



User Manual UM3350

V1751/VX1751

4/8 Channels 10bit 2/1 GS/s Digitizer

Rev. 16 - June 12th, 2017

Purpose of this Manual

This document contains the full hardware description of the V1751 and VX1751 CAEN digitizers and their principle of operating as **Waveform Recording Digitizer** (basing on the hereafter called "**waveform recording firmware**").

The reference firmware revision is: **4.14_0.7**.

For any reference to registers in this user manual, please refer to document [RD1] on the digitizer web page.

For any reference to DPP firmware in this user manual, please refer to documents [RD2] and [RD3] present on the firmware web page.

Change Document Record

Date	Revision	Changes
-	00-15	Old manuals are available on request (see Chap. Technical Support).
June 12 th , 2017	16	Revised layout and improved text.

Symbols, Abbreviated Terms and Notation

ADC	Analog-to-Digital Converter
AMC	ADC & Memory Controller
DAQ	Data Acquisition
DAC	Digital-to-Analog Converter
DC	Direct Current
LVDS	Low-Voltage Differential Signal
PLL	Phase-Locked Loop
ROC	ReadOut Controller
TTT	Trigger Time Tag
USB	Universal Serial Bus

Reference Documents

- [RD1] UM6009 – 751 Registers Description.
- [RD2] UM2088 – DPP-PSD User Manual.
- [RD3] UM2764 – DPP-ZLEplus User Manual.
- [RD4] UM1935 – CAENDigitizer User & Reference Manual.
- [RD5] UM2091 – CAEN WaveDump User Manual.
- [RD6] GD2817 – How to make coincidences with CAEN digitizers.
- [RD7] AN2086 – Synchronization of a multi-board acquisition systems with CAEN digitizers.
- [RD8] AN2472 – CONET1 to CONET2 migration.
- [RD9] GD2512 – CAENUpgrader QuickStart Guide.
- [RD10] GD2484 – CAENScope Quick Start Guide.
- [RD11] UM5960 – CoMPASS User Manual.

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

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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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Safety Notices

CAUTION: this product needs proper cooling.



**USE ONLY CRATES WITH FORCED COOLING AIR FLOW SINCE
OVERHEATING THE BOARD MAY DEGRADE ITS PERFORMANCES!**

CAUTION: this product needs proper handling.



V1751/VX1751 DO NOT SUPPORT LIVE INSERTION (HOT SWAP)!
**REMOVE OR INSERT THE BOARD WHEN THE VME CRATE IS
POWERED OFF!**



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

1 Introduction

The V1751 is a 1-unit wide VME 6U module housing a 8 Channel 10 bit 1 GS/s Flash ADC Waveform Digitizer with 1 V_{pp} input dynamic range on single ended MCX coaxial connectors (see Tab. 1.1). Versions with 200 mV_{pp} single ended customization is also available (see Tab. 1.1). The DC offset is adjustable via a 16-bit DAC on each channel in the ± 0.5 V (@1 V_{pp}), ± 100 mV (@200 mV_{pp}) range. The digitizer can work in Dual Edge Sampling (DES mode) at 2 GS/s. In this mode only half of the channels are enabled for acquisition.

Considering the sampling frequency and bit number, these 751 digitizer family is well suited for fast signals as the ones coming from fast organic, inorganic and liquid scintillators coupled with PMTs or Silicon Photomultiplier, Diamond detectors and others.

A common acquisition trigger signal (common to all the channels) 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. The trigger from one board can be propagated out of the board through the front panel TRG-OUT connector.

During the acquisition, data stream is continuously written in a circular memory buffer. When the trigger occurs, the digitizer writes additional samples for the post trigger and freezes the buffer that can be read by one of the provided readout links.

Each channel has a SRAM digital memory (see Tab. 1.1 for the available memory size options) divided into buffers of programmable size ($1 \div 1024$). The size of the memory doubles when working in DES mode. The readout (from VMEbus or Optical link) of a frozen buffer is independent from the write operations in the active circular buffer (ADC data storage).

V1751 features 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 V1751 can be synchronized to a common clock source ensuring Trigger Time Stamps alignment. Once synchronized, all data will be aligned and coherent across multiple V1751 boards. CLK-IN / CLK-OUT connectors allow for a Daisy-chained clock distribution.

16 general purpose LVDS I/Os FPGA-controlled can be programmed for Busy, Data Ready, Memory Full, or Individual Trig-Out management. An Input Pattern (external signal) can be provided on the LVDS I/Os to be latched to each trigger as an event marker (see Sec. **Front Panel LVDS I/Os**).

An analog output (MON/ Σ) from internal 12-bit 125-MHz DAC, controlled by the FPGA, allows the user to reproduce four types of outgoing information: Trigger Majority, Test Pulses, Memory Occupancy, Voltage Level (see Sec. **Analog Monitor**).

V1751 is equipped with a VME64 interface (VM64X in case of VX1751) where the data readout can be performed in Single Data Transfer (D32), 32/64-bit Block Transfer (BLT, MBLT, 2eVME, 2eSST) and 32/64-bit Chained Block Transfer (CBLT).

The module houses Optical Link interface (CAEN proprietary CONET protocol) supporting transfer rate up to 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 4-link A3818 version (Mod. A2818/A3818, see Tab. 1.1). VME and Optical Link accesses take place on independent paths and are handled by the on-board controller, therefore when accessed through Optical Link the board can be operated outside the VME Crate.

In addition to the waveform recording firmware, CAEN provides for this digitizer two types of Digital Pulse Processing firmware (DPP):

- Pulse Shape Discrimination (DPP-PSD) [RD2], which combines the functionalities of a digital QDC (charge integration) and discriminator of different shapes for particle identification.
- Zero Length Encoding (DPP-ZLEplus) [RD3], for the Zero suppression and data reduction.

These special firmware make the digitizer an enhanced system for Physics Applications.

Board Model	Description
V1751	4/8 Ch. 10 bit 2/1 GS/s Digitizer: 3.6/1.8MS/ch, EP3C16, SE
V1751C	4/8 Ch. 10 bit 2/1 GS/s Digitizer: 28.8/14.4MS/ch, EP3C16, SE
WPERS0175102	x751 Customization - 200mVpp Input Range, SE
DPP Firmware	Description
DDP-PSD 8ch	DDP-PSD Digital Pulse Processing for Pulse Shape Discrimination (8ch x751)
DDP-ZLE 8ch	Digital Pulse Processing Zero Length Encoding for (8ch x 751)
Related Products	Description
A2818	A2818 – PCI Optical Link (Rhos compliant)
A3818A	A3818A – PCIe 1 Optical Link
A3818B	A3818B – PCIe 2 Optical Link
A3818C	A3818C – PCIe 4 Optical Link
V1718	V1718 - VME-USB 2.0 Bridge
V1718LC	V1718LC - VME-USB 2.0 Bridge (Rohs Compliant)
VX1718	VX1718 - VME-USB 2.0 Bridge
VX1718LC	VX1718LC - VME-USB 2.0 Bridge (Rohs Compliant)
V2718	V2718 - VME-PCI Bridge
V2718LC	V2718LC - VME-PCI Bridge (Rohs compliant)
VX2718	VX2718 - VME-PCI Bridge
VX2718LC	VX2718LC - VME-PCI Bridge
V2718LC KIT	V2718KITLC - VME-PCI Bridge (V2718)+PCI Optical Link (A2818)+Optical Fibre 5m duplex (AY2705) (Rohs)
V2718 KIT	V2718KIT - VME-PCI Bridge (V2718) + PCI OpticalLink (A2818) + Optical Fibre 5m duplex (AY2705)
V2718 KIT-B	V2718KITB - VME-PCI Bridge (V2718) + PCIe Optical Link (A3818A) + Optical Fibre 5m duplex (AY2705)
VX2718LC KIT	VX2718KITLC - VME-PCI Bridge (VX2718)+PCI Optical Link (A2818)+Optical Fibre 5m duplex (AY2705) (Rohs)
VX2718 KIT	VX2718KIT - VME-PCI Bridge (VX2718) + PCI OpticalLink (A2818) + Optical Fibre 5m duplex (AY2705)
VX2718 KIT-B	VX2718KITB - VME-PCI Bridge (VX2718) + PCIe Optical Link (A3818A) + Optical Fibre 5m duplex (AY2705)
Accessories	Description
A317	Clock Distribution Cable
A318	SE to Differential Clock Adapter
A654	Single Channel MCX to LEMO Cable Adapter
A654 KIT4	4 MCX TO LEMO Cable Adapter
A654 KIT8	8 MCX TO LEMO Cable Adapter
A659	Single Channel MCX to BNC Cable Adapter
A659 KIT4	4 MCX TO BNC Cable Adapter
A659 KIT8	8 MCX TO BNC Cable Adapter
AI2730	Optical Fibre 30 m simplex
AI2720	Optical Fibre 20 m simplex
AI2705	Optical Fibre 5 m simplex
AI2703	Optical Fibre 30 cm simplex
AY2730	Optical Fibre 30 m duplex
AY2720	Optical Fibre 20 m duplex
AY2705	Optical Fibre 5 m duplex

Tab. 1.1: Table of models and related items. **Note** that the memory size is expressed as MS/ch, where M = 1000 · 1000.

2 Block Diagram

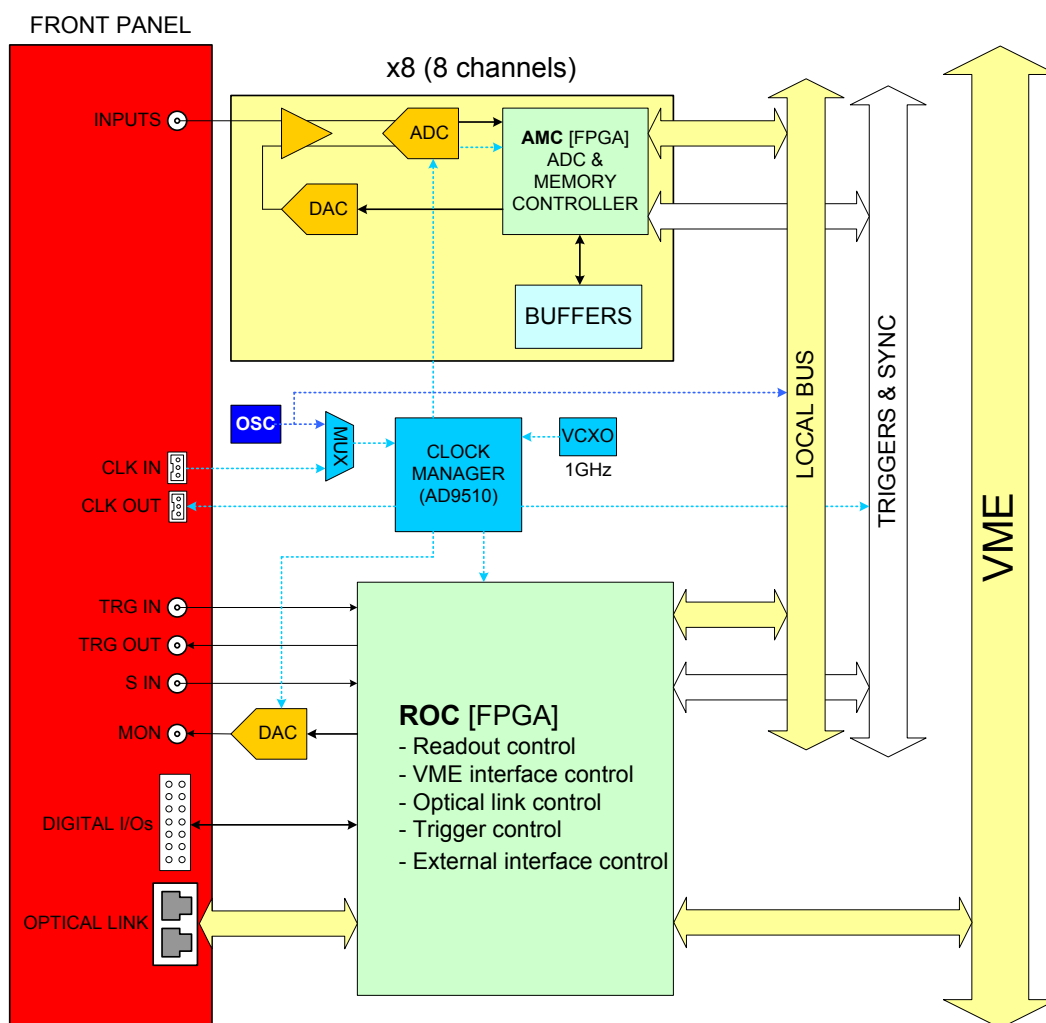


Fig. 2.1: Block Diagram

3 Technical Specifications

GENERAL	Form Factor 1-unit wide, 6U VME64 (V1751) and VME64X (VX1751)		Weight 535 g
ANALOG INPUT	Channels 8 channels Single ended Note: EVEN channels must be disconnected in DES mode	Connector MCX	Bandwidth 500 MHz
	Impedance (Z _{in}) 50 Ω	Full Scale Range (FSR) 1 V _{pp} or customizable to 200 mV _{pp} Abs Max Rating @1V _{pp} : 3 V _{pp} (with V _{rail} max +3 V or −3 V for any DAC offset value) @200 mV _{pp} : 2 V _{pp} (with V _{rail} max +2 V or −2 V for any DAC offset value)	Offset Programmable DAC for DC offset adjustment on each channel in the full range
DIGITAL CONVERSION	Resolution 10 bits	Sampling Rate 1 GS/s (2 GS/s DES mode) simultaneously on each channel	
ADC SAMPLING CLOCK GENERATION	Clock source: internal/external On-board programmable 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, Z _{diff} = 100 Ω	CLK-OUT (AMP Modu IV) DC coupled differential LVDS clock output locked to ADC sampling clock, Z _{diff} = 100 Ω	S-IN (LEMO) SYNC/START front panel digital input NIM/TTL, Z _{in} = 50 Ω
	TRG-IN (LEMO) External trigger digital input NIM/TTL, Z _{in} = 50 Ω	TRG-OUT (LEMO) Trigger digital output NIM/TTL, R _t = 50 Ω	
MEMORY	1.835 MS/ch (3.6 MS/ch in DES mode) or 14.4 MS/ch (28.8 MS/ch in DES mode) (see Tab. 1.1) Multi Event Buffer divisible into 1 ÷ 1024 Independent read and write access Programmable event size and pre/post trigger		
TRIGGER	Trigger Source - Self-trigger: channel over/under-threshold for common (waveform recording firmware) or individual (DPP firmware only) trigger generation - External-trigger: common trigger by TRG IN connector or individual by LVDS connector (DPP firmware only) - Software-trigger: common trigger by software command		Trigger Propagation TRG-OUT programmable digital output Trigger Time Stamp Waveform recording FW/DPP-ZLEplus: 31-bit counter – 16 ns resolution - 17 s range; 48 bit fw extension DPP-PSD: 32-bit counter – 1 ns resolution (1 ps fine time stamp resolution with dCFD) - 4 s range; 48 bit fw extension; 64 bit sw extension

SYNCHRONIZATION	Clock Propagation <i>Daisy chain</i> : through CLK-IN/CLK-OUT connectors <i>One-to-many</i> : clock distribution from an external clock source on CLK-IN connector Clock Cable delay compensation	Acquisition Synchronization Sync, Start/Stop through digital I/O (S-IN or TRG-IN input / TRG-OUT output) Trigger Time Stamps Alignment By S-IN input connector
ADC & MEMORY CONTR.	Altera Cyclone EP1C20 (one FPGA serves 1 channel)	
COMMUNICATION INTERFACE	Optical Link CAEN CONET proprietary protocol Up to 80 MB/s transfer rate Daisy-chain: it is possible to connect up to 8 or 32 ADC modules to a single Optical Link Controller (respectively A2818 or A3818)	VME VME 64X compliant Data transfer mode: BLT32, MBLT64 (70 MB/s using CAEN Bridge), CBLT32/64, 2eVME, 2eSST (up to 200 MB/s)
ANALOG MONITOR	12-bit / 125 MHz DAC FPGA controlled; four operating modes: <ul style="list-style-type: none"> - Test pulses: 1 V_{pp} ramp generator - Majority signal: proportional to the nr. Of channels under/over threshold (steps of 125 mV) - Memory Occupancy signal: proportional to the Multi Event Buffer Occupancy (1 buffer 1mV) - Voltage level: programmable output voltage level 	
LVDS I/O	16 general purpose LVDS I/O controlled by the FPGA: Busy, Data Ready, Memory full, Individual Trig-Out and other functions can be programmed An Input Pattern from the LVDS I/O can be associated to each trigger as an event marker	
SUPPORTED DPP FIRMWARE	DPP-PSD for the Pulse Shape Discrimination DPP-ZLE _{plus} for the Zero Length Encoding	
FIRMWARE UPGRADE	Firmware can be upgraded via VMEbus/Optical Link	
SOFTWARE	General purpose C libraries, configuration tools, readout software (Windows® and Linux® support). LabVIEW™ VIs and demos for Windows® only	
POWER CONSUMPTIONS	6.5 A @ +5V; 200 mA @ +12V, 300 mA @ -12V	

Tab. 3.1: Specification table

4 Packaging and Compliancy

V1751/VX1751 modules are 1-unit wide, 6U VME64/VME64X boards.

