



User Manual UM4279

## V1742/VX1742

32+2 Channel 12bit 5 GS/s Switched Capacitor Digitizer

Rev. 7 - January 27<sup>th</sup>, 2017

# Purpose of this Manual

This document contains the full hardware description of the V1742 and VX1742 CAEN digitizers and their principle of operating as Waveform Recording Digitizer (basing on the hereafter called "default firmware").

The reference firmware revision is: **4.13\_1.01**.

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

## Change Document Record

Date	Revision	Changes
-	00-06	N/A
January 27 <sup>th</sup> , 2017	07	Revised text layout. Improved text description to make it clearer.

## 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] CAEN User Manual UM5698. *742 Register Description*.
- [RD2] CAEN User Guide GD2512. *CAENUpgrader QuickStart Guide*.
- [RD3] CAEN User Manual UM2091. *CAEN WaveDump User Manual*.
- [RD4] CAEN User Manual UM1935. *CAENDigitizer User & Reference Manual*.
- [RD5] CAEN User Manual. *V1718 & VX1718 User & Reference Manual*.
- [RD6] CAEN User Manual. *V2718 & VX2718 User & Reference Manual*.
- [RD7] CAEN User Manual UM1934. *CAENComm User & Reference Manual*.
- [RD8] CAEN User Guide GD5695. *742 Quick Start Guide*.
- [RD9] CAEN Application Note AN2086. *Synchronization of CAEN Digitizers in Multiple Board Acquisition Systems*.

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

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**MADE IN ITALY:** We stress the fact that all the boards are made in Italy because in this globalized world, where getting the lowest possible price for products sometimes translates into poor pay and working conditions for the people who make them, at least you know that who made your board was reasonably paid and worked in a safe environment. (this obviously applies only to the boards marked "MADE IN ITALY", we cannot attest to the manufacturing process of "third party" boards).



# Index

<b>Purpose of this Manual</b> . . . . .	<b>2</b>
<b>Change document record</b> . . . . .	<b>2</b>
<b>Symbols, abbreviated terms and notation</b> . . . . .	<b>2</b>
<b>Reference Documents</b> . . . . .	<b>2</b>
<b>Safety Notices</b> . . . . .	<b>7</b>
<b>1 Introduction</b> . . . . .	<b>8</b>
<b>2 Block Diagram</b> . . . . .	<b>10</b>
<b>3 Technical Specifications</b> . . . . .	<b>11</b>
<b>4 Packaging and Compliancy</b> . . . . .	<b>13</b>
<b>5 Power Requirements</b> . . . . .	<b>15</b>
<b>6 Panels Description</b> . . . . .	<b>16</b>
Front Panel . . . . .	17
Internal Components . . . . .	20
<b>7 Functional Description</b> . . . . .	<b>21</b>
Analog Input Stage . . . . .	21
Domino Ring Sampling . . . . .	21
TR0 and TR1 Inputs . . . . .	22
Clock Distribution . . . . .	23
PLL Mode . . . . .	24
Data correction . . . . .	25
Cell Index Offset correction . . . . .	26
Sample Index Offset correction . . . . .	27
Time correction . . . . .	28
Acquisition Modes . . . . .	30
Acquisition Run/Stop . . . . .	30
Event structure . . . . .	30
Trigger Management . . . . .	33
Software Trigger . . . . .	34
External Trigger . . . . .	34
Fast ("Low Latency") Trigger . . . . .	34
Self-Trigger . . . . .	36
How to work with Self-Trigger . . . . .	37
Multi-board Synchronization . . . . .	38
Front Panel LVDS I/Os . . . . .	40
Mode 0: REGISTER . . . . .	41
Mode 1: TRIGGER . . . . .	41
Mode 2: nBUSY/nVETO . . . . .	42
Mode 3: LEGACY . . . . .	42
Test Pattern Generator . . . . .	43
Reset, Clear and Default Configuration . . . . .	44
Global Reset . . . . .	44
Memory Reset . . . . .	44
Timer Reset . . . . .	44

VMEBus Interface . . . . .	44
Addressing Capabilities . . . . .	44
Address Relocation . . . . .	45
Data Transfer Capabilities and Events Readout . . . . .	46
Single D32 Transfer . . . . .	46
Block Transfer D32/D64, 2eVME . . . . .	46
Chained Block Transfer D32/D64 . . . . .	47
Optical Link Access . . . . .	47
<b>8 Drivers &amp; Libraries</b> . . . . .	<b>48</b>
Drivers . . . . .	48
Libraries . . . . .	48
<b>9 Software Tools</b> . . . . .	<b>50</b>
CAENUpgrader . . . . .	50
CAENComm Demo . . . . .	51
CAEN WaveDump . . . . .	52
<b>10 HW Installation</b> . . . . .	<b>53</b>
Power-on Sequence . . . . .	54
Power-on Status . . . . .	54
<b>11 Firmware and Upgrades</b> . . . . .	<b>55</b>
Default Firmware Upgrade . . . . .	56
Default Firmware File Description . . . . .	56
<b>12 Technical Support</b> . . . . .	<b>57</b>
Returns and Repairs . . . . .	57
Technical Support Service . . . . .	57

## List of Figures

<b>Fig. 2.1</b> Block Diagram . . . . .	10
<b>Fig. 4.1</b> Model view . . . . .	13
<b>Fig. 6.1</b> Front panels view: V1742 on the left, VX1742 on the right . . . . .	16
<b>Fig. 6.2</b> Rotary and dip switches location . . . . .	20
<b>Fig. 7.1</b> Analog input diagram . . . . .	21
<b>Fig. 7.2</b> Input Diagram . . . . .	22
<b>Fig. 7.3</b> TRO logic block diagram . . . . .	22
<b>Fig. 7.4</b> Clock distribution diagram . . . . .	23
<b>Fig. 7.5</b> Sampled waveform (left) and noise histogram (right) before cell index offset correction . . . . .	26
<b>Fig. 7.6</b> Sampled waveform (left) and noise histogram (right) after cell index offset correction . . . . .	26
<b>Fig. 7.7</b> Sampled waveform (left) and noise histogram (right) after sample index offset correction . . . . .	27
<b>Fig. 7.8</b> Sampled TRO signal in GR0 and GR1 before time correction . . . . .	28
<b>Fig. 7.9</b> Sampled TRO signal in GR0 and GR1 after time correction . . . . .	28
<b>Fig. 7.10</b> INL time profile of DRS4 chips 0 and 1 before time correction . . . . .	29
<b>Fig. 7.11</b> INL time profile of DRS4 chips 0 and 1 after time correction . . . . .	29
<b>Fig. 7.12</b> Event Format . . . . .	31
<b>Fig. 7.13</b> Group Data Format . . . . .	32

<b>Fig. 7.14</b> Block diagram of Trigger management . . . . .	33
<b>Fig. 7.15</b> Diagram showing the “Transparent Mode” functioning. The analog input is both sampled by the DRS4 capacitors (analog sampling) and made available at the output for the ADC digital sampling at a smaller rate. The output stage is distorted with respect to the Output mode. . . . .	36
<b>Fig. 7.16</b> Diagram showing the “Output Mode” functioning. the input is no longer sampled and the capacitors hold the acquired samples and send them one at a time to the ADC at a frequency controlled by the FPGA (readout frequency). The output stage is correctly differential. . . . .	36
<b>Fig. 7.17</b> FPGA test waveform . . . . .	43
<b>Fig. 7.18</b> A24 addressing . . . . .	44
<b>Fig. 7.19</b> A32 addressing . . . . .	45
<b>Fig. 7.20</b> CR/CSR addressing . . . . .	45
<b>Fig. 7.21</b> Software relocation of base address . . . . .	45
<b>Fig. 7.22</b> Example of BLT readout . . . . .	46
<b>Fig. 8.1</b> Drivers and software layers . . . . .	49
<b>Fig. 9.1</b> CAENUpgrader Graphical User Interface . . . . .	50
<b>Fig. 9.2</b> CAENComm Demo Java and LabVIEW graphical interface . . . . .	51
<b>Fig. 9.3</b> CAEN WaveDump . . . . .	52
<b>Fig. 10.1</b> Front panel LEDs status at power ON . . . . .	54

## List of Tables

<b>Tab. 1.1</b> Table of models and related items . . . . .	9
<b>Tab. 3.1</b> Specification table . . . . .	12
<b>Tab. 5.1</b> Power requirements table . . . . .	15
<b>Tab. 7.1</b> Examples of DC Offset and Trigger Threshold (in hexadecimal / decimal) for typical signals on TRn connector. Values are valid for mezzanine PCB revision $\geq 1$ . . . . .	35
<b>Tab. 7.2</b> Examples of DC Offset and Trigger Threshold (in hexadecimal / decimal) for typical signals on TRn connector. Values are valid for mezzanine PCB revision 0. . . . .	35
<b>Tab. 7.3</b> Features description when LVDS group is configured as INPUT . . . . .	41
<b>Tab. 7.4</b> Features description when LVDS group is configured as OUTPUT . . . . .	41

## Safety Notices

**CAUTION:** this product needs proper cooling.



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

**CAUTION:** this product needs proper handling.



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

# 1 Introduction

The Mod. V1742 is a 1-unit wide VME 6U module housing 32+2 Channel 12 bit 5 GS/s Switched Capacitor Digitizer sections.

The input dynamic range is  $1 \text{ V}_{\text{pp}}$  on single-ended MCX coaxial connectors (16-bit DAC on each channel to control the DC Offset).

The digitizer is based on the Switched Capacitor Array DRS4 chip<sup>1</sup> (Domino Ring Sampler). This technology relies on a series of 1024 capacitors (analog memory) in which the analog input signal is continuously sampled in a circular way. The sampling frequency is 5 GHz by default and it can be programmed to 2.5 GHz, 1GHz, and 750 MHz. The analog to digital conversion is not simultaneous with the chip sampling phase, and it starts as soon as the trigger condition is met. When the trigger stops the DRS4 chip sampling (holding phase), the analog memory buffer is frozen, and the cell content is made available to the 12 bit ADC for the digital conversion. The digital memory allows to store subsequent events, even if the readout is not yet started. Moreover, since the digital memory buffers work like FIFOs, the readout activity from VME or Optical Link does not affect write operations of subsequent events.

The chip functioning has two major consequences:

1. there is an unavoidable dead-time when the DRS4 chip stops its acquisition and the ADC converts the capacitances (110  $\mu\text{s}$  in case only the analog inputs are digitized, 181  $\mu\text{s}$  when also TRn are digitized).
2. the acquisition window is fixed to 1024 samples, that in case of 5 GHz corresponds to a maximum of about 200 ns. Refer to **Sect. Domino Ring Sampling**.

Moreover, the trigger processing introduces a latency between the trigger arrival and the DRS4 holding phase that varies according to the trigger source. The user must consider it when choosing the proper trigger source for its setup and the type of signal. Four possible trigger sources are available:

1. **Software Trigger**, common to all enabled groups, mainly intended for debug purposes. Refer to **Sect. Software Trigger**.
2. **External Trigger**, trigger on TRG-IN connector, common to all enabled groups. The external trigger latency makes this mode difficult to use at 5 GHz, while all other frequencies can be used with no problem. Refer to **Sect. External Trigger**.
3. **Fast (Low Latency) Local Trigger**, trigger on TR0 and TR1 connectors, common to couples of groups. This mode is called “Fast” or “Low Latency” since the trigger latency is reduced with respect to the external trigger. This trigger mode is convenient for high precision timing measurements, since the TRn can be digitized and reported in the output data to be used as time reference. Refer to **Sect. Fast (“Low Latency”) Trigger**.
4. **Self-trigger**, common to couples of groups. For each group is possible to select combination of channels (logic OR) that provide a trigger whenever the input crosses the threshold. This mode cannot be used at 5 GHz due to the trigger latency and one of the other options must be used. Refer to **Sect. Self-Trigger** for additional details.

The module features the front panel CLK IN/CLK OUT connectors and an internal PLL for clock synthesis from internal/external references. V1742 supports multi-board synchronization allowing all DRS4s to be synchronized with a common clock source and ensuring Trigger Time Stamps alignment. Once synchronized, all data will be aligned and coherent across multiple V1742 boards.

By ordering options (see **Tab. 1.1**), the module is available with digital memory sizes of 128 event/ch or 1024 event/ch.

The VME interface of the module is VME64X compliant, and the data readout can be performed in several data transfer modes: BLT32, MBLT64 (up to 70 MB/s of transfer rate using CAEN Bridge), CBLT32/64, 2eVME, 2eSST (up to 200 MB/s of transfer rate). The built-in daisy chainable Optical Link is able to transfer data at 80 MB/s, thus it is possible to connect up to 8 boards to a single A2818 Controller, or up to 32 to a single A3818 Controller (4-link version, see **Tab. 1.1**).

