, while acquisition continues on another buffer.

An event is therefore composed by the trigger time tag, pre- and post-trigger samples and the event counter.

Overlap between "acquisition windows" may occur (a new trigger occurs while the board is still storing the samples related to the previous trigger); this overlap can be either rejected or accepted (programmable via software).

If the board is programmed to accept the overlapped triggers, as the "overlapping" trigger arrives, the current active buffer is filled up, then the samples storage continues on the subsequent one. In this case events will not have all the same size (see **Fig. 8.8** below)

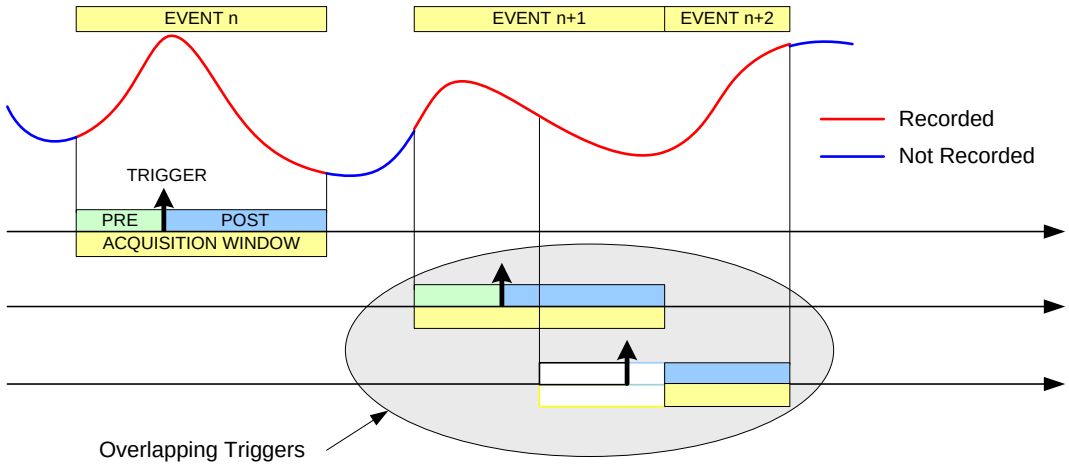


Fig. 8.8: Trigger overlap

A trigger can be refused for the following causes:

- Acquisition is not active.
- Memory is FULL and therefore there are no available buffers.
- The required number of samples for building the pre-trigger of the event is not reached yet; this happens typically as the trigger occurs too early either with respect to the *RUN Acquisition* command (see § **Acquisition Run/Stop**) or with respect to a buffer emptying after a *Memory FULL* status (see § **Acquisition Synchronization**).
- The trigger overlaps the previous one and the board is not enabled for accepting overlapped triggers.

As a trigger is refused, the current buffer is not frozen and the acquisition continues writing on it. The EVENT COUNTER can be programmed in order to be either incremented or not. If this function is enabled, the EVENT COUNTER value identifies the number of the triggers sent (but the event number sequence is lost); if the function is not enabled, the EVENT COUNTER value coincides with the sequence of buffers saved and readout.

Multi-Event Memory Organization

Each channel of the N6730/N6725 features a SRAM memory to store the acquired events. The memory size for the event storage is 640 kS/ch or 5.12 MS/s, according to the board version (**Tab. 1.1**), and it can be divided in a programmable number, N_b, of buffers (N_b from 1 up to 1024) by register address 0x800C as described in **Tab. 8.1** below.

Register Value	Buffer Number (N_b)	Size of one Buffer (Samples)	
		SRAM 640 kS/ch(*)	SRAM 5.12 MS/ch(*)
0x00	1	640k - 10	5.12M - 10
0x01	2	320k - 10	2.56M - 10
0x02	4	160k - 10	1.28M - 10
0x03	8	80k - 10	640k - 10
0x04	16	40k - 10	320k - 10
0x05	32	20k - 10	160k - 10
0x06	64	10k - 10	80k - 10
0x07	128	5k - 10	40k - 10
0x08	256	2560 - 10	20k - 10
0x09	512	1280 - 10	10k - 10
0x0A	1024	640 - 10	5120 - 10

Tab. 8.1: Buffer Organization

Having 640 kS memory size as reference, this means that each buffer contains 640k/N_b samples (e.g. N_b = 1024 means 640 samples in each buffer).

(*)**IMPORTANT:** For AMC FPGA firmware release < **0.2**, the Size of one Buffer related to each Buffer Number must be intended as the number of the samples in **Tab. 8.1**. without decreasing by 10 samples.

Custom Sized Events

In case an event size minor than the buffer size is needed, the user can set the value N_{LOC} at register address 0x8020; the event is so forced to be made by 10*N_{LOC} samples. Setting N_{LOC} = 0, the custom size is disabled. The value of N_{LOC} must be set in order that the relevant number of samples does not exceed the buffer size and it mustn't be modified while the acquisition is running.

Note: Even using the custom size setting, the number of buffers and the buffer size are not affected by N_{LOC}, but they are still determined by N_b.

The concepts of buffer organization and custom size directly affect the width of the acquisition window (i.e. number of the digitized waveform samples per event). The *Record Length* parameter defined in CAEN software (such as WaveDump and CAENScope introduced in § **10**) and the *Set/GetRecordLength()* function of the CAENDigitizer library (refer to **[RD5]**) rely on these concepts.

Event Structure

The event can be readout via Optical Link and/or USB; data format is 32-bit long word (see **Tab. 8.3**)

An event is structured in:

- **Header** (four 32-bit words)
- **Data** (variable size and format)

Header is made by 4 words including the following information:

- **EVENT SIZE (Bit[27:0] of 1st header word)** = It is the size of the event (number of 32-bit long words);
- **BOARD FAIL FLAG (Bit[26] of 2nd header word)** = Implemented from ROC FPGA firmware revision **4.5** on (*reserved* otherwise), this bit is set to "1" in consequence of a hardware problem (e.g. PLL unlocking or over-temperature condition). The user can collect more information about the cause by reading at register address 0x8104 and contact CAEN Support Service if necessary (see § **13**);
- **Bit[24] (2nd header word)** = This bit identifies the event format; it is reserved and **must be 0**;
- **Bit[23:8] (2nd header word)** = Starting from revision **4.6** of the ROC FPGA firmware, these 16 bits can be programmed to provide different trigger information according to the setting of the bits[22:21] at register address 0x811C (**Tab. 8.2**).

Note: for ROC FPGA firmware revisions lower than **4.6**. these bits are *reserved*.

REGISTER 0x811C Bits[22:21]	FUNCTIONAL DESCRIPTION	Bit[23:8] (16 bits in the 2nd header word)
00 (default)	*Not used*	Must be 0
01	Event Trigger Source	Indicates the trigger source causing the event acquisition: Bits[23:19] = 0000 Bit[18] = Software Trigger Bit[17] = External Trigger Bit[16] = 0 Bits[11:8] = Trigger requests from the couple of channels (refer to § **Self-Trigger**)
10	Extended Trigger Time Tag (ETTT)	A 48-bit Trigger Time Tag (ETTT) information is configured, where Bits[23:8] contributes as the 16 most significant bits together to the 32-bit TTT field (4th header word). **Note:** in the 48-bit TTT, the overflow bit is not provided.
11	*Not used*	Must be 0

Tab. 8.2: TRG OPTIONS configuration table

- **CHANNEL MASK** (**Bit[7:0] of 2nd header word**) = It is the mask of the channels participating in the event. This information must be used by the software to acknowledge which channel the samples are coming from.
- **EVENT COUNTER (Bit[23:0] of 3rd header word)** = This is the trigger counter; it can count either accepted triggers only, or all triggers.

- **TRIGGER TIME TAG (Bit[31:0] of 4th header word)** = It is the 31-bit Trigger Time Tag information (31-bit counter and 32nd bit as roll over flag), which is the trigger time reference. If the ETTT option is enabled, then this field becomes the 32 less significant bits of the extended 48-bit trigger time tag information in addition to the 16 bits (MSB) of the TRG OPTIONS field (2nd event word). Note that, in the ETTT case, the roll over flag is no more provided. The trigger time tag is reset either as the acquisition starts or via front panel signal on GPI connector, and increments with 125-MHz frequency (every 4 ADC clock cycles in case of N6730 or 2 ADC clock cycles with N6725). The trigger time tag value is read at half this frequency (62.5 MHz). So, the trigger time tag specifications result in 16 ns resolution and 17 s range (i.e. 8 ns*(2^{31}-1)), which can be extended to 625 h (i.e. 8 ns*(2^{48}-1)) by the Extended Trigger Time Tag option.

Data are the samples from the enabled channels. Data from masked channels are not read.

Event Format Example

Tab. 8.3 shows the event data format of N6730/N6725 when all the 8 channels are enabled. The structure is described in § **Event Structure**.

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
1	0	1	0	EVENT SIZE																												HEADER
RESERVED						BF	RES.	0	RESERVED / TRG OPTIONS																			CHANNEL MASK [7:0]				
RESERVED									EVENT COUNTER																							
TRIGGER TIME TAG																																
0	0	SAMPLE [1] – CH[0]														0	0	SAMPLE [0] – CH[0]														DATA CH0
0	0	SAMPLE [3] – CH[0]														0	0	SAMPLE [2] – CH[0]														
• • •																																
0	0	SAMPLE [N-1] – CH[0]														0	0	SAMPLE [N-2] – CH[0]														
0	0	SAMPLE [1] – CH[1]														0	0	SAMPLE [0] – CH[1]														DATA CH1
0	0	SAMPLE [3] – CH[1]														0	0	SAMPLE [2] – CH[1]														
• • •																																
0	0	SAMPLE [N-1] – CH[1]														0	0	SAMPLE [N-2] – CH[1]														
• • •																																• • •
0	0	0	0	SAMPLE [1] – CH[7]												0	0	SAMPLE [0] – CH[7]														DATA CH7
0	0	SAMPLE [3] – CH[7]														0	0	SAMPLE [2] – CH[7]														
• • •																																
0	0	SAMPLE [N-1] – CH[7]														0	0	SAMPLE [N-2] – CH[7]														

Tab. 8.3: Event Format Example

Acquisition Synchronization

Each channel of the digitizer is provided with a SRAM memory that can be organized in a programmable number N_b of circular buffers (N_b = [1:1024], see **Tab. 8.1**). When the trigger occurs, the FPGA writes further a programmable number of samples for the post-trigger and freezes the buffer, so that the stored data can be read via USB or Optical Link. The acquisition can continue without dead-time in a new buffer.

