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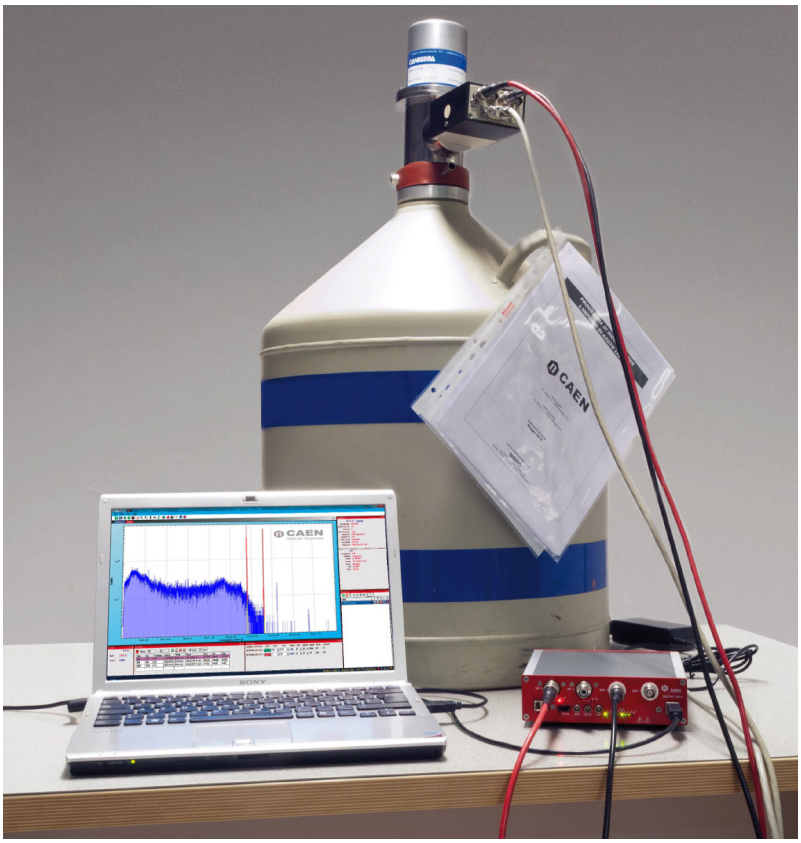

User Manual UM5407

724-781 DPP-PHA Legacy

Register Description and Data Format

Rev. 3 - July 13th, 2020

Purpose of this Manual

The User Manual contains the full description of the DPP-PHA firmware registers for 724 and 781 family series. The description is compliant with the DPP-PHA firmware revision **4.15_128.36**. For future release compatibility check the firmware history files.

Change Document Record

Date	Revision	Changes
September 16th, 2016	00	Initial Release
January 17th, 2019	01	724 and 781 DPP-PHA releases <128.64 become Legacy
July 2nd, 2019	02	Modified register Configuration ROM Board Version.
July 13th, 2020	03	Added Chap. DPP-PHA Memory Organization

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
DPP	Digital Pulse Processing
DPP-QDC	DPP for Charge to Digital Converter
DPP-PHA	DPP for Pulse Height Analysis
DPP-PSD	DPP for Pulse Shape Discrimination
LVDS	Low-Voltage Differential Signal
MCA	Multi-Channel Analyzer
ROC	ReadOut Controller
USB	Universal Serial Bus

Reference Documents

[RD1] UM1935 - CAENDigitizer User & Reference Manual.

[RD2] UM5960 - CoMPASS User Manual.

[RD3] GD2827 - How to make coincidences with CAEN digitizers.

All CAEN documents can be downloaded at:
`www.caen.it/support-services/documentation-area`

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1 Registers and Data Format

All registers described in the User Manual are 32-bit wide. In case of VME access, **A24** and **A32** addressing mode can be used.

Register Address Map

The table below reports the complete list of registers that can be accessed by the user. The register names in the first column can be clicked to be redirected to the relevant register description. The register address is reported on the second column as a hex value. The third column indicates the allowed register access mode, where:

R **Read only**. The register can be accessed in read only mode.
W **Write only**. The register can be accessed in write only mode.
R/W **Read and write**. The register can be accessed both in read and write mode.

According to the attribute reported in the fourth column, the following choices are available:

I **Individual register**. This kind of register has N instances, where N is the total number of channels in the board. Individual registers can be written either in single mode (individual setting) or broadcast (simultaneous write access to all channels). Read command must be individual.
Single access can be performed at address 0x1nXY, where n is the channel number, while broadcast write can be performed at the address 0x80XY. For example:

- access to address 0x1570 to read/write register 0x1n70 for channel 5 of the board;
- to write the same value for all channels in the board, access to 0x8070 (broadcast write). To read the corresponding value, access to the individual address 0x1n70.

C **Common register**. Register with this attribute has a single instance, therefore read and write access can be performed at address 0x80XY only.

Register Name	Address	Mode	Attribute
Number of Events per Aggregate	0x1n34, 0x8034	R/W	I
Pre Trigger	0x1n38, 0x8038	R/W	I
Data Flush	0x1n3C, 0x803C	W	I
Channel n Stop Acquisition	0x1n40, 0x8040	R/W	I
RC-CR2 Smoothing Factor	0x1n54, 0x8054	R/W	I
Input Rise Time	0x1n58, 0x8058	R/W	I
Trapezoid Rise Time	0x1n5C, 0x805C	R/W	I
Trapezoid Flat Top	0x1n60, 0x8060	R/W	I
Peaking Time	0x1n64, 0x8064	R/W	I
Decay Time	0x1n68, 0x8068	R/W	I
Trigger Threshold	0x1n6C, 0x806C	R/W	I
Rise Time Validation Window	0x1n70, 0x8070	R/W	I
Trigger Hold-Off Width	0x1n74, 0x8074	R/W	I
Peak Hold-Off	0x1n78, 0x8078	R/W	I
Baseline Hold-Off	0x1n7C, 0x807C	R/W	I
DPP Algorithm Control	0x1n80, 0x8080	R/W	I
Shaped Trigger Width	0x1n84, 0x8084	R/W	I
Channel n Status	0x1n88	R	I
AMC Firmware Revision	0x1n8C	R	I
DC Offset	0x1n98, 0x8098	R/W	I
Input Dynamic Range/Coarse Gain	0x1nB4, 0x80B4	W	I
Board Configuration	0x8000, 0x8004 (BitSet), 0x8008 (BitClear)	R/W	C
Aggregate Organization	0x800C	R/W	C
Record Length	0x8020	R/W	C
Acquisition Control	0x8100	R/W	C
Acquisition Status	0x8104	R	C
Software Trigger	0x8108	W	C
Global Trigger Mask	0x810C	R/W	C
Front Panel TRG-OUT (GPO) Enable Mask	0x8110	R/W	C
LVDS I/O Data	0x8118	R/W	C
Front Panel I/O Control	0x811C	R/W	C
Channel Enable Mask	0x8120	R/W	C
ROC FPGA Firmware Revision	0x8124	R	C
Voltage Level Mode Configuration	0x8138	R/W	C
Software Clock Sync	0x813C	W	C
Board Info	0x8140	R	C
Analog Monitor Mode	0x8144	R/W	C
Event Size	0x814C	R	C
Time Bomb Downcounter	0x8158	R	C
Fan Speed Control	0x8168	R/W	C
Run/Start/Stop Delay	0x8170	R/W	C
Board Failure Status	0x8178	R	C
Disable External Trigger	0x817C	R/W	C
Trigger Validation Mask	0x8180+(4n), n=ch number	R/W	I
Front Panel LVDS I/O New Features	0x81A0	R/W	C
Buffer Occupancy Gain	0x81B4	R/W	C
Readout Control	0xEF00	R/W	C
Readout Status	0xEF04	R	C
Board ID	0xEF08	R/W	C
MCST Base Address and Control	0xEF0C	R/W	C
Relocation Address	0xEF10	R/W	C
Interrupt Status/ID	0xEF14	R/W	C
Interrupt Event Number	0xEF18	R/W	C
Aggregate Number per BLT	0xEF1C	R/W	C
Scratch	0xEF20	R/W	C

Software Reset	0xEF24	W	C
Software Clear	0xEF28	W	C
Configuration Reload	0xEF34	W	C
Configuration ROM Checksum	0xF000	R	C
Configuration ROM Checksum Length BYTE 2	0xF004	R	C
Configuration ROM Checksum Length BYTE 1	0xF008	R	C
Configuration ROM Checksum Length BYTE 0	0xF00C	R	C
Configuration ROM Constant BYTE 2	0xF010	R	C
Configuration ROM Constant BYTE 1	0xF014	R	C
Configuration ROM Constant BYTE 0	0xF018	R	C
Configuration ROM C Code	0xF01C	R	C
Configuration ROM R Code	0xF020	R	C
Configuration ROM IEEE OUI BYTE 2	0xF024	R	C
Configuration ROM IEEE OUI BYTE 1	0xF028	R	C
Configuration ROM IEEE OUI BYTE 0	0xF02C	R	C
Configuration ROM Board Version	0xF030	R	C
Configuration ROM Board Form Factor	0xF034	R	C
Configuration ROM Board ID BYTE 1	0xF038	R	C
Configuration ROM Board ID BYTE 0	0xF03C	R	C
Configuration ROM PCB Revision BYTE 3	0xF040	R	C
Configuration ROM PCB Revision BYTE 2	0xF044	R	C
Configuration ROM PCB Revision BYTE 1	0xF048	R	C
Configuration ROM PCB Revision BYTE 0	0xF04C	R	C
Configuration ROM FLASH Type	0xF050	R	C
Configuration ROM Board Serial Number BYTE 1	0xF080	R	C
Configuration ROM Board Serial Number BYTE 0	0xF084	R	C
Configuration ROM VCXO Type	0xF088	R	C

Number of Events per Aggregate

Each channel has a fixed amount of RAM memory to save the events. The memory is divided into a programmable number of buffers, called ”aggregates”, whose number of events can be programmed by this register. The maximum number of events per aggregate depends on the aggregate size (which is defined by the number of aggregates per memory, 0x800C), and the event size (which is defined by the record length, 0x1n20, the acquisition mode and the event format, 0x8000).
Note: it is usually recommended to keep this value high to optimize the readout, except in case of small input rate, where it is recommended to use a smaller value (even 1). Since the memory cannot be read until the aggregate is full, setting a a small number of events per aggregate makes the events ready to be read in a shorter time scale. Users can also force the readout through the flush register, 0x1n3C.

Address	0x1n34, 0x8034
Mode	R/W
Attribute	I

Bit	Description
[9:0]	Number of events per aggregate.
[31:10]	Reserved.

Pre Trigger

The Pre Trigger defines the number of samples before the trigger in the waveform saved into memory.