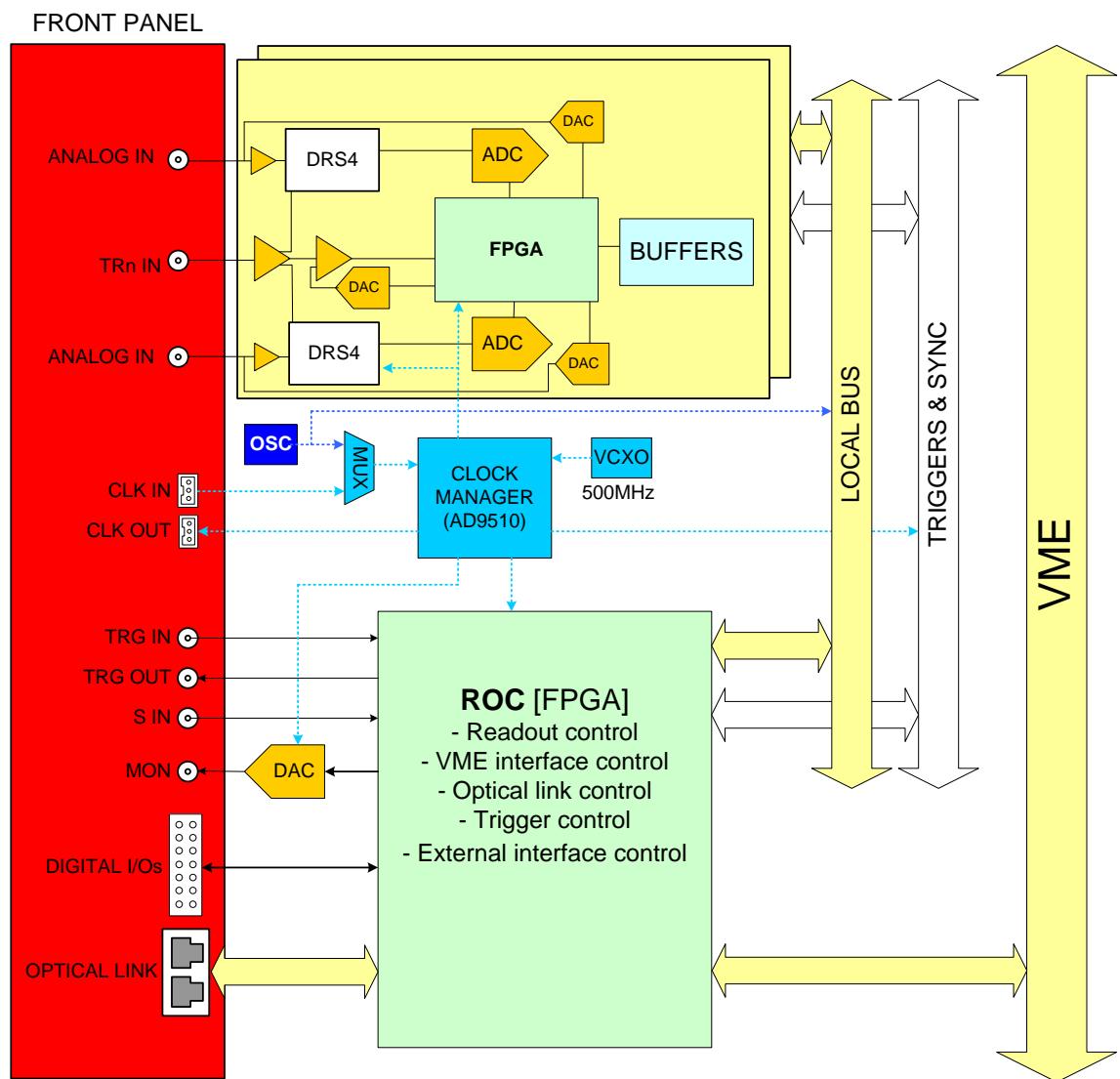
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<sup>1</sup>Designed at Paul Scherrer Institute, PSI. Detailed documentation of the DRS4 chip is available at <http://drs.web.psi.ch/>

Board Model	Description	Product Code
V1742	32+2 Ch. 12 bit 5 GS/s Switched-Capacitor Digitizer: 128 events/ch (1kS/events), EP3C16, SE	WV1742XAAAAA
V1742B	32+2 Ch. 12 bit 5 GS/s Switched-Capacitor Digitizer: 1024 events/ch (1kS/events), EP3C16, SE	WV1742BXAAAA
VX1742	32+2 Ch. 12 bit 5 GS/s Switched-Capacitor Digitizer: 128 events/ch (1kS/events), EP3C16, SE	WVX1742XAAAA
VX1742B	32+2 Ch. 12 bit 5 GS/s Switched-Capacitor Digitizer: 1024 events/ch (1kS/events), EP3C16, SE	WVX1742BXAAA
Related Products	Description	Product Code
A2818	A2818 – PCI Optical Link (Rhos compliant)	WA2818XAAAAA
A3818A	A3818A – PCIe 1 Optical Link	WA3818AXAAAA
A3818B	A3818B – PCIe 2 Optical Link	WA3818BXAAAA
A3818C	A3818C – PCIe 4 Optical Link	WA3818CXAAAA
V1718	V1718 - VME-USB 2.0 Bridge	WV1718XAAAAA
V1718LC	V1718LC - VME-USB 2.0 Bridge (Rohs Compliant)	WV1718LCXAAA
VX1718	VX1718 - VME-USB 2.0 Bridge	WVX1718XAAAA
VX1718LC	VX1718LC - VME-USB 2.0 Bridge (Rohs Compliant)	WV1718LCXAAA
V2718	V2718 - VME-PCI Bridge	WV2718XAAAAA
V2718LC	V2718LC - VME-PCI Bridge (Rohs compliant)	WV2718LCXAAA
VX2718	VX2718 - VME-PCI Bridge	WVX2718XAAAA
VX2718LC	VX2718LC - VME-PCI Bridge	WVX2718LCXAA
V2718LC KIT	V2718KITLC - VME-PCI Bridge (V2718)+PCI Optical Link (A2818)+Optical Fibre 5m duplex (AY2705) (Rohs)	WK2718LCXAAA
V2718 KIT	V2718KIT - VME-PCI Bridge (V2718) + PCI OpticalLink (A2818) + Optical Fibre 5m duplex (AY2705)	WK2718XAAAAA
V2718 KIT-B	V2718KITB - VME-PCI Bridge (V2718) + PCIe Optical Link (A3818A) + Optical Fibre 5m duplex (AY2705)	WK2718XBAAA
VX2718LC KIT	VX2718KITLC - VME-PCI Bridge (VX2718)+PCI Optical Link (A2818)+Optical Fibre 5m duplex (AY2705) (Rohs)	WKX2718LCXAA
VX2718 KIT	VX2718KIT - VME-PCI Bridge (VX2718) + PCI OpticalLink (A2818) + Optical Fibre 5m duplex (AY2705)	WKX2718XAAAA
VX2718 KIT-B	VX2718KITB - VME-PCI Bridge (VX2718) + PCIe Optical Link (A3818A) + Optical Fibre 5m duplex (AY2705)	WKX2718XBAAA
Accessories	Description	Product Code
A317	Clock Distribution Cable	WA317XAAAAAA
A318	SE to Differential Clock Adapter	WA318XAAAAAA
A654	Single Channel MCX to LEMO Cable Adapter	WA654XAAAAAA
A654 KIT4	4 MCX TO LEMO Cable Adapter	WA654K4AAAAA
A654 KIT8	8 MCX TO LEMO Cable Adapter	WA654K8AAAAA
A659	Single Channel MCX to BNC Cable Adapter	WA659XAAAAAA
A659 KIT4	4 MCX TO BNC Cable Adapter	WA659K4AAAAA
A659 KIT8	8 MCX TO BNC Cable Adapter	WA659K8AAAAA
AI2730	Optical Fibre 30 m simplex	WAI2730XAAAA
AI2720	Optical Fibre 20 m simplex	WAI2720XAAAA
AI2705	Optical Fibre 5 m simplex	WAI2705XAAAA
AI2703	Optical Fibre 30 cm simplex	WAI2703XAAAA
AY2730	Optical Fibre 30 m duplex	WAY2730XAAAA
AY2720	Optical Fibre 20 m duplex	WAY2720XAAAA
AY2705	Optical Fibre 5 m duplex	WAY2705XAAAA

**Tab. 1.1:** Table of models and related items

## 2 Block Diagram



**Fig. 2.1:** Block Diagram

### 3 Technical Specifications

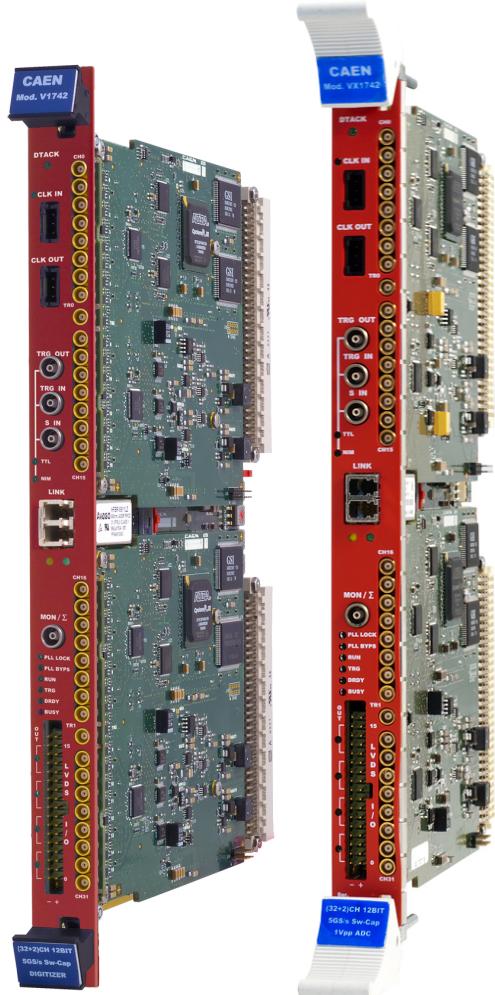
GENERAL	<b>Form Factor</b> 1-unit wide, 6U VME64 (V1742) and VME64X (VX1742)	<b>Weight</b> 520 g
ANALOG INPUT	<b>Channels</b> 32 channels 2 special channels (TR0, TR1) Single ended	<b>Connector</b> MCX
	<b>Impedance</b> $Z_{in} = 50 \Omega$	<b>Bandwidth</b> 500 MHz
		<b>Offset</b> Programmable 16-bit DAC for DC offset adjustment on each channel. Range: $\pm 1 \text{ V}$
DIGITAL CONVERSION	<b>Resolution</b> 12 bits	<b>Sampling Rate</b> 5 GS/s - 2.5 GS/s - 1 GS/s - 0.75 GS/s SW selectable, simultaneously on each channel
	<b>Switched Capacitor Array</b> Domino Ring Sampler chip (DRS4), 8+1 channels with 1024 storage cells each	<b>Dead Time (A/D Conversion)</b> 110 $\mu\text{s}$ , analog inputs only 181 $\mu\text{s}$ , digitizing TR0 and TR1
ADC CLOCK GENERATION	Clock source: internal/external. On-board programmable PLL provides generation of the main board clocks from internal (50 MHz local Oscillator) or external (front panel CLK-IN connector) reference	
DIGITAL I/O	<b>CLK-IN (AMP Modu II)</b> AC coupled differential input clock LVDS, ECL, PECL, LVPECL, CML (single ended NIM/TTL available by A318 adapter) Jitter < 100 ppm requested	<b>CLK-OUT (AMP Modu II)</b> DC coupled differential LVDS clock output locked at ADC sampling clock
	<b>TRG-IN (LEMO)</b> External trigger digital input NIM/TTL $Z_{in} = 50 \Omega$	<b>S-IN (LEMO)</b> SYNC/START front panel digital input NIM/TTL $Z_{in} = 50 \Omega$
		<b>TRG-OUT (LEMO)</b> Trigger digital output NIM/TTL $Z_{in} = 50 \Omega$
MEMORY	128 events/ch or 1024 events/ch (1024 S/event) Multi-event Buffer Independent read and write access; programmable event size and pre/post-trigger	
TRIGGER	<b>Trigger Source</b> - <i>Fast (Low Latency) trigger</i> : Programmable threshold on TR0 and TR1 (each TRn signal drives two 8-ch groups) - <i>Self-trigger</i> : Logic OR combination of channels over/under threshold (each channel self-trigger drives two 8-ch groups) - <i>External-trigger</i> : Common trigger by TRG IN connector - <i>Software-trigger</i> : Common trigger by software command	<b>Trigger Propagation</b> TRG-OUT programmable digital output
SYNCHRONIZATION	<b>Clock Propagation</b> <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	<b>Trigger Time Stamp</b> 30-bit counter 8.5 ns resolution 9 s range
ADC & MEMORY CONTR.	Altera Cyclone EP3C16 (one FPGA manages 16+1 channels)	<b>Acquisition Synchronization</b> Sync, Start/Stop through digital I/O (S-IN or TRG-IN input / TRG-OUT output)
		<b>Trigger Time Stamps Alignment</b> By S-IN input connector

<b>COMMUNICATION INTERFACE</b>	<b>Optical Link</b> 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)	<b>VME</b> VME 64X compliant Data transfer mode: BLT32, MBLT64 (70 MB/s using CAEN Bridge), CBLT32/64, 2eVME, 2eSST (up to 200 MB/s)
<b>LVDS I/O</b>	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	
<b>FIRMWARE UPGRADE</b>	Firmware can be upgraded via VMEbus/Optical Link	
<b>SOFTWARE UPGRADE</b>	General purpose C libraries, configuration tools, readout software (Windows and Linux support)	
<b>POWER CONSUMPTIONS</b>	5.5 A @ +5V; 200 mA @ +12V, 300 mA @ -12V	

**Tab. 3.1:** Specification table

## 4 Packaging and Compliancy

V1742/VX1742 modules are 1-unit wide, 6U VME64/VME64X boards.



**Fig. 4.1:** 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 MAY DEGRADE THE MODULE PERFORMANCES!**

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

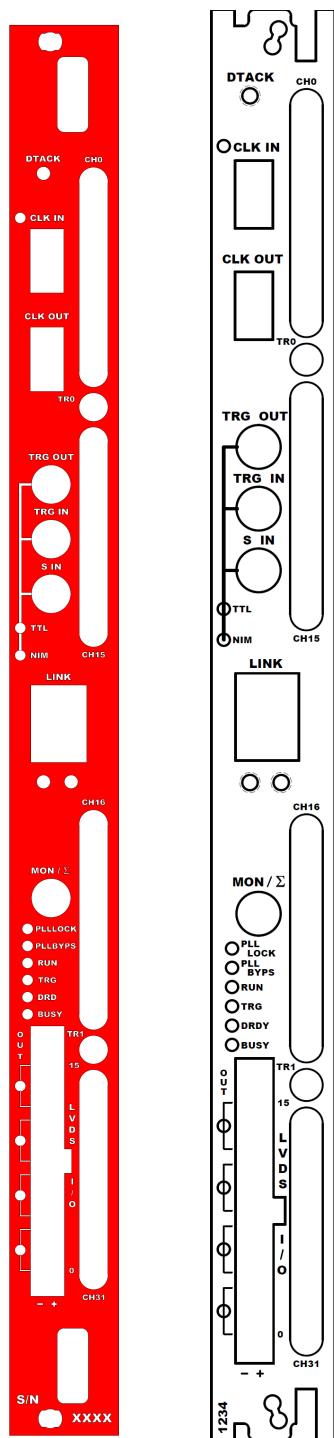
## 5 Power Requirements

The table below resumes the V1742/VX1742 power consumptions per relevant power supply rail.