When all buffers are filled, the board is considered FULL: no trigger is accepted and the acquisition stops (i.e. the samples coming from the ADC are not written into the memory, so they are lost). As soon as at least one buffer is readout, the board exits the FULL condition and acquisition restarts.

Note: When the acquisition restarts, no trigger is accepted until at least the entire buffer is written. This means that the dead time is extended for a certain time (depending on the size of the acquisition window) after the board exits the FULL condition.

A way to eliminate this extra dead time is by setting bit[5] = 1 at register address 0x8100. The board is so programmed to enter the FULL condition when N-1 buffers are written: no trigger is then accepted, but samples writing continues in the last available buffer. As soon as one buffer is readout and becomes free, the boards exits the FULL condition and can immediately accept a new trigger. This way, the FULL reflects the BUSY condition of the board (i.e. inability to accept triggers); if required, the BUSY signal can be provided out on the digitizer front panel through the GPO LEMO connector (bits[19:18] and bits[17:16] at register address 0x811C).

Note: when bit[5] = 1, the minimum number of circular buffers to be programmed is N = 2.

In some cases, the BUSY propagation from the digitizer to other parts of the system has some latency and it can happen that one or more triggers occur while the digitizer is already FULL and unable to accept those triggers. This condition causes event loss and it is particularly unsuitable when there are multiple digitizers running synchronously, because the triggers accepted by one board and not by other boards cause event misalignment.

In this cases, it is possible to program the BUSY signal to be asserted when the digitizer is close to FULL condition, but it has still some free buffers (Almost FULL condition). In this mode, the digitizer remains able to accept some more triggers even after the BUSY assertion and the system can tolerate a delay in the inhibit of the trigger generation. When the Almost FULL condition is enabled by setting the Almost FULL level (register address 0x816C) to X, the BUSY signal is asserted as soon as X buffers are filled, although the board still goes FULL (and rejects triggers) when the number of filled buffers is N or N-1, depending on bit[5] at register address 0x8100 as described above.

It is possible to provide the BUSY signal on the digitizer front panel TRG-OUT output (bit[20], bits[19:18] and bits[17:16] at register address 0x811C are involved).

Trigger Management

According to the default firmware operating, all the channels in a board share the same trigger (board common trigger), that is to say they acquire an event simultaneously and in the same way (a determined number of samples and position with respect to the trigger).

Note: For the trigger management in the DPP firmware operating, please refer to **[RD9]** and **[RD10]**.

The generation of a common acquisition trigger is based on different trigger sources (configurable at register address 0x810C):

- **Software trigger**
- **External trigger**
- **Self-trigger**
- **Coincidence**

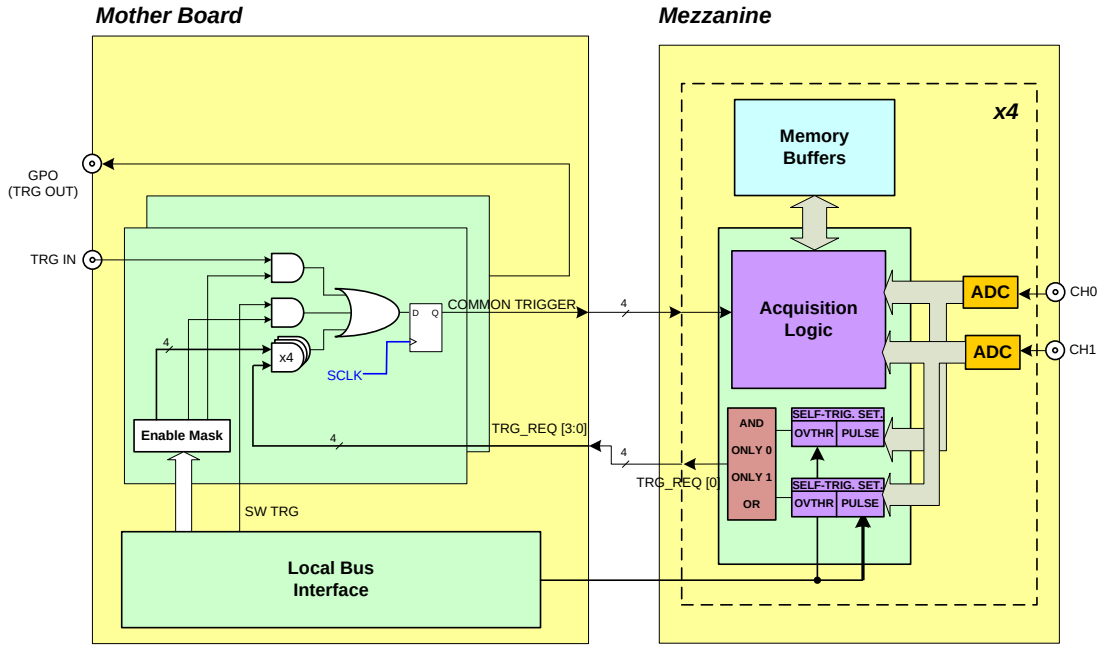


Fig. 8.9: Trigger Management block diagram

Software Trigger

Software triggers are internally produced via a software command (write access at register address 0x8108) through USB or Optical Link.

External Trigger

A TTL or NIM external signal can be provided in the front panel TRG-IN connector (configurable at register address 0x811C). If the external trigger is not synchronized with the internal clock, a 1-clock period jitter occurs.

Self-Trigger

Each channel is able to generate a self-trigger signal when the digitized input pulse exceeds a configurable threshold (register address 0x1n60). The self-triggers of each couple of adjacent channels are then processed to provide out a single trigger request. The trigger requests are propagated to the central trigger logic where they are ORed to produce the board common trigger, which is finally distributed back to all channels causing the event acquisition (see **Fig. 8.9**). **Fig. 8.10** schematizes the self-trigger and trigger request logic having the channel 0 and channel 1 couple as an example.

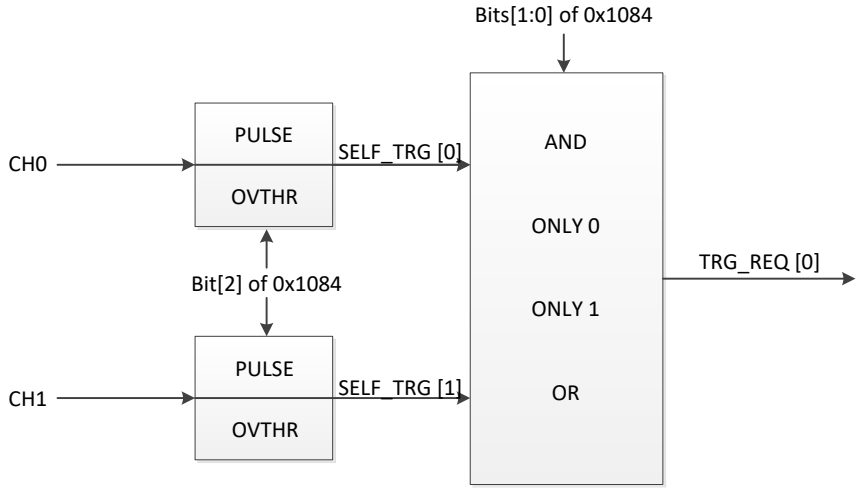


Fig. 8.10: Self Trigger and Trigger Request logic for Ch0 and Ch1 couple. A single trigger request signal is generated

The FPGA, by register address 0x1n84, can be programmed in order the self-trigger to be:

- an *over/under-threshold signal* (see **Fig. 8.11**). This signal can be programmed to be active (i.e. "1") as long as the input pulse is over the threshold or under the threshold (depending on the trigger polarity bit at register address 0x8000).

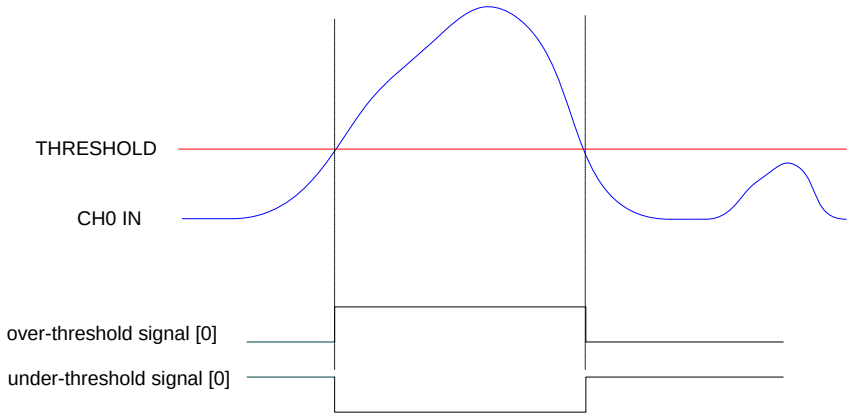


Fig. 8.11: Channel over/under threshold signal

- a *pulse of configurable width* (see **Fig. 8.12**). The width parameter can be set at register address 0x1n70.