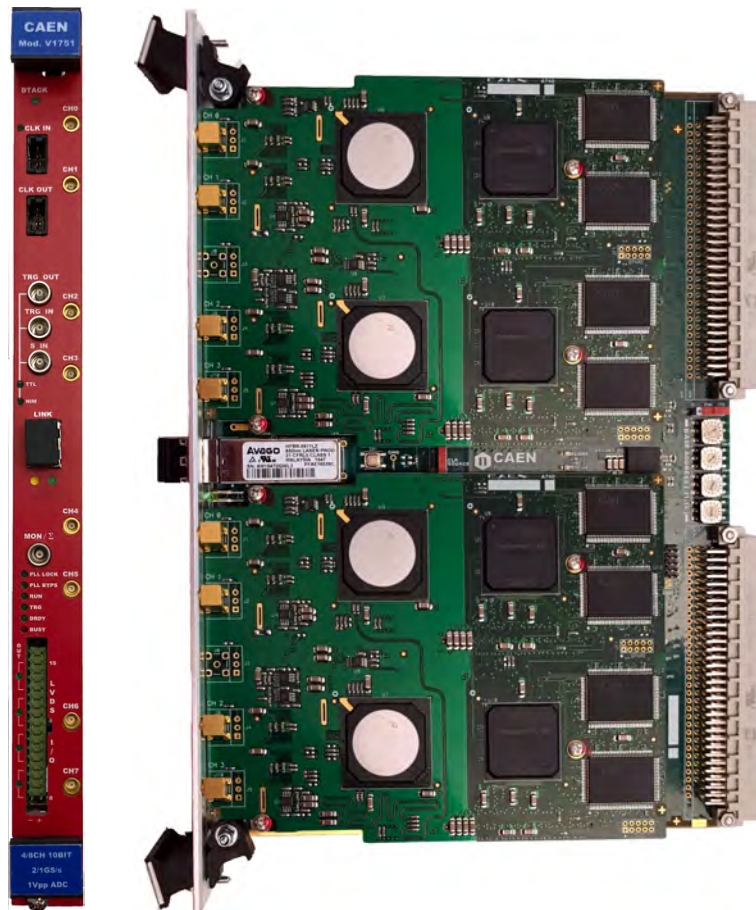


Fig. 4.1: V1751 model view

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.



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

CAUTION: this product needs proper handling.



V1751/VX1751 DO NOT SUPPORT LIVE INSERTION (HOT SWAP)! REMOVE OR INSERT THE BOARD WHEN THE VME CRATE IS POWERED OFF!



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

CAEN provides the specific document “Precautions for Handling, Storage and Installation”, available in the documentation tab of the product’s web page, that is mandatory to read before operating with CAEN equipment.

5 Power Requirements

The table below resumes the V1751/VX1751 power consumptions per relevant power supply rail.

MODULE	SUPPLY VOLTAGE		
	+5 V	+12 V	-12 V
V1751/VX1751	6.5 A	200 mA	300 mA

Tab. 5.1: Power requirements table

6 Temperature Protection

ADC chips temperature readout

The V1751 features an internal ADC temperature monitoring system, useful in order to estimate the steady thermal state of the ADCs and to perform the calibration procedure (see Sec. **Channel Calibration**). Since each ADC manages two channels (0-1, 2-3, 4-5, 6-7) identical temperature values will be found for couples of channels; such values can be readout using register 0x1nA8.

ADC chips over temperature protection

Each ADC will be automatically powered off whenever the core temperature reaches 90°C. The relevant channels will not therefore participate any more to data event, and bit[7] and bit[8] of register 0x1n88 will set to 1 (channel power down and over-temperature flags respectively).

When the ADC core temperature decreases under 65°C, the bit[8] will return to 0, and the relevant channels can be restored to normal operation following these steps:


- Wait until bit 8 of 0x1n88 register returns to 0
- Set bit[0] = 0 of 0x1n9C; bit[7] of 0x1n88 will return to 0.
- Perform a calibration procedure on the restored channels (see Sec. **Channel Calibration**)


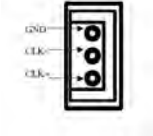
7 Panels Description




Fig. 7.1: Front panel view of V1751

Front Panel



ANALOG INPUT		
	FUNCTION Input connectors from CH0 to CH7 receive the input analog signals.	MECHANICAL SPECS Series: MCX connectors. Type: CS 85MCX-50-0-16. Manufacturer: SUHNER Suggested plug: MCX-50-2-16 type. Suggested cable: RG174 type.
	ELECTRICAL SPECS Input dynamics: 1 V _{pp} Input impedance (Z _{in}): 50 Ω. Absolute max analog input voltage: @1 V _{pp} : 3 V _{pp} (with V _{rail} max +3 V or -3 V) @200 mV _{pp} : 2 V _{pp} (with V _{rail} max +2 V or -2 V) for any DAC offset value. Note: 200 (50 Ω) mV _{pp} input range is available by ordering option (see Tab. 1.1).	

CLOCK IN/CLOCK OUT		
	FUNCTION Input and output connectors for the external clock.	MECHANICAL SPECS Series: AMPMODU connectors. Type: 3-102203-4 (3-pin). Manufacturer: AMP Inc.
	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 (CLK-IN); DC (CLK-OUT). Z _{diff} : 100 Ω.	PINOUT 


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



TRG-IN / TRG-OUT / S-IN		
	FUNCTION <ul style="list-style-type: none"> TRG-OUT: digital output connector to propagate: <ul style="list-style-type: none"> probes from the mezzanines; S-IN signal. TRG-IN: digital input connector for the external trigger. S-IN: SYNC/START/STOP digital input connector configurable as reset of the time stamp (see Sec. Reset, Clear and Default Configuration) or to start/stop the acquisition (see Sec. Acquisition Run/Stop). 	MECHANICAL SPECS Series: 101 A 004 connectors. Type: DLP 101 A 004-28. Manufacturer: FISCHER. Alternatively: Type: EPL 00 250 NTN. Manufacturer: LEMO.
	ELECTRICAL SPECS Signal level: NIM or TTL. TRG-IN/S-IN Input impedance (Z _{in}): 50 Ω TRG-OUT requires 50 Ω termination.	


TTL (GREEN), NIM (GREEN): indicate the standard TTL or NIM set for TRG-OUT, TRG-IN, and S-IN.

OPTICAL LINK PORT		
	FUNCTION Optical LINK connector for data readout and flow control. Daisy chainable. Compliant with Multimode 62.5/125 μm cable featuring LC connectors on both sides.	MECHANICAL SPECS Series: SFF Transceivers. Type: FTLF8519F-2KNL (LC connectors). Manufacturer: FINISAR.
	ELECTRICAL SPECS Transfer rate: up to 80 MB/s.	PINOUT  TX (red wrap) RX (black wrap)



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

MON / Σ		
	FUNCTION Analog Monitor output connector with 4 programmable modes (see Sec. Analog Monitor): <ul style="list-style-type: none"> - Trigger Majority - Test Pulses - Memory Occupancy - Voltage Level 	MECHANICAL SPECS Series: 101 A 004 connectors. Type: DLP 101 A 004-28. Manufacturer: FISCHER. Alternatively: Type: EPL 00 250 NTN. Manufacturer: LEMO.
	ELECTRICAL SPECS 12-bit (125 MHz) DAC output. $1 V_{pp}$ on $R_t = 50 \Omega$	

DIAGNOSTICS LEDs	
 	<p>DTACK (GREEN): indicates there is a VME read/write access to the board;</p> <p>PLL LOCK (GREEN): indicates the PLL is locked to the reference clock;</p> <p>PLL BYPS (GREEN): not used;</p> <p>RUN (GREEN): indicates the acquisition is running (data taking). See Sec. Acquisition Run/Stop;</p> <p>TRG (GREEN): indicates the trigger is accepted;</p> <p>DRDY (GREEN): indicates the event/data is present in the Output Buffer;</p> <p>BUSY (RED): indicates all the buffers are full for at least one channel.</p>

LVDS I/Os CONNECTOR		
	FUNCTION 16-pin connector with programmable general purpose LVDS I/O signals organized in 4 independent signal groups: 0÷3; 4÷7; 8÷11; 12÷15. In/Out direction is software controlled. Different selectable modes (see Sec. Front Panel LVDS I/Os): <ul style="list-style-type: none"> - Register - Trigger - nBusy/nVeto - Legacy 	MECHANICAL SPECS Series : TE - AMPMODU Mod II Series Type: 5-826634-0 34 pin (lead spacing: 2.54 mm; row pitch: 2.54 mm) Manufacturer: AMP Inc.
	ELECTRICAL SPECS Level: differential LVDS Z _{diff} : 100 Ω	

LVDS I/O LEDs (GREEN): Each LED close to a 4-pin group lights on if the pins are set as outputs.

LABELS	
	Two blue labels on each insertion/extraction handle on the VME front panel report: <ul style="list-style-type: none"> - Manufacturer name and board's model - Brief functional description of the module
	A little silver label on the bottom of the VME board's front panel reports: <ul style="list-style-type: none"> - 4-digit Serial Number (S/N)

Internal Components

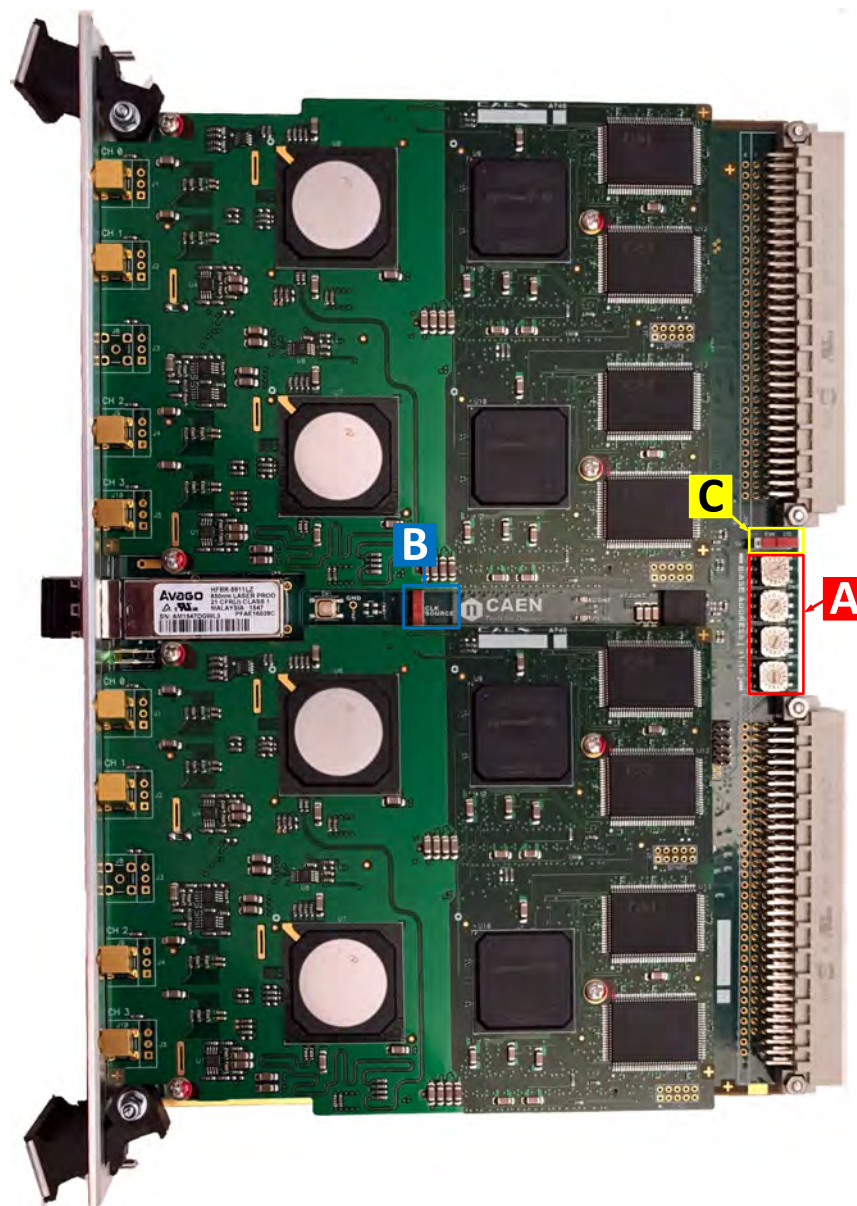


Fig. 7.2: Rotary and dip switches location

A	SW3,4,5,6: "Base Address [31:16]"	Type: Rotary Switches	Function: Set the VME Base Address of the module
B	SW2: "CLOCK SOURCE" INT/EXT	Type: Dip Switch	Function: Selects the clock source (External or Internal)
C	SW7: "FW" BKP/STD	Type: Dip Switch	Function: Selects "Standard" (STD) or "Backup" (BKP) FLASH page as first to be read at power-on to load the FW on the FPGAs (default position is STD); see Sec. Firmware Upgrade

Clock Distribution

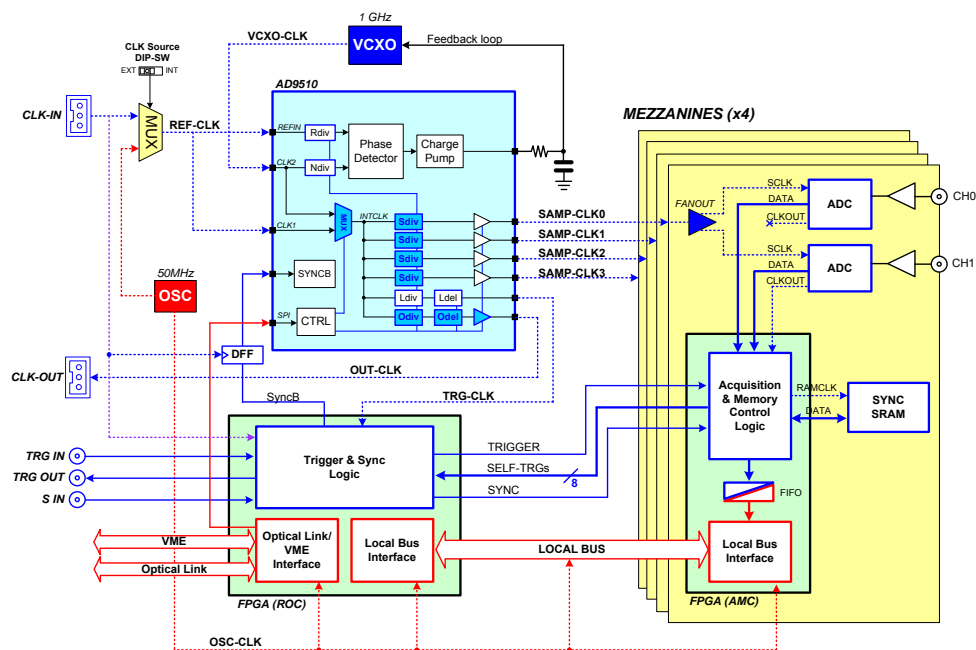


Fig. 8.2: Clock distribution diagram

The clock distribution of the module takes place on two domains: OSC-CLK and REF-CLK.