MODULE	SUPPLY VOLTAGE		
	+5 V	+12 V	-12 V
V1742/VX1742	5.5 A	200 mA	300 mA
V1742B/VX1742B	5.5 A	200 mA	300 mA

**Tab. 5.1:** Power requirements table

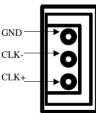
## 6 Panels Description



**Fig. 6.1:** Front panels view: V1742 on the left, VX1742 on the right

## Front Panel

ANALOG INPUT	
	<p><b>FUNCTION</b> Input connectors from CH0 to CH31 receive the input analog signals. TR0 and TR1 connectors receive the fast (low latency) trigger, and they can be also digitized</p> <p><b>MECHANICAL Specs</b> Series: MCX connectors. Type: CS 85MCX-50-0-16. Manufacturer: SUHNER Suggested plug: MCX-50-2-16 type. Suggested cable: RG174 type.</p> <p><b>ELECTRICAL Specs</b> Input dynamics: - 1 V<sub>pp</sub> for CH0-CH31; - 2 V<sub>pp</sub> for TR0 and TR1 (PCB Rev <math>\geq</math> 1); - 3 V<sub>pp</sub> for TR0 and TR1 (PCB Rev = 0) Input impedance (Z<sub>in</sub>): 50 Ω. Absolute max analog input voltage (for 1V<sub>pp</sub> FSR): 3V<sub>pp</sub> (with Vrail max +3V or -3V) for any DAC offset in single ended configuration.</p>

CLOCK IN/CLOCK OUT	
	<p><b>FUNCTION</b> Input and output connectors for the external clock.</p> <p><b>ELECTRICAL Specs</b> Sign. type: differential (LVDS, ECL, PECL, LVPECL, CML). CAEN provides single ended-to-differential A318 cable adapter (see <b>Tab. 1.1</b>) for CLK-IN. Coupling: AC (CLK-IN); DC (CLK-OUT). <math>Z_{diff}</math>: 100 Ω.</p> <p><b>MECHANICAL Specs</b> Series: AMPMODU connectors. Type: 3-102203-4 (3-pin). Manufacturer: AMP Inc.</p> <p><b>PINOUT</b></p> 

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

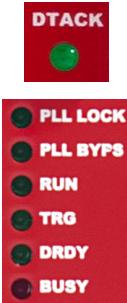
TRG-IN / TRG-OUT / S-IN	
	<p><b>FUNCTION</b></p> <ul style="list-style-type: none"> <li>• TRG-OUT: digital output connector to propagate:             <ul style="list-style-type: none"> <li>- probes from the mezzanines;</li> <li>- S-IN signal.</li> </ul> </li> <li>• TRG-IN: digital input connector for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

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

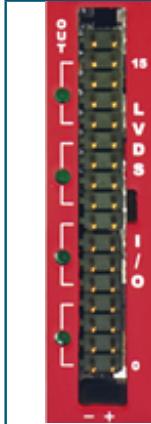
OPTICAL LINK PORT		MECHANICAL SPECS
	<b>FUNCTION</b> Optical LINK connector for data readout and flow control. Daisy chainable. Compliant with Multimode 62.5/125 µm cable featuring LC connectors on both sides.	<b>Series:</b> SFF Transceivers. <b>Type:</b> FTLF8519F-2KNL (LC connectors). <b>Manufacturer: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

DIAGNOSTICS LEDs	
	<b>DTACK (GREEN):</b> indicates there is a VME read/write access to the board; <b>TTL (GREEN):</b> indicates the standard TTL is set for TRG OUT, TRG IN, S IN; <b>NIM (GREEN):</b> indicates the standard NIM is set for TRG OUT, TRG IN, S IN; <b>PLL LOCK (GREEN):</b> indicates the PLL is locked to the reference clock; <b>PLL BYPS (GREEN):</b> indicates the PLL drives directly the ADCs. PLL circuit is switched off and PLL LOCK LED is turned off; <b>RUN (GREEN):</b> indicates the acquisition is running (data taking). See <b>Sect. Acquisition Run/Stop</b> ; <b>TRG (GREEN):</b> indicates the trigger is accepted; <b>DRDY (GREEN):</b> indicates the event/data is present in the Output Buffer; <b>BUSY (RED):</b> indicates all the buffers are full for at least one channel.

### 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 Sect. Front Panel

#### LVDS I/Os:

- Register
- Trigger
- nBusy/nVeto
- Legacy

#### ELECTRICAL Specs

Level: differential LVDS

$Z_{\text{diff}}$ : 100  $\Omega$

#### MECHANICAL Specs

Series : TE - AMPMODU Mod II Series

Type: 5-826634-0 (lead spacing: 2.54 mm; row pitch: 2.54 mm)

Manufacturer: AMP Inc.

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

### LABELS

**CAEN**  
Mod. V1742

(32+2)CH 12BIT  
5GS/s Sw-Cap  
DIGITIZER

Two blue labels on each insertion/extraction handle on the VME front panel report:

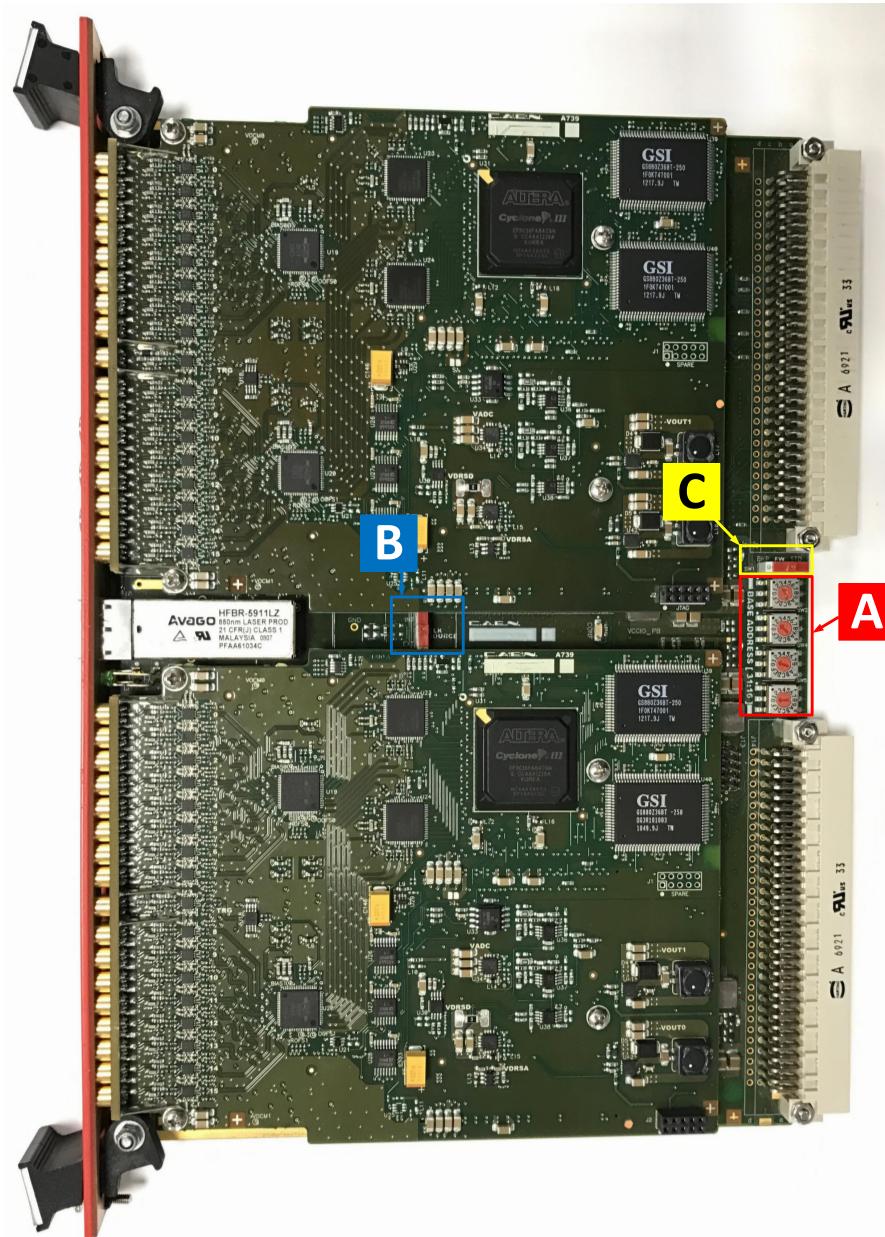
- Manufacturer name and board's model
- Brief functional description of the module

S/N

A little silver label on the bottom of the VME board's front panel reports:

- 4-digit Serial Number (S/N)

## Internal Components



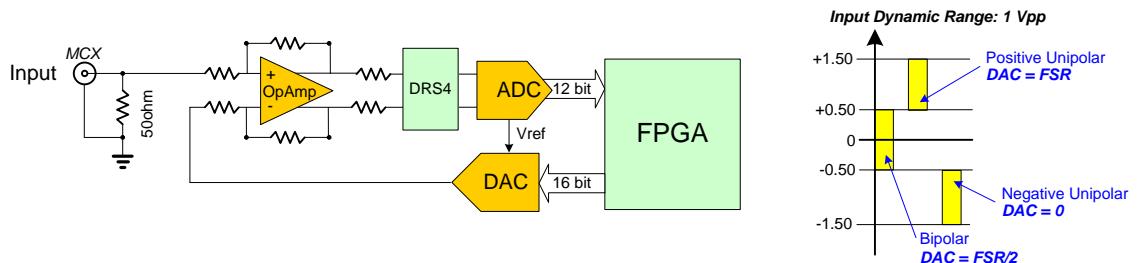
**Fig. 6.2:** Rotary and dip switches location

<b>A</b>	<b>SW3: "Base Address [31:16]"</b>	<b>Type:</b> Dip Switch	<b>Function:</b> Selects the clock source (External or Internal)
<b>B</b>	<b>SW2,4,5,6: "CLOCK SOURCE" INT/EXT</b>	<b>Type:</b> Rotary Switches	<b>Function:</b> Set the VME Base Address of the module
<b>C</b>	<b>JP2: "FW" BKP/STD</b>	<b>Type:</b> Dip Switch	<b>Function:</b> Selects between the "Standard" (STD) and the "Backup" (BKP) FLASH page as the first to be read at power-on to load the FW on the FPGAs (default position is STD); see <b>Sect. Default Firmware Upgrade</b>

# 7 Functional Description

## Analog Input Stage

The input dynamic is  $1 \text{ V}_{\text{pp}}$  on single ended MCX coaxial connectors ( $Z_{\text{in}} = 50 \Omega$ ). A 16-bit DAC allows to add up to  $\pm 1 \text{ V}$  DC offset in order to preserve the full dynamic range also with uni-polar, positive, and negative input signal. The input bandwidth ranges from DC to 500 MHz.



**Fig. 7.1:** Analog input diagram

An additional channel is available on the TRn connector. The TRn can act as a fast trigger (refer to **Sect. TR0 and TR1 Inputs**) and it can also be digitized and saved into memory. The TRn appears as the ninth channel of each group in the final readout. The TRn input dynamics is  $2 \text{ V}_{\text{pp}}$  for Mezzanine PCB revision  $\geq 1$ , and  $3 \text{ V}_{\text{pp}}$  for Mezzanine PCB revision = 0<sup>1</sup>. The input dynamics is then attenuated by a factor of 2 (3 in the latter case) to make it compliant with the  $1 \text{ V}_{\text{pp}}$  dynamics of the other channels. The 16-bit DAC then allows the user to adjust the DC offset making the TRn suitable for uni-polar, positive, and negative signals.

## Domino Ring Sampling

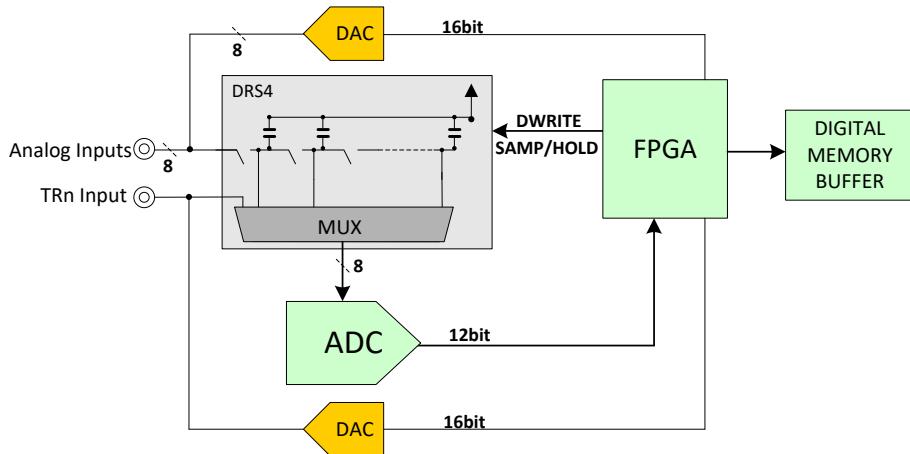
The analog input signals are continuously sampled by the DRS4 (Domino Ring Sampler) chip<sup>2</sup> which consists of an on-chip inverter chain (domino wave circuit) generating a maximum of 5 GS/s sampling frequency; 2.5 GS/s, 1 GS/s, and 750 MS/s frequencies can be also programmed. The board has one chip per group, and each chip consists of 1024 capacitor cells per channel, which perform the analog sampling of the input (high frequency analog sampling). The record length of the acquisition is constrained by the cell number, and it is fixed to 1024 samples. Options 512, 256, and 136 can be selected by software to reduce the amount of data to be transferred, but all the 1024 cells are converted anyway (no dead-time reduction). The DRS4 chip continuously samples the input in a circular way (samples are overwritten) until a trigger signal stops its acquisition (holding phase). Then the cells release their capacitances at a readout frequency controlled by the FPGA (Output Mode).

The analog samples are digitized by the 12-bit ADC at a frequency of 29.296 MHz (low frequency digital sampling). The ADC output is stored by the FPGA into the Digital Memory Buffer. Data is then available for readout (for the data format refer to **Sect. Event structure**).

The single TRn is split into the two DRS4 chips (see also **Sect. TR0 and TR1 Inputs**). Delay lines are equal in the two paths, anyway small differences in the digitized samples are possible due to differences in the chips and in the ADCs. When the digitization of the TRn is enabled, there is a double conversion that increases the dead-time from 110  $\mu\text{s}$  when only the inputs are converted to 181  $\mu\text{s}$  when also the TRn are converted.