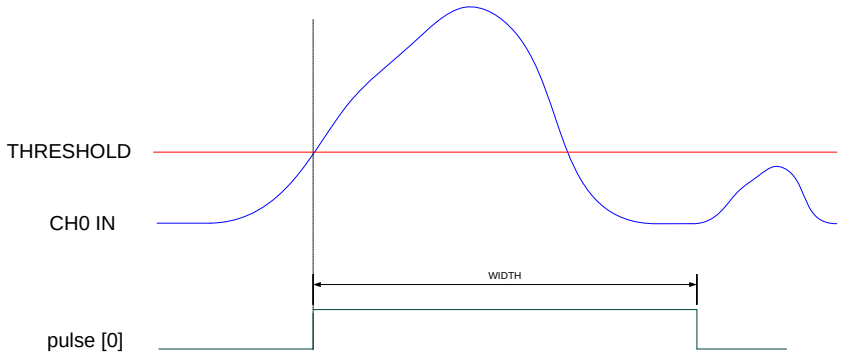


Fig. 8.12: Channel pulse signal

The FPGA, by register address 0x1n84, can be programmed in order the trigger request for a couple of adjacent channels to be the

AND,

ONLY CH(n),

ONLY CH(n+1),

OR

of the relevant self-trigger signals (see **Fig. 8.10**).

Default Conditions: by default, the FPGA is programmed so that the trigger request is the OR of two pulses of 4ns-width.

Note: the above described configurability of both the self-trigger logic and the trigger request logic are supported only by AMC FPGA firmware releases > **0.1**.
Previous firmware don't implement the register address 0x1n84 as well as the 0x1n70, the self-trigger is intended only as the over/under threshold signal and a trigger request is intended only as the OR of the self-triggers couple.

Trigger Coincidence Level

Operating with the default firmware, the acquisition trigger is a board common trigger. This common trigger allows the coincidence acquisition mode to be performed through the Majority operation.

Note: From AMC FPGA firmware release > **0.1**, it is possible to program the self-trigger logic as described in § **Self-Trigger**.

Enabling the coincidences is possible by writing at register address 0x810C:

- Bits[3:0] enable the trigger request signals to participate in the coincidence;
- Bits[23:20] set the coincidence window (T_{TVAW}) linearly in steps of the Trigger clock (8 ns);
- Bits[26:24] set the Majority (i.e. Coincidence) level; the coincidence takes place when:

Number of enabled trigger requests > Majority level

Supposing bits[3:0] = FF (i.e. all the 4 trigger request are enabled) and bits[26:24] = 01 (i.e. Majority level = 1), a board common trigger is issued whenever at least two of the enabled trigger requests are in coincidence within the programmed T_{TVAW}.

The Majority level must be smaller than the number of trigger requests enabled via bits[3:0] mask. By default, bits[26:24] = 00 (i.e. Majority level = 0), which means the coincidence acquisition mode is disabled and the T_{TVAW} is meaningless. In this case, the board common trigger is simple OR of the signals from the enabled channels pairs.

Fig. 8.13 and **Fig. 8.14** show the trigger management in case the coincidences are disabled

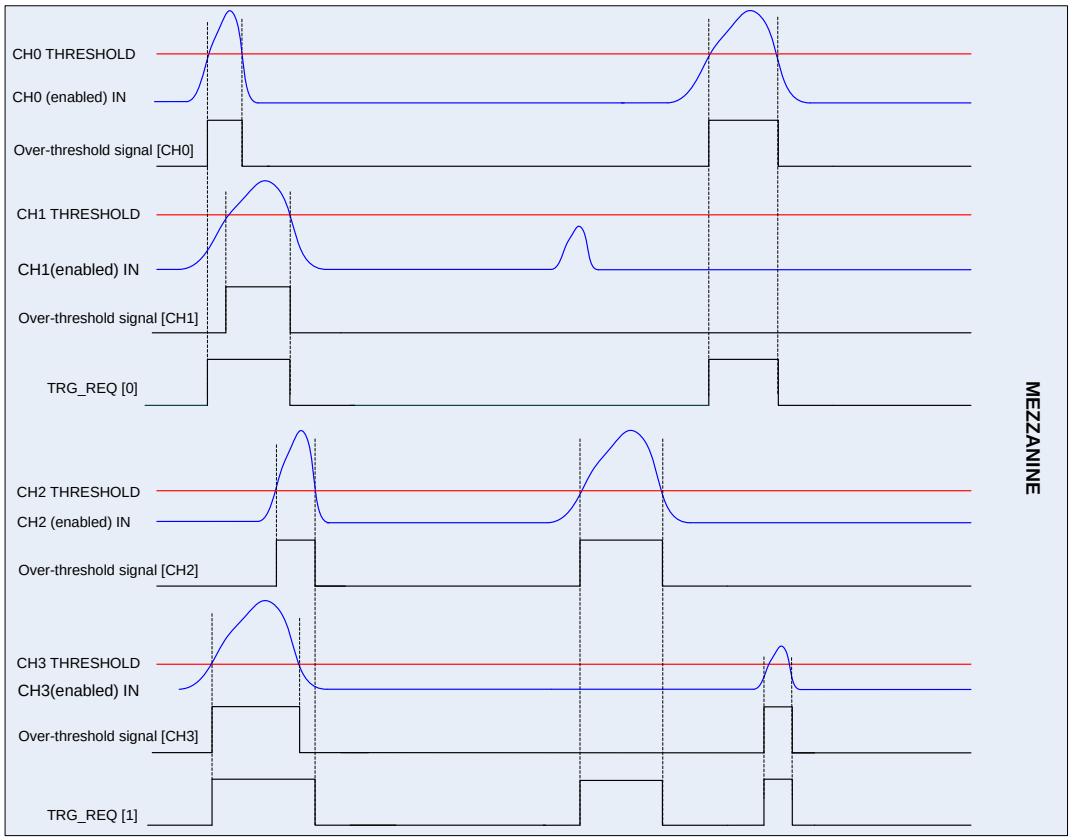


Fig. 8.13: Trigger request management at mezzanine level with Majority level = 0

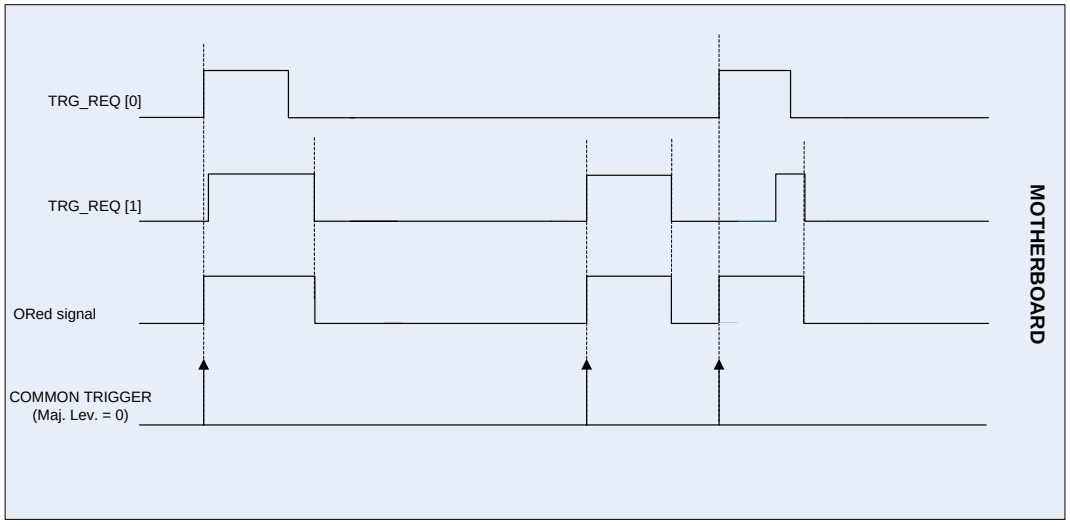


Fig. 8.14: Trigger request management at motherboard level with Majority level = 0

Fig. 8.15 and shows the trigger management in case the coincidences are enabled with Majority level = 1 and T_{TVAW} is a value different from 0. In order to simplify the description, CH1 and CH3 channels are considered disabled, so that the relevant trigger requests are the over-threshold signals from CH0 and CH1.

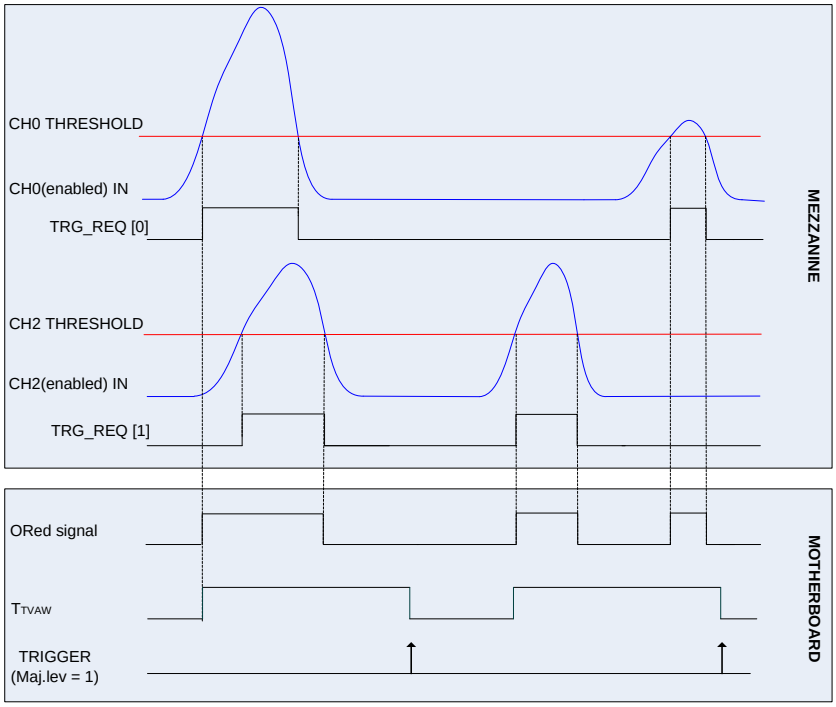


Fig. 8.15: Trigger request relationship with Majority level = 1 and $T_{TVAW} \neq 0$

Note: with respect to the position where the common trigger is generated, the portion of input signal stored depends on the programmed length of the acquisition window and on the post trigger setting.