Address	0x1n38, 0x8038
Mode	R/W
Attribute	I

Bit	Description
[9:0]	Number of pre trigger samples according to the formula Ns = N * 2, where Ns is the pre trigger and N is the register value. For example, write N = 10 to set 20 samples of pre trigger. Each sample corresponds to 10 ns.
[31:10]	Reserved

Data Flush

Data events are grouped into aggregates of N events each, where N can be programmed through register 0x1n34. As soon as an aggregate reaches N events then it is ready to be read. An aggregate containing a number of events smaller than N cannot be read and must be forced to flush its current data. This is for example the case of low input rate, where the board might appear empty (no data) even if a small amount of events is already stored in the buffer, or at the end of the run where the last aggregate might be incomplete. A write access to this register forces the read of the current incomplete aggregate.

Address	0x1n3C, 0x803C
Mode	W
Attribute	I

Bit	Description
[31:0]	A write access to this register causes the flush of the current aggregate.

Channel n Stop Acquisition

This register performs the stop acquisition of a single channel n. If bit[0] = 0, then channel n starts the acquisition as the global run is active, together with any other enabled channel. Note that if the global run is not active, writing 0 in this register does not produce any effect. If bit[0] = 1 and the global run is active, then channel n stops the acquisition independently on the other enabled channels.
It is possible to drive the start/stop acquisition independently on each channel by the following steps:
1. Set the individual stop acquisition on each desired channel (bit[0] = 1).
2. Enable the global run through register Acquisition Control 0x8100 (no channel will start the acquisition);
3. Set bit[0] = 0 to start the individual acquisition, then bit[0] = 1 to stop it.
4. When all channels are individually stopped, disable the global run.

Address	0x1n40, 0x8040
Mode	R/W
Attribute	I

Bit	Description
[0]	Options are: 0: Run; 1: Stop.
[31:1]	Reserved

RC-CR2 Smoothing Factor

Defines the number of samples of a moving average filter used for the RC-CR2 signal formation.

Address	0x1n54, 0x8054
Mode	R/W
Attribute	I

Bit	Description
[5:0]	Write the desired number of samples. Options are: 0x1: 1 sample; 0x2: 2 samples; 0x4: 4 samples; 0x8: 8 samples; 0x10: 16 samples; 0x20: 32 samples.
[31:6]	Reserved

Input Rise Time

This register defines the time constant of the derivative component of the PHA fast discriminator filter.
In case of RC-CR2 this value must be equal (or 50% more) to the input rising edge, in such a way the RC-CR2 peak value corresponds to the height of the input signal.

Address	0x1n58, 0x8058
Mode	R/W
Attribute	I

Bit	Description
[7:0]	Rise Time expressed in sampling clock units (10 ns)
[31:8]	Reserved

Trapezoid Rise Time

Sets the Trapezoid Rise Time, i.e. the Shaping Time of the energy filter.
Note: the sum of Trapezoid Rise Time and Trapezoid Flat Top (see register 0x1n60) should not exceed 15 us for 724 series. Values are x2, x4, x8 according to the decimation factor (bits[9:8] of 0x1n80).

Address	0x1n5C, 0x805C
Mode	R/W
Attribute	I

Bit	Description
[9:0]	Trapezoid Rise Time value expressed in sampling clock unit (10 ns).
[31:10]	Reserved

Trapezoid Flat Top

Sets the Trapezoid Flat Top width.
Note: the sum of the Trapezoid Rise Time (see register 0x1n5C) and Trapezoid Flat Top should not exceed 15 us for 724 series. Values are x2, x4, x8 according to the decimation factor (bits[9:8] of 0x1n80).

Address	0x1n60, 0x8060
Mode	R/W
Attribute	I

Bit	Description
[9:0]	Trapezoid Flat Top duration expressed in sampling clock unit (10 ns).
[31:10]	Reserved

Peaking Time

Position in the flat top region where the samples are used for the calculation of the peak height. The peaking time is referred to the trigger position or to the trigger validation signal according to the trigger mode. Check the User Manual for further details.

Address	0x1n64, 0x8064
Mode	R/W
Attribute	I

Bit	Description
[10:0]	Peaking time expressed in sampling clock unit (10 ns).
[31:11]	Reserved

Decay Time

This register corresponds to the trapezoid pole-zero cancellation. The user must set this register equal to the decay time of the pre-amplifier.

Address	0x1n68, 0x8068
Mode	R/W
Attribute	I

Bit	Description
[15:0]	Decay time expressed in sampling clock unit (10 ns).
[31:16]	Reserved

Trigger Threshold

Threshold of the Trigger and Timing filter of the DPP-PHA algorithm. The threshold arms the RC-CR2 signal and the event is identified (trigger) on the RC-CR2 zero crossing.

Address	0x1n6C, 0x806C
Mode	R/W
Attribute	I

Bit	Description
[13:0]	Trigger Threshold value expressed in LSB unit.
[31:14]	Reserved

Rise Time Validation Window

The Rise Time Validation Window is used by the rise time discriminator (RTD) to reject pulses that overlap in the rise time. Such events are identified by a longer RC-CR2 signal (the RC-CR2 gets longer to reach the zero crossing and therefore to trigger) than the RC-CR2 of a single pulse. The rise time validation window starts in correspondence with the RC-CR2 threshold crossing and lasts for the duration written in this register. If no trigger occurs within this acceptance window, the algorithm consider the event as a pile- up and reject it.

Address	0x1n70, 0x8070
Mode	R/W
Attribute	I

Bit	Description
[9:0]	Rise Time Validation Window expressed in sampling clock unit (10 ns). When 0, the RTD is disabled.
[31:10]	Reserved

Trigger Hold-Off Width

The Trigger Hold-Off is a logic signal of programmable width generated by the trigger logic in correspondence of the fast discriminator output. Other triggers are inhibited for the overall Trigger Hold-Off duration.

Address	0x1n74, 0x8074
Mode	R/W
Attribute	I

Bit	Description
[5:0]	Trigger Hold-Off width expressed in steps of 80 ns.
[31:6]	Reserved

Peak Hold-Off

The Peak Hold-off starts at the end of the trapezoid flat top and defines how close must be two trapezoids to be considered piled-up. Zero is the case where the flat top of one trapezoid starts exactly at the end of the flat top of the previous one.

Address	0x1n78, 0x8078
Mode	R/W
Attribute	I

Bit	Description
[7:0]	Peak hold-off expressed in steps of 80 ns.
[31:8]	Reserved

Baseline Hold-Off

The Baseline Hold-off defines how long the baseline is kept frozen beyond the end of the trapezoid; after that time, the baseline starts to be calculated again. Depending on the baseline mean value, the baseline itself might take some time to recover after the hold-off.

Address	0x1n7C, 0x807C
Mode	R/W
Attribute	I

Bit	Description
[7:0]	Baseline Hold-Off expressed in steps of the sampling clock unit (10 ns).
[31:8]	Reserved

DPP Algorithm Control

Management of the DPP algorithm features

Address	0x1n80, 0x8080
Mode	R/W
Attribute	I

Bit	Description
[5:0]	Trapezoid Rescaling: the trapezoid generated by the energy filter in the FPGA is k*M times higher than the input pulse, where k is the trapezoid rise time and M is the input signal decay time. This value is internally represented over 48 bits and must be rescaled to 15 bit (i.e. 32K channels) before it is used to calculate the energy value (=pulse height). The trapezoid rescaling SHF defines how many bits are right shifted (i.e. division by 2^{SHF}) before applying the mask with 0x3FFF and extract the 15 bit value of the pulse height. Use a value for SHF such that $2^{SHF} <= M*k < 2^{(SHF+1)}$.
[7:6]	Reserved
[9:8]	Decimation: the input signal samples can be averaged within the number of samples defined by the decimation. This has the analogous effect of reducing the sampling frequency of the board. Options are: 00: Decimation disabled; 01: 2 samples (50 MSps); 10: 4 samples (25 MSps); 11: 8 samples (12.5 MSps).
[11:10]	Decimation Gain. This gain can be used in conjunction with the decimation (see bits[9:8]) to multiply the input samples by the same factor of the decimation and avoid losses in the resolution. Decimation gain is added to the trapezoid rescaling (bits[5:0]). Options are: 00: Digital Gain = 1; 01: Digital Gain = 2 (only with decimation >= 2 samples); 10: Digital Gain = 4 (only with decimation >= 4 samples); 11: Digital Gain = 8 (only with decimation = 8 samples).
[13:12]	Peak Mean: corresponds to the number of samples for the averaging window of the trapezoid height calculation. Note: for a correct energy calculation the Peak Mean should be contained in the flat region of the Trapezoid Flat Top. Options are: 00: 1 sample; 01: 4 samples; 10: 16 samples; 11: 64 samples.
[14]	Reserved
[15]	Enable Spike Rejection. When this bit is enabled triggers are inhibited until the ”Input Rise Time” duration is reached (register 0x1n58). In case of noisy signals this feature is quite useful to avoid triggering on spikes on the rise time of the RC- CR2 signal, which do not corresponds to real signals. This feature allows also the user to set lower values of the trigger threshold. Options are: 0: disabled; 1: enabled.
[16]	Invert Input: Individual setting for the input signal inversion. The DPP-PHA algorithm is designed to work with positive signals. In case of negative polarity the signal is inverted in the FPGA to make it positive. Options are: 0: positive polarity; 1: negative polarity.
[17]	Pulse Identification on RC-CR or RC-CR2 signal. Events are usually identified on the zero crossing of the RC-CR2 signal. For fast input signals it is possible to trigger on the zero crossing of the RC-CR signal (which becomes bipolar for fast signals). Options are: 0: Trigger on RC-CR2; 1: Trigger on RC-CR.

[19:18]	Trigger Mode. Options are: 00: Normal mode. Each channel self-triggers independently from the other channels; 01: Neighbour mode. Each channel can self-trigger independently from the other channels and it saves the event also when either the previous or the consecutive channel triggers as well; 10: Coincidence mode. Each channel can self-trigger independently from the other channels and it saves the event only when a validation signal occurs within its coincidence window (register 0x1n84); 11: Anti-coincidence mode. Each channel can self-trigger independently from the other channels and it saves the event only when no validation signal occurs within its coincidence window (register 0x1n84).
[22:20]	Baseline averaging window: number of samples for the baseline average calculation. Options are: 000: the baseline is not evaluated, and the energy values are not subtracted by the baseline; 001: 16 samples; 010: 64 samples; 011: 256 samples; 100: 1024 samples; 101: 4096 samples; 110: 16384 samples; 111: reserved.
[23]	Reserved.
[24]	Disable Self Trigger. When disabled, the self-trigger (fast discriminator output) is still propagated to the mother board for coincidence logic and TRG-OUT front panel connector, though it is not used by the channel to acquire the event. Options are: 0: self-trigger used to acquire and propagated to the trigger logic; 1: self-trigger only propagated to the trigger logic.
[25]	Fake Event in case of Time Reset signal from GPI (S-IN in case of VME form factor). Set this bit to 1 to enable a fake-event write in case of reset from GPI. The fake event is tagged by bit[3] of the EXTRAS word of the Channel Aggregate data format. Check the User Manual for further details. Options are: 0: disabled; 1: enabled.
[26]	Fake Event in case of Time Stamp roll over. Set this bit to 1 to enable a fake- event saving in case of internal time stamp roll over. The fake event is tagged from bit[3] of the EXTRAS word of the Channel Aggregate data format. Check the User Manual for further details. Options are: 0: disabled; 1: enabled.
[27]	Energy calculation in case of piled-up events. When a pile-up occurs the board returns energy = 0; set this bit if you want the energy evaluated also for piled- up events. Events are flagged as pile-up though bit[16] of the last word of the Channel Aggregate data format. The energy value is anyway not corrected. Check the User Manual for further details. Options are: 0: disabled; 1: enabled.
[31:28]	Reserved.