<sup>1</sup>To check the PCB revision number, read bit[9] of register 0x1n88 [RD1]

<sup>2</sup>Detailed documentation of the DRS4 is available at <http://drs.web.psi.ch/>



**Fig. 7.2:** Input Diagram

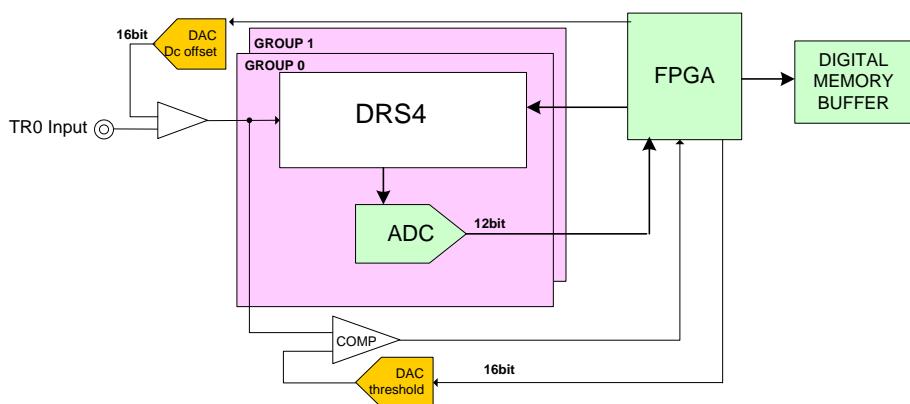
## TR0 and TR1 Inputs

The module features two fast trigger inputs TR0 and TR1 with extended level amplitude (NIM/LVTTL compliant); TR0 is common to group 0 (ch[7..0]) and group 1 (ch[15..8]), TR1 to group 2 (ch[23..16]) and group 3 (ch[31..24]). TRn signal can be used as external trigger (see [Sect. Trigger Management](#)). Moreover they can be also sampled into the DRS4s analog memory buffers for applications where high resolution timing and time analysis with a common reference signal (like a trigger or system clock) is required; this is achieved by setting bit[11]=1 of register 0x8000.

**IMPORTANT:** The TRn input is attenuated by a factor of 2 (PCB revision  $\geq 1$ ), or 3 (PCB revision 0) to make it compliant with the  $1\text{ V}_{\text{pp}}$  dynamics of the DRS4 chip. For signals higher than  $2\text{ V}_{\text{pp}}$  ( $3\text{ V}_{\text{pp}}$ ) it is recommended to use an external attenuator.

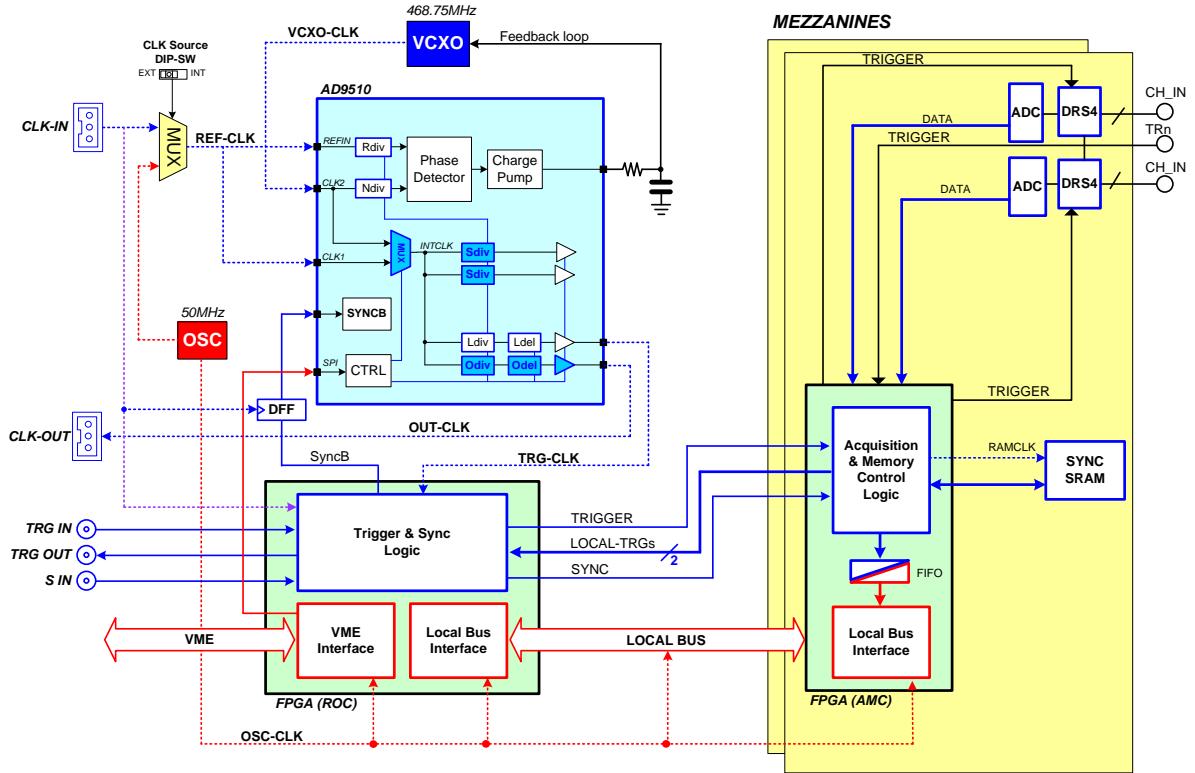
To properly handle bipolar signals and also unipolar positive or negative signal, a 16-bit DAC allows the user to add a DC offset to TRn; offset value can be programmed via register 0x1nDC.

When the TRn signals are used as triggers they are processed by an internal comparator, whose threshold can be programmed via register 0x1nD4: when the TRn crosses the threshold, the FPGA stops the DRS4 acquisition and controls the sample digitalization. Examples of TRn DC Offset and Threshold are reported in [Sect. Fast \("Low Latency"\) Trigger](#)



**Fig. 7.3:** TR0 logic block diagram

## Clock Distribution



**Fig. 7.4:** Clock distribution diagram

The module clock distribution takes place on two domains: OSC-CLK and REF-CLK, where OSC-CLK is a fixed 50-MHz clock provided by an on-board oscillator, and REF-CLK provides the ADC sampling clock. OSC-CLK handles both VME and Local Bus (communication between motherboard and mezzanine boards; see red traces in the above figure).

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

The board uses an integrated phase-locked-loop (PLL) with a selectable internal or external reference clock source, and a clock distribution device, AD9510, which manages the REF-CLK, and generates the trigger logic synchronization clock (TRG-CLK) and the clock output (OUT-CLK).

Both clocks can be generated from the internal oscillator (50 MHz) or from external clock input. By default, the board uses the internal clock as PLL reference (REF-CLK).

The external clock can be selected by SW3 on-board switch (see **Sect. Internal Components**). The external clock signal must be differential (LVDS, ECL, PECL, LVPECL, CML) with a jitter lower than 100ppm (see **Tab. 3.1**).

Refer to the AD9510 datasheet for more details:

[http://www.analog.com/UploadedFiles/Data\\_Sheets/AD9510.pdf](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

As introduced in **Sect. Clock Distribution**, the source of the REF-CLK signal (see **Fig. 7.4**) 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 SW3 (see **Sect. Internal Components**). The following options are allowed:

1. 50 MHz internal clock source – This is the standard operating mode, where the default AD9510 configuration does not require to be changed. OSC-CLK = REF-CLK.
2. 58.594 MHz external clock source – In this case, the user is required to program the AD9510 dividers to lock the VCXO to REF-CLK. CLK-IN = REF-CLK. Please contact CAEN (**Sect. Technical Support**) to receive the PLL programming file. The PLL programming can be achieved through the CAENUpgrader tool [**RD2**].
3. External clock source different from 58.594 MHz – In this case, the user is required to program the AD9510 dividers to lock the VCXO to REF-CLK. In principle, the allowed external frequencies are sub-multiples of the VCXO frequency (468.75 MHz). CLK-IN = REF-CLK. Please contact CAEN (see **Sect. Technical Support**) indicating the required reference clock frequency to check its feasibility and receive the PLL programming file.

## Data correction

The DRS4 chip needs data corrections because of the unavoidable differences in the chip construction process. The corrections are managed at software level, since the firmware on-board retrieves the raw data. There are three available corrections:

1. Cell Index Offset correction, which compensates the signal offset for the differences in cell amplitudes;
2. Sample Index Offset correction, which corrects the signal offset for a noise over the last 30 samples;
3. Time correction, which compensates the differences of the delay line of the chips.

The default correction tables are provided by CAEN in the memory flash of the board. Wavedump software [**RD3**] (and the underlying CAENDigitizer library [**RD4**]) then can retrieve the tables and make the appropriate corrections.

The user can leave the software automatically apply all the corrections, or decide which correction applies to which group through the CORRECTION\_LEVEL function of WaveDump.

If the user wants to apply its own corrections, he/she can use the CAENDigitizer function GetCorrectionTable [**RD4**] to retrieve the default correction files from the board and modify them with his/her own values.

The list of CAENDigitizer functions to be used on-line are:

- **LoadDRS4CorrectionData**, loads the correction parameters stored on board. The correction parameters to load depend on the operating sampling frequency.
- **DecodeEvent**, decode the event and apply the correction to data if LoadDRS4CorrectionData has been previously called.
- **Enable/Disable DRS4Correction**, enables/disables the data correction in the x742 series. When enabled, the data correction through the DecodeEvent function only applies if LoadDRS4CorrectionData has been previously called, otherwise the DecodeEvent runs the same, but data will be provided out not compensated.
- **GetCorrectionTables**, reads the correction tables from the x742 digitizer flash memory, related to the selected sampling frequency, and fills in a structure with the read values. In this way, the stored correction table become available for the user.

Finally, it is also possible to save the raw data and apply the corrections off-line. An example code is available in the CAENDigitizer library. To access the code, download and install the CAENDigitizer library (the prior installation of CAENVMElib [**RD5**], [**RD6**] and CAENComm library [**RD7**] are required) and include the examples in the installation. Then access to the subfolder called "x742\_DataCorrection".

*C:/Program Files/CAEN/Digitizers/Library/Samples/x742\_DataCorrection*

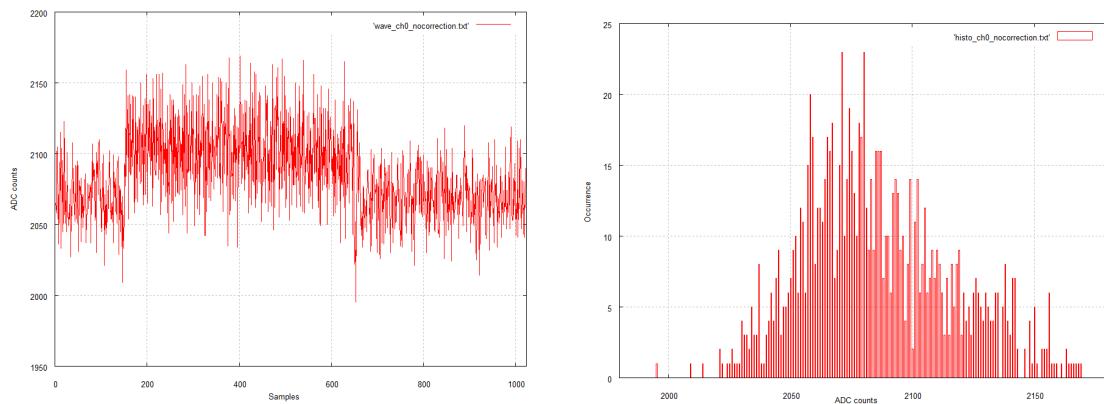
Here the list of CAENDigitizer functions [**RD4**] to be used off-line.

- **LoadCorrectionTables**, loads the correction tables stored onto the board into a user defined structure.
- **ApplyDataCorrection**, applies the desired correction data (configured through a mask) to the raw data acquired by the user.
- **GetNumEvents**, gets the current number of events stored in the acquisition buffer.
- **GetEventPtr**, retrieves the event pointer of a specified event in the acquisition buffer.
- **X742\_DecodeEvent**, decodes a specified event stored in the acquisition buffer writing data in Evt memory.

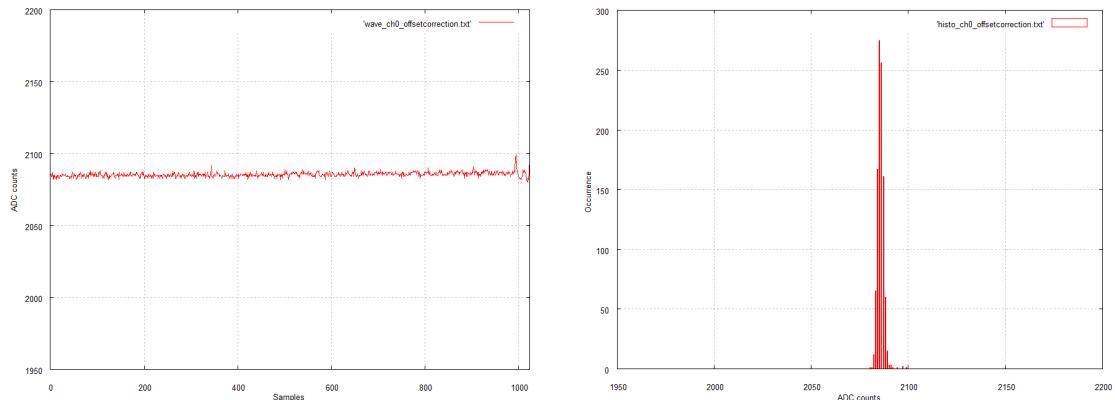
## Cell Index Offset correction

The analog capacitors of the DRS4 chip might have small differences between each other due to the construction processes. According to the cell index where the stop acquisition arrives, the same input signal can be reconstructed in different ways. For this reason it is required a cell amplitude calibration to compensate for the amplitude differences in the capacitors. The correction adjusts the baseline of the input (i.e. its offset).