Fig. 8.16 shows the trigger management in case the coincidences are enabled with Majority level = 1 and T_{TVAW} = 0 (i.e. 1 clock cycle). In order to simplify the description, CH1 and CH3 channels are considered disabled, so that the relevant trigger requests are the over-threshold signals from CH0 and CH1.

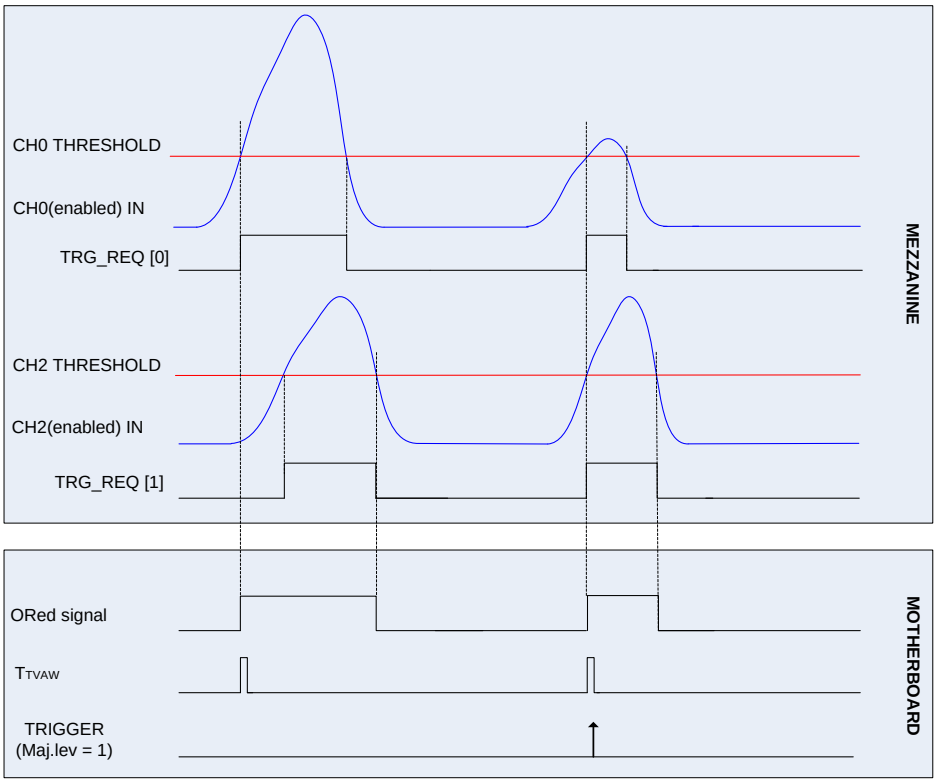


Fig. 8.16: Trigger request relationship with Majority level = 1 and T_{TVAW} = 0

In this case, the common trigger is issued if at least two of the enabled trigger requests are instantaneously in coincidence (no TTVAW is waited).

Note: a practical example of making coincidences with the digitizer in the standard operating is detailed in **[RD11]**.

Trigger Distribution

As described in § **Trigger Management**, the OR of all the enabled trigger sources, synchronized with the internal clock, becomes the common trigger of the board that is fed in parallel to all channels, consequently provoking the capture of an event. By default, only the Software Trigger and the External Trigger participate in the common acquisition trigger (refer to the red path on top of **Fig. 8.17**).

A Trigger Out signal is also generated on the relevant front panel GPO connector (NIM or TTL), and allows to extend the trigger signal to other boards. Thanks to its configurability (see **Fig. 8.17**), GPO can propagate out:

- the OR of all the enabled trigger sources (only the Software Trigger is provided by default, as in the red path of **Fig. 8.17**);
- the OR, AND or MAJORITY exclusively of the channel trigger requests.

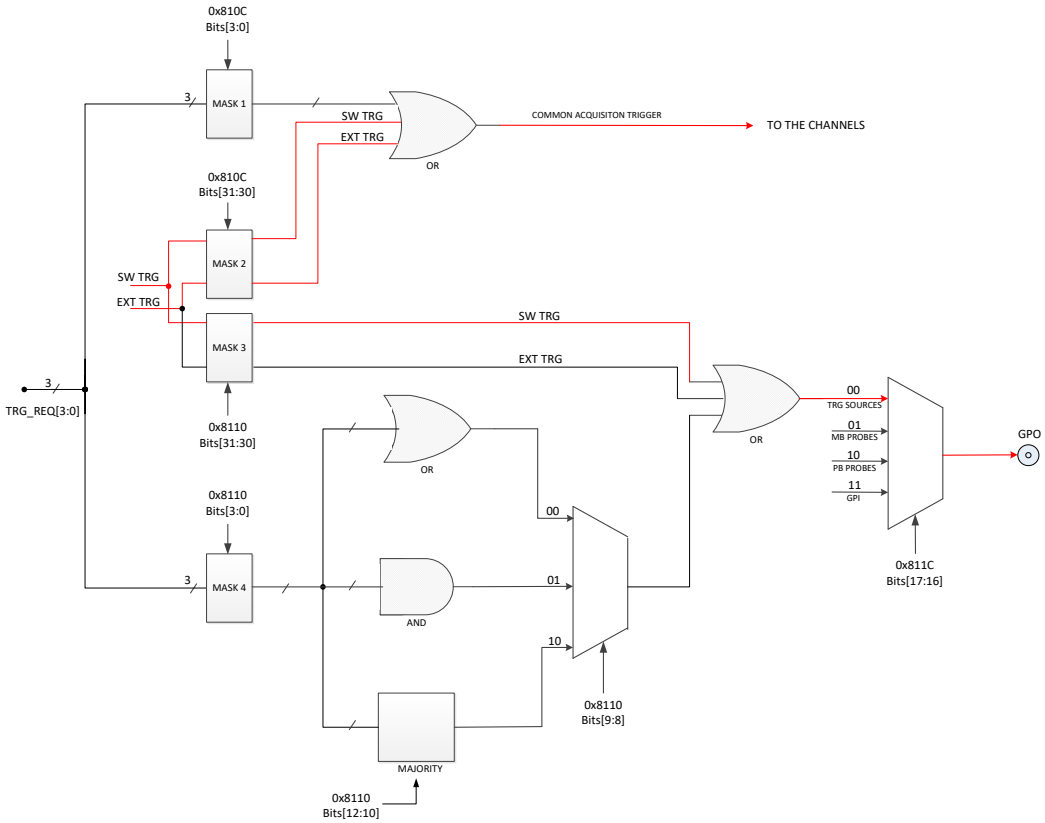


Fig. 8.17: Trigger configuration on GPO front panel output connector

The registers involved in the GPO programming are:

- Register address 0x8110;
- Register address 0x811C.

Note: Refer to **[RD2]** for registers complete description.

Example

For instance, it could be required to start the acquisition on all the channels of a multi-board system as soon as one of the channels of a board (board "n") crosses its threshold. Trigger Out signal is then fed to an external Fan Out logic unit; the obtained signal has then to be provided to the external trigger input TRG-IN of all the boards in the system (including the board which generated the Trigger Out signal). In this case, the programming steps to perform are following described.

1. Register 0x8110 on board "n":
   - Enable the desired trigger request as Trigger Out signal on board "n" (by bits[3:0] mask);
   - Disable Software Trigger and External Trigger as Trigger Out signal on board "n" (bits[31:30] = 00);
   - Set Trigger Out signal as the OR of the enabled trigger requests on board "n" (bits[9:8] = 00).
2. Register 0x811C on board "n":
   - Configure the digitizer to propagates on GPO the internal trigger sources according to the 0x8110 settings (i.e. the enabled trigger request, in the specific case) on board "n" (bits[17:16] = 00).
3. Register 0x810C on all the boards in the system (including board "n"):
   - Enable External Trigger to participate in the board's common acquisition trigger, disable Software Trigger and the Trigger Requests from the channels (bits[31:30] = 01; bits[3:0] = 0000).

Reset, Clear and Default Configuration

Global Reset

Global Reset is performed at power-on of the module or via software by write access at register address 0xEF24 (whatever 32-bit value can be written). It allows to clear the data off the Output Buffer, the event counter and performs a FPGAs global reset, which restores the FPGAs to the default configuration. It initializes all counters to their initial state and clears all detected error conditions.

Memory Reset

The Memory Reset clears the data off the Output Buffer.

The Memory Reset can be forwarded via a write access at register address 0xEF28 (whatever 32-bit value can be written).

Timer Reset

The Timer Reset allows to initialize the timer which allows to tag an event. The Timer Reset can be forwarded with a pulse sent to the front panel GPI input (leading edge sensitive).

Data Transfer Capabilities

N6730 and N6725 feature a Multi-Event digital memory per channel, configurable by the user to be divided into 1 up to 1024 buffers, as detailed in **Multi-Event Memory Organization**. Once they are written in the memory, the events become available for readout via USB or Optical Link. During the memory readout, the board can store other events (independently from the readout) on the available free buffers. The acquisition process is so "dead timeless" until the memory becomes full (see **Acquisition Synchronization**).

The events are readout sequentially and completely, starting from the Header of the first available event, followed by the samples of the enabled channels (from 0 to 7) as reported in **Tab. 8.3**. Once an event is completed, the relevant memory buffer becomes free and ready to be written again (old data are lost). After the last word in an event, the first word (Header) of the subsequent event is readout. It is not possible to readout an event partially.

The size of the event (EVENT SIZE) is configurable and depends on register addresses 0x8020 and 0x800C, as well as the number of enabled channels.

Block Transfers

The Block Transfer readout mode allows to read N complete events sequentially, where N is set at register address 0xEF1C or by using the *SetMaxNumEventsBLT* function of the CAENDigitizer library (consult **[RD5]** at p. 19).