Shaped Trigger Width

The Shaped Trigger (i.e. Fast Discriminator Output) is a logic signal generated by a channel in correspondence with its local self- trigger. It is used to propagate the trigger to the other channels of the board and to other external boards, as well as to feed the coincidence trigger logic.

Address	0x1n84, 0x8084
Mode	R/W
Attribute	I

Bit	Description
[7:0]	Shaped Trigger (Fast Discriminator Output) width in steps of 10 ns.
[31:8]	Reserved

Channel n Status

This register contains the status information of channel n.

Address	0x1n88
Mode	R
Attribute	I

Bit	Description
[1:0]	Reserved.
[2]	If 1, the SPI bus is busy.
[31:3]	Reserved.

AMC Firmware Revision

Returns the DPP firmware revision (mezzanine level).
To control the mother board firmware revision see register 0x8124.
For example: if the register value is 0xC3218303:
- Firmware Code and Firmware Revision are 131.3;
- Build Day is 21;
- Build Month is March;
- Build Year is 2012.

NOTE: since 2016 the build year started again from 0.

Address	0x1n8C
Mode	R
Attribute	I

Bit	Description
[7:0]	Firmware revision number.
[15:8]	Firmware DPP code. Each DPP firmware has a unique code.
[19:16]	Build Day (lower digit).
[23:20]	Build Day (upper digit).
[27:24]	Build Month. For example: 3 means March, 12 is December.
[31:28]	Build Year. For example: 0 means 2000, 12 means 2012. NOTE: since 2016 the build year started again from 0.

DC Offset

This register allows to adjust the baseline position (i.e. the 0 Volt) of the input signal on the ADC scale. The ADC scale ranges from 0 to 2^{NBit} - 1, where NBit is the number of bits of the on-board ADC. The DAC controlling the DC Offset has 16 bits, i.e. it goes from 0 to 65535 independently from the NBit value and the board type.
Typically a DC Offset value of 32K (DAC mid-scale) corresponds to about the ADC mid-scale. Increasing values of DC Offset make the baseline decrease. The range of the DAC is about 5% (typ.) larger than the ADC range, hence DAC settings close to 0 and 64K correspond to ADC respectively over and under range.
WARNING: before writing this register, it is necessary to check that bit[2] = 0 at 0x1n88, otherwise the writing process will not run properly!

Address	0x1n98, 0x8098
Mode	R/W
Attribute	I

Bit	Description
[15:0]	DC Offset value in DAC LSB unit.
[31:16]	Reserved.

Input Dynamic Range/Coarse Gain

The analog input stage of 781 series has 4 programmable gains. This register modifies the analog gains of channel n and therefore its input dynamics.
In case of 782 series, together with the hardware jumper that allows the user to select gain = x0.2 and x1, it is possible to get 4 programmable gains.
NOTE: 724 series has a fixed gain and this register is not used.

Address	0x1nB4, 0x80B4
Mode	W
Attribute	I

Bit	Description
[3:0]	Select the channel input range for x781 series. Options are: 0x5: 0.3 Vpp; 0x6: 1.0 Vpp; 0x9: 3.0 Vpp; 0xA: 10 Vpp.
[31:4]	Reserved

Board Configuration

This register contains general settings for the board configuration.

Address	0x8000, 0x8004 (BitSet), 0x8008 (BitClear)
Mode	R/W
Attribute	C

Bit	Description
[0]	Reserved: must be 0.
[1]	Reserved: must be 0
[2]	Trigger Propagation: enables the propagation of the individual trigger from mother board individual trigger logic to the mezzanine. This is required in case of coincidence trigger mode
[3]	Reserved: must be 0
[4]	Reserved: must be 1.
[7:5]	Reserved: must be 0
[8]	Individual trigger: must be 1
[9]	Reserved: must be 0
[10]	Reserved: must be 0
[11]	Dual Trace: in oscilloscope or mixed mode, it is possible to plot two different waveforms. When the dual trace is enabled, the samples of the two signals are interleaved, thus each waveform is recorded at half of the ADC frequency. The two analog probes can be selected from bits[13:12] and bits[15:14] respectively.
[13:12]	Analog Probe 1: Selects which signal is associated to the Analog trace 1 in the readout data. Options are: 00: Input; 01: RC-CR (input 1st derivative); 10: RC-CR2 (input 2nd derivative); 11: Trapezoid (output of the trapezoid filter).
[15:14]	Analog Probe 2: Selects which signal is associated to the Analog trace 2 in the readout data. Options are: 00: Input; 01: Threshold, which is referred to the RC-CR2 signal; 10: Trapezoid - Baseline; 11: Baseline (of the trapezoid).
[16]	Waveform Recording: enables the data recording of the waveform. The user must define the number of samples to be saved in the Record Length (register 0x1n20). According to the Analog Probe option one or two waveforms are saved. Options are: 0: disabled; 1: enabled.
[17]	Energy Mode: When enabled, the height of the trapezoid (which corresponds to the peak amplitude of the pulses) is saved into the event data (last word of the event). Options are: 0: Energy Mode disabled. 1: Energy Mode enabled.
[18]	Time Stamp Recording: When enabled, the time stamp of the event (which corresponds to the zero crossing in the timing filter) is saved into the event data (first word of the event). 0: Time Stamp recording disabled. 1: Time Stamp recording enabled.
[19]	Reserved: must be 0

[23:20]	Digital Virtual Probe 1: when the mixed (or oscilloscope) mode is enabled, the following digital virtual probes can be selected. Check the User Manual for further details. 0000: shows the RT Discrimination Width; 0001: ”Armed”, digital input showing where the RC-CR2 crosses the Threshold; 0010: ”Peak Run”, starts with the trigger and last for the whole event; 0011: ”Peak Abort”, corresponds to the time interval when the energy calculation is disabled due to the pile-up event; 0100: ”Peaking”, shows where the energy is calculated; 0101: ”Trg Validation Win”, digital input showing the trigger validation acceptance window TVAW; 0110: ”BSL Holdoff”, shows the baseline hold-off parameter; 0111: ”TRG Holdoff”, shows the trigger hold-off parameter; 1000: ”Trg Validation”, shows the trigger validation signal TRG_VAL ; 1001: ”Acq Veto”, this is 1 when either the input signal is saturated or the memory board is full.
[24]	Enable the FORMAT Word in the aggregate data. It must be 1.
[31:25]	Reserved

Aggregate Organization

The internal memory of the digitizer can be divided into a programmable number of aggregates, where each aggregate contains a specific number of events. This register defines how many aggregates can be contained in the memory. Note: this register must not be modified while the acquisition is running.

Address	0x800C
Mode	R/W
Attribute	C

Bit	Description
[3:0]	Aggregate Organization Nb: the number of aggregates is equal to N_aggr = 2^{Nb}. The corresponding values of Nb and N_aggr are: Nb: N_aggr 0x0 - 0x1: Not used 0x2 : 4 0x3 : 8 0x4 : 16 0x5 : 32 0x6 : 64 0x7 : 128 0x8 : 256 0x9 : 512 0xA : 1024
[31:4]	Reserved: must be 0

Record Length

Sets the record length for the waveform acquisition

Address	0x8020
Mode	R/W
Attribute	C

Bit	Description
[15:0]	Number of samples in the waveform according to the formula Ns = N * 2, where Ns is the record length and N is the register value. For example, write N = 10 to acquire 20 samples. Each sample corresponds to 10 ns.
[31:16]	Reserved

Acquisition Control

This register manages the acquisition settings.

Address	0x8100
Mode	R/W
Attribute	C

Bit	Description
[1:0]	Start/Stop Mode Selection (default value is 00). Options are: 00 = SW CONTROLLED. Start/stop of the run takes place on software command by setting/resetting bit[2] of this register; 01 = S-IN/GPI CONTROLLED (S-IN for VME, GPI for Desktop/NIM). If the acquisition is armed (i.e. bit[2] = 1), then the acquisition starts when S-IN/GPI is asserted and stops when S-IN/GPI returns inactive. If bit[2] = 0, the acquisition is always off; 10 = FIRST TRIGGER CONTROLLED. If the acquisition is armed (i.e. bit[2] = 1), then the run starts on the first trigger pulse (rising edge on TRG-IN); this pulse is not used as input trigger, while actual triggers start from the second pulse. The stop of Run must be SW controlled (i.e. bit[2] = 0); 11 = LVDS CONTROLLED (VME only). It is like option 01 but using LVDS (RUN) instead of S-IN. The LVDS can be set using registers 0x811C and 0x81A0.
[2]	Acquisition Start/Arm (default value is 0). When bits[1:0] = 00, this bit acts as a Run Start/Stop. When bits[1:0] = 01, 10, 11, this bit arms the acquisition and the actual Start/Stop is controlled by an external signal. Options are: 0 = Acquisition STOP (if bits[1:0]=00); Acquisition DISARMED (others); 1 = Acquisition RUN (if bits[1:0]=00); Acquisition ARMED (others).
[3]	Reserved.
[5:4]	Reserved
[6]	PLL Reference Clock Source (Desktop/NIM only). Default value is 0. Options are: 0 = internal oscillator (50 MHz); 1 = external clock from front panel CLK-IN connector. NOTE: this bit is reserved in case of VME boards.
[7]	Reserved.
[8]	LVDS I/O Busy Enable (VME only). Default value is 0. The LVDS I/Os can be programmed to accept a Busy signal as input, or to propagate it as output. Options are: 0 = disabled; 1 = enabled. NOTE: this bit is supported only by VME boards and meaningful only if the LVDS new features are enabled (bit[8]=1 of register 0x811C). Register 0x81A0 should also be configured for nBusy/nVeto.
[9]	LVDS I/O Veto Enable (VME only). Default value is 0. The LVDS I/Os can be programmed to accept a Veto signal as input, or to transfer it as output. Options are: 0 = disabled (default); 1 = enabled. NOTE: this bit is supported only by VME boards and meaningful only if the LVDS new features are enabled (bit[8]=1 of register 0x811C). Register 0x81A0 should also be configured for nBusy/nVeto.
[10]	Reserved.