OSC-CLK is a fixed 50-MHz clock coming from a local oscillator which handles VMEbus, Optical Link and Local Bus, that takes care of the communication between motherboard and mezzanines (see red traces in Fig. 8.2).

REF-CLK handles ADC sampling, trigger logic, and acquisition logic (samples storage into RAM, buffer freezing on trigger) through a clock chain. REF-CLK can be either an external (via the front panel CLK-IN connector) or an internal (via the 50-MHz local oscillator) source. In the latter mode, OSC-CLK and REF-CLK will be synchronous (the operation mode remains the same).

REF-CLK clock source selection can be done by an on-board dedicated dip switch (see Fig. 7.2) between the following modes:

- INT mode (default) means REF-CLK is the 50 MHz of the local oscillator (REF-CLK = OSC-CLK);
- EXT mode means REF-CLK source is the external frequency fed on CLK-IN connector.

The external clock signal must be differential (LVDS, ECL, PECL, LVPECL, CML) with a jitter lower than 100 ppm (see Chap. **Technical Specifications**). CAEN provides the A318 cable to adapt single ended signals coming from an external clock unit into the differential CLK-IN connector (see Tab. 1.1).

The V1751 is equipped with a phase-locked-loop (PLL) and clock distribution device, AD9510. It receives the REF-CLK and generates the sampling clock for ADCs and the mezzanine FPGA (SAMP-CLK0 up to SAMP-CLK3), as well as the trigger logic synchronization clock (TRG-CLK) and the output clock (CLK-OUT).

AD9510 configuration can be changed and stored into non-volatile memory. Changing the AD9510 configuration is primarily intended to be used for external PLL reference clock frequency change (see Sec. **PLL Mode**). The V1751 locks to an external 50 MHz reference clock with default AD9510 configuration.

Refer to the AD9510 datasheet for more details:

http://www.analog.com/UploadedFiles/Data_Sheets/AD9510.pdf

(in case the active link above does not work, copy and paste it on the internet browser)

PLL Mode

The Phase Detector within the AD9510 device allows to couple REF-CLK with an external VCXO, which provides the nominal ADCs frequency (1 GS/s).

As introduced in Sec. **Clock Distribution**, the source of the REF-CLK signal (see Fig. 8.2) can be external on CLK-IN front panel connector or internal from the 50 MHz local oscillator. Programming the REF-CLK source internal or external can be performed by acting on the on-board dip switch SW2 (see Sec. **Internal Components**).

The following options are allowed:

1. 50 MHz internal clock source - this is the standard operation mode: the AD9510 dividers do not require to be reprogrammed (the digitizer works in the AD9510 default configuration). The clock source selection dip switch SW2 is in default INT mode. REF-CLK = OSC-CLK.
2. 50 MHz external clock source - in this case, the clock source is taken from an external device; the AD9510 dividers do not need to be reprogrammed as the external frequency is the same as the default one. The clock source selection dip switch must be set in EXT mode. CLK-IN = REF-CLK = OSC-CLK.
3. External clock source different from 50 MHz - the clock source is externally provided as in point 2, but the AD9510 dividers must now be reprogrammed to lock the the VCXO to the new REF-CLK in order to provide out the nominal sampling frequency at 1 GS/s. The clock source selection dip switch must be set in EXT mode. CLK-IN = REF-CLK \neq OSC-CLK.

If the digitizer is locked, the PLL-LOCK front panel LED must be on.



Note: the user can configure the clock parameters, generate the PLL programming file and load it on the board by using the CAENUpgrader software tool (see Chap. **Software Tools**).

Reducing the Sampling Frequency

In case the board is required to work at a sampling frequency (SAMP-CLK) lower than the nominal, it can be achieved by reprogramming the AD9510 dividers. REF-CLK can be configured as in Sec. **PLL Mode**. Not all the frequencies are admitted and a lower frequency limit must be considered, due to the internal electronics. Please contact CAEN (see Sec. **Technical Support**) to check the feasibility.

Trigger Clock

The TRG-CLK logic works at 125 MHz, equal to $1/8$ of the sampling frequency: $\text{TRG-CLK} = 1/8 \cdot \text{SAMPL-CLK}$. Eight samples of trigger “uncertainty” occurs over the acquisition window (16 samples uncertainty in DES mode).

Output Clock

The AD9510 output can be available on the front panel CLK-OUT connector (see Fig. 8.2). This option is particularly useful in case of multi-board synchronization to propagate the clock reference source in Daisy Chain. This option can be enabled by the user while configuring the PLL programming file in the CAENUpgrader software.

DES Mode

The board can be programmed to operate in Dual Edge Sampling (DES) mode, at 2 GS/s. DES Mode is configurable by setting bit[12] = 1 of register 0x8000 (see **[RD1]**).



Note: Only even channels are managed when operating the digitizer in DES mode.

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).

The diagram below synthesises the flow for a proper calibration:

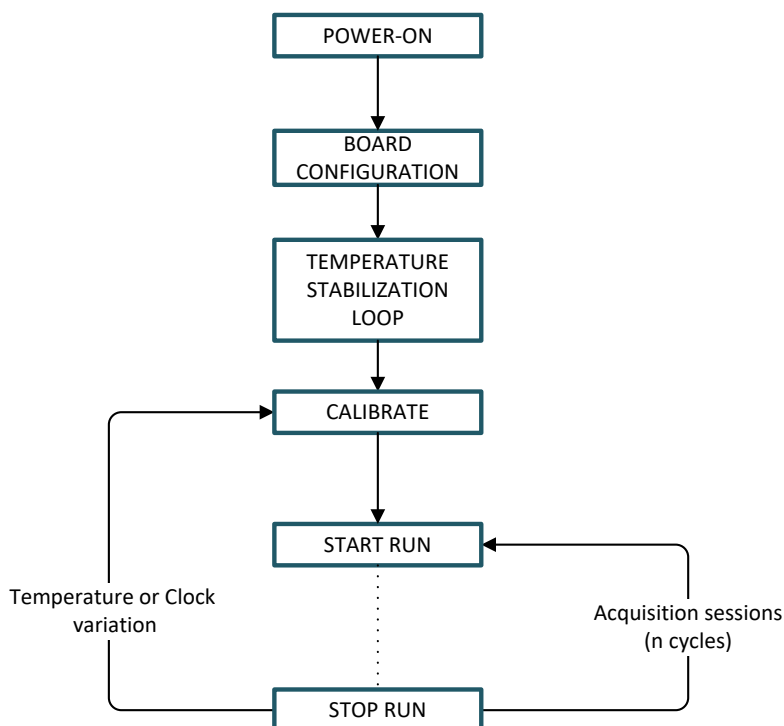


Fig. 8.3: Diagram of the ADCcalibration flow.

- At low level, the ADCs temperature can be read at the register address 0x1nA8 **[RD1]**, while the calibration must be performed through register address 0x809C. The following steps are required:
 - set bit[1] = 0 of register 0x809C;

- set bit[1] = 1 of register 0x809C. The self calibration process will start simultaneously on each channel of the board and bit[6] of register 0x1n88 will be set to 0;
- poll bit[6] of register 0x1n88 until it returns to 1 (few milliseconds);
- set again bit[1] = 0 of register 0x809C.

Steps in case of DES mode are:

- make sure that EVEN channels are disconnected;
- disable EVEN channels;
- enable DES mode by setting bit[12] = 1 of register 0x8000;
- set bit[1] = 0 of register 0x809C;
- set bit[1] = 1 of register 0x809C. The self calibration process will start simultaneously on each channel of the board and bit[6] of register 0x1n88 will be set to 0;
- poll bit[6] of register 0x1n88 until it returns to 1 (few milliseconds);
- set again bit[1] = 0 of register 0x809C.



Note: Whenever switching from Normal mode to DES mode and vice-versa, the ADC calibration must be repeated.



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 starting the calibration.



Note: At power-on, a Sync command is also issued by the firmware to the ADCs to synchronize all of them to the board's clock. In the standard operating, this command is not required to be repeated by the user. If a Sync command is intentionally issued (write access at register address 0x813C), the user must consider that a new calibration procedure is needed for a correct board operating.

- At the library level, developers can exploit the CAENDigitizer library (see Sec. **Libraries**) dedicated routines which are *ReadTemperature()* function for temperature readings and the *Calibrate()* function which executes the channel calibration steps above described.



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 ([RD4]).

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

◇ **WaveDump**

1. Launch WaveDump. This software performs an automatic ADC calibration and displays a message when it is completed (see Fig. 8.4). This allows the user to start using the program sure

```

***** Wave Dump 3.7.2 20160420 *****
Opening Configuration File WaveDumpConfig.txt
Connected to CAEN Digitizer Model DT5725
ROC FPGA Release is 04.10 - Build 0401
AMC FPGA Release is 00.06 - Build 0401
ADC Calibration successfully executed.
[sl start/stop the acquisition, [ql quit, [SPACE] help

```

Fig. 8.4: Automatic calibration at WaveDump first run

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

- At any time, the user can check the channel temperatures (with the acquisition not running) by issuing multiple “m” commands from the keyboard.
- In case of significant variations, issuing a “c” command provokes a manual channel calibration to be executed (see Fig. 8.5).

```

Reading at 4.49 MB/s (Trg Rate: 1137.62 Hz)
Reading at 4.47 MB/s (Trg Rate: 1133.66 Hz)
Acquisition stopped
CH00: 31 C
CH01: 31 C
CH02: 31 C
CH03: 31 C
CH04: 28 C
CH05: 28 C
CH06: 28 C
CH07: 28 C

CH00: 31 C
CH01: 31 C
CH02: 31 C
CH03: 31 C
CH04: 29 C
CH05: 29 C
CH06: 29 C
CH07: 29 C

ADC Calibration successfully executed.

```

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

- A new acquisition can start.

Please, refer to WaveDump User Manual for complete software description ([RD5]).

◇ DPP-PSD Control Software

- Launch DPP-PSD Control Software
- Connect to the digitizer
- 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
- Go to the “General” tab and press the “Calibrate” button
- Start the acquisition

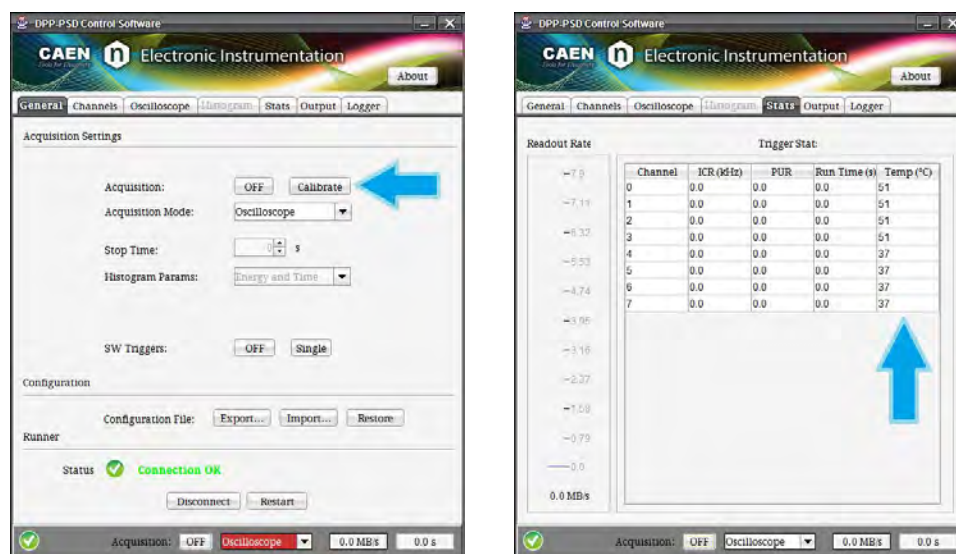


Fig. 8.6: Channel calibration in DPP-PSD Control Software

Acquisition Run/Stop

The acquisition can be started and stopped in different ways, according to bits[2:0] of register 0x8100 [RD1]:

- 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.
- S-IN CONTROLLED (bits[1:0] = 01): bit[2] = 1 arms the acquisition and the Start is issued as the S-IN signal is set high and the Stop occurs when it is set low. If bit[2] = 0 (disarmed), 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]).
- LVDS I/Os CONTROLLED: this mode acts like the S-IN CONTROLLED (bits[1:0] = 01), but using the configurable features of the signals on the LVDS I/Os connector (see Sec. **Front Panel LVDS I/Os**).

Acquisition Triggering: Samples and Events

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

- store a 31-bit counter value of the Trigger Time Tag (TTT).
The counter (representing a time reference), like the Trigger Logic Unit (see Fig. 8.2), operates at a frequency of 125 MHz (i.e. 8 ns, that is to say 8 ADC clock cycles). Due to the way acquired data is 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 via register address 0x8114 [RD1]; the acquisition window width (also referred to as record length) is determined via register addresses 0x800C and 0x8020; then, the buffer is frozen for readout purposes, while the 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 overlapping triggers (by writing at register address 0x8000 [RD1]), as the overlapping trigger arrives, the current active buffer is filled up, then the samples storage continues on the subsequent one. In this case, not all events will have the same size (see Fig. 8.7).

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 event pre-trigger is not reached yet; this happens typically as the trigger occurs too early either with respect to the RUN Acquisition command (see Sec. **Acquisition Run/Stop**) or with respect to a buffer emptying after a Memory FULL status (see Sec. **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,

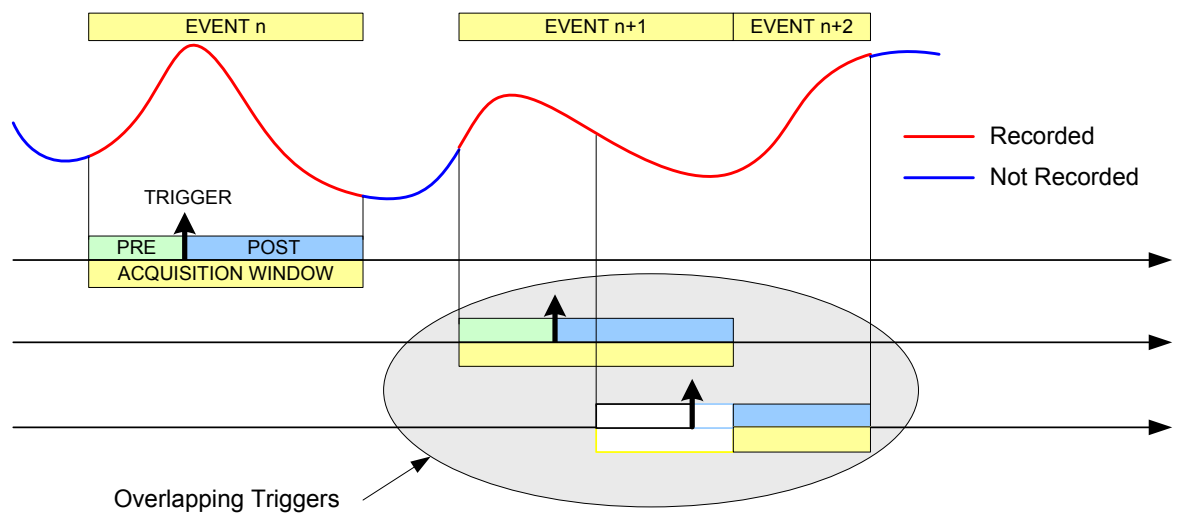


Fig. 8.7: Trigger Overlap

the EVENT COUNTER value identifies the trigger number 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 V1751 features a SRAM memory to store the acquired events. The memory size in the standard event storage mode is 1.75 MS or 13.73 MS¹, where $M = 1024 \cdot 1024$, according to the board version (see Tab. 1.1). The channel memory can be divided in a programmable number of buffers, N_b (N_b from 1 up to 1024), by the register address 0x800C [RD1], as described in Tab. 8.1.