Taking into account the internal noise of each channel, **Fig. 7.5** shows the sampled waveform on the left and the noise distribution histogram on the right, measured as the occurrence of the ADC counts. Plots are made before the correction. **Fig. 7.6** shows the same quantities after the correction. As expected, the noise in **Fig. 7.6** is flatter with no patterns, and its distribution has a smaller RMS.



**Fig. 7.5:** Sampled waveform (left) and noise histogram (right) before cell index offset correction

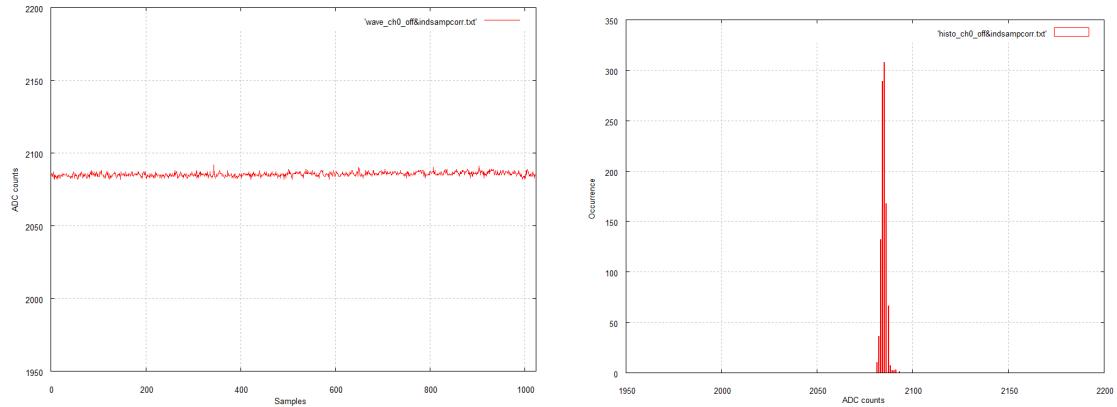


**Fig. 7.6:** Sampled waveform (left) and noise histogram (right) after cell index offset correction

## Sample Index Offset correction

From Fig. 7.6 it is possible to see a fixed pattern over the last about 30 samples of the waveform. Therefore it is required to perform an additional calibration, called "Sample Index", that corrects for the latest samples.

Fig. 7.7 shows the result on the baseline after the correction, where the pattern on the latest samples has been corrected.



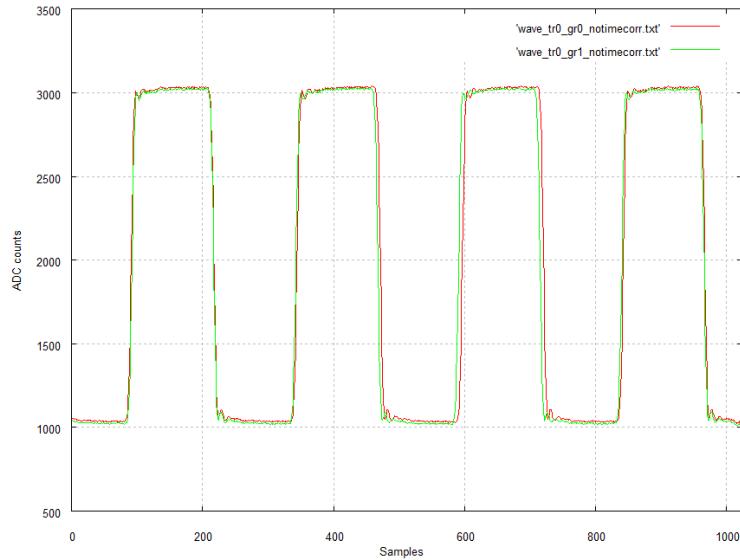
**Fig. 7.7:** Sampled waveform (left) and noise histogram (right) after sample index offset correction

## Time correction

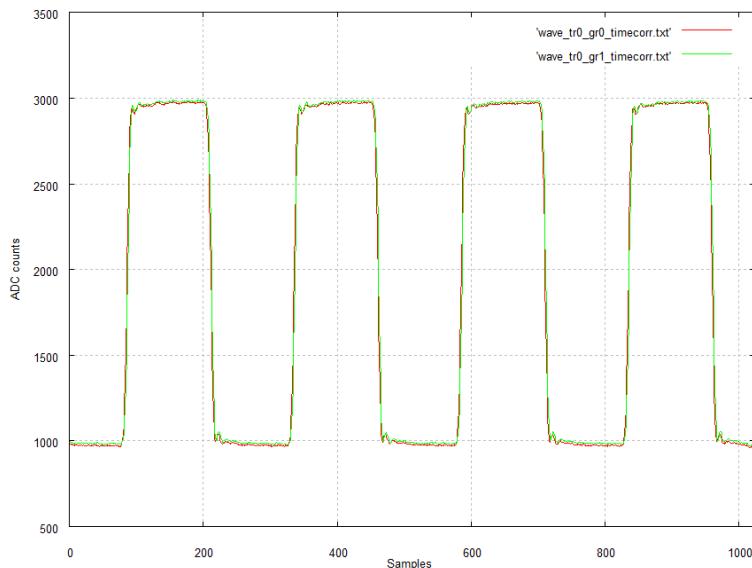
The sampling sequence is handled by the DRS4 through 1024 physical delay lines; the unavoidable construction differences between such delay lines must be compensated through a time calibration.

**Fig. 7.8** and **Fig. 7.9** show the fast trigger signal (TR0) sampled by the DRS4 chip related to Group 0 and Group 1, before and after the time correction respectively. High discrepancies can be seen before the correction, while the differences after the correction are extremely reduced.

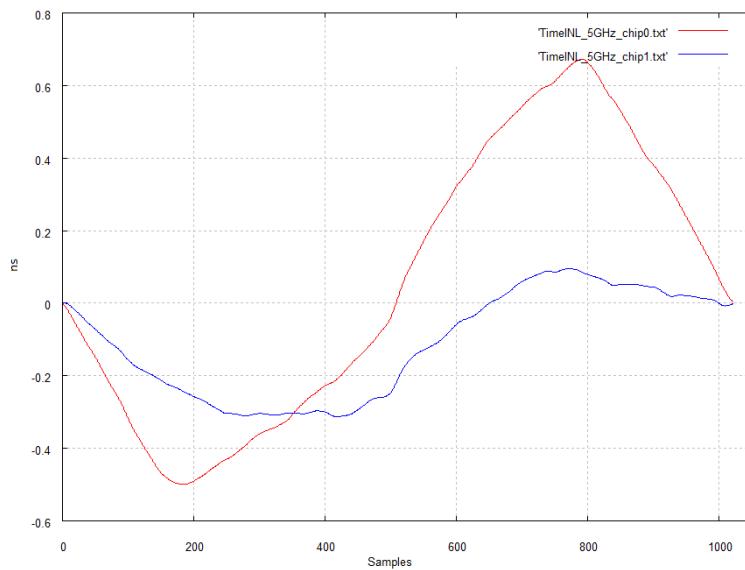
To measure the differences between the data and the ideal time value of the DRS4 chip, the Integral Non-Linearity (INL) has been calculated and reported in **Fig. 7.10** and **Fig. 7.11** before and after the correction respectively. As expected, the INL shows a better agreement after the correction.



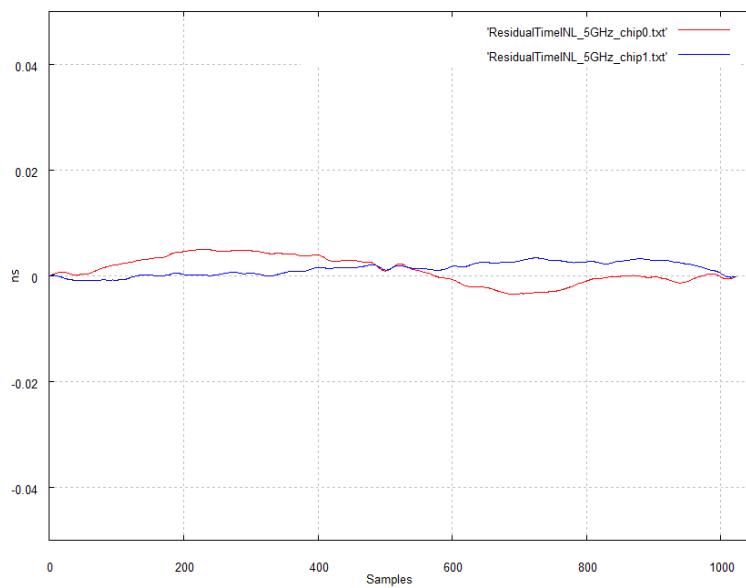
**Fig. 7.8:** Sampled TR0 signal in GR0 and GR1 before time correction



**Fig. 7.9:** Sampled TR0 signal in GR0 and GR1 after time correction



**Fig. 7.10:** INL time profile of DRS4 chips 0 and 1 before time correction



**Fig. 7.11:** INL time profile of DRS4 chips 0 and 1 after time correction

## Acquisition Modes

### Acquisition Run/Stop

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

- 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 [Sect. Front Panel LVDS I/Os](#)).

### Event structure

The event can be readout via VMEbus or Optical Link; data format is 32-bit long word (see [Fig. 7.12](#)).

An event is structured as:

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

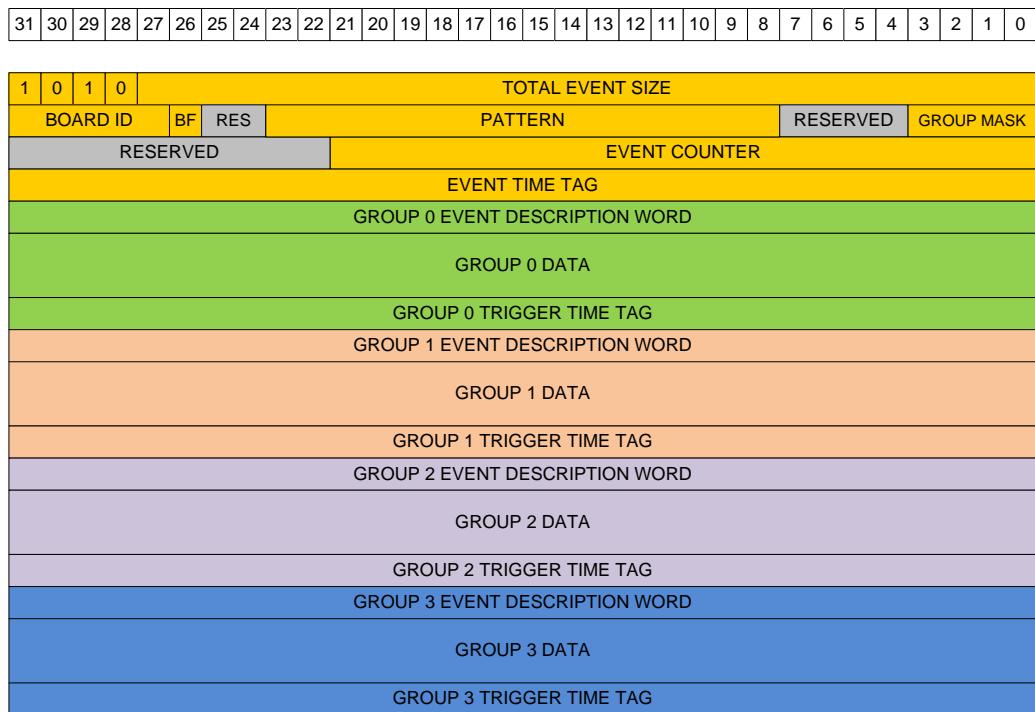
The Header is composed by four words, namely:

- **TOTAL EVENT SIZE** (Bit[27:0] of 1st header word), this is the total size of the event, i.e. the number of 32-bit long words to be read;
- **BOARD ID** (Bit[31:27] of 2nd header word), this 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), this bit is set to “1” in consequence of a hardware problem (e.g. PLL unlocking or over-temperature condition). The user can collect more information about the cause by reading at register address 0x8104 and contact CAEN Support Service if necessary (see [Sect. Technical Support](#));
- **PATTERN** (Bit[23:8] 2nd header word) = It is the 16-bit PATTERN latched on the LVDS I/Os as the trigger arrives (VME boards only).
- **GROUP MASK** (Bit[3:0] of the 2nd header word) = It is the mask of the groups participating to the event. This information must be used by the software to retrieve from which groups the samples belong. For example, in case of events from GR1 and GR3, GROUP MASK = 0xA, in case of events from GR0 and GR1, GROUP MASK = 0x3.
- **EVENT COUNTER** (Bit[23:0] of 3rd header word) : It is the trigger counter; it can count either accepted triggers only, or all triggers.
- **EVENT TIME TAG** (4th header word): it is a 31-bit counter and the 32nd bit as roll over flag; the counter is reset when the acquisition starts or by an external signal (see [Sect. Timer Reset](#)) and it is incremented at each trigger clock hit. It corresponds to the time when the event is created in the digitizer memory and it does not correspond to any physical quantity.



**Note:** The physical time of arrival of the pulse can be read in the Group Trigger Time Tag.

After the header, the data from the enabled groups is reported consecutively. The group data format for group 0 is reported in [Fig. 7.13](#).



**Fig. 7.12:** Event Format

Each group is composed by 8 channels (group 0 = channel 0 – 7, group 1 = channel 8 – 15, etc.) and by the special channel TRn: such signal is common to two groups; it can be used as Local Trigger or “digitized” and stored with the data for high resolution timing analysis between the ADC channels and the TRn itself (refer to Sect. **TR0 and TR1 Inputs**).