[11]	LVDS I/O RunIn Enable Mode (VME only). Default value is 0. The LVDS I/Os can be programmed to accept a RunIn signal as input, or to transfer it as output. Options are: 0 = run on RunIn level (default), start and stop acquisition take place upon the signal level (RunIn is active low); 1 = start acquisition on RunIn rising edge (stop is not controlled). NOTE: this bit is supported only by VME boards and meaningful only if the LVDS new features are enabled (bit[8]=1 of register 0x811C). Register 0x81A0 must also be configured for nBusy/nVeto. NOTE: This register is valid from ROC FPGA fw revision 4.16 on.
[12]	VetoIn as veto for TRG-OUT (VME boards only). When the LVDS VetoIn signal is enabled (bit[9] = 1 in the 0x8100 register), this bit permits to use VetoIn to inhibit the triggers on TRG-OUT connector. The duration of the veto signal on TRG- OUT can be optionally extended by a time value set in the 0x81C4 register. Such function is useful in particular cases of synchronization of a multi-board system. Options are: 0 = VetoIn not used (default) 1 = VetoIn used for TRG-OUT inhibit NOTE: this bit is reserved in case of Desktop and NIM digitizers or ROC FPGA firmware rel. <= 4.16 .
[31:13]	Reserved.

Acquisition Status

This register monitors a set of conditions related to the acquisition status.

Address	0x8104
Mode	R
Attribute	C

Bit	Description
[1:0]	Reserved.
[2]	Acquisition Status. It reflects the status of the acquisition and drivers the front panel 'RUN' LED. Options are: 0 = acquisition is stopped ('RUN' is off); 1 = acquisition is running ('RUN' lits).
[3]	Event Ready. Indicates if any events are available for readout. Options are: 0 = no event is available for readout; 1 = at least one event is available for readout. NOTE: the status of this bit must be considered when managing the readout from the digitizer.
[4]	Event Full. Indicates if at least one channel has reached the FULL condition. Options are: 0 = no channel has reached the FULL condition; 1 = the maximum number of events to be read is reached.
[5]	Clock Source. Indicates the clock source status. Options are: 0 = internal (PLL uses the internal 50 MHz oscillator as reference); 1 = external (PLL uses the external clock on CLK-IN connector as reference).
[6]	Reserved.
[7]	PLL Unlock Detect. This bit flags a PLL unlock condition. Options are: 0 = PLL has had an unlock condition since the last register read access; 1 = PLL has not had any unlock condition since the last register read access. NOTE: flag can be restored to 1 via read access to register 0xEF04.
[8]	Board Ready. This flag indicates if the board is ready for acquisition (PLL and ADCs are correctly synchronized). Options are: 0 = board is not ready to start the acquisition; 1 = board is ready to start the acquisition. NOTE: this bit should be checked after software reset to ensure that the board will enter immediately in run mode after the RUN mode setting; otherwise, a latency between RUN mode setting and Acquisition start might occur.
[14:9]	Reserved.
[15]	S-IN (VME boards) or GPI (DT/NIM boards) Status. Reads the current logical level on S-IN (GPI) front panel connector.
[16]	TRG-IN Status. Reads the current logical level on TRG-IN front panel connector.
[31:17]	Reserved.

Software Trigger

Writing this register causes a software trigger generation which is propagated to all the enabled channels of the board.

Address	0x8108
Mode	W
Attribute	C

Bit	Description
[31:0]	Write whatever value to generate a software trigger.

Global Trigger Mask

This register sets which signal can contribute to the global trigger generation.

Address	0x810C
Mode	R/W
Attribute	C

Bit	Description
[7:0]	Bit n corresponds to the trigger request from channel n (n = 0,...,3 for DT, and NIM boards; n = 0,...,7 for VME boards) that participates to the global trigger generation. Options are: 0 = Trigger request does not participate to the global trigger generation; 1 = Trigger request participates to the global trigger generation. NOTE: in case of DT and NIM boards bits[7:4] are reserved.
[19:8]	Reserved.
[23:20]	Majority Coincidence Window. Sets the time window (10 ns steps) for the majority coincidence. Majority level must be set different from 0 through bits[26:24].
[26:24]	Majority Level. Sets the majority level for the global trigger generation. For a level m, the trigger fires when at least m+1 of the enabled trigger requests (bits[7:0] or [3:0]) are over-threshold inside the majority coincidence window (bits[23:20]). NOTE: The majority level must be smaller than the number of channel enabled via bits[7:0] mask (or [3:0]).
[28:27]	Reserved.
[29]	LVDS Trigger (VME boards only). When enabled, the trigger from LVDS I/O participates to the global trigger generation (in logic OR). Options are: 0 = disabled; 1 = enabled.
[30]	External Trigger (default value is 1). When enabled, the external trigger on TRG-IN participates to the global trigger generation in logic OR with the other enabled signals. Options are: 0 = disabled; 1 = enabled.
[31]	Software Trigger (default value is 1). When enabled, the software trigger participates to the global trigger signal generation in logic OR with the other enabled signals. Options are: 0 = disabled; 1 = enabled.

Front Panel TRG-OUT (GPO) Enable Mask

This register sets which signal can contribute to generate the signal on the front panel TRG-OUT LEMO connector (GPO in case of DT and NIM boards).

Address	0x8110
Mode	R/W
Attribute	C

Bit	Description
[7:0]	Bit n corresponds to the trigger request from channel n (n=0,...,3 in case of DT and NIM boards; n = 0,..., 7 in case of VME boards) that participates to the TRG-OUT (GPO) signal. Options are: 0 = Trigger request does not participate to the TRG-OUT (GPO) signal; 1 = Trigger request participates to the TRG-OUT (GPO) signal. NOTE: In case of DT and NIM boards bis[7:4] are reserved.
[9:8]	TRG-OUT (GPO) Generation Logic. The enabled trigger requests (bits [7:0] or [3:0]) can be combined to generate the TRG-OUT (GPO) signal. Options are: 00 = OR; 01 = AND; 10 = Majority; 11 = Reserved.
[12:10]	Majority Level. Sets the majority level for the TRG-OUT (GPO) signal generation. Allowed level values are between 0 and 7 for VME boards, and between 0 and 3 for DT and NIM boards. For a level m, the trigger fires when at least m+1 of the trigger requests are generated by the enabled channels (bits [7:0] or [3:0]) .
[28:13]	Reserved.
[29]	LVDS Trigger Enable (VME boards only). If the LVDS I/Os are programmed as outputs, they can participate in the TRG-OUT (GPO) signal generation. They are in logic OR with the other enabled signals. Options are: 0 = disabled; 1 = enabled.
[30]	External Trigger (default value is 1). When enabled, the external trigger on TRG-IN can participate in the TRG-OUT (GPO) signal generation in logic OR with the other enabled signals. Options are: 0 = disabled; 1 = enabled.
[31]	Software Trigger (default value is 1). When enabled, the software trigger can participate in the TRG-OUT (GPO) signal generation in logic OR with the other enabled signals. Options are: 0 = disabled; 1 = enabled.

LVDS I/O Data

This register allows to read out the logic level of the LVDS I/Os if the LVDS pins are configured as outputs, and to set the logic level of the LVDS I/Os if the pins are configured as inputs.
NOTE: this register is supported by VME boards only.

Address	0x8118
Mode	R/W
Attribute	C

Bit	Description
[15:0]	LVDS I/O Data (VME boards only). It is the logic level of the corresponding nth LVDS I/O to read out or write, according to its direction (0x811C, bit[5:2]). A write operation sets the corresponding pin logic state if configured as output, while a read operation returns the logic state of the corresponding pin if configured as input. In case of Old LVDS I/O Features (0x811C, bit[8] = 0), the general purpose I/O option must be set (0x811C, bit[7:6] = 00). In case of New LVDS I/O Features (0x811C, bit[8] = 1), REGISTER mode must be set (0000 option in the 0x81A0 register).
[31:16]	Reserved.

Front Panel I/O Control

This register manages the front panel I/O connectors. Default value is 0x000000.

Address	0x811C
Mode	R/W
Attribute	C

Bit	Description
[0]	LEMO I/Os Electrical Level. This bit sets the electrical level of the front panel LEMO connectors: TRG-IN, TRG-OUT (GPO in case of DT and NIM boards), S-IN (GPI in case of DT and NIM boards). Options are: 0 = NIM I/O levels; 1 = TTL I/O levels.
[1]	TRG-OUT Enable (VME boards only). Enables the TRG-OUT LEMO front panel connector. Options are: 0 = enabled (default); 1 = high impedance. NOTE: this bit is reserved in case of DT and NIM boards.
[2]	LVDS I/O [3:0] Direction (VME boards only). Sets the direction of the signals on the first 4-pin group of the LVDS I/O connector. Options are: 0 = input; 1 = output. NOTE: this bit is reserved in case of DT and NIM boards.
[3]	LVDS I/O [7:4] Direction (VME boards only). Sets the direction of the second 4-pin group of the LVDS I/O connector. Options are: 0 = input; 1 = output. NOTE: this bit is reserved in case of DT and NIM boards.
[4]	LVDS I/O [11:8] Direction (VME boards only). Sets the direction of the third 4- pin group of the LVDS I/O connector. Options are: 0 = input; 1 = output. NOTE: this bit is reserved in case of DT and NIM boards.
[5]	LVDS I/O [15:12] Direction (VME boards only). Sets the direction of the fourth 4-pin group of the LVDS I/O connector. Options are: 0 = input; 1 = output. NOTE: this bit is reserved in case of DT and NIM boards.
[7:6]	LVDS I/O Signal Configuration (VME boards only). Valid for old LVDS I/O features only (0x811C, bit[8] = 0). Options are: 00 = general purpose I/Os: LVDS I/Os work as register; I/O direction is configured through bit[5:2]; the logic level is read out or set in the 0x8118 register. 01 = programmed I/Os: direction and function of the LVDS signals are fixed (see the tabled signal pinout in the digitizer User Manual). 10 = pattern mode: LVDS signals are inputs and their value is written into the header PATTERN field of the event (see the digitizer User Manual); 11 = reserved. NOTE: these bits are reserved in case of DT and NIM boards.