Note: in case of DES mode, values must be multiplied by 2.

Register Value BUFFER_CODE	Number of Buffers (N_b)	Size of one Buffer	
		SRAM 2.33 MB/ch (1.75 MS)	SRAM 18.3 MB/ch (13.73 MS)
0x00	1	2.333 MB/ch (1.75 MS)	18.3 MB/ch (13.73 MS)
0x01	2	1.167 MB/ch (896 kS)	9.1 MB/ch (6.8 MS)
0x02	4	597.2 kB/ch (448 kS)	4.6 MB (3.4 MS)
0x03	8	298.6 kB/ch (224 kS)	2.3 MB/ch (1.7 MS)
0x04	16	149.3 kB/ch (112 kS)	1.1 MB/ch (878.7 kS)
0x05	32	74.6 kB/ch (56 kS)	586.2 kB/ch (439.3 kS)
0x06	64	37.3 kB/ch (28 kS)	293.1 kB/ch (219.7 kS)
0x07	128	18.7 kB/ch (14 kS)	146.6 kB/ch (109.8 kS)
0x08	256	9.3 kB/ch (7 kS)	73.3 kB/ch (54.9 kS)
0x09	512	4.7 kB/ch (3.5 kS)	36.6 kB/ch (27.4 kS)
0x0A	1024	2.3 kB/ch (1.75 kS)	18.3 kB/ch (13.7 kS)

Tab. 8.1: Buffer organization of 751 family series. For each value of buffer size it is reported the memory size and the number of samples of one buffer, where $k = 1024$ and $M = 1024 \cdot 1024$.

Having 1.75 MS memory size as reference, this means that each buffer contains $1.75M/N_b$ samples (e.g. $N_b = 1024$ means 1.75k samples in each buffer).

Custom size events

In case an event size less than the buffer size is needed, the user can set the N_LOC value at register address 0x8020 [RD1], where N_LOC is the number of memory locations. The size of the event is so forced to be according to the formula:

$$1 \cdot N_LOC = 7 \cdot N_{\text{Sample}} \text{ (normal mode)}$$

$$1 \cdot N_LOC = 14 \cdot N_{\text{Sample}} \text{ (DES mode)}$$

When $N_LOC = 0$ the custom size is disabled.



Note: The value of N_LOC must be set in order that the relevant number of samples does not exceed the buffer size and it must not be modified while the acquisition is running. 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 Chap. **Software Tools**) and the `Set/GetRecordLength()` functions of the CAENDigitizer library (see Sec. **Libraries**) rely on these concepts.

¹Memory size is 1.8 MS and 14.4 MS in case of $M = 1000 \cdot 1000$

Event structure

The event can be readout via VMEbus or Optical Link; data format is 32-bit long word (see Fig. 8.8).

An event is structured as:

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

Header

The Header consists of four words including the following information:

- **EVENT SIZE** (bits[27:0] of 1st header word) is the total size of the event, i.e. the number of 32-bit long words to be read.
- **BOARD ID** (bits[31:27] of 2nd header word) is the GEO address, meaningful for VME64X modules.
- **BOARD FAIL FLAG** (bit[26] of 2nd header word) implemented from ROC FPGA firmware revision 4.5 on (reserved otherwise), it is set to “1” in consequence of a hardware problem (e.g. PLL unlocking). The user can collect more information about the cause by reading at register address 0x8104 and contact CAEN Support Service if necessary (see Chap. **Technical Support**).
- **PATTERN** (bits[23:8] of 2nd header word) is the 16-bit PATTERN latched on the LVDS I/Os as the trigger arrives.



Note: Starting from revision 4.6 of the ROC FPGA firmware, these 16 bits can be programmed to provide trigger information according to the setting of the bits[22:21] at register address 0x811C (see Tab 8.2).

REGISTER 0x811C Bits[22:21]	FUNCTIONAL DESCRIPTION	PATTERN /TRG OPTIONS INFORMATION (16 bits in the 2 nd header word)
00 (default)	PATTERN	Pattern of the 16 LVDS signals .
01	Event Trigger Source	Indicates the trigger source causing the event acquisition: Bits[23:19] = 00000 Bit[18] = Software Trigger Bit[17] = External Trigger Bit[16] = Trigger from LVDS connector Bits[15:8] = Channel self-trigger (refer to Sec. 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 (4 th header word). Note: in the ETTT option, the overflow bit is not provided.
11	Not used	If configured, it acts like “00” setting.

Tab. 8.2: Pattern/Trg Options configuration table.

- **CHANNEL MASK** (bits[7:0] of 2nd header word) is the mask of the channels participating in the event (e.g. CH5 and CH7 participating → Channel Mask = 0xA). This information must be used by the software to acknowledge from which channel the samples are coming (the first event contains the samples from the channel with the lowest number).



Note: in DES mode even channels are automatically disabled.

- **EVENT COUNTER** (bits[23:0] of 3rd header word) is the trigger counter; it can count either accepted triggers only, or all triggers (bit[3] of register address 0x8100).
- **TRIGGER TIME TAG** (bits[31:0] of 4th header word) is the 31-bit Trigger Time Tag (TTT) 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 48-bit Extended 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 at the start of acquisition, or via front panel signal on S-IN or LVDS I/O connectors, and increments with 250 MHz frequency (i.e. every 8 ADC clock cycles). The TTT value is read at half the frequency (i.e. 125 MHz) so that the specifications are 16 ns resolution and 17 s range ($8 \text{ ns} \times (2^{31} - 1)$), which can be extended to 625 h ($8 \text{ ns} \times (2^{48} - 1)$) if ETTT is enabled.

Data

Data are the stored samples. Data from masked channels are not read. When operating in DES mode the EVEN channels are automatically disabled. Bits[31:30] of the data words identifies how many samples are stored in the corresponding word. The example in Sec. **Event Format Examples** shows the case of two samples in the last word.

Event Format Examples

The event format is shown in the following figure (case of 8 channels enabled):

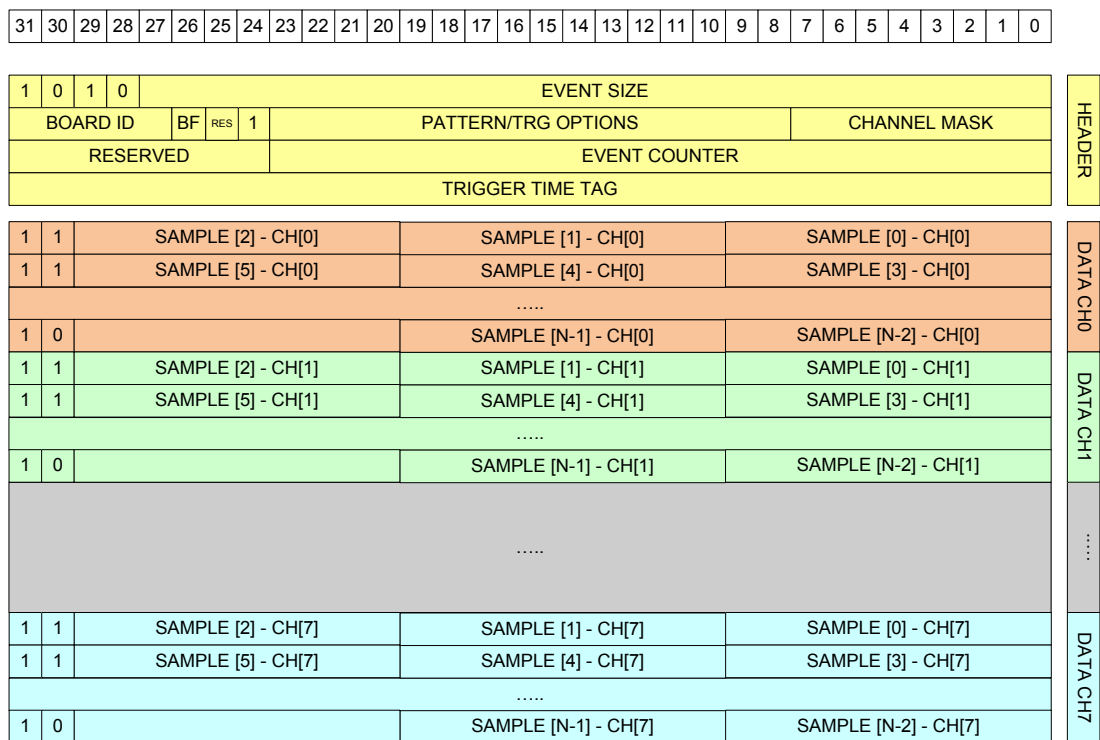


Fig. 8.8: Event Format in Normal Mode

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 VME or Optical Link. The acquisition can continue 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 one buffer is read out and freed, the board exits the FULL condition and acquisition restarts.

IMPORTANT: 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 $\text{bit}[5] = 1$ at register address 0x8100 **[RD1]**. The board is so programmed to enter the FULL condition when $N_b - 1$ buffers are filled: no trigger is then accepted, but samples writing continues in the last available buffer. As soon as one buffer is read out and becomes free, the board 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).



Note: when $\text{bit}[5] = 1$, the minimum number of circular buffers to be programmed is $N_b = 2$.

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 these 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 to "X" (register address 0x816C **[RD1]**), 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_b or $N_b - 1$, depending on $\text{bit}[5]$ at register address 0x8100 as above described.

It is possible to provide the BUSY signal on the digitizer front panel TRG-OUT output ($\text{bit}[20]$, $\text{bits}[19:18]$ and $\text{bits}[17:16]$ at register address 0x811C are involved **[RD1]**). In case of multi-board setup, the BUSY signal can be propagated among boards through the front panel LVDS I/O connector (see Sec. **Front Panel LVDS I/Os**).

Trigger Management

When operating the waveform recording firmware, all board channels share the same trigger (board common trigger), so they acquire an event simultaneously and in the same way (determined number of samples according to buffer organization and custom size settings, as well as position with respect to the trigger defined by the post-trigger).

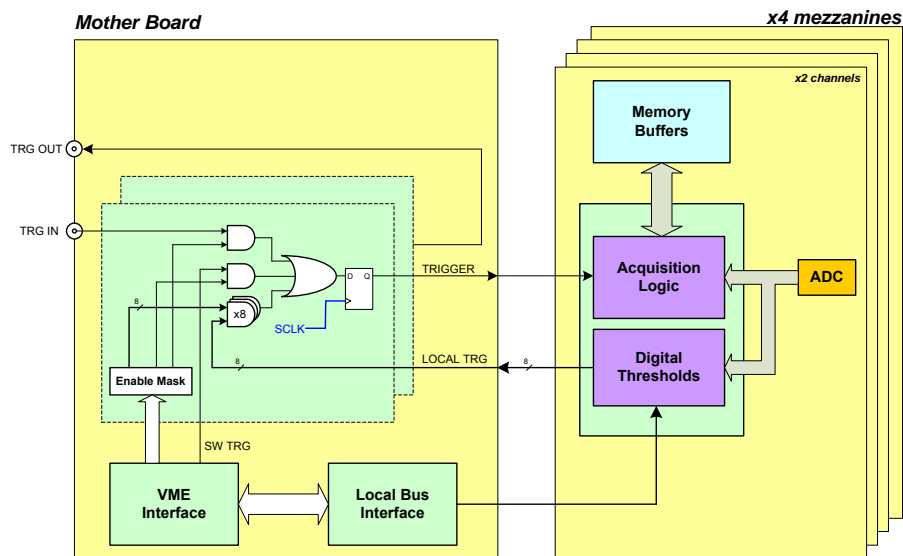


Fig. 8.9: Block diagram of Trigger management.

- **Software Trigger**
- **External Trigger**
- **Self-trigger**
- **Coincidences**
- **TRG-IN as Gate**
- **LVDS I/O Trigger**

Software Trigger

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

External Trigger

A TTL or NIM external signal can be provided to 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 can generate a self-trigger signal (SELF-TRG) when the digitized input pulse exceeds a configurable threshold set through the register address 0x1n80 **[RD1]**.

The individual self-triggers from all channels are propagated to the central trigger logic on the motherboard (see Fig. 8.9) where they participate in logic OR to produce the board common trigger, which is finally distributed back to all channels on the mezzanines causing the event acquisition (see Sec. **Trigger distribution**).

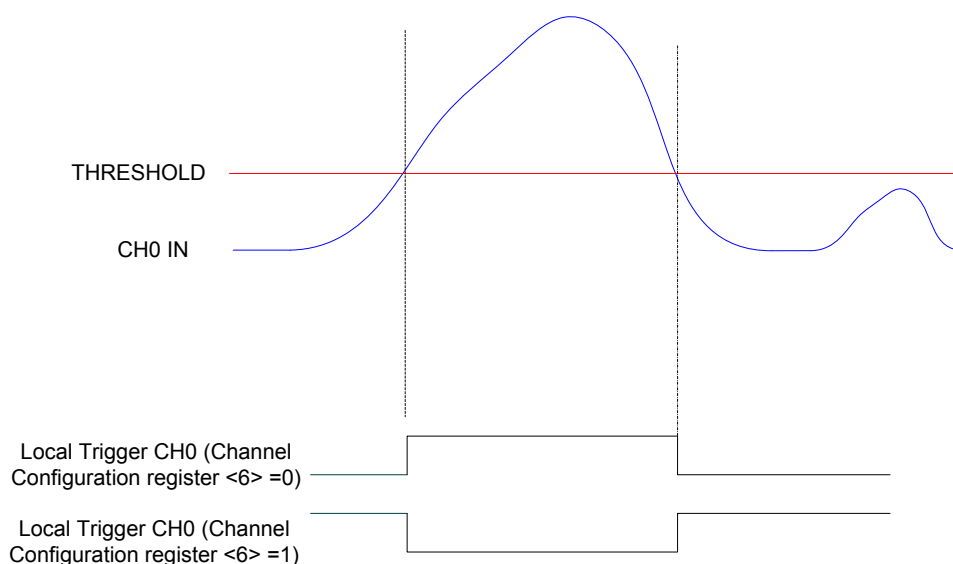


Fig. 8.10: Self-trigger generation.

Bits[7:0] of register 0x810C allows the user to program which channel participates to the global trigger generation.

LVDS I/O Trigger

LVDS I/O specific pins on the front panel dedicated connector can be programmed as trigger inputs and enabled to participate in the common trigger generation with other trigger sources. Refer to Sec. **Front Panel LVDS I/Os** for details.

Trigger coincidence level

Operating the waveform recording firmware, the acquisition trigger is common to the whole board. This common trigger allows the coincidence acquisition mode to be performed through the Majority operation.

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

- Bits[7:0] enable a specific channel self-trigger 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:

$$\text{Number of enabled channels} > \text{Majority level}$$

Supposing that bits[7:0] = FF (i.e. all channels are enabled) and bits[26:24] = 01 (i.e. Majority level = 1), a common trigger is issued whenever at least two of the enabled self-triggers are in coincidence within the programmed T_{TVAW} .

The Majority level must be smaller than the number of channels enabled via bits[7:0] 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 common trigger is simple OR of the enabled channel self-triggers.



Note: in order not to overload the plots but preserve the clearness of concept, only CH0 and CH1 are supposed to be fed with input pulses in the following figures.

Fig. 8.11 shows the trigger management in case the coincidences are disabled.