When developing programs, the readout process can be implemented on different basis :

- Using **Interrupts**: as soon as the programmed number of events is available for readout, the board sends an interrupt to the PC over the optical communication link **(not supported by USB)**.
- Using **Polling** (interrupts disabled): by performing periodic read accesses to a specific register of the board it is possible to know the number of events present in the board and perform a BLT read of the specific size to read them out..
- Using **Continuous Read** (interruptions disabled): continuous data read of the maximum allowed size (e.g. total memory size) is performed by the software without polling the board. The actual size of the block read is determined by the board that terminates the BLT access at the end of the data, according to the configuration of of register address 0xEF1C, or the library function *SetMaxNumEventsBLT* mentioned above. If the board is empty, the BLT access is immediately terminated and the "Read Block" function will return 0 bytes (it is the *ReadData* function in the CAENDigitizer Library, refer to **[RD5]**)

Whatever the method from above, it is suggested to ask the board for the maximum of the events per block being set. Furthermore, the greater this maximum, the greater the readout efficiency, despite of a greater memory allocation required on the host station side that is actually not a real drawback, considering the features of the personal computers available on the market.

Note: Involved registers and library functions are detailed respectively in **[RD2]** and **[RD5]**.

Single Data Transfer

This mode allows to readout a word per time, from the header (actually 4 words) of the first available event, followed by all the words until the end of the event, then the second event is transferred. The exact sequence of the transferred words is shown in **Event Structure**.

It is suggested, after the 1st word is transferred, to check the EVENT SIZE information and then do as many cycles as necessary (actually EVENT SIZE -1) in order to read completely the event.

Optical Link and USB Access

The board houses a USB2.0 compliant port, providing a transfer rate up to 30 MB/s, and a daisy chainable Optical Link (communication path which uses optical fiber cables as physical transmission line) providing transfer rate up to 80 MB/s. The latter allows to connect up to 8 N6730/N6725 boards to a single A2818 PCI Optical Link Controller or up to 32 boards to a single A3818 PCIe Optical Link Controller. Detailed information on CAEN PCI/PCIe Controllers can be find at www.caen.it:

Home / Products / Modular Pulse Processing Electronics / PCI/PCIe / Optical Controllers

The parameters for read/write accesses via optical link are Address Modifier, Base Address, data Width, etc.; wrong parameter settings cause Bus Error.

Bit[3] at register address 0xEF00 allows to enable the module to broadcast an interrupt request on the Optical Link; the enabled Optical Link Controllers propagate the interrupt on the PCI bus as a request from the Optical Link is sensed. Interrupts can also be managed at the CAENDigitizer library level (see “Interrupt Configuration” in **[RD5]**).

9 Drivers & Libraries

Drivers

In order to interface with the N6730/N6725, CAEN provides the drivers for all the different types of physical communication channels featured by the board and compliant with Windows and Linux OS:

- **USB 2.0 Drivers** are downloadable on CAEN website (www.caen.it) in the "Software/Firmware" tab at the N6730 and N6725 web page (**login required**).

Note: For Microsoft Windows OS, the USB driver installation is detailed in **[RD3]**.

- **Optical Link Drivers** are managed by the A2818 PCI card or the A3818 PCIe card. The driver installation package is available on CAEN website in the "Software/Firmware" area at the A2818 or A3818 page (**login required**)

Note: For the installation of the Optical Link driver, refer to the User Manual of the specific Controller.

Libraries

CAEN libraries are a set of middleware software required by CAEN software tools 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** is a set of ANSI C functions which permit a user program to use and configure the CAEN Bridges and Controllers V1718/VX1718 (VME-USB2.0 Bridge), V2718/VX2718 (VME-PCI/PCIe Optical Link Bridge), A2818/A3818 (PCI/PCIe-CONET Controller).

  The CAENVMELib installation package is available on CAEN website in the 'Download' area at the CAENVMELib Library page.

- **CAENComm** library 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 is based in turn on CAENVMELib and it 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 CAENComm installation package is available on CAEN website in the 'Download' area at the CAENComm Library page.

- **CAENDigitizer** 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 which is based on CAENVMELib, as said above. For this reason, **the CAENVMELib and CAENComm libraries must be already installed on the host PC before installing the CAENDigitizer**.

  The CAENDigitizer installation package is available on CAEN website in the 'Download' area at the CAENDigitizer Library page.

The CAENComm (and so the CAENDigitizer) supports the following communication channels:

PC → USB → N6730/N6725

PC → PCI (A2818) → CONET → N6730/N6725

PC → PCIe (A3818) → CONET → N6730/N6725

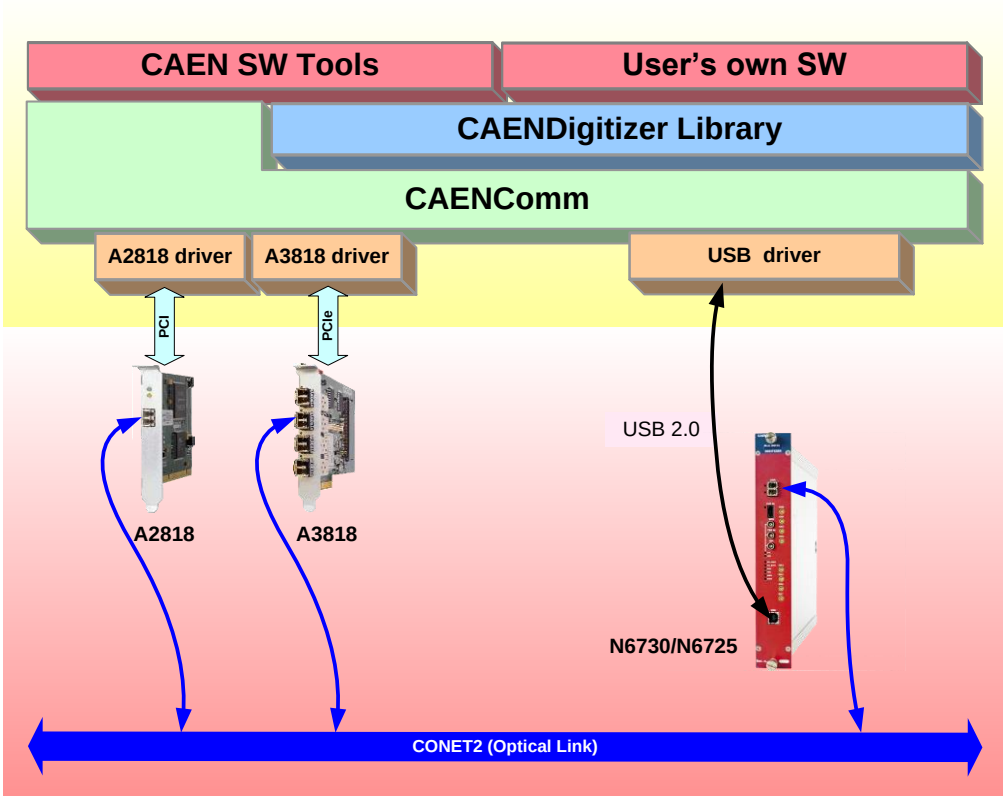


Fig. 9.1: Libraries and drivers required for the N6730

If required to be installed apart by the user (see § **10**), CAEN Libraries are available for download on CAEN web site (www.caen.it) in the "Download" tab at the library web page:

Home / Products / Firmware/Software / Digitizer Software / Software Libraries / <CAEN Library>

Install first CAENVMELib, then CAENComm library, finally CAENDigitizer library.

10 Software Tools

CAEN provides software tools to interface the N6730/N6725, which are available for free download on www.caen.it at:

Home / Products / Firmware/Software / Digitizer Software

CAENUpgrader

CAENUpgrader is a free software composed of command line tools together with a Java Graphical User Interface.

Specifically for the N6730/N6725, CAENUpgrader allows in few easy steps to:

- Upload different firmware versions on the board
- Select which copy of the stored firmware must be loaded at power-on
- Read the firmware release of the board and the bridge (when used)
- Manage the firmware license, in case of pay firmware
- Upgrade the internal PLL
- Get the Board Info file, useful in case of support

CAENUpgrader can operate with Windows and Linux, 32 and 64-bit OSs.

The program relies on the CAENComm and CAENVMELib libraries (see § **9**) and requires third-party Java SE6 (or later) to be installed.

Note: Windows version of CAENUpgrader is stand-alone (the required libraries are installed locally with the program), while the version for Linux needs the required libraries to be previously installed by the user.

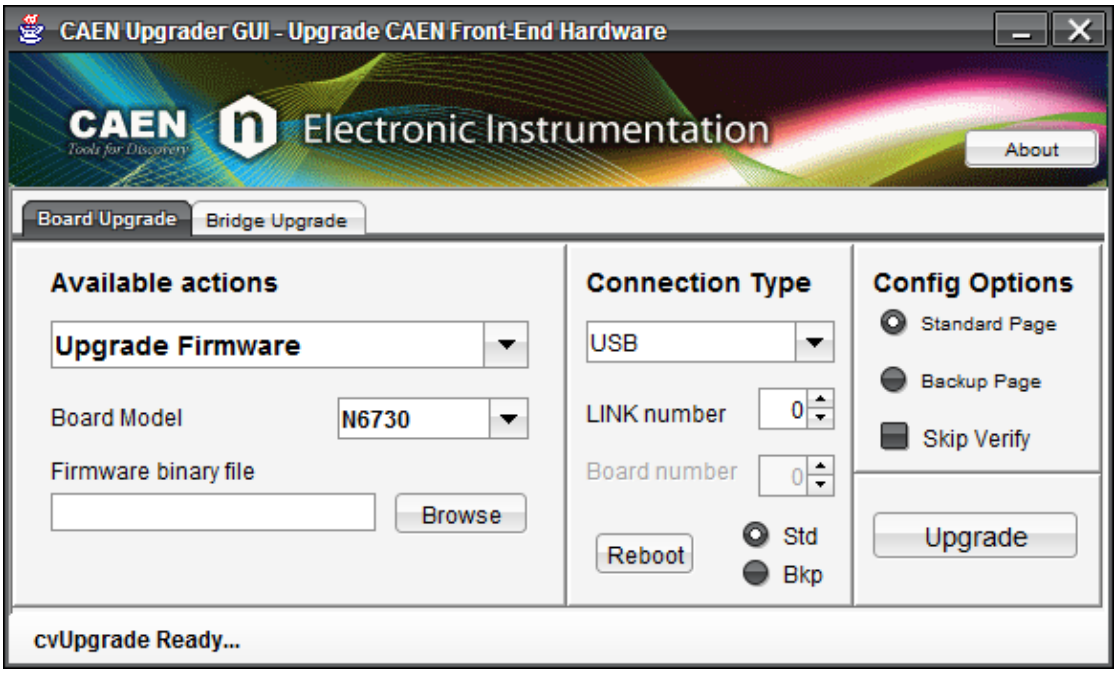


Fig. 10.1: CAENUpgrader Graphical User Interface

CAENUpgrader installation package can be downloaded on CAEN web site (**login required**) at:

Home / Products / Firmware/Software / Digitizer Software / Configuration Tools

The reference document for installation instructions and program detailed description is **[RD1],** downloadable at the same page above, in the *Documentation* tab.