[8]	LVDS I/O New Features Selection (VME boards only). Options are: 0 = LVDS old features; 1 = LVDS new features. The new features options can be configured through register 0x81A0. Please, refer to the User Manual for all details. NOTE: LVDS I/O New Features option is valid from motherboard firmware revision 3.8 on. NOTE: this bit is reserved in case of DT and NIM boards.
[9]	LVDS I/Os Pattern Latch Mode (VME boards only). Options are: 0 = Pattern (i.e. 16-pin LVDS status) is latched when the (internal) global trigger is sent to channels, in consequence of an external trigger. It accounts for post-trigger settings and input latching delays; 1 = Pattern (i.e. 16-pin LVDS status) is latched when an external trigger arrives. NOTE: this bit is reserved in case of DT and NIM boards.
[10]	TRG-IN control. The board trigger logic can be synchronized either with the edge of the TRG-IN signal, or with its whole duration. Note: this bit must be used in conjunction with bit[11] = 0. Options are: 0 = trigger is synchronized with the edge of the TRG-IN signal; 1 = trigger is synchronized with the whole duration of the TRG-IN signal.
[11]	TRG-IN to Mezzanines (channels). Options are: 0 = TRG-IN signal is processed by the motherboard and sent to mezzanine (default). The trigger logic is then synchronized with TRG-IN; 1 = TRG-IN is directly sent to the mezzanines with no mother board processing nor delay. This option can be useful when TRG-IN is used to veto the acquisition. NOTE: if this bit is set to 1, then bit[10] is ignored.
[13:12]	Reserved.
[14]	Force TRG-OUT (GPO). This bit can force TRG-OUT (GPO in case of DT and NIM boards) test logical level if bit[15] = 1. Options are: 0 = Force TRG-OUT (GPO) to 0; 1 = Force TRG-OUT (GPO) to 1.
[15]	TRG-OUT (GPO) Mode. Options are: 0 = TRG-OUT (GPO) is an internal signal (according to bits[17:16]); 1= TRG-OUT (GPO) is a test logic level set via bit[14].
[17:16]	TRG-OUT (GPO) Mode Selection. Options are: 00 = Trigger: TRG-OUT/GPO propagates the internal trigger sources according to register 0x8110; 01 = Motherboard Probes: TRG-OUT/GPO is used to propagate signals of the motherboards according to bits[19:18]; 10 = Channel Probes: TRG-OUT/GPO is used to propagate signals of the mezzanines (Channel Signal Virtual Probe); 11 = S-IN (GPI) propagation.
[19:18]	Motherboard Virtual Probe Selection (to be propagated on TRG- OUT/GPO). Options are: 00 = RUN/delayedRUN: this is the RUN in case of ROC FPGA firmware rel. less than 4.12. This probe can be selected according to bit[20]. 01 = CLKOUT: this clock is synchronous with the sampling clock of the ADC and this option can be used to align the phase of the clocks in different boards; 10 = CLK Phase; 11 = BUSY/UNLOCK: this is the board BUSY in case of ROC FPGA firmware rel. 4.5 or lower. This probe can be selected according to bit[20].
[22:21]	Pattern Configuration. Configures the information given by the 16-bit PATTERN field in the header of the event format (VME only). Option are: 00 = PATTERN: 16-bit pattern latched on the 16 LVDS signals as one trigger arrives (default); Other options are reserved.

[31:23]	Reserved.

Channel Enable Mask

This register enables/disables selected channels to participate in the event readout. Disabled channels are not operative.
WARNING: this register must not be modified while the acquisition is running.

Address	0x8120
Mode	R/W
Attribute	C

Bit	Description
[7:0]	Channel Enable Mask. Default value is 0xFF. Bit n can enable/disable selected channel n to participate to the event readout. Options are: 0: disabled; 1: enabled. NOTE: bits[7:4] are reserved in case of DT and NIM boards.
[31:8]	Reserved.

ROC FPGA Firmware Revision

This register contains the motherboard FPGA (ROC) firmware revision information.
The complete format is:
Firmware Revision = X.Y (16 lower bits)
Firmware Revision Date = Y/M/DD (16 higher bits)
EXAMPLE 1: revision 3.08, November 12th, 2007 is 0x7B120308.
EXAMPLE 2: revision 4.09, March 7th, 2016 is 0x03070409.
NOTE: the nibble code for the year makes this information to roll over each 16 years.

Address	0x8124
Mode	R
Attribute	C

Bit	Description
[7:0]	ROC Firmware Minor Revision Number (Y).
[15:8]	ROC Firmware Major Revision Number (X).
[31:16]	ROC Firmware Revision Date (Y/M/DD).

Voltage Level Mode Configuration

When the Voltage Level Mode is enabled (bit[2:0] = 100 (bin) of register 0x8144), this register sets the DAC value to be provided on the front panel MON/Sigma output LEMO connector: 1 LSB = 0.244 mV, terminated on 50 Ohm.
NOTE: this register is supported by VME boards only.

Address	0x8138
Mode	R/W
Attribute	C

Bit	Description
[11:0]	DAC Voltage Setting (VME boards only). The corresponding output value is multiplied by 0.244 mV.
[31:12]	Reserved

Software Clock Sync

At power-on, a Sync command is issued by the firmware to the ADCs to synchronize all of them to the clock of the board. In the standard operating, this command is not required to be repeated by the user.
A write access to this register (any value) forces the PLL to re-align all the clock outputs with the reference clock.
EXAMPLE: in case of Daisy chain clock distribution among VME boards, during the initialization and configuration, the reference clocks along the Daisy chain can be unstable and a temporary loss of lock may occur in the PLLs; although the lock is automatically recovered once the reference clocks return stable, it is not guaranteed that the phase shift returns to a known state. This command allows the board to restore the correct phase shift between the CLK-IN and the internal clocks.
NOTE: this register is supported by VME boards only.
NOTE: the command must be issued starting from the first to the last board in the clock chain.

Address	0x813C
Mode	W
Attribute	C

Bit	Description
[31:0]	Write whatever value to generate a Sync command.

Board Info

This register contains the specific information of the board, such as the digitizer family, the channel memory size and the channel density.

Address	0x8140
Mode	R
Attribute	C

Bit	Description
[7:0]	Digitizer Family Code: 0x0: 724 digitizer family; 0xD: 781 MCA family.
[15:8]	Channel Memory Size Code. Options are: 1: each channel is equipped with 512 kS acquisition memory; 8: each channel is equipped with 4 MS acquisition memory. For 780 and 781 this is always 1.
[23:16]	Equipped Channels Number. Options are: 0x2 for DT and NIM 2-ch boards; 0x4 for DT and NIM 4-ch boards; 0x8 for VME boards.
[31:24]	Reserved.

Analog Monitor Mode

This register selects which output mode is provided on the MON/Sigma front panel LEMO connector.
NOTE: this register is supported by VME boards only.

Address	0x8144
Mode	R/W
Attribute	C

Bit	Description
[2:0]	Analog Monitor Mode (VME boards only). Options are: 000 = Trigger Majority mode; 001 = Test mode; 010 = reserved; 011 = Buffer Occupancy mode; 100 = Voltage Level mode; Others = reserved. Please, refer to the digitizer User Manual for a detailed description.
[31:3]	Reserved.

Event Size

This register contains the current available event size in 32-bit words. The value is updated after a complete readout of each event.

Address	0x814C
Mode	R
Attribute	C

Bit	Description
[31:0]	Event Size (32-bit words).

Time Bomb Downcounter

This is a down counter value. If the value is constant, the firmware license is enabled and the current firmware can be used without any time limitation. If the value decreases with time, the firmware will stop working (no possibility to enter RUN mode) after 30 minutes after module power-on. If the value is 0, the time bomb has expired, and module is not allowed to enter in RUN mode without power cycling the module.

Address	0x8158
Mode	R
Attribute	C

Bit	Description
[31:0]	Down counter value. If this value is constant the DPP firmware is licensed

Fan Speed Control

This register manages the on-board fan speed in order to guarantee an appropriate cooling according to the internal temperature variations.
NOTE: from revision 4 of the motherboard PCB (see register 0xF04C of the Configuration ROM), the automatic fan speed control has been implemented, and it is supported by ROC FPGA firmware revision greater than 4.4 (see register 0x8124).
Independently of the revision, the user can set the fan speed high by setting bit[3] = 1. Setting bit[3] = 0 will restore the automatic control for revision 4 or higher, or the low fan speed in case of revisions lower than 4.
NOTE: this register is supported by Desktop (DT) boards only.

Address	0x8168
Mode	R/W
Attribute	C

Bit	Description
[2:0]	Reserved: Must be 0.
[3]	Fan Speed Mode. Options are: 0 = slow speed or automatic speed tuning; 1 = high speed.
[5:4]	Reserved: Must be 1.
[31:6]	Reserved: Must be 0.

Run/Start/Stop Delay

When the start of Run is given synchronously to several boards connected in Daisy chain, it is necessary to compensate for the delay in the propagation of the Start (or Stop) signal through the chain. This register sets the delay between the arrival of the Start signal at the input of the board (either on S-IN/GPI or TRG- IN) and the actual start of Run. The delay is usually zero for the last board in the chain and rises going backwards along the chain.

Address	0x8170
Mode	R/W
Attribute	C

Bit	Description
[7:0]	Delay value in steps of 20 ns.
[31:8]	Reserved.

Board Failure Status

This register monitors a set of board errors. In case of a failure, bit[26] in the second word of the event format header is set to 1 during data readout (refer to the digitizer User Manual for event structure description). Reading at this register checks which kind of error occurred.
NOTE: in case of problems with the board, the user is recommended to contact CAEN for support.

Address	0x8178
Mode	R
Attribute	C

Bit	Description
[3:0]	Internal Communication Timeout. Options are: 0000 = no error; Others = Timeout Error occurred.
[4]	PLL Lock Loss. Options are: 0 = no error; 1 = PLL Lock Loss occurred.
[31:5]	Reserved.

Disable External Trigger

The External Trigger on TRG-IN connector can be disabled through this register. Any functionality related to TRG-IN is disabled as well.

Address	0x817C
Mode	R/W
Attribute	C

Bit	Description
[0]	Options are: 0: external trigger enabled; 1: external trigger disabled.
[31:1]	Reserved

Trigger Validation Mask

Sets the trigger validation logic

Address	0x8180+(4n), n=ch number
Mode	R/W
Attribute	I

Bit	Description
[7:0]	Bit n corresponds to the trigger request from channel n (n=0,...,3 in case of DT and NIM boards; n = 0,..., 7 in case of VME boards) which participates to the generation of the trigger validation signal. Options are: 0 = Trigger request does not participate to the trigger validation signal; 1 = Trigger request participates to the trigger validation signal. NOTE: In case of DT and NIM boards bis[7:4] are reserved.
[9:8]	Operation Mask. Sets the logic operation among the enabled trigger request signals. Options are: 00: OR; 01: AND; 10: majority; 11: reserved.
[12:10]	Sets the majority level. For a level m the majority fires when at least m+1 trigger requests are high.
[27:13]	Reserved
[28]	LVDS I/O Global Trigger: when enabled (VME form factor only) the global trigger from LVDS I/O participates to the trigger validation generation (in logic OR). Options are: 0: disabled; 1: enabled.
[29]	LVDS I/O Individual Trigger: when enabled (VME form factor only) the individual trigger from LVDS I/O participates to the trigger validation generation (in logic OR). Options are: 0: disabled; 1: enabled.
[30]	External Trigger: when enabled the external trigger from TRG-IN front panel connector participates to the trigger validation generation (in logic OR). Options are: 0: disabled; 1: enabled.
[31]	Software Trigger: when enabled the software trigger participates to the trigger validation generation (in logic OR). Options are: 0: disabled; 1: enabled.