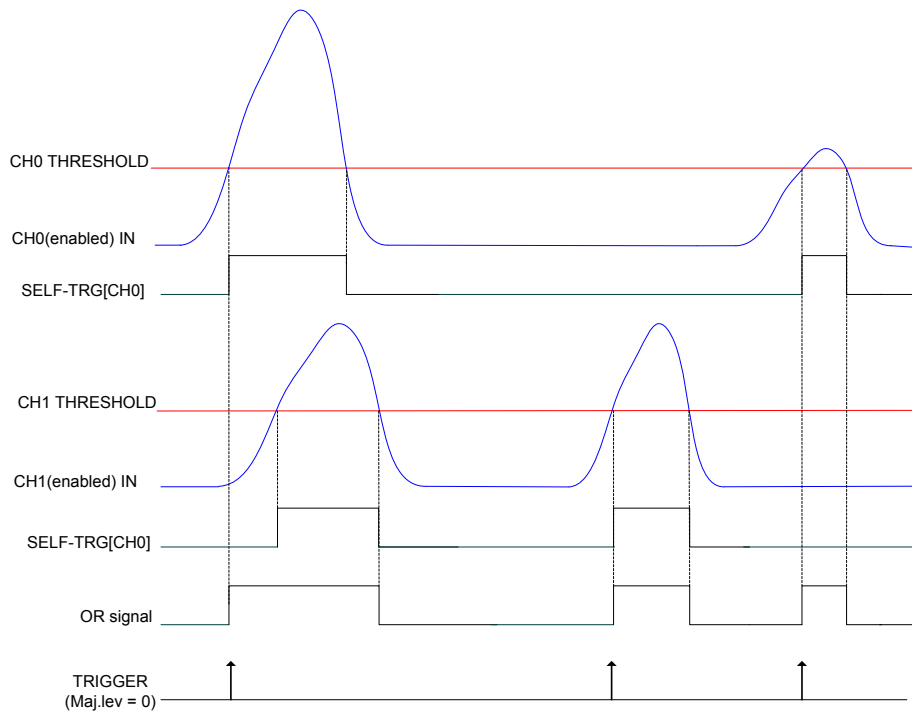


Fig. 8.11: Self-trigger relationship with Majority level = 0.

Fig. 8.12 shows the trigger management in case the coincidences are enabled with Majority level = 1 and T_{TVAW} is a value different from 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.

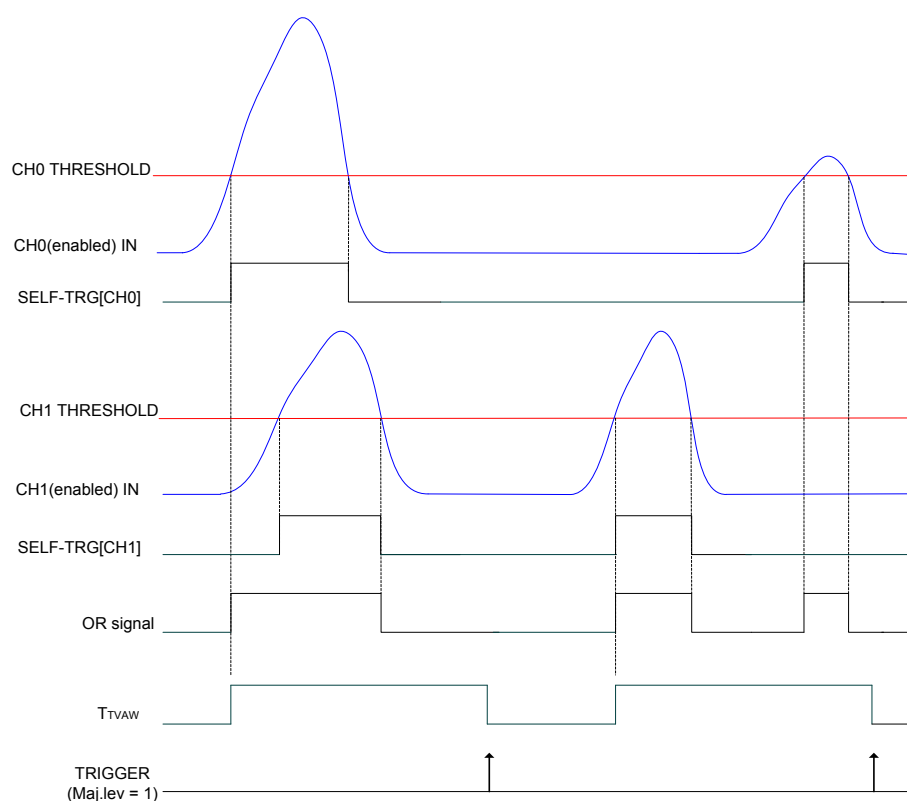


Fig. 8.12: Self-trigger relationship with Majority level = 1 and $T_{TVAW} \neq 0$.

Fig. 8.13 shows the trigger management in case the coincidences are enabled with Majority level = 1 and $T_{TVAW} = 0$ (i.e. 1 clock cycle).



Note: CAEN provides a guide to coincidences including a practical example of making coincidences with the waveform recording firmware **[RD6]**.

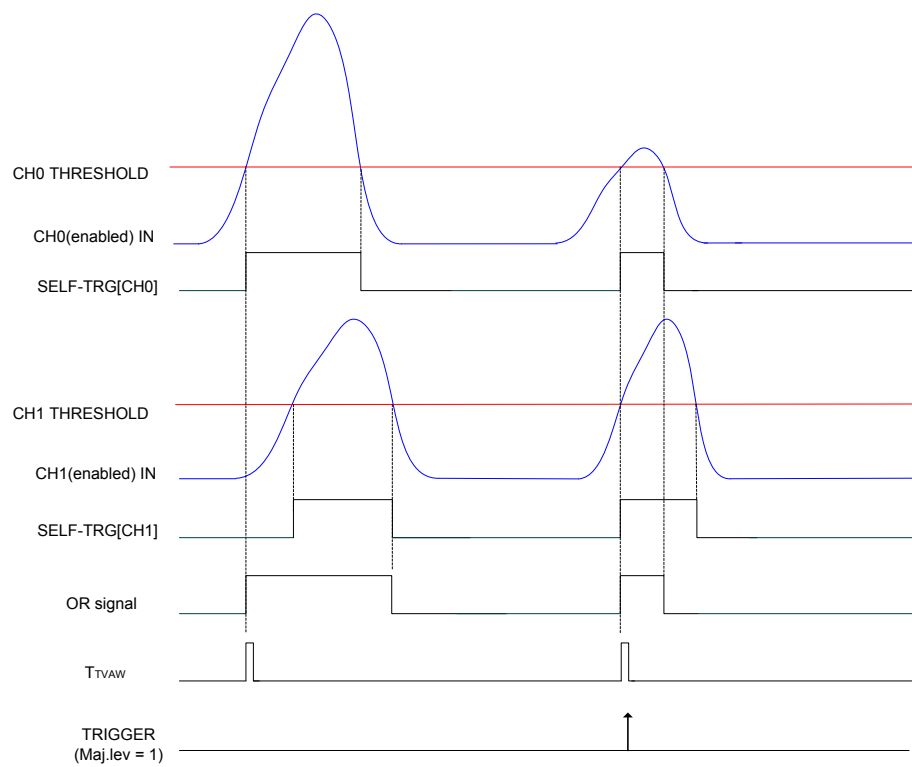


Fig. 8.13: Self-trigger relationship with Majority level = 1 and $T_{TVAW} = 0$.

TRG-IN as Gate

It is possible to configure TRG-IN as a gate for trigger anti-veto function. The common acquisition trigger is then issued upon the AND between the external signal on TRG-IN and the other trigger sources but the software trigger (i.e. the software trigger cannot participate in the Trigger as Gate mode).

This mode is enabled by setting bit[27] = 1 of register 0x810C and bit[10] = 1 of register 0x811C. The trigger sources participating in AND with TRG-IN are configurable through register 0x810C as well.

Trigger distribution

As described in Sec. **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 causing 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. 8.14).

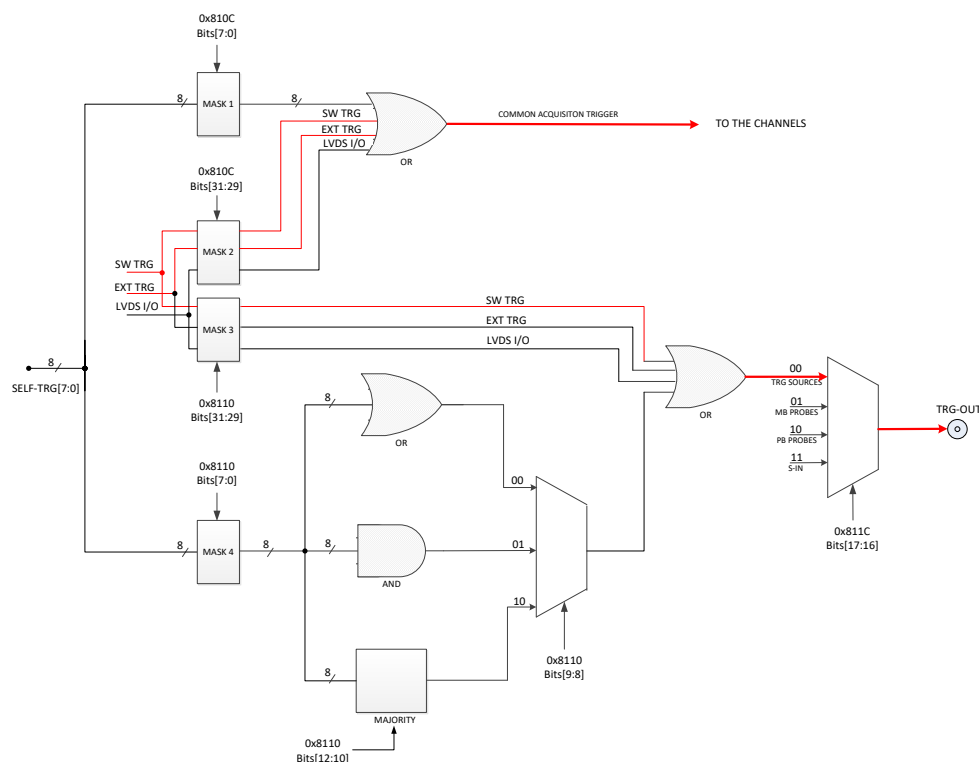


Fig. 8.14: Trigger configuration of TRG-OUT front panel connector.

A Trigger Out signal is also generated on the relevant front panel TRG-OUT connector (NIM or TTL), and allows to extend the trigger signal to other boards. Thanks to its configurability, TRG-OUT 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. 8.14);
- the OR, AND or MAJORITY exclusively of the channel self-triggers.

The registers involved in the TRG-OUT programming are:

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

Example

It could be required to start the acquisition on all the channels of a multi-board system as soon as one of the board channels (board “n”) crosses its threshold. Trigger Out signal is then fed to an external Fan Out logic unit (e.g. CAEN V2495 board); 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 thereafter described.

1. Register 0x8110 on board “n”:
 - Enable the desired self-trigger as Trigger Out signal on board “n” (by bits[7:0] mask).
 - Disable Software Trigger, External Trigger and LVDS I/O Trigger as Trigger Out signal on board “n” (bits[31:29] = 000).
 - Set Trigger Out signal as the OR of the enabled self-trigger on board “n” (bits[9:8] = 00).
2. Register 0x811C on board “n”:
 - Configure the digitizer to propagate on TRG-OUT the internal trigger sources according to the 0x8110 settings (i.e. the enabled self-trigger, 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 common acquisition trigger, disable Software Trigger , LVDS I/O Trigger and the channel self-triggers (bits[31:29] = 010; bits[7:0] = 00000000)

Multi-board Synchronization

When multi-board systems are involved in an experiment, it is necessary to synchronize different boards. In this way, the user can acquire from N boards with Y channel each, like if they were just one board with $(N \times Y)$ channels.

The main issue synchronizing a multi-board system is to propagate the sampling clock among the boards. This is made through input/output daisy chain connections among the digitizers. One board must be chosen to be the “master” board that propagates its own clock to the others. A programmable phase shift can adjust possible delays in the clock propagation. This allows to have both the ADC sampling clock and the time reference in common for all boards. Having the same time reference means that the acquisition starts/stops at the same time, and that the time stamps of different boards are aligned to the same absolute time.

There are several ways to implement the trigger logic. The synchronization tool allows to propagate the trigger to all boards and acquire the events accordingly. Moreover, in case of busy state of one or more boards, the acquisition is inhibited for all boards.

As a detailed guide to multi-board synchronization, CAEN provides a dedicated Application Note **[RD7]**.

Front Panel LVDS I/Os

The V1751 is provided with 16 general purpose programmable LVDS I/O signals (see Chap. **Panels Description**). From the ROC FPGA firmware revision 3.8 on, a more flexible configuration management has been introduced, which allows these signals to be programmed in terms of direction (INPUT/OUTPUT) and functionality by groups of 4.

THE USER MUST SET BIT[8] = 1 AT 0x811C IN ORDER TO ENABLE THE NEW LVDS I/Os CONFIGURATION MODES

NOTE ABOUT LVDS I/Os CONFIGURATIONS IMPLEMENTED IN ROC FW RELEASES <3.8

THE WAVEFORM RECORDING FIRMWARE MAKES ALSO AVAILABLE THE OLD CONFIGURATIONS (bit[8] = 0). USERS WHOSE SOFTWARE BASES ON THE OLD LVDS I/Os CONFIGURATION MANAGEMENT CAN REFER TO THE USER MANUAL OF THE RELEVANT DIGITIZER OR CAN CONTACT CAEN FOR INFORMATION (see Chap. **Technical Support**).

SINCE THIS COULD BE NO LONGER GUARANTEED IN THE FUTURE, THE USER IS HEARTLY RECOMMENDED TO TAKE THE NEW CONFIGURATION MANAGEMENT AS REFERENCE!

The direction of the signals are set by the bits[5:2] at register address 0x811C:

Bit[2] → LVDS I/O[3:0]

Bit[3] → LVDS I/O[7:4]

Bit[4] → LVDS I/O[11:8]

Bit[5] → LVDS I/O[15:12]

Where setting the bit to 0 enables the relevant signals in the group as INPUT, while 1 enables them as OUTPUT.

By default, the new modes are disabled (i.e. bit[8] = 0) and the status of the LVDS I/O signals is congruent with the old Programmed I/O mode (see Tab. 8.3).

Nr.	Direction	Function	Description
0	out	Ch 0 self-trigger	The over-threshold information from the relevant channel
1	out	Ch 1 self-trigger	
2	out	Ch 2 self-trigger	
3	out	Ch 3 self-trigger	
4	out	Ch 4 self-trigger	
5	out	Ch 5 self-trigger	
6	out	Ch 6 self-trigger	
7	out	Ch 7 self-trigger	
8	out	Memory Full	Memory full flag
9	out	Event Data Ready	Board event data ready flag
10	out	Channels Trigger	OR of the new event to be read signal
11	out	RUN Status	Board run flag
12	in	Trigger Time Tag Reset (active low)	Reset of the trigger time tag counter
13	in	Memory Clear (active low)	Clear command of all channel memories
14	-	reserved	N.A.
15	-	reserved	N.A.

Tab. 8.3: Front Panel LVDS I/Os default settings.

When enabled (i.e. bit[8] = 1), the new management allows each group of 4 signals of the LVDS I/O 16-pin connector to be configured in one of the 4 following modes (according to bits[15:0] at register address 0x81A0):

- Mode 0 (bits[n+3:n] = 0000): REGISTER
- Mode 1 (bits[n+3:n] = 0001): TRIGGER
- Mode 2 (bits[n+3:n] = 0010): nBUSY/nVETO
- Mode 3 (bits[n+3:n] = 0011): LEGACY

where n = 0, 4, 8, 12.



Note: Whatever option is set, the LVDS I/Os are always latched with the trigger and the relevant status of the 16 signals is always written into the header Pattern field (see Sec. **Event structure**); the user can then choose to read it out or not.