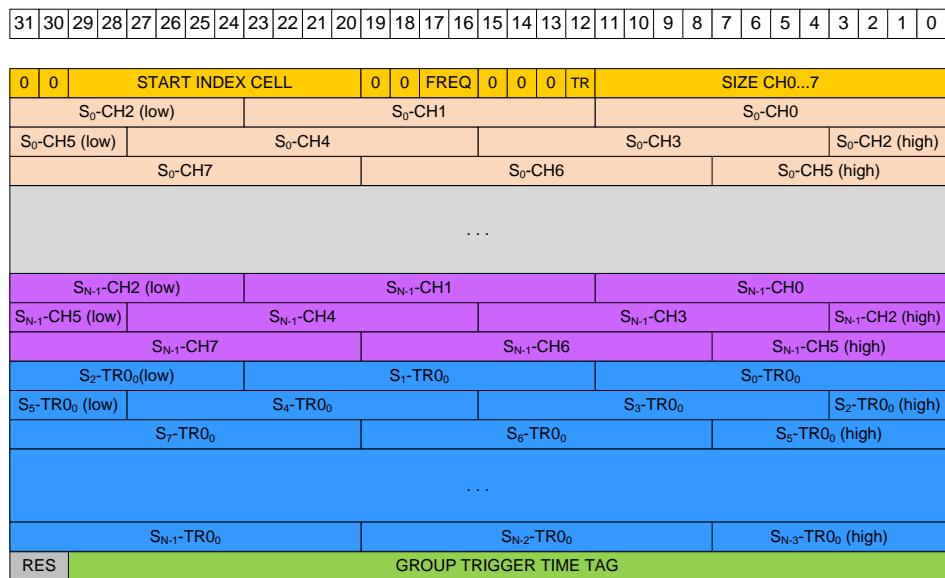


**Note:** TR0 (TR1) is split into the two DRS4 of the mezzanine and follows two different path (two different ADCs and two memory buffers). This might imply that the digitized samples of TRn might have small differences from one group to the other.

TR0 can trigger both Group 0 and Group 1 and it is stored in both group data (referring to Fig. 7.13 the label TR0<sub>0</sub> indicates that the TR0 is saved into group 0).

In the **Group Event Description** word (yellow in the figure) the following fields are shown:

- **START INDEX CELL** (Bits[29:20]), it is the index cell of the DRS4 chip, corresponding to the first sample of the event;
- **FREQ** (Bit[17:16]), it is the sampling frequency of the DRS4 chip, whose options are:
  - 00 = 5 GS/s;
  - 01 = 2.5 GS/s;
  - 10 = 1 GS/s;
  - 11 = 750 MS/s.
- **TR** (Bit[12]), indicates whether the TRn has been digitized and it is available in the readout. Options are:
  - 0 = TRn signal not present in the readout
  - 1 = TRn signal present in the readout
- **SIZE CH0...7** (Bit[11:0]). It is the number of words to be read for the CH0...7 samples. Considering that each channel has 1024 samples, and that one sample is written in three words, “SIZE CH0...7” is 0xC00.



**Fig. 7.13:** Group Data Format

The **GROUP DATA** corresponds to the waveform samples, where each sample is reported from the lowest channel index to the highest.

If the readout of TRn is disabled, data related to such channel (light blue in **Fig. 7.13**) are not present in the event; if readout of TRn is enabled, data size related to such channel is Size TRn = (SIZE CH0...7)/8.

The **GROUP TRIGGER TIME TAG** records the Trigger arrival time into a 30-bit number (steps of 8.5 ns). This is the physical trigger information of the event.

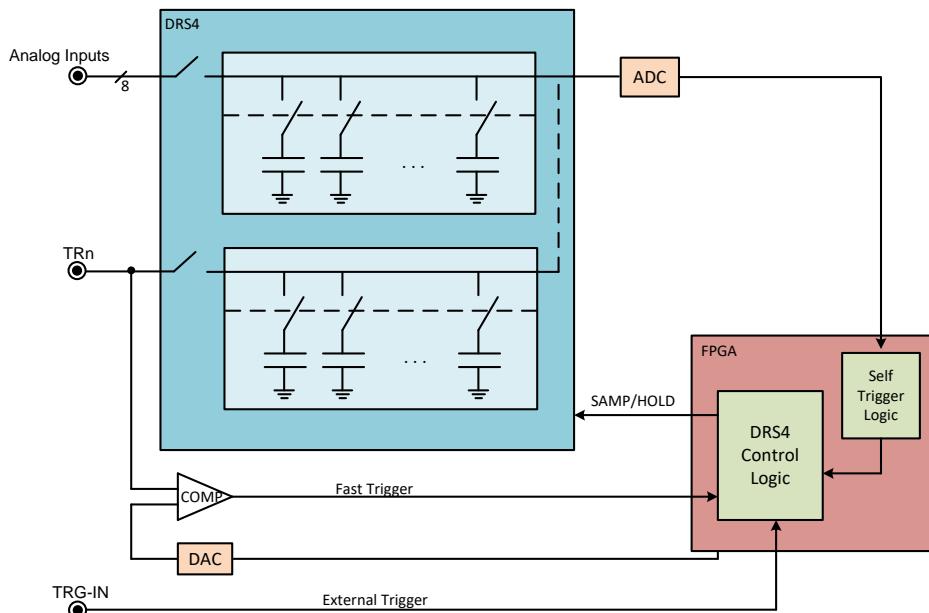
## Trigger Management

Once a trigger condition is met, the DRS4 chip stops its sampling phase and the analog capacitances are converted (holding phase) by a 12-bit ADC. There are four possible trigger sources:

- **Software Trigger** (common to all enabled groups). The trigger is issued through a software write on the relevant FPGA register. This mode is mainly used for debugging purposes.
- **External Trigger** (trigger on TRG-IN connector, common to all enabled groups). The TRG-IN connector accepts NIM and TTL input logic, which can be programmed via software. More details are in [Sect. External Trigger](#).
- **Fast (Low Latency) Local Trigger** (trigger on TR0 and TR1 connectors, common to couples of groups<sup>3</sup>). This mode is called “Fast” or “Low Latency” since the latency from the trigger arrival and the DRS4 stop acquisition is significantly reduced with respect to the External Trigger mode. See [Sect. Fast \(“Low Latency”\) Trigger](#).
- **Self-trigger** (common to couples of groups<sup>4</sup>), the acquisition is controlled by combinations in logic OR of the channel self-triggers. See [Sect. Self-Trigger](#).

During the analog to digital conversion process, the board cannot handle other triggers. The corresponding dead-time is equal to 110 µs when only the inputs are digitized, and 181 µs when also the TRn are digitized.

**Fig. 7.14** shows the block diagram of the 742 trigger management.



**Fig. 7.14:** Block diagram of Trigger management

<sup>3</sup>TR0 manages the acquisition of group 0 and group 1, while TR1 manages the acquisition of group 2 and group 3 (VME form factor only).

<sup>4</sup>Channels of group 0 and group 1 manage the acquisition of the two groups simultaneously, while channels of group 2 and group 3 manage the acquisition of the other two groups simultaneously (VME form factor only).

## Software Trigger

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

## External Trigger

A TTL or NIM external signal can be provided in the front panel TRG-IN connector (configurable at register address 0x811C).

The TRG-IN signal is first processed by the mother board with a clock of about 58 MHz, and sent to the DRS4 to stop its acquisition with a latency of about 115 ns and a jitter of about 17 ns<sup>5</sup>. The latency of the external trigger makes this mode difficult to use at 5 GHz, where the maximum acquisition window is about 200 ns (1024 samples of 200 ps).

## Fast ("Low Latency") Trigger

The trigger signal is fed into TR0 and TR1 connectors, and it is common to couples of groups<sup>6</sup>. The TRn connector accepts signals with maximum amplitude of 2 V<sub>pp</sub> in case of Mezzanine PCB revision  $\geq 1$  (3 V<sub>pp</sub> in case of Mezzanine PCB revision = 0)<sup>7</sup>.

**IMPORTANT:** The TRn input is attenuated by a factor of 2 (PCB revision  $\geq 1$ ), or 3 (PCB revision 0) to make it compliant with the 1 V<sub>pp</sub> dynamics of the DRS4 chip. For signals higher than 2 V<sub>pp</sub> (3 V<sub>pp</sub>) it is recommended to use an external attenuator.

This mode is called "Fast" or "Low Latency" since the latency from the trigger arrival and the DRS4 holding phase is reduced to about 42 ns with a jitter of about 8.5 ns. The signal on TRn is sent to a comparator with programmable threshold (no mother-board processing) whose output is sampled at about 117 MHz (twice the external trigger processing). When the TRn signal crosses the threshold, the acquisition of the DRS4 chip is stopped and the digitalization process starts.

This trigger mode is convenient for high precision timing measurements, since the TRn can be digitized as the other analog inputs and reported in the output data as channel number 8 of each group. The trigger can therefore be used as a time reference for the input. The DRS4 sampling period becomes the time jitter of the trigger with respect to an input of the same group, which can reach 200 ps in case of sampling at 5 GHz. The resolution in a time of flight measurement reaches up to 50 ps in case of signals and TRn in the same TRn group, and 100 ps for signals and TRn in different groups.



**Note:** TR0 (TR1) is split into the two DRS4 of the mezzanine and follows two different path (two different ADCs and two memory buffers). This might imply that the digitized samples of TRn might have small differences from one group to the other.

Since the TRn acts as an input signal, it is possible to adjust its baseline position (i.e. the 0 Volt) to cover the full scale. This permits the use of several types of signals, bi-polar, negative, and positive. A list of accepted signals is reported in [Tab. 7.1](#) and [7.2](#). The TRn signal is then sent to a comparator that compares the TRn to the Trigger Threshold. When TRn crosses the threshold the trigger is issued.

[Tab. 7.1](#) and [7.2](#) report few examples of DC Offset and Threshold values (hexadecimal / decimal) for typical signals that can be fed into the TRn connector. The reported Threshold values allow the user to trigger at half of the signal height.

An example on how to set the TRn triggering mode is reported in [\[RD8\]](#).

<sup>5</sup>The TRG-IN latency has been reduced to 115 ns from ROC firmware revision 4.07, while for firmware revisions less than 4.07 the latency was 255 ns with a jitter of about 34 ns.

<sup>6</sup>TR0 manages the acquisition of group 0 and group 1, while TR1 manages the acquisition of group 2 and group 3 (VME form factor only).

<sup>7</sup>To check the PCB revision number, read bit[9] of register 0x1n88 [\[RD1\]](#)

Mezzanine PCB Rev. $\geq 1$	
ECL signal on TRn	TRn DC Offset = 0x55A0 / 21920 TRn Threshold = 0x6666 / 26214
NIM signal on TRn	TRn DC Offset = 0x8000 / 32768 TRn Threshold = 0x51C6 / 20934
Negative signal on TRn: $V = 0 \div -400\text{mV}$	TRn DC Offset = 0x8000 / 32768 TRn Threshold = 0x5C16 / 23574
Negative signal on TRn: $V = 0 \div -200\text{mV}$	TRn DC Offset = 0x8000 / 32768 TRn Threshold = 0x613E / 24894
Bipolar signal on TRn	TRn DC Offset = 0x8000 / 32768 TRn Threshold = 0x6666 / 26214
TTL on TRn or Positive signal on TRn: $V = 0 \div \geq 2\text{V}$	TRn DC Offset = 0xA800 / 43008 TRn Threshold = 0x6666 / 26214
Positive on TRn: $V = 0 \div 2\text{V}$	TRn DC Offset = 0x91A7 / 37287 TRn Threshold = 0x6666 / 26214

**Tab. 7.1:** Examples of DC Offset and Trigger Threshold (in hexadecimal / decimal) for typical signals on TRn connector.  
Values are valid for mezzanine PCB revision  $\geq 1$ .

Mezzanine PCB Rev. 0	
NIM signal on TRn	TRn DC Offset = 0x1000 / 4096 TRn Threshold = 0x717D / 29053
Negative signal on TRn: $V = 0 \div -400\text{mV}$	TRn DC Offset = 0x1000 / 4096 TRn Threshold = 0x6E72 / 28274
Bipolar signal on TRn	TRn DC Offset = 0x1000 / 4096 TRn Threshold = 0x6C80 / 27776
Positive on TRn: $V = 0 \div 2\text{V}$	TRn DC Offset = 0x4000 / 16384 TRn Threshold = 0x7158 / 29016

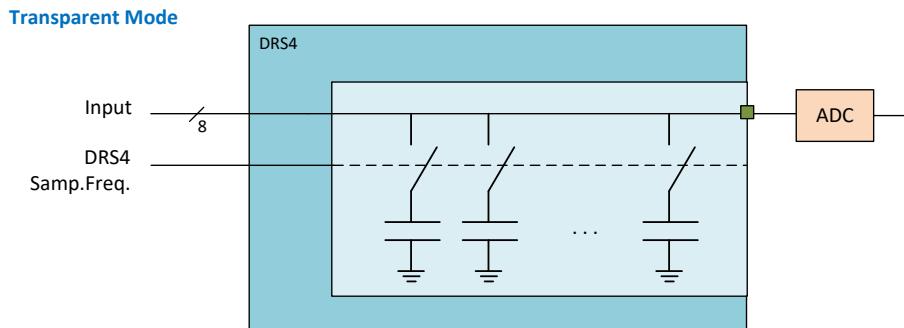
**Tab. 7.2:** Examples of DC Offset and Trigger Threshold (in hexadecimal / decimal) for typical signals on TRn connector.  
Values are valid for mezzanine PCB revision 0.

## Self-Trigger

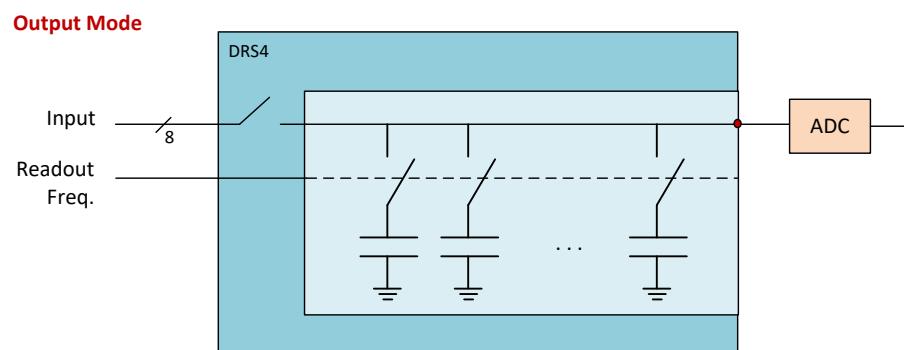
The self-trigger mode is available on 742 series from AMC firmware revision 0.4. In self-trigger mode each channel can self-trigger on its own input – leading edge discrimination – and logic OR combinations of the self-triggers enable the groups to acquire at the same time. In particular, channels of group 0 and channels of group 1 control the acquisition of the two groups simultaneously, while channels of group 2 and channels of group 3 control the acquisition of the other two groups simultaneously. Refer to register 0x1nA8 [RD1] for more details.