Front Panel LVDS I/O New Features

If the LVDS I/O new features are enabled (bit[8] = 1 of 0x811C), this register programs the functions of the front panel LVDS I/O 16-pin connector. It is possible to configure the LVDS I/O pins by group of four (4).
Options are:
1) 0000 = REGISTER, where the four LVDS I/O pins act as register (read/write according to the configured input/output option);
2) 0001 = TRIGGER, where each group of four LVDS I/O pins can be configured to receive an input trigger for each channel (DPP Firmware only), or to propagate out the trigger request;
3) 0010 = nBUSY/nVETO, where each group of four LVDS I/O pins can be configured as inputs (0 = nBusyIn, 1 = nVetoIn, 2 = nTrigger In, 3 = nRun In) or as outputs (0 = nBusy, 1 = nVeto, 2 = nTrigger Out, 3 = nRun);
4) 0011 = LEGACY, that is to say according to the old LVDS I/O configuration (i.e. ROC FPGA firmware revisions lower than 3.8), where the LVDS can be configured as 0 = nclear TTT, and 1 = 2 = 3 = reserved in case of input LVDS setting, while they can be configured as 0 = Busy, 1 = Data ready, 2 = Trigger, 3 = Run in case of output LVDS setting.
Please refer to the Front Panel LVDS I/Os section of the digitizer User Manual for detailed description.
NOTE: LVDS I/O new features are supported from ROC FPGA firmware revision 3.8 on.
NOTE: this register is supported by VME boards only.

Address	0x81A0
Mode	R/W
Attribute	C

Bit	Description
[3:0]	LVDS I/O pins[3:0] Configuration.
[7:4]	LVDS I/O pins[7:4] Configuration.
[11:8]	LVDS I/O pins[11:8] Configuration
[15:12]	LVDS I/O pins[15:12] Configuration.
[16]	This bit permits selecting whether the nTrigger signal, when configured as output (in nBusy/nVeto LVDS I/O mode), is a copy of the signal sent on the TRG- OUT connector or a copy of the acquisition common trigger. Options are: 0 = nTrigger output is a copy of TRG-OUT signal 1 = nTrigger output is a copy of the acquisition common trigger. NOTE: this bit is reserved for ROC FPGA firmware revisions less than 4.9.
[31:17]	Reserved.

Buffer Occupancy Gain

If the Buffer Occupancy Mode is selected (bit[2:0] = 011 of 0x8144), the LEMO MON/Sigma output connector provides a voltage level whose amplitude increases in fixed steps exactly with the number of events in the event buffer. Each step of the output voltage level is 0.976 mV. A gain can be applied to the step by this register. Allowed values are in the range [0:A]. The default value, 0, means no gain applied while writing 0xn means that the fixed step is $0.976*2^n$ mV.
NOTE: this register is supported from ROC FPGA firmware revision 4.9 on.
NOTE: this register is supported by VME boards only.

Address	0x81B4
Mode	R/W
Attribute	C

Bit	Description
[3:0]	Buffer Occupancy Gain.
[31:4]	Reserved.

Readout Control

This register is mainly intended for VME boards, anyway some bits are applicable also for DT and NIM boards.

Address	0xEF00
Mode	R/W
Attribute	C

Bit	Description
[2:0]	VME Interrupt Level (VME boards only). Options are: 0 = VME interrupts are disabled; 1,..,7 = sets the VME interrupt level. NOTE: these bits are reserved in case of DT and NIM boards.
[3]	Optical Link Interrupt Enable. Options are: 0 = Optical Link interrupts are disabled; 1 = Optical Link interrupts are enabled.
[4]	VME Bus Error / Event Aligned Readout Enable (VME boards only). Options are: 0 = VME Bus Error / Event Aligned Readout disabled (the module sends a DTACK signal until the CPU inquires the module); 1 = VME Bus Error / Event Aligned Readout enabled (the module is enabled either to generate a Bus Error to finish a block transfer or during the empty buffer readout in D32). NOTE: this bit is reserved (must be 1) in case of DT and NIM boards.
[5]	VME Align64 Mode (VME boards only). Options are: 0 = 64-bit aligned readout mode disabled; 1 = 64-bit aligned readout mode enabled. NOTE: this bit is reserved (must be 0) in case of DT and NIM boards.
[6]	VME Base Address Relocation (VME boards only). Options are: 0 = Address Relocation disabled (VME Base Address is set by the on-board rotary switches); 1 = Address Relocation enabled (VME Base Address is set by register 0xEF0C). NOTE: this bit is reserved (must be 0) in case of DT and NIM boards.
[7]	Interrupt Release mode (VME boards only). Options are: 0 = Release On Register Access (RORA): this is the default mode, where interrupts are removed by disabling them either by setting VME Interrupt Level to 0 (VME Interrupts) or by setting Optical Link Interrupt Enable to 0; 1 = Release On Acknowledge (ROAK). Interrupts are automatically disabled at the end of a VME interrupt acknowledge cycle (INTACK cycle). NOTE: ROAK mode is supported only for VME interrupts. ROAK mode is not supported on interrupts generated over Optical Link. NOTE: this bit is reserved (must be 0) in case of DT and NIM boards.
[8]	Extended Block Transfer Enable (VME boards only). Selects the memory interval allocated for block transfers. Options are: 0 = Extended Block Transfer Space is disabled, and the block transfer region is a 4kB in the 0x0000 - 0x0FFC interval; 1 = Extended Block Transfer Space is enabled, and the block transfer is a 16 MB in the 0x00000000 - 0xFFFFFFFC interval. NOTE: in Extended mode, the board VME Base Address is only set via the on- board [31:28] rotary switches or bits[31:28] of register 0xEF10. NOTE: this register is reserved in case of DT and NIM boards.
[31:9]	Reserved.

Readout Status

This register contains information related to the readout.

Address	0xEF04
Mode	R
Attribute	C

Bit	Description
[0]	Event Ready. Indicates if there are events stored ready for readout. Options are: 0 = no data ready; 1 = event ready.
[1]	Reserved.
[2]	Bus Error (VME boards) / Slave-Terminated (DT/NIM boards) Flag. Options are: 0 = no Bus Error occurred (VME boards) or no terminated transfer (DT/NIM boards); 1 = a Bus Error occurred (VME boards) or one transfer has been terminated by the digitizer in consequence of an unsupported register access or block transfer prematurely terminated in event aligned readout (DT/NIM). NOTE: this bit is reset after register readout at 0xEF04.
[3]	VME FIFO Flag. Options are: 0 = VME FIFO not empty; 1 = VME FIFO is emplty.
[31:4]	Reserved.

Board ID

The meaning of this register depends on which VME crate it is inserted in.
In case of VME64X crate versions, this register can be accessed in read mode only and it contains the GEO address of the module picked from the backplane connectors; when CBLT is performed, the GEO address will be contained in the Board ID field of the Event header (see the User Manual for further details).
In case of other crate versions, this register can be accessed both in read and write mode, and it allows to write the correct GEO address (default setting = 0) of the module before CBLT operation. GEO address will be contained in the Board ID field of the Event header (see the User Manual for further details).
NOTE: this register is supported by VME boards only.

Address	0xEF08
Mode	R/W
Attribute	C

Bit	Description
[4:0]	GEO Address (VME boards only).
[31:5]	Reserved.

MCST Base Address and Control

This register configures the board for the VME Multicast Cycles.
NOTE: this register is supported by VME boards only.

Address	0xEF0C
Mode	R/W
Attribute	C

Bit	Description
[7:0]	These bits contain the most significant bits of the MCST/CBLT address of the module set via VME, that is the address used in MCST/CBLT operations.
[9:8]	Board Position in Daisy chain. Options are: 00 = board disabled; 01 = last board; 10 = first board; 11 = intermediate board.
[31:10]	Reserved.

Relocation Address

If address relocation is enabled through register 0xEF00 (bit[6] = 1), this register sets the VME Base Address of the module.
NOTE: this register is supported by VME boards only.

Address	0xEF10
Mode	R/W
Attribute	C

Bit	Description
[15:0]	These bits contain the A31...A16 bits of the address of the module. If bit[6] = 1 of 0xEF00, they set the VME Base Address of the module.
[31:16]	Reserved.

Interrupt Status/ID

This register contains the STATUS/ID that the module places on the VME data bus during the Interrupt Acknowledge cycle.
NOTE: this register is supported by VME boards only.

Address	0xEF14
Mode	R/W
Attribute	C

Bit	Description
[31:0]	STATUS/ID (VME boards only).

Interrupt Event Number

This register sets the number of events that causes an interrupt request. If interrupts are enabled, the module generates a request whenever it has stored in memory a Number of Events > INTERRUPT EVENT NUMBER.

Address	0xEF18
Mode	R/W
Attribute	C

Bit	Description
[9:0]	INTERRUPT EVENT NUMBER.
[31:10]	Reserved.

Aggregate Number per BLT

This register sets the maximum number of complete aggregates which has to be transferred for each block transfer (via VME BLT/CBLT cycles or block readout through Optical Link).

Address	0xEF1C
Mode	R/W
Attribute	C

Bit	Description
[9:0]	Number of complete aggregates to be transferred for each block transfer (BLT).
[31:10]	Reserved.

Scratch

This register can be used to write/read words for test purposes.

Address	0xEF20
Mode	R/W
Attribute	C

Bit	Description
[31:0]	SCRATCH.

Software Reset

All the digitizer registers can be set back to their default values on software reset command by writing any value at this register, or by system reset from backplane in case of VME boards.

Address	0xEF24
Mode	W
Attribute	C

Bit	Description
[31:0]	Whatever value written at this location issues a software reset. All registers are set to their default values (actual settings are lost).

Software Clear

All the digitizer internal memories are cleared:
- automatically by the firmware at the start of each run;
- on software command by writing at this register;
- by hardware (VME boards only) through the LVDS interface properly configured.

A clear command does not change the registers actual value, except for resetting the following registers:
- Event Stored;
- Event Size;
- Channel / Group n Buffer Occupancy.

This register resets also the trigger time stamp.

Address	0xEF28
Mode	W
Attribute	C

Bit	Description
[31:0]	Whatever value written at this location generates a software clear.

Configuration Reload

A write access of any value at this location causes a software reset, a reload of Configuration ROM parameters and a PLL reconfiguration.

Address	0xEF34
Mode	W
Attribute	C

Bit	Description
[31:0]	Write whatever value to perform a software reset, a reload of Configuration ROM parameters and a PLL reconfiguration.

Configuration ROM Checksum

This register contains information on 8-bit checksum of Configuration ROM space.

Address	0xF000
Mode	R
Attribute	C

Bit	Description
[7:0]	Checksum.
[31:8]	Reserved.

Configuration ROM Checksum Length BYTE 2

This register contains information on the third byte of the 3-byte checksum length (i.e. the number of bytes in Configuration ROM to checksum).

Address	0xF004
Mode	R
Attribute	C

Bit	Description
[7:0]	Checksum Length: bits[23:16].
[31:8]	Reserved.

Configuration ROM Checksum Length BYTE 1

This register contains information on the second byte of the 3-byte checksum length (i.e. the number of bytes in Configuration ROM to checksum).

Address	0xF008
Mode	R
Attribute	C

Bit	Description
[7:0]	Checksum Length: bits[15:8].
[31:8]	Reserved.