	REGISTER	TRIGGER	nBUSY/nVETO	LEGACY
LVDS IN [15:12]	Reg[15:12]	<i>Not available</i>	15: nRunIn 14: nTriggerIn 13: nVetoIn 12: nBusyIn	15: reserved 14: reserved 13: reserved 12: nClear_TTT
LVDS IN [11:8]	Reg[11:8]	<i>Not available</i>	11: nRunIn 10: nTriggerIn 9: nVetoIn 8: nBusyIn	11: reserved 10: reserved 9: reserved 8: nClear_TTT
LVDS IN [7:4]	Reg[7:4]	<i>Not available</i>	7: nRunIn 6: nTriggerIn 5: nVetoIn 4: nBusyIn	7: reserved 6: reserved 5: reserved 4: nClear_TTT
LVDS IN [3:0]	Reg[3:0]	<i>Not available</i>	3: nRunIn 2: nTriggerIn 1: nVetoIn 0: nBusyIn	3: reserved 2: reserved 1: reserved 0: nClear_TTT

Tab. 8.4: Features description when LVDS group is configured as INPUT

	REGISTER	TRIGGER	nBUSY/nVETO	LEGACY
LVDS OUT [15:12]	Reg[15:12]	TrigOut_Ch[7:4]	15: nRun 14: nTrigger 13: nVeto 12: nBusy	15: Run 14: Trigger 13: DataReady 12: Busy
LVDS OUT [11:8]	Reg[11:8]	TrigOut_Ch[3:0]	11: nRun 10: nTrigger 9: nVeto 8: nBusy	11: Run 10: Trigger 9: DataReady 8: Busy
LVDS OUT [7:4]	Reg[7:4]	TrigOut_Ch[7:4]	7: nRun 6: nTrigger 5: nVeto 4: nBusy	7: Run 6: Trigger 5: DataReady 4: Busy
LVDS OUT [3:0]	Reg[3:0]	TrigOut_Ch[3:0]	3: nRun 2: nTrigger 1: nVeto 0: nBusy	3: Run 2: Trigger 1: DataReady 0: Busy

Tab. 8.5: Features description when LVDS group is configured as OUTPUT

Mode 0: REGISTER

Direction is INPUT: the logic level of the LVDS I/O signals can be read at register address 0x8118.

Direction is OUTPUT: the logic level of the LVDS I/O signals can be written at register address 0x8118.

Mode 1: TRIGGER

Direction is INPUT: Not available.

Direction is OUTPUT: the TrgOut_Ch[(n+3) : n] signals (n = 0, 4) consist of the channel self-triggers coming directly from the mezzanines.

Mode 2: nBUSY/nVETO

nBusy Signal

nBusyIn (INPUT) is an active low signal which, if enabled, is used to generate the nBusy signal (OUTPUT) as below.

The Busy signal (fed out on LVDS I/Os or TRG-OUT LEMO connector) is:

$$\text{Almost_Full OR (LVDS_BusyIn AND BusyIn_enable)}$$

where

- **Almost_Full** indicates the filling of the Buffer Memory up to a programmable level (12-bit range) set at register address 0x816C;
- **LVDS_BusyIn** is available in nBUSY/nVETO configuration (see Tab. 8.5);
- **BusyIn_enable** is set at register address 0x8100, bit[8].

nVETO Signal

Direction is INPUT: nVETOIn is an active low signal which, if enabled (register address 0x8100, bit[9] = 1), is used to veto the generation of the common trigger propagated to the channels for the event acquisition.

Direction is OUTPUT: the nVETO signal is the copy of nVETOIn.

nTrigger Signal

Direction is INPUT: nTriggerIn is an active low signal which, if enabled, is a real trigger able to cause the event acquisition. It can be propagated to TRG-OUT LEMO connector or to the individual triggers.

Direction is OUTPUT: nTrigger signal is the copy of the trigger signal propagated to the TRG-OUT LEMO connector or copy of the acquisition common trigger. This is selected by bit[16] of the 0x81A0 register.

nRun Signal

Direction is INPUT: nRunIn is an active low signal which can be used as Start for the digitizer (register address 0x8100, bits[1:0] = 11). It is possible to program the Start on the level or on the edge of the nRunIn signal (register address 0x8100, bit[11]).

Direction is OUTPUT: nRun signal is the inverse of the internal Run of the board.

Mode 3: LEGACY

Legacy Mode has been introduced in order the LVDS connector (properly programmed) to be able to feature the same I/O signals available in the ROC FPGA firmware revisions lower than 3.8.

nClear_TTT Signal

It is the only signal available as INPUT. It is the Trigger Time Tag (TTT) reset, like in the old configuration.

Busy Signal

The Busy signal is active high and it is exactly the inverse of the nBusy signal (see Sec. **Mode 2: nBUSY/nVETO**).

In case register address 0x816C is set to 0x0 and the BusyIn signal is disabled, the Busy is the FULL signal present in the old configuration.

DataReady Signal

The DataReady is an active high signal indicating that the board has data available for readout (the same as the DataReady front panel LED does).

Trigger Signal

The active high Trigger signal is the copy of the acquisition trigger (common trigger) sent from the motherboard to the mezzanines (it is neither the signal provided out on the TRG-OUT LEMO connector nor the inverse of the signal sent to the LVDS connector).

Run Signal

The Run signal is active high and represents the inverse of the nRun signal (see Sec. **Mode 2: nBUSY/nVETO**).

Analog Monitor

The board houses a 12bit (125 MHz) DAC with $0 \div 1$ V dynamics on a 50Ω load (see Fig. 2.1), whose input is controlled by the ROC FPGA and the signal output (driving 50Ω) is available on the MON/ Σ output connector. MON output of more boards can be summed by an external Linear Fan In.

The DAC control logic implements four operating modes according to the value of bits[2:0] at register address 0x8144:

- Trigger Majority Mode (0x8144 = 0x0)
- Test Mode (0x8144 = 0x1)
- Buffer Occupancy Mode (0x8144 = 0x3)
- Voltage Level Mode (0x8144 = 0x4)

Trigger Majority Mode

It is possible to generate a Majority signal with the DAC: a voltage signal whose amplitude is proportional to the number of channels under/over threshold (1 step = 125 mV); this allows, via an external discriminator, to produce a common trigger signal, as the number of triggering channels has exceeded a particular threshold.

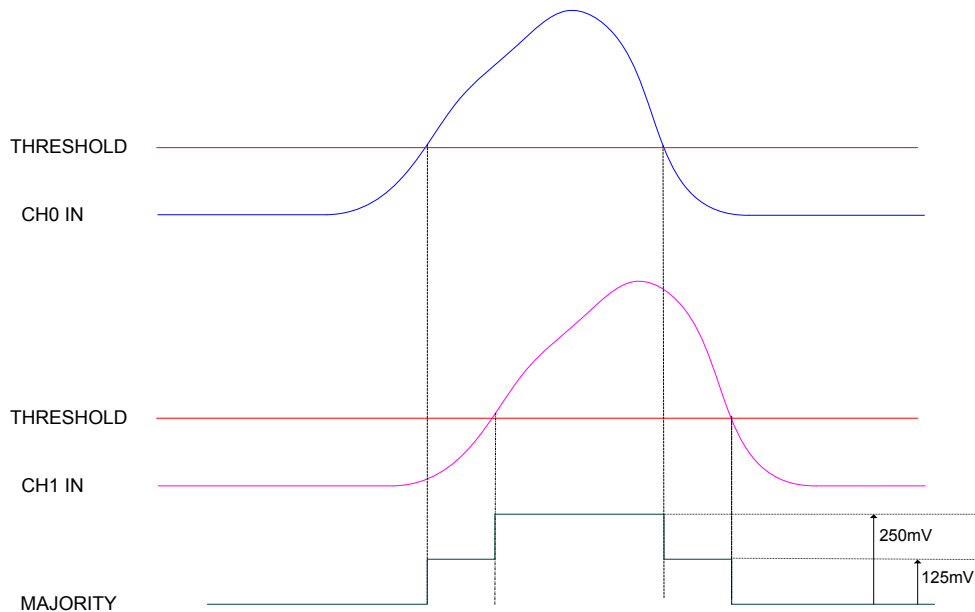


Fig. 8.15: Majority logic (2 channels over-threshold; bit[6]=0 register address 0x8000).

In the example depicted in Fig. 8.15, the MON output provides a signal whose amplitude is proportional to the number of channels over the trigger threshold.

Test Mode

In this mode the MON output provides a sawtooth signal with 1 V amplitude and 30.52 kHz frequency.

Buffer Occupancy Mode

In this mode, MON output connector provides a voltage value increasing, proportionally with the number of buffers filled with events, in fixed steps of 0.976 mV given by:

$$\frac{V_{\max}}{N_{\text{bmax}}}$$

where $V_{\max} \approx 1$ V and $N_{\text{bmax}} = 1024$ is the Maximum_Number_of_Buffers (i.e. the value of the register address 0x800C, as introduced in Sec. **Multi-Event Memory Organization**).

Example: if 0x800C = 0x4 (i.e. 16 buffers), the maximum Buffer Occupancy output voltage level is given by $0.976 \text{ mV} \times 16$.

This mode allows to test the readout efficiency: in fact, if the average event readout throughput is as fast as trigger rate, then MON out value remains constant; otherwise if MON out value grows in time, this means that readout rate is slower than trigger rate.

Starting from revision **4.9** of the ROC FPGA (motherboard) firmware, it is possible to apply a digital gain to the fixed step, particularly when the memory is organized in a small number of buffers. The gain can be set as powers of two ranging between $2^0 = 1$ (no gain, which is the default setting) and 2^A , where the exponent is the value to write at register address 0x81B4.

Voltage Level Mode

In this mode, MON out provides a voltage value programmable via the 12-bit 'N' parameter written in the 0x8138 register, with: $V_{\text{mon}} = 1/4096 \times N$ (Volt).

Test Pattern Generator

The FPGA AMC can emulate the ADC and write into memory a sawtooth signal for test purposes. It can be enabled via register 0x8000. Fig. 8.16 shows the test ramps for even and odd channels respectively.

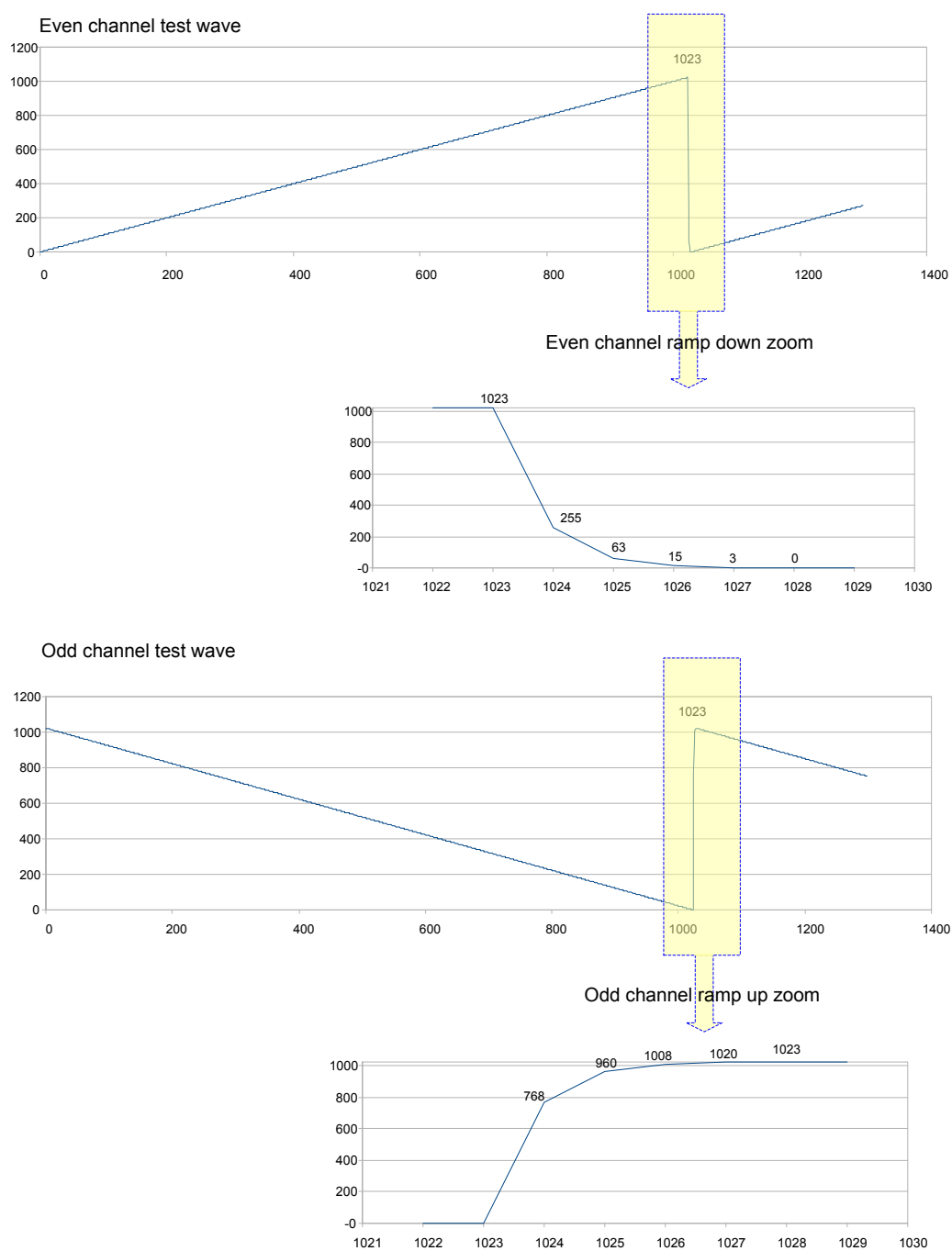


Fig. 8.16: FPGA Test Waveform.

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 . 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 . In the old LVDS I/O configuration (ROC FPGA revision before **3.8**), it is also possible to perform a memory clear by sending a pulse to the front panel dedicated Memory Clear input (see Tab. **8.3**).

Timer Reset

The Timer Reset allows to initialize the timer which tags an event. The Timer Reset can be forwarded with a pulse sent either to the LVDS I/O dedicated input (see Tab. **8.3** and Sec. **Mode 3: LEGACY**) or to the S-IN input (leading edge sensitive).

VMEBus Interface

The module is provided with a fully compliant VME64/VME64X interface, whose main features are:

- EUROCARD 9U Format
- J1/P1 and J2/P2 with either 160 pins (5 rows) or 96 (3 rows) connectors
- A24, A32 and CR-CSR address modes
- D32, BLT/MBLT, 2eVME, 2eSST data modes
- MCST write capability
- CBLT data transfers
- RORA interrupter
- Configuration ROM

Addressing Capabilities

- **Base address:** the module works in A24/A32 mode The Base Address of the module is selected through four rotary switches (see Fig. 7.2), then it is validated only with either a power-ON cycle or a System Reset (see Sec. **Reset, Clear and Default Configuration**).

ADDRESS MODE	ADDRESS RANGE	NOTES
A24	[0x000000:0xFF0000]	SW2 and SW3 ignored

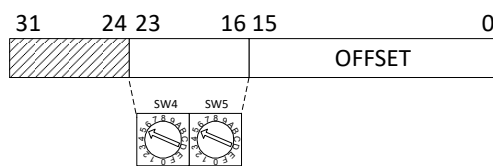


Fig. 8.17: A24 addressing.

ADDRESS MODE	ADDRESS RANGE	NOTES
A32	[0x00000000:0xFFFF0000]	

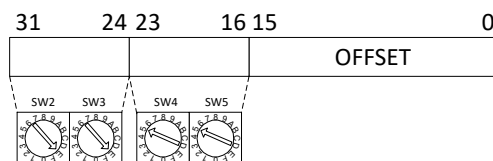


Fig. 8.18: A32 addressing.

- **CR/CSR address:** the addressing is based on the slot number taken from the relevant backplane lines. The recognised Address Modifier for this cycle is 2F. *This feature is implemented only on versions with 160-pin connectors.*

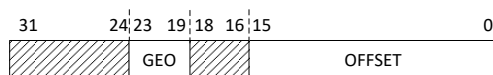


Fig. 8.19: CR/CSR addressing.