The DRS4 chip has two operating modes: “Transparent” and “Output”. In Transparent mode (see Fig. 7.15), the input pulse is both sampled by the DRS4 capacitors (analog sampling) at high frequency, and made available at the output for the ADC digital sampling at a smaller rate, about 30 MHz. In transparent mode, the output stage is not a pure differential, since it has an offset and it is attenuated with respect to the signal correctly shaped. Transparent mode is the standard operating mode of the DRS4 chip, which continuously samples the input.

In Output mode (see Fig. 7.16), the input is no longer sampled and the capacitors hold the acquired samples and send them one at a time to the ADC at a frequency controlled by the FPGA (readout frequency). The Output mode starts when a trigger condition is met (see Fig. 7.14). Samples in Output mode are those available in the readout for the user and they are correctly shaped.



**Fig. 7.15:** Diagram showing the “Transparent Mode” functioning. The analog input is both sampled by the DRS4 capacitors (analog sampling) and made available at the output for the ADC digital sampling at a smaller rate. The output stage is distorted with respect to the Output mode.



**Fig. 7.16:** Diagram showing the “Output Mode” functioning. the input is no longer sampled and the capacitors hold the acquired samples and send them one at a time to the ADC at a frequency controlled by the FPGA (readout frequency). The output stage is correctly differential.

Since the Self-Trigger Logic inside the FPGA reads data from the ADC while the DRS4 chip works in Transparent mode, the Trigger Threshold has to be referred to the values read in Transparent mode itself, rather

to the values reported in Output mode.

To correctly set the threshold value, it is first required to make an acquisition in Transparent mode to visualize the waveform as sampled by the ADC.

Considering that the ADC frequency is about 30 MHz, it is important that the input can be sampled by the ADC itself. In particular, the pulse width should be greater than 30 ns, and the input frequency should be high enough to visualize some pulses.

**IMPORTANT:** The procedure of reading from the ADC and processing data by the FPGA introduces a latency of about 250 ns before the DRS4 holding phase. This mode is therefore not compliant with the DRS4 frequency = 5 GHz, but it can be useful when the board works at 2.5 GS/s, 1 GS/s, or 750 MS/s.

## How to work with Self-Trigger

To work with the channel self-trigger feature, the board must be configured appropriately according to the following steps.

- Set the DC offset of each channel (at least those which are required to acquire) to ensure that the entire input signal is within the input dynamics of the board. To verify this, it is suggested to make acquisitions in the standard mode ("Output Mode") using the SW trigger.
- Set the board to perform the acquisition in "Transparent Mode" (set bit[13] = 1 of register 0x8000).
- Make acquisitions in "Transparent Mode" using the SW trigger. No corrections are made in Transparent mode. For each channel of interest, check the value of the signal in this acquisition mode and choose the threshold for triggering.
- Set the threshold value for each channel of interest via register 0x1n80, where n is the group index.
- Enable the channels of interest to generate a Channel Trigger via register 0x1nA8.
- Set the board to perform the acquisition in "Output Mode" (set back bit[13] = 0 of register 0x8000).

The board is so ready to acquire data when triggers are generated by the channels.

Refer also to **[RD8]** for a practical example and **[RD1]** for the registers description:

## 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 in the synchronization of 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 same ADC sampling clock, and the same time reference 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 is aligned to the same absolute time.

The user must than take care of the proper run and trigger propagation to all boards and, in case of busy state of one or more boards, to inhibit the acquisition for all boards.

The steps to be performed to synchronize two or more V1742 are the following:

### 1. Clock synchronization.

- a Choose one “master” board, and connect its CLK-OUT to the CLK-IN connector of the first “slave” board. The dip switch “CLOCK SOURCE” (see **Sect. Internal Components**) of the master board is set to INTERNAL.

Connect the CLK-OUT of the first slave board to the CLK-IN of the second slave board, and so on. The dip switch “CLOCK SOURCE” of the slave boards is set to EXTERNAL.

CAEN can provide A317 cables for clock distribution.

- b Program the PLL of the master board to work with its internal 50 MHz oscillator and to provide on CLK-OUT connector the 58.594 MHz clock. Contact CAEN (**Sect. Technical Support**) to receive the PLL programming file.

Program the PLL of the slave boards to accept on CLK-IN and to provide on CLK-OUT the 58 MHz clock.

Check the clock delay between the boards and program again the slaves to compensate for the delay.

**NOTE:** in case of fast trigger on TRn it is not required to achieve high precision in the clock alignment, since the time reference is defined by the common TRn (see next point)

- 2. **Fast Trigger.** To achieve high time precision in the measurement, it is recommended to use the Fast trigger mode using the TRn connector (see **Sect. Fast (“Low Latency”) Trigger**) and to digitize and save it in the data. The TRn acts as a common reference time for the channels. To ensure a precise time alignment make sure that a common trigger is split in all the TRn by using cables of the same length.

**NOTE:** Use the Group Trigger Time Tag as time reference of the trigger (see **Sect. Event structure**), while the Event Trigger Time Tag is the time when the event is composed by the FPGA.

- 3. **Run propagation.** The start of the run is made via software and it is propagated from the master board to the slaves through either TRG-OUT/S-IN daisy chain, or through the LVDS I/O.

#### a TRG-OUT/S-IN daisy chain:

- i Connect the TRG-OUT of the master to the S-IN of the slave, and so on.
- ii Program the TRG-OUT to be synchronized with the start run (bits[17:16] and bits[19:18] of register 0x811C).
- iii Program the acquisition to be controlled by S-IN (bits[2:0] of register 0x8100).

#### b LVDS I/O daisy chain:

- i Connect the LVDS O of the master to the LVDS I of the slave, and so on.
- ii Program the LVDS I/O as nRUN option of the nBUSY/nVETO mode (see **Sect. Mode 2: nBUSY/nVETO**).
- iii Program the acquisition to be controlled by the LVDS I/O (bits[2:0] of register 0x8100).

The delay in the run propagation can be compensated via software.

4. **Busy management.** The acquisition of all boards should be inhibited when at least one board is busy to avoid that one board acquires while the others are busy. The logic OR of all busy can be propagated from the TRG-OUT connector of the last board through the following steps:
  - a Propagate the busy from master to the slaves through the LVDS I/O connectors (refer to registers 0x811C, 0x81A0, and 0x8110).
  - b Program the TRG-OUT connector of the last slave to propagate out the OR of the busy (busy from its groups and busy from the LVDS) through register 0x811C.

The TRG-OUT signal than can be used to directly veto the TRn source before it is fed into the board, or it can be propagated to the TRG-IN connector of all boards. In the latter case the steps are as follows:

- a Use an external FAN IN/FAN OUT board to split the TRG-OUT signal.
- b Feed the fan out output to the TRG-IN connector of all boards of the chain.
- c Program the veto from TRG-IN (refer to registers 0x8000 and 0x811C).

A detailed guide to multi-board synchronization can be found in [RD9]. Though it doesn't apply specifically to V1742 modules, it represents a valid reference to approach CAEN multi-board synchronization concepts and architecture. Please contact CAEN (see **Sect. Technical Support**) for details and support.

## Front Panel LVDS I/Os

The V1742 and VX1742 are provided with 16 general purpose programmable LVDS I/O signals. In the default firmware, CAEN has developed for its digitizer series a new and more flexible configuration management that has been introduced from the release 3.8 of the ROC FPGA firmware and allows the LVDS I/Os signals to be programmed in terms of direction (INPUT/OUTPUT) and functionality by groups of 4. Only the description of the new configuration modes is given in this paragraph.

**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 DEFAULT FIRMWARE OF V1742 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 (see **Sect. Technical Support**) FOR INFORMATION.

**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. 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 **Sect. Event structure**) the user can then choose to readout it or not.

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

**Tab. 7.3:** 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
LVDS OUT [11:8]	Reg[11:8]	TrigOut_Ch[3:0]	11: nRun 10: nTrigger 9: nVeto 8: nBusy
LVDS OUT [7:4]	Reg[7:4]	TrigOut_Ch[7:4]	7: nRun 6: nTrigger 5: nVeto 4: nBusy
LVDS OUT [3:0]	Reg[3:0]	TrigOut_Ch[3:0]	3: nRun 2: nTrigger 1: nVeto 0: nBusy

**Tab. 7.4:** 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: TrigOut\_Ch[3:0] are the trigger requests from the couples of channels CH0-CH1, CH2-CH3, CH4-CH5 and CH6-CH7, according to the logic described in **Sect. Trigger Management**. Similarly, TrigOut\_Ch[7:4] TrigOut\_Ch[7:4] are the trigger requests from the couples of channels CH8-CH9, CH10-CH11, CH12-CH13, and CH14-CH15.

## Mode 2: nBUSY/nVETO

### nBusy Signal

nBusIn (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:

**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. 7.4**);
- 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: reserved.

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 **Sect. 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).

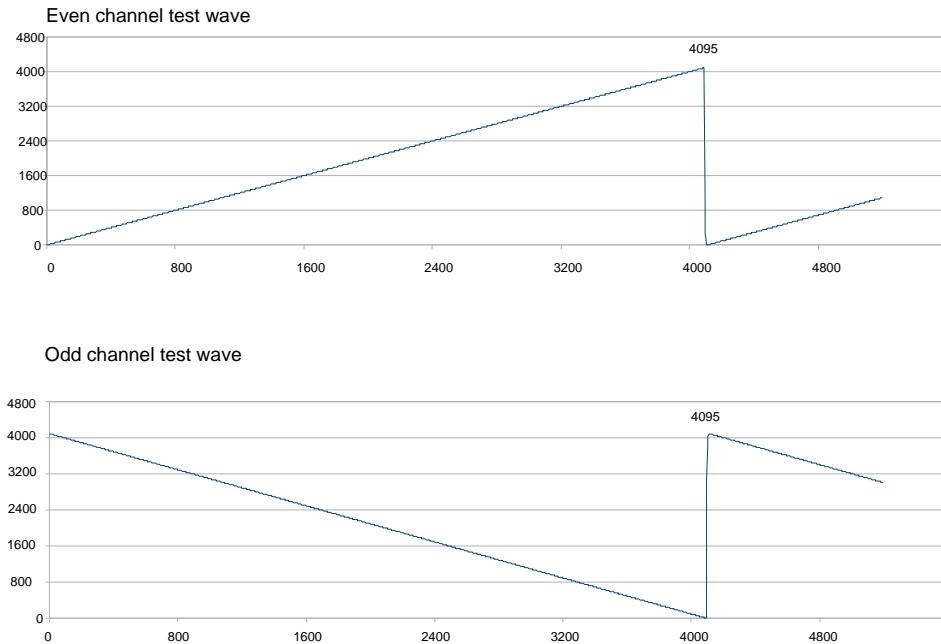
**Trigger Signal** The active high Trigger signal is the copy of the acquisition trigger (common trigger) sent from the motherboard to the mezzanines (it is neither the signal provided out on the TRG-OUT LEMO connector nor the inverse of the signal sent to the LVDS connector).

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

## Test Pattern Generator

The FPGA can emulate the ADC and write into memory a saw tooth signal for test purposes. It can be enabled via Group Configuration register.

The following figure shows the test waveforms for even and odd groups respectively.



**Fig. 7.17:** FPGA test waveform

Since an event is made up of up to 1024 samples, the test event samples only a “portion” of the saw tooth; the start point of the sampling can be programmed via Initial Test Wave Value register; for example if this register is set to 0x0FF then the channels in the even groups sample the ramp between 255 and 1278; the channels in the odd groups instead sample the complementary value, therefore between 3840 and 2817.

## Reset, Clear and Default Configuration

### Global Reset

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

### Memory Reset

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

### Timer Reset

The Timer Reset allows to initialize the timer which allows to tag an event. The Timer Reset can be forwarded with a pulse sent to the front panel Trigger Time Tag Reset input (see **Sect. Front Panel LVDS I/Os**) or to the S-IN input (leading edge sensitive).

## VMEBus Interface

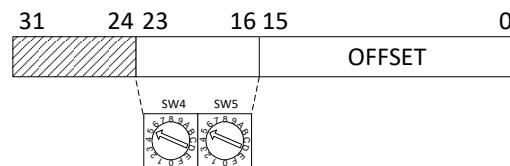
The module is provided with a fully compliant VME64/VME64X interface, whose main features are:

- 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

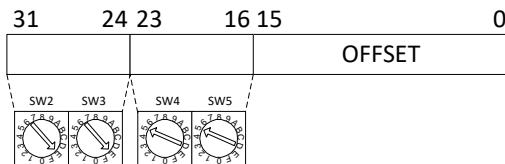
- Base address: the module works in A24/A32 mode. The Base Address of the module is selected through four rotary switches (see **Fig. 6.2**), then it is validated only with either a Power-ON cycle or a System Reset (see **Sect. Global Reset**).

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



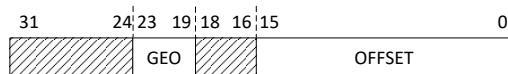
**Fig. 7.18: A24 addressing**

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



**Fig. 7.19: A32 addressing**

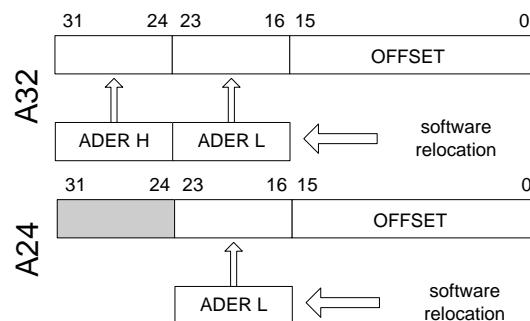
- **CR/CSR address:** the addressing is based on the slot number taken from the relevant backplane lines. The recognised Address Modifier for this cycle is 2F. *This feature is implemented only on versions with 160-pin connectors.*



**Fig. 7.20: CR/CSR addressing**

## Address Relocation

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



**Fig. 7.21: Software relocation of base address**

## Data Transfer Capabilities and Events Readout

The event, once it is written in the memory, becomes available for the 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 readout sequentially and completely, starting from the Header of the first available event, followed by the samples of the enabled groups as reported in [Fig. 7.12](#). Once an event is completed, the relevant memory buffer becomes free and ready to be written again (old data are lost). After the last word in an event, the first word (Header) of the subsequent event is readout. It is not possible to readout an event partially.