Configuration ROM Checksum Length BYTE 0

This register contains information on the first byte of the 3-byte checksum length (i.e. the number of bytes in Configuration ROM to checksum).

Address	0xF00C
Mode	R
Attribute	C

Bit	Description
[7:0]	Checksum Length: bits[7:0].
[31:8]	Reserved.

Configuration ROM Constant BYTE 2

This register contains the third byte of the 3-byte constant.

Address	0xF010
Mode	R
Attribute	C

Bit	Description
[7:0]	Constant: bits[23:16] = 0x83.
[31:8]	Reserved.

Configuration ROM Constant BYTE 1

This register contains the second byte of the 3-byte constant.

Address	0xF014
Mode	R
Attribute	C

Bit	Description
[7:0]	Constant: bits[15:8] = 0x84.
[31:8]	Reserved.

Configuration ROM Constant BYTE 0

This register contains the first byte of the 3-byte constant.

Address	0xF018
Mode	R
Attribute	C

Bit	Description
[7:0]	Constant: bits[7:0] = 0x01.
[31:8]	Reserved.

Configuration ROM C Code

This register contains the ASCII C character code (identifies this as CR space).

Address	0xF01C
Mode	R
Attribute	C

Bit	Description
[7:0]	ASCII 'C' Character Code.
[31:8]	Reserved.

Configuration ROM R Code

This register contains the ASCII R character code (identifies this as CR space).

Address	0xF020
Mode	R
Attribute	C

Bit	Description
[7:0]	ASCII 'R' Character Code.
[31:8]	Reserved.

Configuration ROM IEEE OUI BYTE 2

This register contains information on the third byte of the 3-byte IEEE Organizationally Unique Identifier (OUI).

Address	0xF024
Mode	R
Attribute	C

Bit	Description
[7:0]	IEEE OUI: bits[23:16].
[31:8]	Reserved.

Configuration ROM IEEE OUI BYTE 1

This register contains information on the second byte of the 3-byte IEEE Organizationally Unique Identifier (OUI).

Address	0xF028
Mode	R
Attribute	C

Bit	Description
[7:0]	IEEE OUI: bits[15:8].
[31:8]	Reserved.

Configuration ROM IEEE OUI BYTE 0

This register contains information on the first byte of the 3-byte IEEE Organizationally Unique Identifier (OUI).

Address	0xF02C
Mode	R
Attribute	C

Bit	Description
[7:0]	IEEE OUI: bits[7:0].
[31:8]	Reserved.

Configuration ROM Board Version

This register contains the board version information.

Address	0xF030
Mode	R
Attribute	C

Bit	Description
[7:0]	Board Version Code. Options for 724 VME form factor are: V1724, VX1724: 0x11 V1724B, VX1724B: 0x40 V1724C, VX1724C: 0x12 V1724D, VX1724D: 0x41 V1724E, VX1724E: 0x42 V1724F, VX1724F: 0x43 V1724G: 0x44. Options for 724 Desktop/NIM form factor are: DT5724/N6724: 0x11 DT5724A/N6724A: 0x13 DT5724D: 0x41 DT5724E: 0x42 DT5724B/N6724B: 0x45 DT5724C/N6724C: 0x46 DT5724F/N6724F: 0x47 DT5724G/N6724G: 0x48. Options for 781 MCA family are: DT5781/N6781: 0xE0; DT5781A/N6781A: 0xE1.
[31:8]	Reserved.

Configuration ROM Board Form Factor

This register contains the information of the board form factor.

Address	0xF034
Mode	R
Attribute	C

Bit	Description
[7:0]	Board Form Factor CAEN Code. Options are: 0x00 = VME64; 0x01 = VME64X; 0x02 = Desktop; 0x03 = NIM.
[31:8]	Reserved.

Configuration ROM Board ID BYTE 1

This register contains the MSB of the 2-byte board identifier.

Address	0xF038
Mode	R
Attribute	C

Bit	Description
[7:0]	Board Number ID: bits[15:8].
[31:8]	Reserved.

Configuration ROM Board ID BYTE 0

This register contains the LSB information of the 2-byte board identifier.

Address	0xF03C
Mode	R
Attribute	C

Bit	Description
[7:0]	Board Number ID: bits[7:0].
[31:8]	Reserved.

Configuration ROM PCB Revision BYTE 3

This register contains information on the fourth byte of the 4-byte hardware revision.

Address	0xF040
Mode	R
Attribute	C

Bit	Description
[7:0]	PCB Revision: bits[31:24].
[31:8]	Reserved.

Configuration ROM PCB Revision BYTE 2

This register contains information on the third byte of the 4-byte hardware revision.

Address	0xF044
Mode	R
Attribute	C

Bit	Description
[7:0]	PCB Revision: bits[23:16].
[31:8]	Reserved.

Configuration ROM PCB Revision BYTE 1

This register contains information on the second byte of the 4-byte hardware revision.

Address	0xF048
Mode	R
Attribute	C

Bit	Description
[7:0]	PCB Revision: bits[15:8].
[31:8]	Reserved.

Configuration ROM PCB Revision BYTE 0

This register contains information on the first byte of the 4-byte hardware revision.

Address	0xF04C
Mode	R
Attribute	C

Bit	Description
[7:0]	PCB Revision: bits[7:0].
[31:8]	Reserved.

Configuration ROM FLASH Type

This register contains information on which FLASH type (storing the FPGA firmware) is present on-board.

Address	0xF050
Mode	R
Attribute	C

Bit	Description
[7:0]	FLASH Type. Options are: 0x00 = 8 Mb FLASH; 0x01 = 32 Mb FLASH.
[31:8]	Reserved.

Configuration ROM Board Serial Number BYTE 1

This register contains information on the MSB of the board serial number.

Address	0xF080
Mode	R
Attribute	C

Bit	Description
[7:0]	Board Serial Number: bits[15:8].
[31:8]	Reserved.

Configuration ROM Board Serial Number BYTE 0

This register contains information on the LSB of the board serial number.

Address	0xF084
Mode	R
Attribute	C

Bit	Description
[7:0]	Board Serial Number: bits[7:0].
[31:8]	Reserved.

Configuration ROM VCXO Type

This register contains information on which type of VCXO is present on-board.

Address	0xF088
Mode	R
Attribute	C

Bit	Description
[31:0]	VCXO Type Code. Options for VME Digitizers are: 0 = AD9510 with 1 GHz; 1 = AD9510 with 500 MHz (not programmable); 2 = AD9510 with 500 MHz (programmable). Options for Desktop/NIM Digitizers are: Reserved (value = 0).

2 DPP-PHA Memory Organization

Memory Organization

Each channel has a fixed amount of RAM memory to save the events. The memory is divided into a programmable number of buffers (also called "aggregates"), where each buffer contains a programmable number of events. The event format is programmable as well. The board registers involved are the following:

- "Aggregate Organization" (*Nb*), address 0x800C: defines how many aggregates can be contained in the memory ($n_{aggr} = 2^{Nb}$).
- "Number of Events per Aggregate" (*Ne*), address 0x1n34: defines the number of events contained in one aggregate. The maximum allowed value is 1023.
- "Record Length" (*Ns*), address 0x8020: defines the number of samples for the waveform acquisition, when enabled (*rec_len = Ns * 2* for 724, 781 and 782 series).
- "Board Configuration", address 0x8000: defines the acquisition mode and the event data format.

Note: Those who need to write their own DAQ software, must take care to choose the Ne value according to the event and buffer size, as explained in the examples in the next section.

Information about the use of these parameters in the CAENDigitizer library can be found in **[RD1]**. According to the programmed event format, an event can contain a certain number of samples of the waveform, one trigger time stamp, the energy, and the Extras information.

724 and 781 series

The following section describes the structure of the memory organization of 724, 781, and 782 series. The physical memory of a board is made of memory locations, each of 32-bit (4B) In terms of location occupancy:

FORMAT + SIZE = 1 location.

Trigger Time Stamp = 1 location;

Waveform (if enabled) = 1 location every 2 samples;

Energy/EXTRAS = 1 location;

Therefore, the events size can be easily calculated. Fig. **2.1** shows how the data are saved into the physical memory.

Note: Fig. **2.1** refers to the event storage into the physical memory of the board. Data are then organized in a different format for the event readout. The event readout format is shown in the **Event Data Format** section.

As previously said, the "Record Length" and the "Board Configuration" settings determine the event size; the user must calculate the number of event per buffer (*Ne*) and the number of buffers (2^{Nb}) accordingly. When the board runs in List Mode, the event memory contains only three locations, one for the FORMAT+SIZE, on for the Trigger Time Tag, and one for the Energy and EXTRAS. Therefore it is very small and it is suggested to use a big value for Ne to make the buffer size as big as at least a few KB. Small buffer size results in low readout bandwidth. The only drawback of setting high values for *Ne* is that the events are not available for the readout until the buffer is complete; hence there is some latency between the arrival of a trigger and the readout of the relevant event data. Conversely, when the board runs in Oscilloscope Mode, especially when the record length is large, it is more convenient to keep *Ne* low (typically 1).

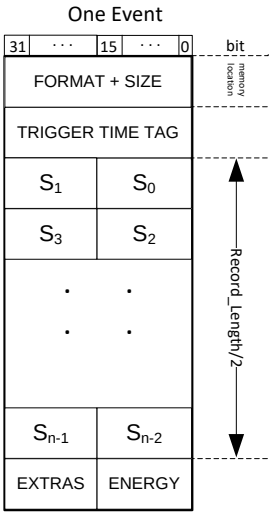

Fig. 2.1: Data organization into the Internal Memory of 724 and 781 series.

Event Data Format

The data format provided by the firmware is grouped into aggregates of events. Each aggregate of channels is then grouped into the board aggregate, and finally into block transfer. Those who need to write their own acquisition software must take care of the following sections.

Channel Aggregate Data Format for 724 and 781 series

The Channel Aggregate is composed by the set of Ne events, where Ne is the programmable number of events contained in one aggregate (see the previous section). The structure of the Channel Aggregate of two events (EVENT 0 and EVENT 1) is shown in Fig. **2.2**, where:

"CHANNEL AGGREGATE" DATA FORMAT

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	BIT
FI												AGGREGATE SIZE																				SIZE
DT	ES	EE	ET						AP1		AP2		DP			NUM SAMPLES/2																FORMAT
TT		TRIGGER TIME TAG																														EVENT 0
T_1	D_1	S_1														T_0	D_0	S_0														
T_3	D_3	S_3														T_2	D_2	S_2														
T_{n-1}	D_{n-1}	S_{n-1}														T_{n-2}	D_{n-2}	S_{n-2}														
													EXTRAS			PU	PEAK (ENERGY)															
TT		TRIGGER TIME TAG																														EVENT 1
T_1	D_1	S_1														T_0	D_0	S_0														
T_3	D_3	S_3														T_2	D_2	S_2														
T_{n-1}	D_{n-1}	S_{n-1}														T_{n-2}	D_{n-2}	S_{n-2}														
													EXTRAS			PU	PEAK (ENERGY)															

Fig. 2.2: Channel Aggregate Data Format scheme.