Address Relocation

The bit[15:0] of register address 0xEF10 allow to set via software the board Base Address (valid values $\neq 0$). Such register allows to overwrite the rotary switches settings; its setting is enabled via bit[6] of the register address 0xEF00. The used addresses are:

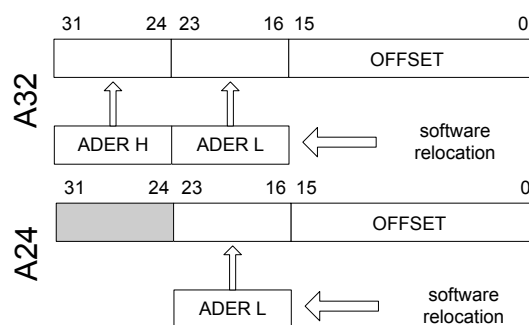


Fig. 8.20: Software relocation of base address

Data Transfer Capabilities and Events Readout

The board features a Multi-Event digital memory per channel, configurable by the user to be divided into 1 up to 1024 buffers, as detailed in Sec. **Multi-Event Memory Organization**. Once they are written in the memory, the events become available for readout via VMEbus or Optical Link. During the memory readout, the board can store other events (independently from the readout) on the available free buffers.

The events are read out 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 . 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 read out an event partially.

The size of an event (EVENT SIZE) is configurable and depends on register addresses 0x8020 and 0x800C , as well as on the number of enabled channels. The board supports D32 single data readout, Block Transfer BLT32 and MBLT64, 2eVME and 2eSST cycles. Sustained readout rate is up to 60 MB/s with MBLT64, up to 100 MB/s with 2eVME and up to 160 MB/s with 2eSST.

Block Transfer D32/D64, 2eVME, and 2eSST

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 [RD4].

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** (interrupts 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 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).

The event is configurable as indicated in the introduction of the paragraph, namely:

$$[\text{Event Size}] = [8 * (\text{Buffer Size})] + [16 \text{ bytes}]$$

Then, it is necessary to perform as many cycles as required in order to readout the programmed number of events.

It is suggested to enable BERR signal during BLT32 cycles, in order to end the cycle avoiding filler readout. The last BLT32 cycle will not be completed, it will be ended by BERR after the #N event in memory is transferred (see example in the figure below).

Since some 64-bit CPU cut off the last 32-bit word of a transferred block, if the number of words composing such block is odd, it is necessary to add a dummy word (which has then to be removed via software) in order to avoid data loss. This can be achieved by setting the ALIGN64 bit (bit[5]) at register address 0xEF00.

MBLT64 cycle is similar to the BLT32 cycle, except that the address and data lines are multiplexed to form 64 bit address and data buses.

The 2eVME allows to achieve higher transfer rates thanks to the requirement of only two edges of the two control signals (DS and DTACK) to complete a data cycle

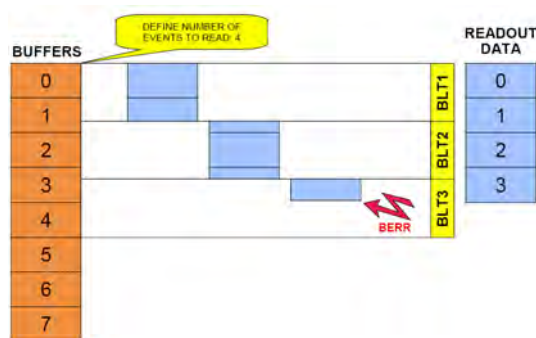


Fig. 8.21: Example of BLT readout

Chained Block Transfer D32/D64

The V1751 allows to readout events from more daisy chained boards (Chained Block Transfer mode).

The technique which handles the CBLT is based on the passing of a token between the boards; it is necessary to verify that the used VME crate supports such cycles.

Several contiguous boards, in order to be Daisy chained, must be configured as “first”, “intermediate” or “last” via register address 0xEF0C. A common Base Address is then defined via the same register; when a BLT cycle is executed at the address $\text{CBLT_Base} + 0x0000 \div 0x0FFC$, the “first” board starts to transfer its data, driving DTACK properly; once the transfer is completed, the token is passed to the second board via the IACKIN-IACKOUT lines of the crate, and so on until the “last” board, which completes the data transfer and asserts BERR (which has to be enabled): the Master then ends the cycle and the slave boards are rearmed for a new acquisition.

If the size of the BLT cycle is smaller than the events size, the board which has the token waits for another BLT cycle to begin (from the point where the previous cycle has ended).

Single D32 Transfer

This mode allows the user 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 Sec. **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 $\text{EVENT SIZE} - 1$) in order to read completely the event.

Optical Link Access

The board houses a daisy chainable Optical Link (communication path which uses optical fiber cables as physical transmission line) able to transfer data at 80 MB/s, therefore it is possible to connect up to eight V1751 to a single Optical Link Controller by using the A2818 PCI card or up to thirty-two V1751 with the A3818 PCIe card.

Detailed information on CAEN PCI/PCIe Controllers can be find at www.caen.it:

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

The parameters for read/write accesses via Optical Link are the same used by VME cycles (Address Modifier, Base Address, data Width, etc); wrong parameter settings cause Bus Error.

Bit[3] at register address 0xEF00 enables the module to broadcast an interrupt request on the Optical Link; the enabled Optical Link Controllers propagate the interrupt on the PCI bus when a request from the Optical Link is sensed. Interrupts can also be managed at the CAENDigitizer library level (see "Interrupt Configuration" [RD4]).

VME and Optical Link accesses take place on independent paths and are handled by board internal controller, with VME having higher priority; anyway it is better to avoid accessing the board via VME and Optical Link simultaneously.



Note: CONET2 is CAEN proprietary serial protocol developed to allow the optical link communication between the host PC, equipped with a A2818 or a A3818 Controller, and a CAEN CONET slave. CONET2 is 50% more efficient in the data rate transfer than the previous CONET1 version. The two protocol versions are not compliant to eachother and before to migrate from CONET1 to CONET2 it is recommended to read the instructions provided by CAEN in the dedicated Application Note [RD8].

9 Drivers & Libraries

Drivers

In order to interface with the board, CAEN provides the drivers for the supported physical communication channels and compliant with Windows® and Linux® OS:

- **CONET Optical Link**, managed by the A2818 PCI card or the A3818 PCIe card. The driver installation package is available on CAEN website in the “Software/Firmware” tab 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 card.

- **USB 2.0 Drivers** are managed by the V1718 USB-to-VME Bridge. The driver installation package is available on CAEN website in the “Software/Firmware” area at the V1718 page (**login required**).



Note: For the installation of the USB driver, refer to the User Manual of the V1718 Bridge.

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.):

- **CAENDigitizer** is a library of functions designed specifically for the Digitizer families supporting both waveform recording firmware and 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 CAENDigitizer installation package and relevant documentation **[RD4]** are available on CAEN website in the “Download” tab at the CAENDigitizer 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 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, the relevant documentation and the link to the required CAENVMELib, are available on CAEN website in the “Download” tab at the CAENComm Library page.

CAENComm (and other libraries here described) supports the following communication channels (Fig. 9.1):

PC → USB (V1718) → VMEbus → V1751(VX1751)

PC → PCI/PCIe (A2818/A3818) → CONET → V1751(VX1751)

PC → PCI/PCIe (A2818/A3818) → CONET (V2718) → VMEbus → V1751(VX1751)

WHEN TO INSTALL CAEN LIBRARIES:

WINDOWS® compliant CAEN software = NOT. CAEN software for Windows® OS are stand-alone, which means the program locally installs the DLL files of the required libraries.

LINUX® compliant CAEN software = YES. CAEN software for Linux® OS is not stand-alone. The user must install the required libraries apart to run the software.

WINDOWS® and LINUX® compliant customized software = YES. The user must install the required libraries apart in case of custom software development.

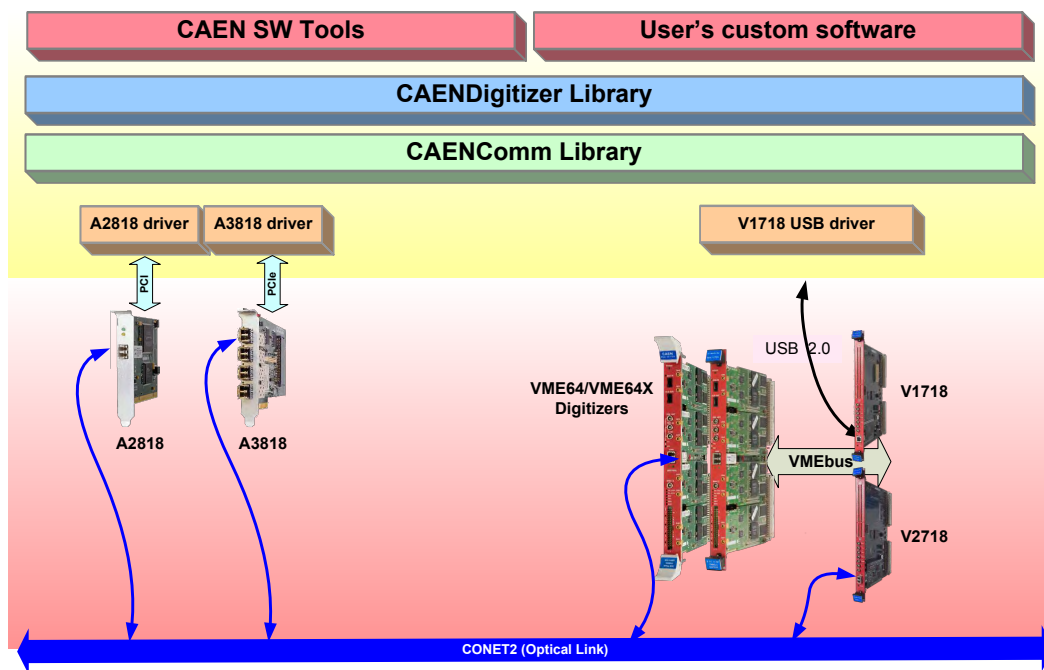


Fig. 9.1: Drivers and software layers.

10 Software Tools

CAEN provides software tools to interface the 751 digitizer family, which are available for free download at www.caen.it following the path:

Home / Products / Firmware/Software / Digitizer Software

CAENUpgrader

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

CAENUpgrader, for the V1751 , allows in few easy steps to:

- Upload different FPGA firmware versions on the digitizer
- Read the firmware release of the digitizer and the bridge (when included in the communication chain)
- Manage the firmware license, in case of DPP firmware
- Generate a programming file to configure the internal PLL
- Upgrade the internal PLL
- Get the Board Info file, useful in case of support

The software relies on the CAENComm and CAENVMELib libraries (see Chap. **Drivers & Libraries**) and requires third-party Java™ SE 8 update 40 (or later) to be installed.

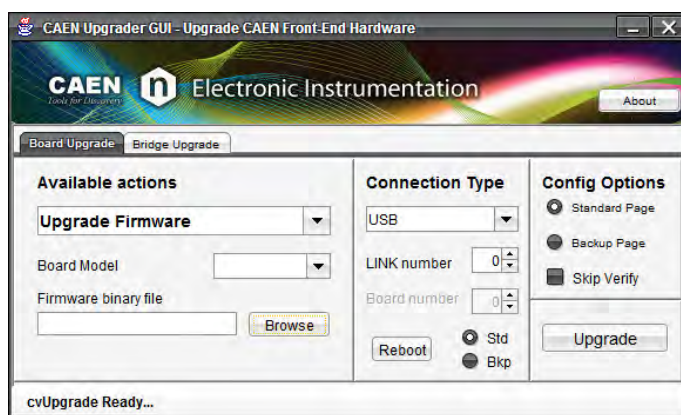


Fig. 10.1: CAENUpgrader Graphical User Interface

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

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

CAEN provides a guide to the software features and usage **[RD9]**, free downloadable at the web page above.



Note: CAENUpgrader is available for Windows® platforms (32 and 64-bit) as stand-alone version (all the required CAEN libraries are installed locally with the program). Only the drivers for the specific communication link must be installed apart by the user. The CAENUpgrader version for Linux® platform is not stand-alone, so it needs the required libraries to be installed apart by the user.

CAENComm Demo

CAENComm Demo is simple software 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

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 provides the Demo description in the CAENComm library User Manual, free downloadable at the web page above.



Note: CAENComm Demo is available for Windows® platforms (32 and 64-bit) and requires CAENComm and CAENVMELib as additional software to be installed by the user (see Chap. **Drivers & Libraries**).

DPP-ZLEplus Control Software

DPP-ZLEplus Control Software is a demo application introducing the user to understand the principle of operation of the Digital Pulse Processing for the Zero Length Encoding (DPP-ZLEplus).

The user can make an entire acquisition through this software, as well use the source code to develop his/her customized readout program. Indeed, the package includes the C source files and the Visual Studio project (compliant with Visual Studio Professional 2010).

The DPP-ZLEplus Control Software is a C-based application that programs the Digitizer according to a set of parameters in the configuration text file, starts/stops the acquisition and manages the data readout. The waveforms elaborated by the DPP-ZLEplus algorithm are plotted using gnuplot, an external plotting tool, or saved to output text files.

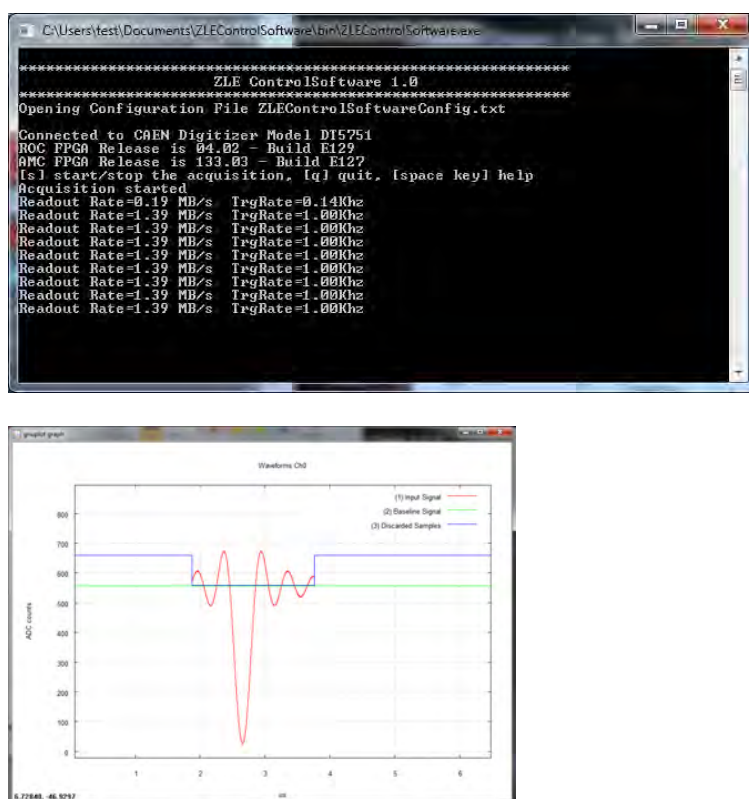


Fig. 10.3: Screen-shots of DPP-ZLEplus Control Software.

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

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

CAEN provides the software User Manual [RD3], free downloadable at the web page above.

DPP-ZLEplus Control Software does not work with waveform recording firmware.

CAEN WaveDump

WaveDump is a basic console application, with no graphics, supporting only CAEN digitizers running the waveform recording 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.