CAENComm Demo

CAENComm Demo is a simple program developed in C/C++ source code and provided both with Java and LabVIEW GUI interface. The demo mainly allows for a full board configuration at low level by direct read/write access to the registers and may be used as a debug instrument.

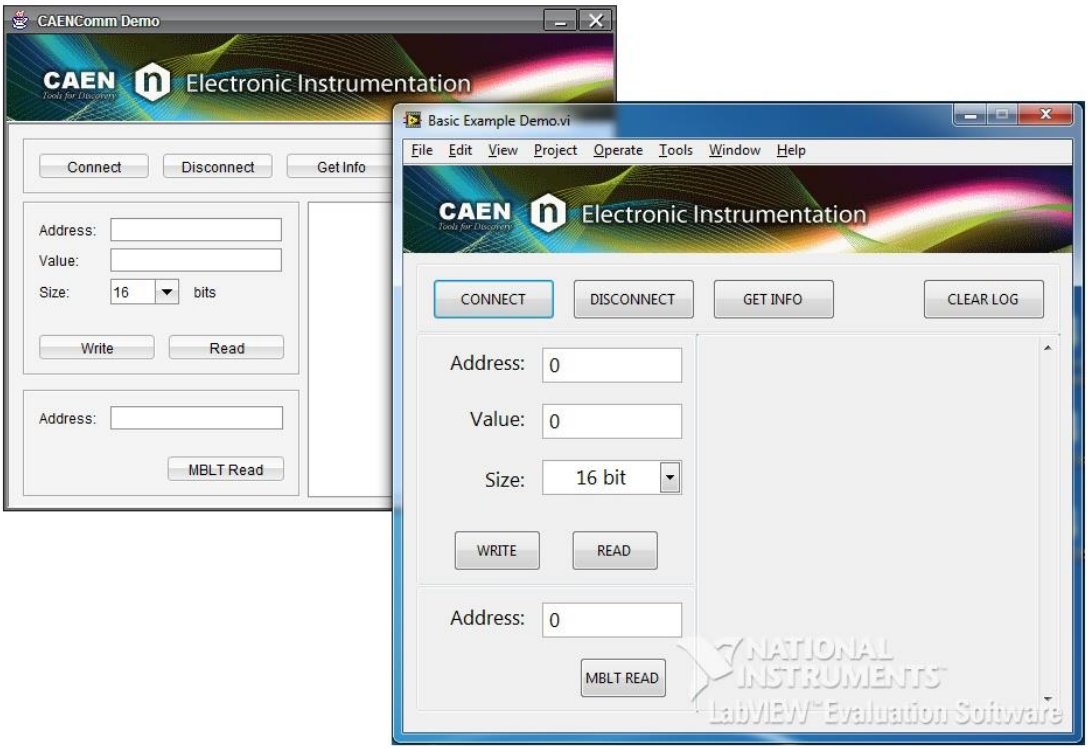


Fig. 10.2: CAENComm Demo Java and LabVIEW graphical interface

CAENComm Demo can operate with Windows OSs, 32 and 64-bit. It requires CAENComm and CAEVMElib libraries as additional software to be installed (see § **9**).

The Demo is included in the CAENComm library installation Windows package, which can be downloaded on CAEN web site (**login required**) at:

Home / Products / Firmware/Software / Digitizer Software / Software Libraries / CAENComm Library

CAEN WAVEDump

WaveDump is a basic console application, with no graphics, supporting only CAEN digitizers running the default firmware. It allows the user to program a single board (according to a text configuration file containing a list of parameters and instructions), to start/stop the acquisition, read the data, display the readout and trigger rate, apply some post-processing (e.g. FFT and amplitude histogram), save data to a file and also plot the waveforms using Gnuplot (third-party graphing utility: www.gnuplot.info).

WaveDump is a very helpful example of C code demonstrating the use of libraries and methods for an efficient readout and data analysis. Thanks to the included source files and the VS project, starting with this demo is strongly recommended to all those users willing to write the software on their own.

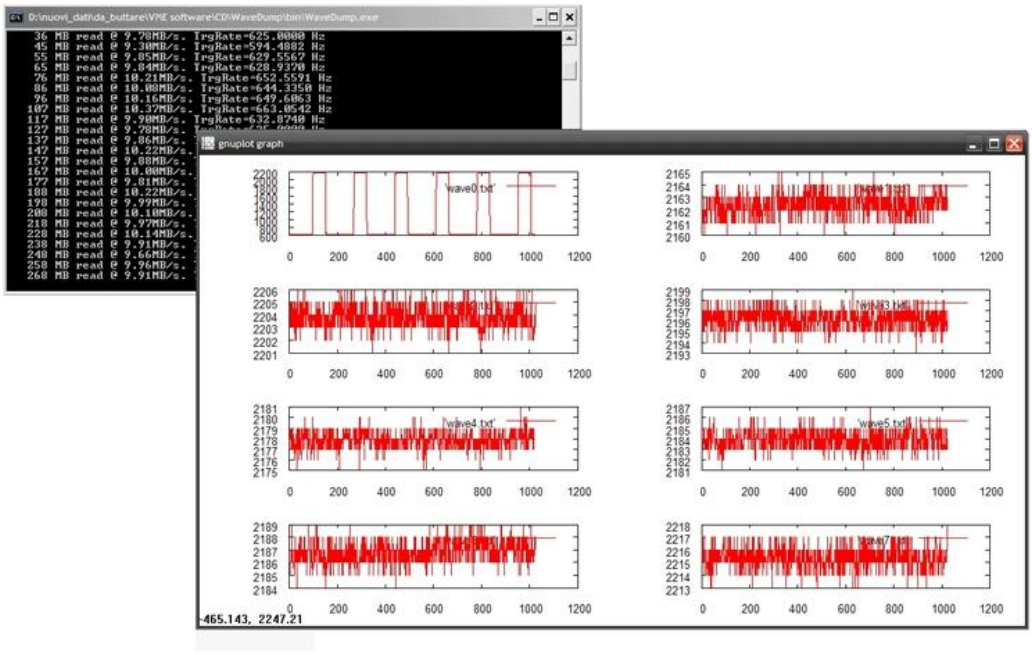


Fig. 10.3: CAEN WaveDump

CAEN WaveDump can operate with Windows and Linux, 32 and 64-bit OSs.

The program relies on the CAENDigitizer, CAENComm and CAENVMELib libraries (see § **9**). Linux users are required to install the third-party Gnuplot.

Note: Windows version of WaveDump is stand-alone (the required libraries are installed locally with the program), while the version for Linux needs the required libraries to be previously installed by the user.

The installation packages can be downloaded on CAEN web site (**login required**) at:

Home / Products / Firmware/Software / Digitizer Software / Readout Software

The reference documents for installation instructions and program detailed description are **[RD6]** and **[RD7]**, downloadable at the same page above, in the *Documentation* tab.

CAENScope

In a brand new framework, CAENScope software implements the features of an easy-to-use digital oscilloscope to be used with CAEN digitizers running the default firmware.

Note: CAENScope support for 725 digitizer family is **COMING SOON**

CAENScope user friendly interface presents different sections to easily manage the digitizer configuration and plot the waveforms. Once connected, the program retrieves the digitizer information. Different parameters can be set for the channels, the trigger and the trace visualization (up to 12 traces can be simultaneously plotted). Signals are recordable to files in two different formats: Binary (SQLite db) and Text (XML). It is also possible to save and restore the program settings.