The size of the event (EVENT SIZE) is configurable and depends on register addresses 0x8020 [**RD1**], as well as on the number of enabled groups.

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.

### 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 [Sect. Event structure](#).

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

### Block Transfer D32/D64, 2eVME

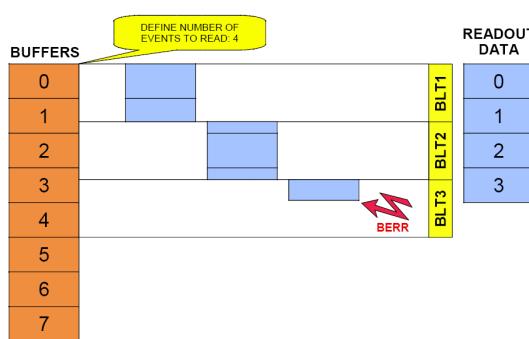
The Block Transfer readout mode allows to read N complete events sequentially, where N is set at register address 0xEF1C [**RD1**], or by using the SetMaxNumEventsBLT function of the CAENDigitizer library (refer to [\[RD4\]](#)).

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

[Event Size] = [8\*(Buffer Size)] + [16 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).



**Fig. 7.22:** Example of BLT readout

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

## **Chained Block Transfer D32/D64**

The V1742 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 CBLT\_Base + 0x0000 ÷ 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).

## **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 V1742 to a single Optical Link Controller by using the A2818 PCI card or up to thirty-two V1742 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](http://www.caen.it:Home/Products/Modular%20Pulse%20Processing%20Electronics/PCI/PCIe/Optical%20Controller)

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 [**RD1**] allows to enable the module to broadcast an interrupt request on the Optical Link; the enabled Optical Link Controllers propagate the interrupt on the PCI bus as a request from the Optical Link is sensed. Interrupts can also be managed at the CAENDigitizer library level (see “Interrupt Configuration” in [**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.

# 8 Drivers & Libraries

## Drivers

In order to interface with the board, CAEN provides the drivers for all the different types of physical communication channels featured by the board 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” area at the A2818 or A3818 page (**login required**)



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

## Libraries

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

- **CAENDigitizer** is a library of functions designed specifically for the Digitizer family and it supports also the boards running the DPP firmware. The CAENDigitizer library is based on the CAENComm 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 are available on CAEN website in the ‘Download’ area at the CAENDigitizer Library page.

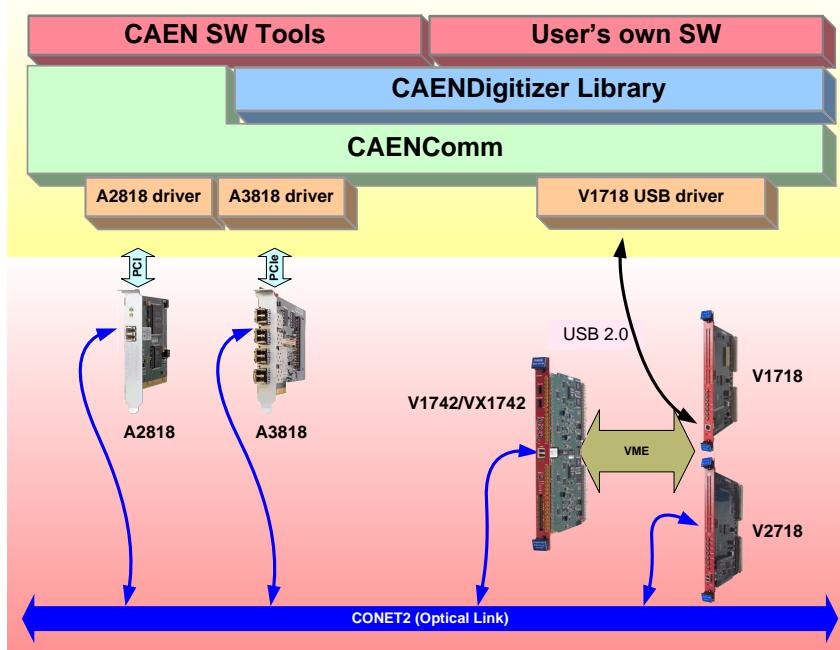
- **CAENComm** library manages the communication at low level (read and write access). The purpose of the CAENComm is to implement a common interface to the higher software layers, masking the details of the physical channel and its protocol, thus making the libraries and applications that rely on the 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’ area at the CAENComm Library page.

CAENComm (and so the CAENDigitizer) supports the following communication channels (**Fig. 8.1**):

PC → USB (V1718) → VMEbus → V1742(VX1742)

PC → PCI/PCIe (A2818/A3818) → CONET → V1742(VX1742)

PC → PCI/PCIe (A2818/A3818) → CONET (V2718) → VMEbus → V1742(VX1742)



**Fig. 8.1:** Drivers and software layers

If required to be installed apart by the user (see **Sect. Software Tools**), CAEN Libraries are available for download on CAEN web site ([www.caen.it](http://www.caen.it)) in the “Download” tab at the library web page:

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

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

## 9 Software Tools

CAEN provides software tools to interface the 742 digitizer series, which are available for free download on [www.caen.it](http://www.caen.it) at:

*Home / Products / Firmware/Software / Digitizer Software*

### CAENUpgrader

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

Specifically for the x742, CAENUpgrader allows in few easy steps to:

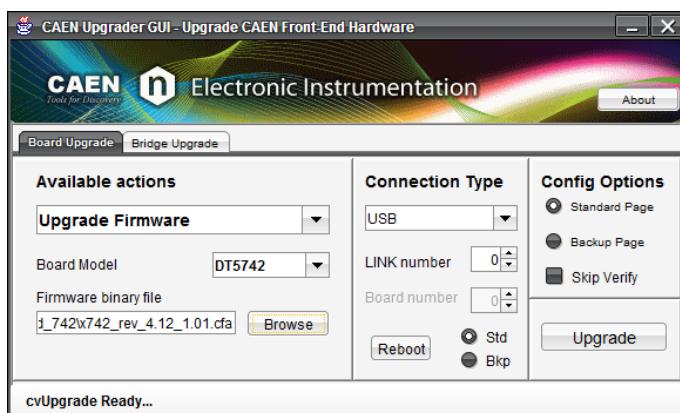
- Upload different FPGA firmware versions on the board
- Read the firmware release of the board and the bridge (when used)
- Manage the firmware license, in case of paid firmware
- Upgrade the internal PLL
- Get the Board Info file, useful in case of support

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

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



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



**Fig. 9.1:** CAENUpgrader Graphical User Interface

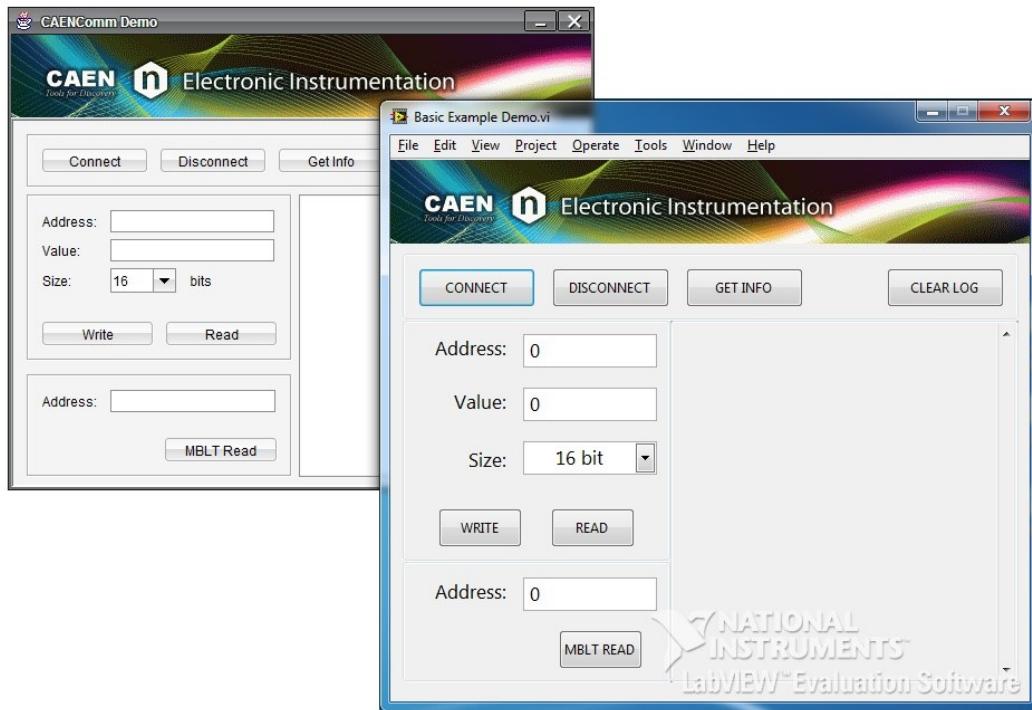
CAENUpgrader installation package can be downloaded on CAEN web site (**login required**) at:

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

The reference document for installation instructions and program detailed description is **[RD2]**, downloadable at the same page above, in the Documentation tab.

## CAENComm Demo

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



**Fig. 9.2:** CAENComm Demo Java and LabVIEW graphical interface

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

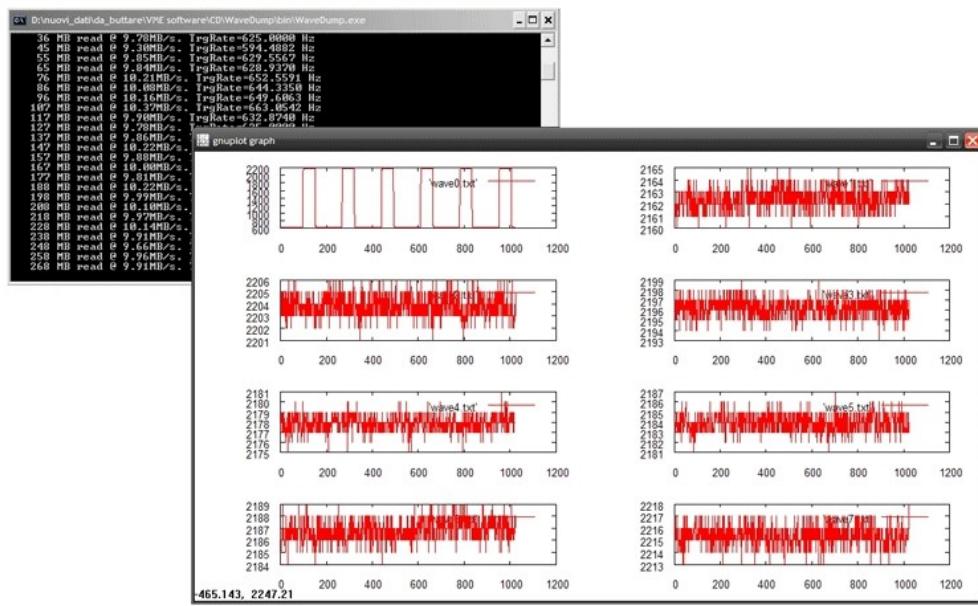
The Demo is included in the CAENComm library installation Windows package, which can be downloaded on CAEN web site (**login required**) at:

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

## CAEN WaveDump

**WaveDump** is a basic console application, with no graphics, supporting only CAEN digitizers running the default firmware. It allows the user to program a single board (according to a text configuration file containing a list of parameters and instructions), to start/stop the acquisition, read the data, display the readout and trigger rate, apply some post-processing (e.g. FFT and amplitude histogram), save data to a file and also plot the waveforms using Gnuplot (third-party graphing utility: [www.gnuplot.info](http://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. 9.3:** CAEN WaveDump

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

The program relies on the CAENDigitizer, CAENComm and CAENVMElib libraries (see **Sect. Drivers & Libraries**). Linux users are required to install the third-party Gnuplot.



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

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

[Home / Products / Firmware/Software / Digitizer Software / Readout Software / CAEN WaveDump](http://www.caen.it/Products/Firmware/Software/Digitizer%20Software/Readout%20Software/CAEN%20WaveDump)

The reference documents for installation instructions and program detailed description are **[RD3]**, downloadable at the same page above, in the Documentation tab.

## 10 HW Installation

- The V1742 fits into 6U VME crates.
- VX1742 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 MAY DEGRADE THE MODULE PERFORMANCES!**

**CAUTION:** this product needs proper handling.



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

## Power-on Sequence

To power on the board, follow this procedure:

1. Insert the V1742 into the crate;
2. power up the crate.

## Power-on Status

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

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

After the power-on, the front panel LEDs status is that only the NIM and PLL LOCK remain ON (see **Fig. 10.1**).



**Fig. 10.1:** Front panel LEDs status at power ON

# 11 Firmware and Upgrades

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

**ROC FPGA MAINBOARD FPGA** (Readout Controller + Communication Interface):

FPGA Altera Cyclone EP1C20.

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

FPGA Altera Cyclone EP4CE30

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

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

V1742 digitizers are equipped with an on-board dedicated SW1 dip switch, set on STD position by default, allowing to select the first FLASH page to be read at power-on (see **Sect. Internal Components**).

It is possible to upgrade the board firmware via VMEbus or Optical Link by writing the FLASH with the CAENUpgrader software (see **Sect. 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!**

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 SW1 DIP SWITCH POSITION MAY NOT CORRESPOND TO THE FLASH PAGE FIRMWARE COPY LOADED ON THE BOARD FPGAs**

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

## Default Firmware Upgrade

The V1742 is delivered running a default firmware to operate the board for waveform recording. The default firmware updates are available for download on CAEN website [www.caen.it](http://www.caen.it) in the Software/Firmware tab of the V1742 web page (**login required**):  
*Home / Products / Modular Pulse Processing Electronics / VME / Digitizers / V1742*

## Default Firmware File Description

The programming file has the extension .CFA (CAEN Firmware Archive) and is a sort of archive format file aggregating all the default firmware files compatible with one or more digitizer families. CFA and its name follow this general scheme:

x742\_revX.Y\_W.Z.CFA

where:

- x742 are all the supported boards: DT5742, N6742, V1742, VX1742
- X.Y is the major/minor revision number of the mainboard FPGA
- W.Z is the major/minor revision number of the channel FPGA

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

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

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



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



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