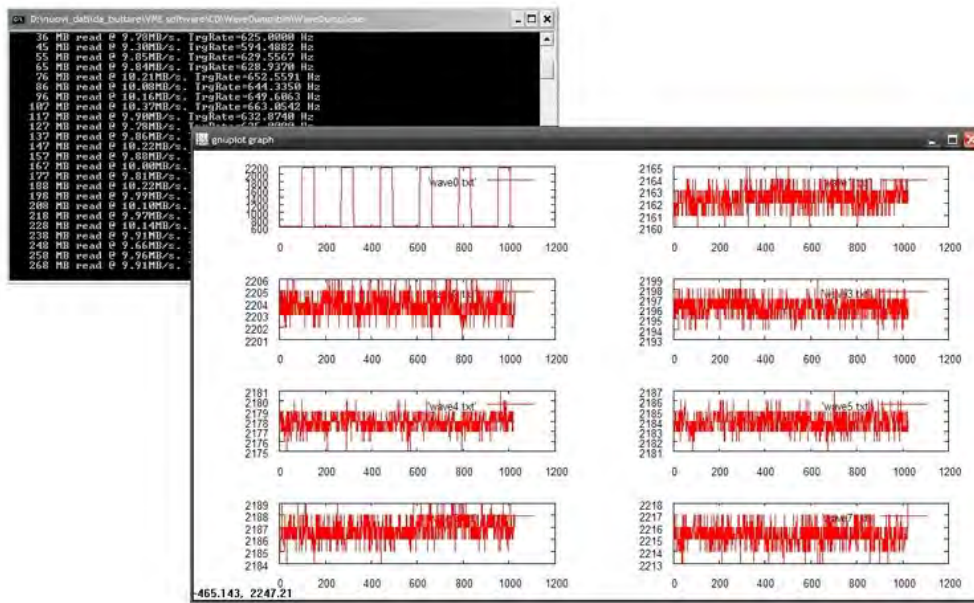


Fig. 10.4: CAEN WaveDump

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

Home / Products / Firmware/Software / Digitizer Software / Readout Software / CAEN WaveDump

CAEN provides the software User Manual [RD5] and a guide for getting started with it, free downloadable at the web page above.



Note: CAEN WaveDump can operate with Windows® and Linux® platforms (32 and 64 bits); the software relies on the CAENDigitizer, CAENComm and CAENVMELib libraries (see Chap. **Drivers & Libraries**). Windows® versions of WaveDump are stand-alone (all required libraries are present within the software package), while the Linux® versions need the required libraries to be previously installed by the user. Moreover Linux® users are required to install the third-party Gnuplot.

CAEN WaveDump does not work with digitizers running DPP firmware.

CAEN Scope

In a brand new framework, CAENScope software allows to manage the CAEN digitizers running the waveform recording firmware.

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, trigger and trace visualization (up to 12 traces) can be simultaneously plotted. Signals can be recorded to files in two different formats: Binary (SQLite db) and Text (XML). It is also possible to save and restore the program settings.

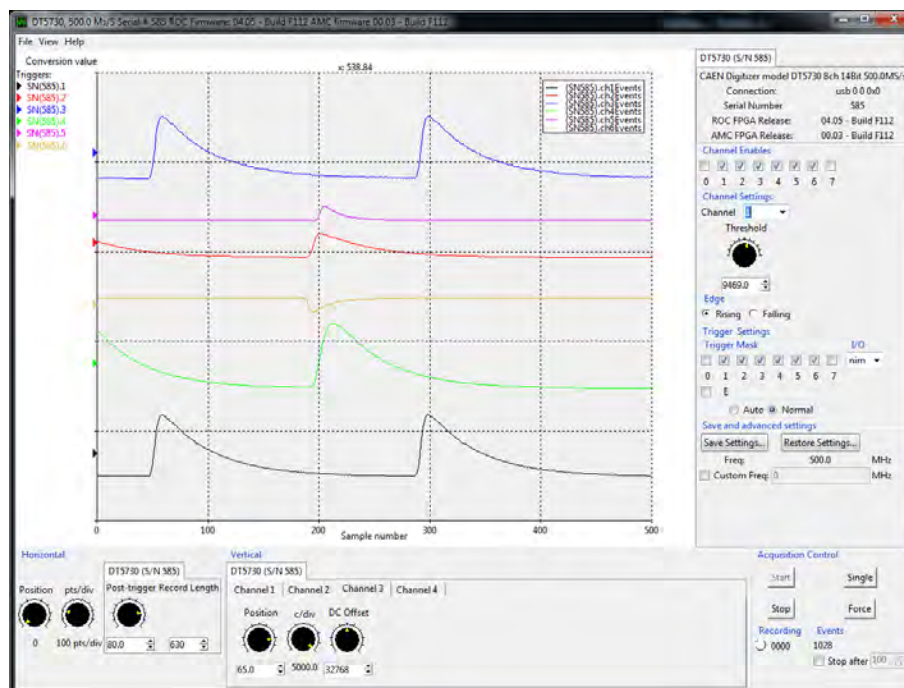


Fig. 10.5: CAENScope main frame.

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

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

CAEN provides the software User Manual [RD10], free downloadable at the web page above.

Note: Windows® and Linux® versions are stand-alone. The software downloads the required CAENDigitizer, CAENComm and CAENVMELib libraries.

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.).

CAENScope does not work with digitizers running DPP firmware.

DPP-PSD Control Software

DPP-PSD Control Software is a demo application introducing the user to understand the principle of operation of the Digital Pulse Processing for the Pulse Shape Discrimination (DPP-PSD). It can manage single-board communication and acquisition of CAEN 720, 725, 730, and 751 Digitizer series running DPP-PSD firmware and the DT5790 Digital Pulse Analyzer.

DPP-PSD Control Software is based on a Java Graphical User Interface for the parameters setting (connection, DPP algorithm, acquisition, etc.), a C console application working as an acquisition engine (DPPRunner) and a third-party graphing utility (Gnuplot: www.gnuplot.info). The GUI directly handles the acquisition engine through run time commands and generates also a textual configuration file that contains all the selected parameters values. This file is read by DPPRunner, which programs the Digitizer according to the parameters, starts the acquisition and manages the data readout.

The software can operate in the Oscilloscope mode, where digitized input waveforms and digital signals from the internal filters are monitored in order to better tune the DPP parameters, and in the Histogram mode, where energy (i.e. charge) and time histograms (built by the software) can be monitored.

According to the operating mode, raw data like waveforms or charges, PSD and time stamp lists, as well as energy or time histograms can be saved to output files for off-line analysis.

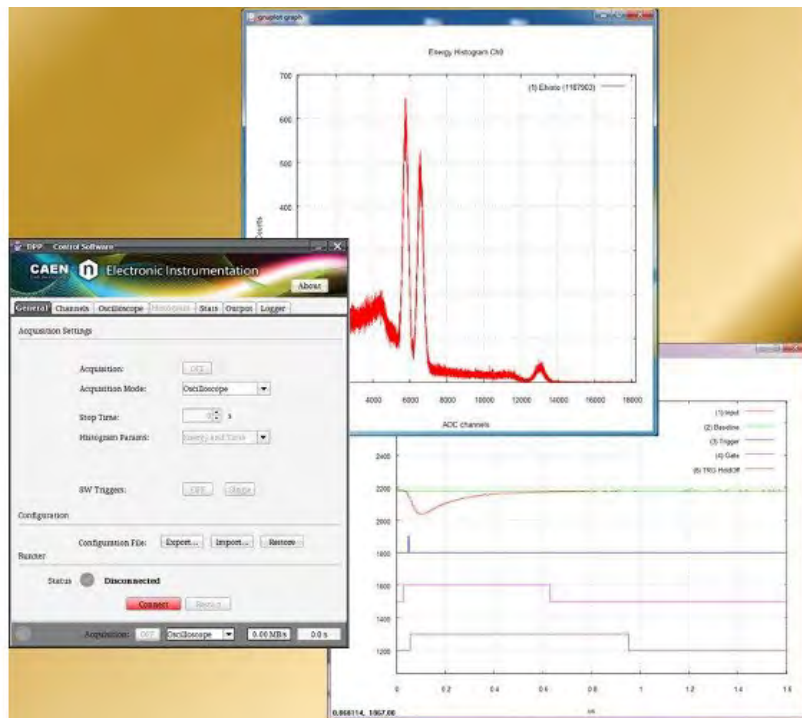


Fig. 10.6: CAEN DPP-PSD Control Software.

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

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

CAEN provides the software User Manual [RD2], free downloadable at the web page above.

CAEN DPP-PSD Control Software does not work with waveform recording firmware.

CoMPASS

CoMPASS (CAEN Multi-Parameter Spectroscopy Software) is the new software from CAEN able to implement a Multi-parametric DAQ for Physics Applications, where the detectors can be connected directly to the digitizers inputs and the software acquires energy, timing, and PSD spectra.

CoMPASS software has been designed as a user-friendly interface to manage the acquisition with all the CAEN DPP algorithm. CoMPASS can manage multiple boards, even in synchronized mode, and the event correlation between different channels (hardware and/or software), apply energy and PSD cuts, calculate and show the statistics (trigger rates, data throughput, etc...), save the output data files (raw data, lists, waveforms, spectra) and use the saved files to run off-line with different processing parameters.

CoMPASS Software supports CAEN x720, x724, x725, x730, x740D, x751 digitizer families running the DPP-PSD, DPP-PHA and DPP-QDC firmware, and the x781 MCA family.

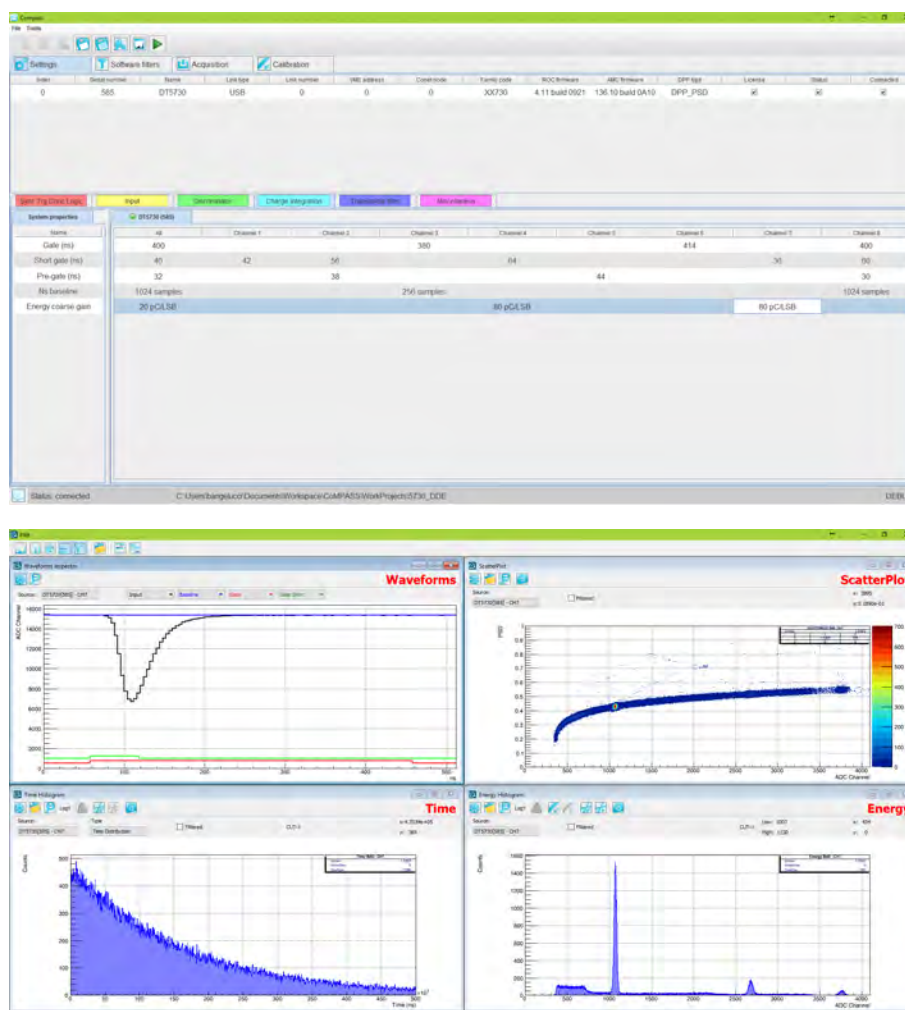


Fig. 10.7: CoMPASS software tool.

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

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

CAEN provides the software User Manual **[RD11]**, free downloadable at the web page above.

CoMPASS does not work with waveform recording firmware.

11 HW Installation

- The V1751 fits into 6U VME crates.
- VX1751 versions require VME64X compliant 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 THE BOARD MAY DEGRADE ITS PERFORMANCES!

CAUTION: this product needs proper handling.



V1751/VX1751 DO NOT SUPPORT LIVE INSERTION (HOT SWAP)! REMOVE OR INSERT THE BOARD WHEN THE VME CRATE IS POWERED OFF!



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

Power-on Sequence

To power on the board, perform the following steps:

1. Insert the V1751 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, only the NIM and PLL LOCK LEDs must stay ON (see Fig. 11.1).



Fig. 11.1: Front panel LEDs status at power-on.

12 Firmware and Upgrades

The board hosts one FPGA on the mainboard and two FPGAs per mezzanine (i.e. one FPGA per channel). 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 EP1C20

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 waveform recording firmware, the board is delivered equipped with the same firmware version on both pages.

At power-on, a micro-controller reads the FLASH memory and programs the module automatically loading the first working firmware copy, that is the STD one in normal operating.

The on-board dedicated SW7 dip switch, set on STD position by default, allows to select the first FLASH page to be read at power-on (see Sec. **Internal Components**).

It is possible to upgrade the board firmware via VMEbus or Optical Link by writing the FLASH with the CAENUpgrader software (see Chap. **Software Tools**).

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 VMEbus OR OPTICAL LINK AGAIN AND THE BOARD NEEDS TO BE SENT TO CAEN FOR REPAIR!

Firmware Upgrade

All firmware updates are available for download on CAEN website www.caen.it (**login required**) at the following path:

Home / Products / Modular Pulse Processing Electronics / VME / Digitizers / V1751

Different firmware are available for the 751 family:

- The waveform recording firmware;
- The special DPP firmware for Physics Applications:
 - DPP-PSD firmware to use the digitizer as a digital replacement Dual Gate QDC, Discriminator and Gate Generator.
 - DPP-ZLE*plus* firmware to transfer the waveform in a compact format performing an advanced Zero Suppression algorithm.

DPP firmware updates can also be found at the relevant DPP firmware web page:

Home / Products / Firmware/Software / DPP Firmware/Software Tools (Digitizer) / DPP Firmware / <DPP-FIRMWARE>

Firmware File Description

The programming file has the extension .CFA (CAEN Firmware Archive). It is an archiving file format that aggregates all the programming files of the same firmware kind which are compatible with the same digitizer family.

The CFA naming convention follows this general scheme:

- x751_rev_X.Y_W.Z.CFA for the waveform recording firmware

where x751 are all the supported boards (the 751 family includes DT5751, N6751, V1751, VX1751), X.Y is the major/minor revision number of the mainboard FPGA, and W.Z is the major/minor revision number of the channel FPGA.

The major revision number of the channel FPGA is a fixed number specific for each DPP and digitizer family, and it can be equal or greater than 128 (for example,). The waveform recording firmware major revision number is not fixed and it is less than 128.



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 are included in the CAENUpgrader guide [RD9].

Troubleshooting

In case of upgrade 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.

BECAUSE OF AN UPGRADE FAILURE, THE SW7 DIP SWITCH POSITION MAY NOT CORRESPOND TO THE FLASH PAGE FIRMWARE COPY LOADED ON THE BOARD FPGAs.

Note: old versions of the digitizer motherboard have a slightly different FLASH management. Use CAENUpgrader 1.6.0 or later to get the BoardInfoFile (using the "Get Information" function) and check that the FLASH_TYPE=0. Alternatively, use a software utility like CAENComm Demo to read at register address 0xF050 and check that bit[7]=0.

In this case, at power-on, the micro-controller loads exactly the firmware copy from the FLASH page selected through the SW7 dip switch (e.g. STD by default) .

When a failure occurs during the upgrade of the STD page of the FLASH, which compromises the communication with the V1751 , the user can perform the following recovering procedure as first attempt:



- force the board to reboot loading the copy of the firmware stored on the BKP page of the FLASH. For this purpose, power off the crate, switch the dedicated SW1 switch to BKP position and power on the crate .
- use CAENUpgrader to read the firmware revision (in this case the one of the BKP copy). If this succeeds, it is so possible to communicate again with the board;
- use CAENUpgrader to load the proper firmware file on the STD page, then power off the crate, switch SW7 back to STD position and power on the crate.

If neither of the procedures here described succeeds, it is recommended to send the board back to CAEN in repair (see Chap. **Technical Support**).

13 Technical Support

CAEN support services are available for the user by accessing the *Support & Services* area on CAEN website at <http://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 experts can provide technical support 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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