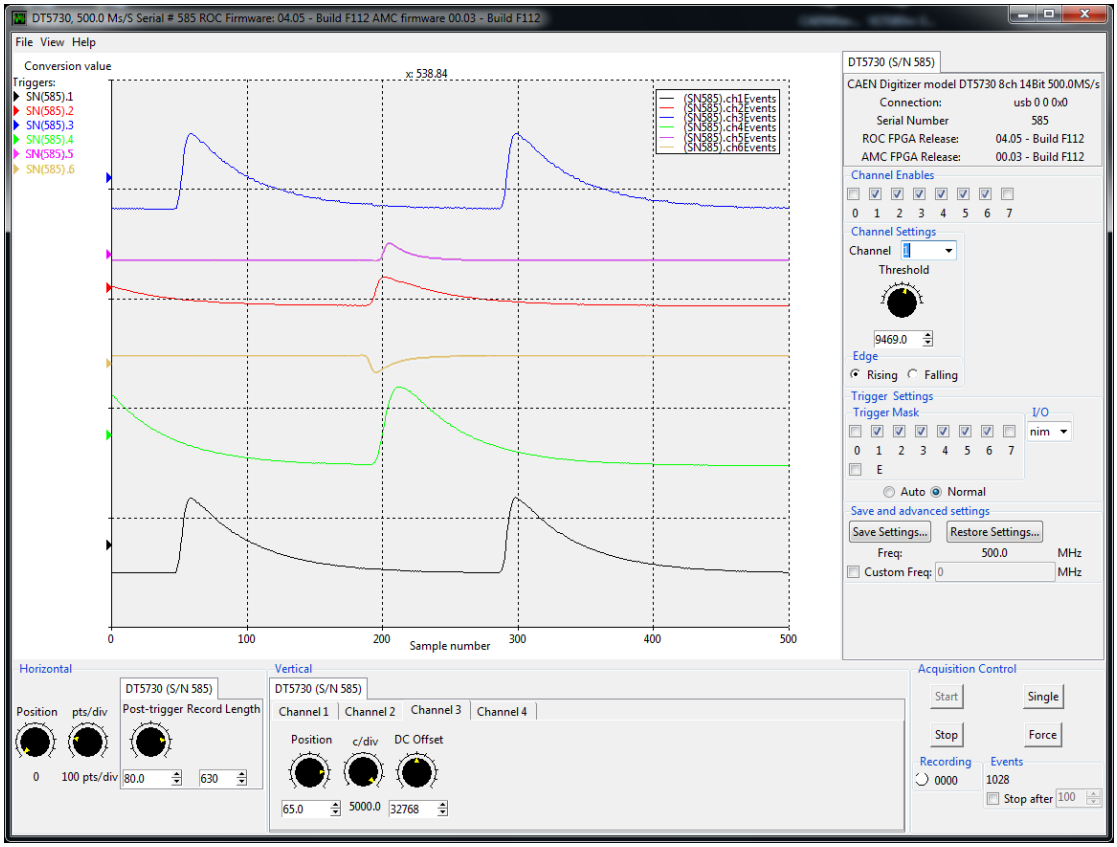


Fig. 10.4: CAENscope main frame

CAENScope can operate with Windows and Linux, 32 and 64-bit OSs. Linux users are required to install the following packages:

- sharutils;
- libXft;
- libXss (specifically for Debian derived distributions, e.g. Debian, Ubuntu, etc.);
- libXScrnSaver (specifically for RedHat derived distributions, e.g. RHEL, Fedora, Centos, etc.).

The program relies on the CAENDigitizer, CAENComm and CAENVMELib libraries.

Note: Windows version of CAENScope is stand-alone (the required libraries are installed locally with the program), while the version for Linux needs the required libraries to be previously installed by the user.

The installation packages can be downloaded on CAEN web site (**login required**) at:

Home / Products / Firmware/Software / Digitizer Software / Readout Software / CAENSCOPE

The reference document for installation instructions and program detailed description is **[RD8]**, downloadable at the same page above, in the *Documentation* tab.

DPP Control Software

The DT730 and DT5725 can be equipped (on payment) with a special DPP-PSD firmware.

DPP-PSD Control Software is a software interface for configuration, acquisition, data plotting to be used with the digitizers who can run the DPP-PSD special firmware. It allows the user to set the parameters for the acquisition, to configure the DPP, to perform the data readout, the histogram collection and the spectrum or waveform plotting and saving. The program doesn't feature data analysis, but can be easily interfaced to software tools for offline analysis.

DPP-PSD Control Software is available both for Windows and Linux platforms.

The program relies on the CAENDigitizer, CAENComm and CAENVMELib libraries (see § **9**). Third-party Java SE6 (or later) needs to be installed.

Note: Windows version of DPP-PSD Control Software is stand-alone (the required libraries are installed locally with the program; only the communication driver must be installed apart by the user), while the version for Linux needs the required libraries to be already installed apart.

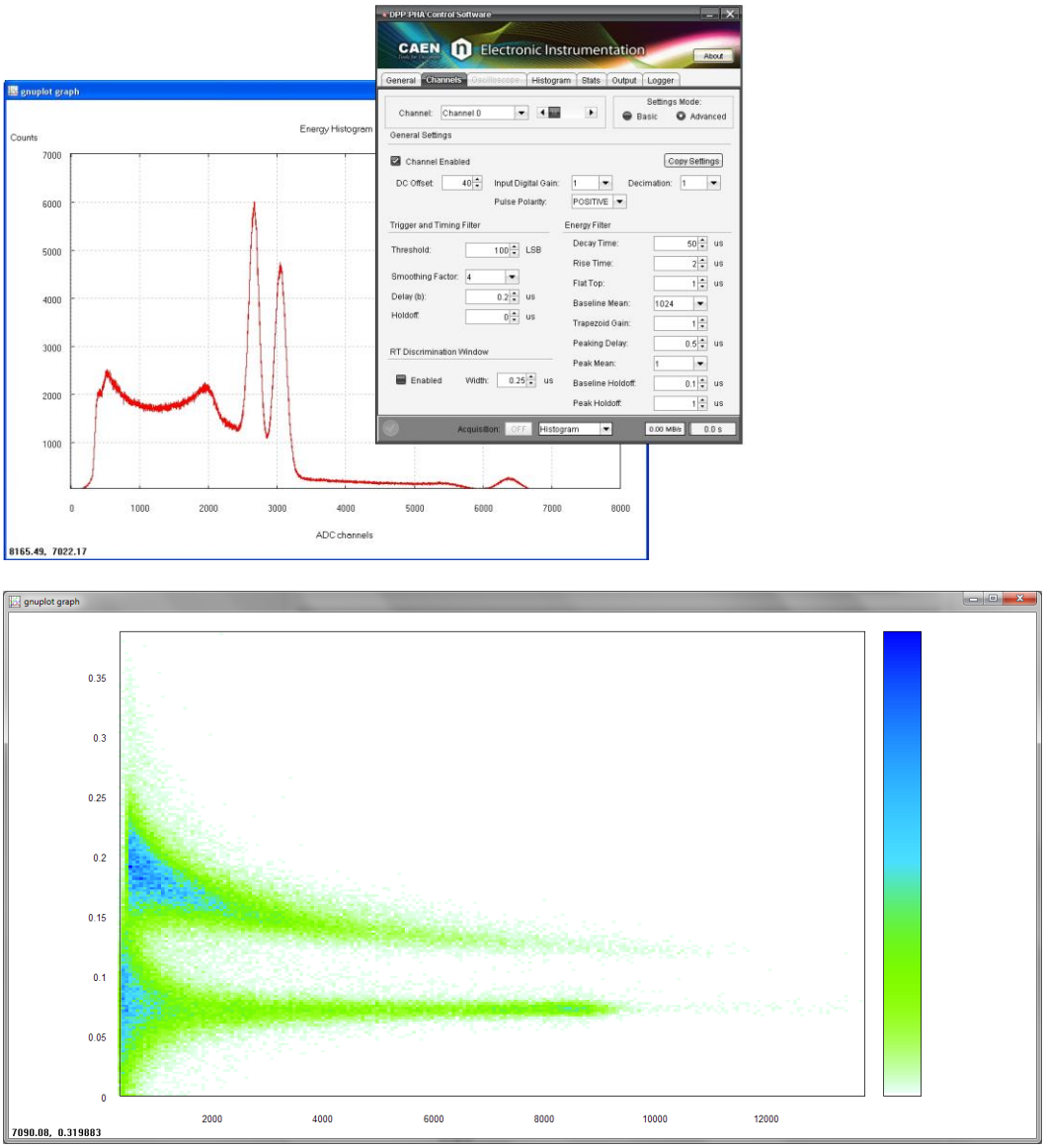


Fig. 10.5: DPP-PSD Control Software: Top – DPP settings Tab and typical ^{60}Co Total Charge Spectrum; Bottom - PSD 2-D Scatter Plot

The installation package can be downloaded on CAEN web site (www.caen.it) at:

Home / Products / Firmware/Software / Digitizer Software / Readout Software / <DPP-TYPE> Control Software

The reference document for installation instructions and program detailed description is **[RD9]**.

MC²Analyzer (MC²A)

MC²Analyzer (MC²A) is a software specifically designed for digitizers running the special DPP-PHA firmware (724, 725 and 730 families) and the Digital MCAs (x780 Dual Digital MCA, x781 Dual/Quad Digital MCA, DT5770).

The software is able to completely control and manage a set of boards acquiring data simultaneously, making therefore a multi-board system a "Multichannel - Multichannel Analyzer".

MC²A allows the user to set all the relevant DPP-PHA parameters for each acquisition channel (like trigger threshold, shaping parameters, etc.), handle the communication with the connected boards, run the data acquisition and plot both waveforms for on-line monitoring of the acquisition and histograms. It can also control the HV power supplies provided in the x780.

Moreover, it is able to perform advanced mathematical analysis on both the ongoing histograms and collected spectra: peak search, background subtraction, peak fitting, energy calibration, ROI selection, dead time compensation, histogram rebin and other features available.

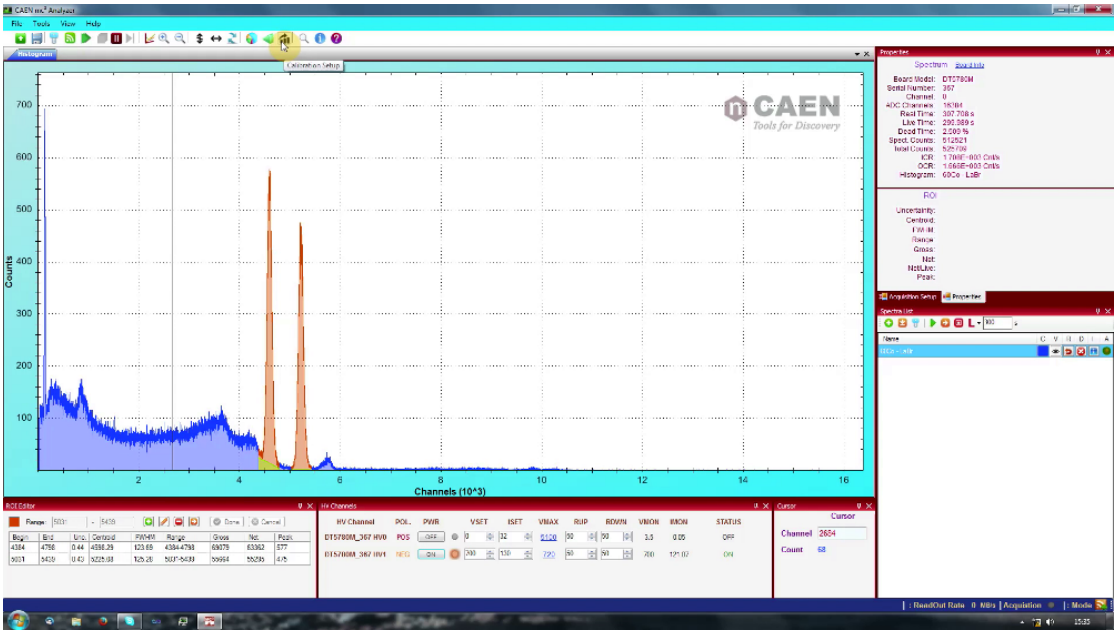


Fig. 10.6: MC²Analyzer (MC²A) software tool

MC²Analyzer is currently available only for Windows platforms. The installation package can be downloaded on CAEN web site (www.caen.it) at:

Home / Products / Firmware/Software / Digitizer Software / Readout Software

The reference document for installation instructions and program detailed description is **[RD10]**.

Note: Windows version of MC²Analyzer is stand-alone (the required libraries are installed locally with the program; only the communication driver must be installed apart by the user).

11 HW Installation

- The Module fits into all NIM crates.
- **Use only crates with forced cooling air flow**
- Turn the crate OFF before board insertion/removal
- Remove all cables connected to the front panel before board insertion/removal

CAUTION: this product needs proper cooling:

USE ONLY CRATES WITH FORCED COOLING AIR FLOW SINCE OVERHEATING MAY DEGRADE THE MODULE PERFORMANCES!

CAEN HEARTLY RECOMMEND TO MONITOR THE TEMPERATURE OF THE ADC CHIPS DURING THE BOARD OPERATION BY READING AT REGISTER ADDRESS 0x1nA8 (SEE **[RD2]**FOR DETAILS)

CAUTION: this product needs proper handling.

ALL CABLES MUST BE REMOVED FROM THE FRONT PANEL BEFORE EXTRACTING THE BOARD FROM THE CRATE!

Power-on Sequence

To power on the board, follow this procedure:

1. Insert the N6730/N6725 into the crate:
2. Power up the crate.

Power-on Status

At power-on, the module is in the following status:

- the Output Buffer is cleared;
- registers are set to their default configuration.

After the power-on, the front panel LEDs status is that only the NIM and PLL LOCK remain ON (see **Fig. 11.1)**.

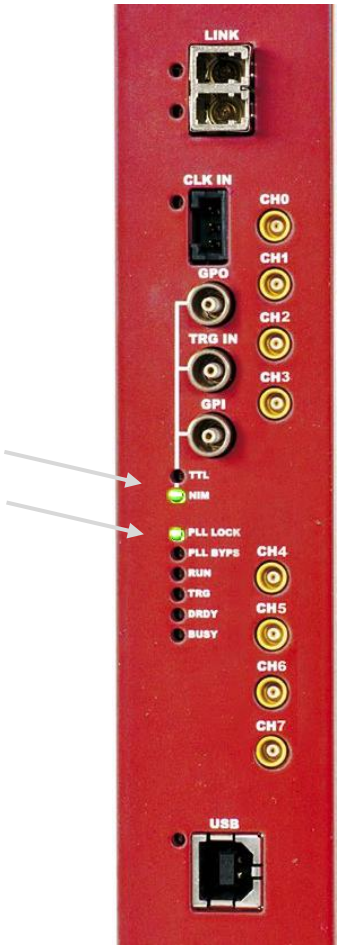


Fig. 11.1: Front panel LEDs status at power ON

AFTER POWER-ON, CAEN RECOMMENDS TO PERFORM THE CHANNEL CALIBRATION AS DESCRIBED AT PAGE 23 IN ORDER TO ACHIEVE THE BEST DEVICE PERFORMANCE

12 Firmware and Upgrades

The board hosts one FPGA on the mainboard and two FPGAs on the mezzanine (i.e. one FPGA per 4 channels). The channel FPGAs firmware is identical. A unique file is provided that will update all the FPGAs at the same time.

ROC FPGA MAINBOARD FPGA (Readout Controller + VME interface):

FPGA Altera Cyclone EP1C20.

AMC FPGA MEZZANINE FPGA (ADC readout/Memory Controller):

FPGA Altera Cyclone EP4CE30

The firmware is stored onto the on-board FLASH memory. Two copies of the firmware are stored in two different pages of the FLASH, referred to as Standard (STD) and Backup (BKP). In case of default firmware, the board is delivered equipped with the same firmware version on both pages.

At power-on, a microcontroller reads the FLASH memory and programs the module automatically loading the first working firmware copy, that is the STD one by default.

It is possible to upgrade the board firmware via USB or Optical Link by writing the FLASH with the CAENUpgrader software (see § **10**).

IT IS STRONGLY SUGGESTED TO OPERATE THE DIGITIZER UPON THE STD COPY OF THE FIRMWARE. UPGRADES ARE SO RECOMMENDED ONLY ON THE STD PAGE OF THE FLASH. THE BKP COPY IS TO BE INTENDED ONLY FOR RECOVERY USAGE. IF BOTH PAGES RESULT CORRUPTED, THE USER WILL NO LONGER BE ABLE TO UPLOAD THE FIRMWARE VIA USB OR OPTICAL LINK AGAIN AND THE BOARD NEEDS TO BE SENT TO CAEN IN REPAIR!

In case of upgrading failure (e.g. STD FLASH page is corrupted), the user can try to reboot the board: after a power cycle, the system programs the board automatically from the alternative FLASH page (e.g. BKP FLASH page) if this is not corrupted as well. The user can so perform a further upgrade attempt on the STD page to restore the firmware copy.

At power-on, if the user cannot communicate with the board, it needs to be sent back to CAEN in repair (see § **13**).

Default Firmware Upgrade

The N6730 and N6725 are delivered running a default firmware to operate the board for waveform recording.

The default firmware updates are available for download on CAEN website (www.caen.it) in the *Software/Firmware* tab at the N6730/N6725 web pages **(login required)**:

Home / Products / Modular Pulse Processing Electronics / NIM / Digitizers / N6730 (or N6725)

Upgrade File Description

The programming file has the extension .CFA (CAEN Firmware Archive) and is a sort of archive format file aggregating all the default firmware files compatible with the same family of digitizers.

CFA and its name follows this general scheme:

x730_revX.Y_W.Z.CFA

x725_revX.Y_W.Z.CFA

where:

- x730 (x725) are all the boards the file is compliant to: DT5730 (DT5725), N6730 (N6725), V1730 (V1725), VX1730 (VX1725)
- X.Y is the major/minor revision number of the mainboard FPGA
- W.Z is the major/minor revision number of the channel FPGA

DPP Firmware Upgrade

CAEN provides N6730 and N6725 with special with special DPP-PSD and DPP-PHA firmware for Physics Applications. The digitizer running DPP-PSD firmware becomes a digital replacement of dual gate QDC, discriminator and gate generator. The digitizer running DPP-PHA firmware becomes a digital replacement of Shaping Amplifier and Peak Sensing ADC (Multi-Channel Analyzer) by means of digital trapezoidal filters.

- The DPP-PSD firmware updates are available for download on CAEN website in the *Download* tab **(login required)** at:

Home / Products / Firmware/Software / Digitizer Software / Readout Software / DPP-PSD Control Software

- The DPP-PHA firmware updates are available for download on CAEN website in the *Download* tab **(login required)** at:

Home / Products / Firmware/Software / Digitizer Software / Readout Software / DPP-PHA Control Software

Upgrade File Description

The programming file has the extension .CFA (CAEN Firmware Archive) and is a sort of archive format file aggregating all the DPP-PSD firmware files compatible with the same family of digitizers

CFA and its name follows this general scheme:

X730_ DPP-PSD_rev_X.Y_136.Z.CFA

X725_DPP-PSD_rev_X.Y_136.Z.CFA

x730_DPP-PHA_rev_X.Y_139.Z.CFA

x725_DPP-PHA_rev_X.Y_139.Z.CFA

where the major revision number of the channel FPGA (136 or 139) is fixed for the specific DPP algorithm and digitizer family. The other fields have the same meaning as in the default firmware file description.

Note: DPP special firmware is a pay firmware requiring a license to be purchased. If not licensed, the firmware can be loaded but it will run fully functional with a time limitation per power cycle (30 minutes). Details on the license ordering procedure can be found in **[RD1]**.

Note: if the DPP firmware license is included in the same order of a N6730 (N6725), the customer will be delivered with the digitizer already running the licensed (i.e. unlocked) special firmware. Once unlocked, upgrading the same kind of DPP firmware requires no further licensing.

13 Technical Support

CAEN support services are available for the user by accessing the *Support & Services* area on CAEN website at www.caen.it.

Returns and Repairs

Users who need for product(s) return and repair have to fill and send the Product Return Form (PRF) in the *Returns and Repairs* area at *Home / Support & Services*, describing the specific failure. A printed copy of the PRF must also be included in the package to be shipped.

Contacts for shipping are reported on the website at *Home / Contacts*.

Technical Support Service

CAEN makes available the technical support of its specialists at the e-mail addresses below:

support.nuclear@caen.it
(for questions about the hardware)

support.computing@caen.it
(for questions about software and libraries)

CAEN SpA is acknowledged as the only company in the world providing a complete range of High/Low Voltage Power Supply systems and Front-End/Data Acquisition modules which meet IEEE Standards for Nuclear and Particle Physics. Extensive Research and Development capabilities have allowed CAEN SpA to play an important, long term role in this field. Our activities have always been at the forefront of technology, thanks to years of intensive collaborations with the most important Research Centres of the world. Our products appeal to a wide range of customers including engineers, scientists and technical professionals who all trust them to help achieve their goals faster and more effectively.

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CAEN
Tools for Discovery
Electronic Instrumentation

UM3147 - N6730/N6725 User Manual rev. 2 - 10 June 2016
00108-12-N6730-MUTX