FI: when 1, the second word is the Format Info

DT: Dual trace enabled flag (0 = disabled, 1 = enabled)

ES: Waveform (samples) enabled flag

EE: Energy enabled flag

ET: Trigger Time Stamp enabled flag

AP1: Analog Probe 1 Selection. AP1 can be selected among:

00 = “Input”: the input signal from pre-amplified detectors

01 = “RC-CR”: first step of the trigger and timing filter

10 = “RC-CR2”: second step of the trigger and timing filter

11 = “Trapezoid”: trapezoid resulting from the energy filter

AP2: Analog Probe 2 Selection. AP2 can be selected among:

00 = “Input”: the input signal from pre-amplified detectors

01 = “Threshold”: the RC-CR2 threshold value

10 = “Trapezoid-BL”: the trapezoid shape minus its baseline

11 = “Baseline”: displays the trapezoid baseline

DP: Digital Virtual Probe Selection. DP can be selected among:

0000 = “TRG Window”: shows the RT Discrimination Width

0001 = “Armed”: digital input showing where the RC-CR2 crosses the Threshold

0010 = “Peak Run”: starts with the trigger and last for the whole event (see **[RD2]**)

0011 = “Pile-Up”: shows when there is a pile-up event and corresponds to the time interval when the energy calculation is disabled due to the pile-up event

0100 = “Peaking”: shows where the energy is calculated

0101 = “Trg Validation Win”: digital input showing the trigger validation acceptance window TVAW (refer to **[RD3]**)

0110 = “BSL Holdoff: shows the baseline hold-off parameter

0111 = “TRG Holdoff”: shows the trigger hold-off parameter

1000 = “Trg Validation”: shows the trigger validation signal TRG_VAL (refer to **[RD3]**)

1001 = “Acq Veto”: this is 1 when either the input signal is saturated or the memory board is full

TT: Trigger Type (0=self-trigger, 1=external trigger)

S_m (m = 0, 2, 4n – 2): Even Samples of AP1 at time t = m

$S_{m'}$ ($m' = 1, 3, 4n - 1$): if DT=0, then $S_{m'}$ corresponds to the odd Samples of AP1 at time $t = m'$. Otherwise, if DT=1, they correspond to the even Samples of AP2 at time $t = m' - 1$

T_n: bit identifying in which sample the Trigger occurred

D_n: Digital Virtual Probe for each sample. The Probe type can be read from the “DP” field in the header

PU: Pile Up. This bit is usually set to zero. The user can recognize a pile up event when also the Energy value is zero. The user can also choose to have this bit equal to 1 in case of pile-up event, by enabling bit[27] of 0x1n80 register address. In that case, the energy value is what read from the algorithm

EXTRAS: bit[0] = DEAD_TIME. This is set to 1 when a dead time occurred before this event. The dead time can be due to either a signal saturation or a full memory status. Check Fig. **2.3** and Fig. **2.4** for more details

bit[1] = ROLL_OVER. Identify a trigger time stamp roll-over that occurred before this event

bit[2] = TT_RESET. Identify a trigger time stamp reset forced from external signals in S-IN (GPI for Desktop)

bit[3] = FAKE_EVENT. This is a fake event (which does not correspond to any physical event) that identifies a time stamp roll-over. The roll-over can be due to an external or internal reset. The user can set bit[25] = 1 of register 0x1n80 to enable the fake-event saving in case of reset from S-IN, and bit[26] = 1 of register 0x1n80 to enable the fake-event saving in case of internal roll-over. In the first case the event will have both bit[3] and bit[2] set to 1, while in the second case the event will have both bit[3] and bit[1] set to 1.

Note: DEAD_TIME in case of signal saturation (see Fig. **2.3**). If the input signal is over-range (exceeds the input dynamic range of 16k ADC channels) then the acquisition is inhibited. As soon as the input signal is in saturation an event is saved with the corresponding time stamp, and bit[15] set to 1. The energy value is set to the maximum. This event has to be discarded for the energy spectrum, anyway it can be considered for the dead-time calculation. Once the signal is out of saturation a new trigger is inhibited for a time window of 2*Decay Time. The first event after the saturation is tagged with bit[16] = 1.

Note: DEAD_TIME in case of FULL board memory (see Fig. **2.4**). When the memory of the board is full (which is usually due to a write event), the board is not able any more to transfer the event data. When the board is ready again, the first event after the FULL will have the bit[16] set to 1, and the energy value as read from the algorithm. The dead-time is equal to the time difference between the last trigger occurred and the trigger after the FULL status.

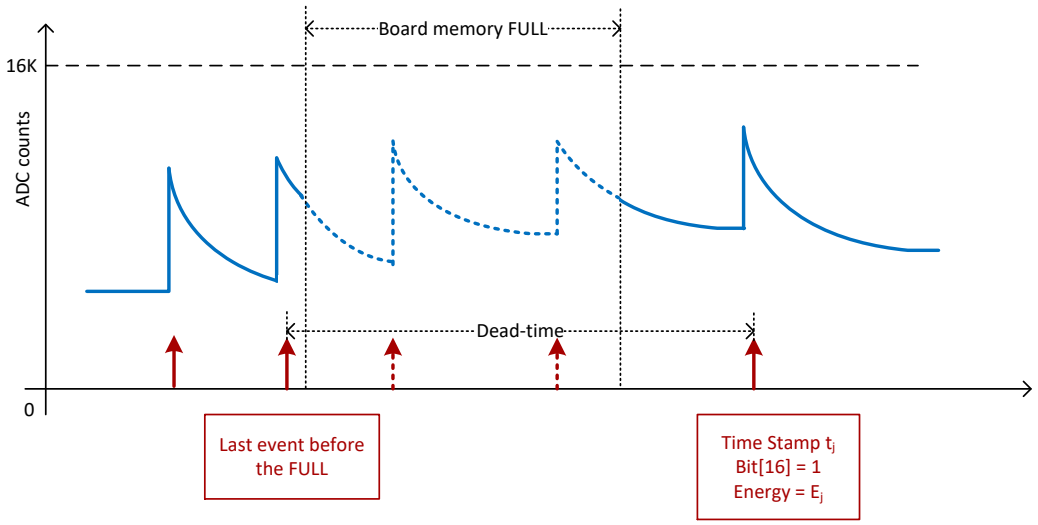

Fig. 2.3: Dead-time in case of signal saturation.

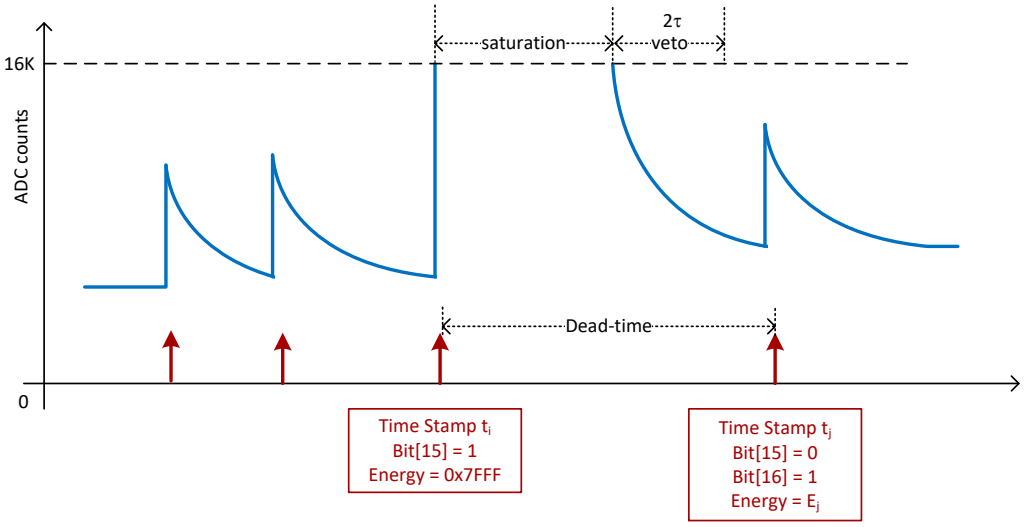

Fig. 2.4: Dead-time in case of FULL memory status. Events in the FULL are identified but not saved.

Board Aggregate Data Format

For each readout request (occurring when at least one channel has available data to be read) the "interface FPGA (ROC)" reads one aggregate from each enabled channel memory. No more than one aggregate per channel is read each time. The set of Channel Aggregates is the Board Aggregate. If one channel has no data, that channel does not come into the Board Aggregate. The data format when all 8 channels of a VME have available data is as shown in Fig. **2.5**, where:

"BOARD AGGREGATE" DATA FORMAT

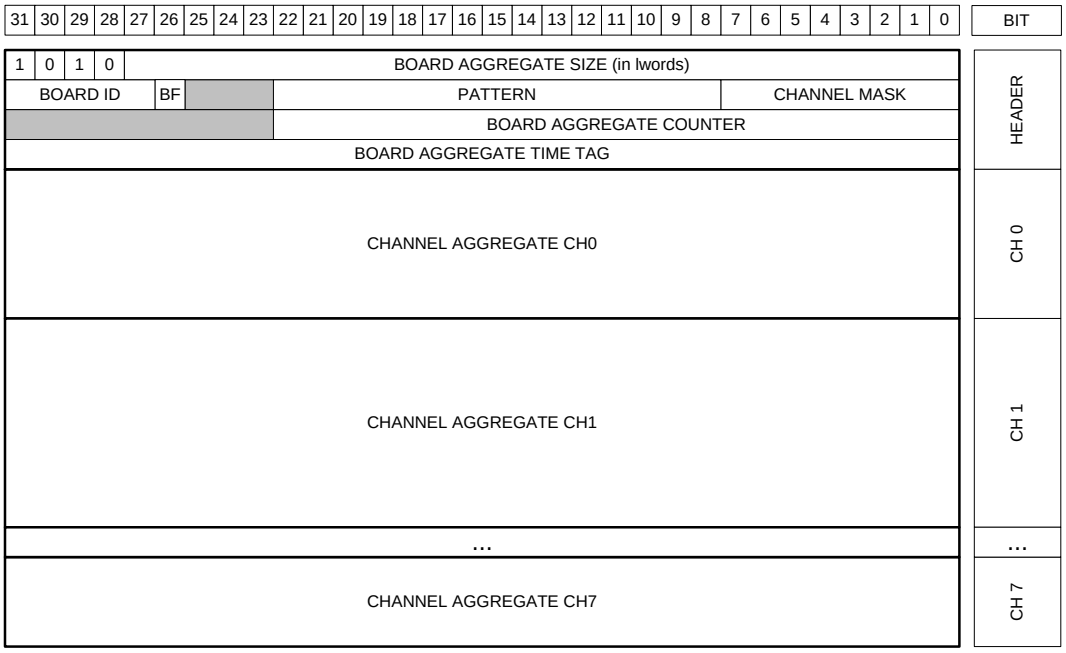

Fig. 2.5: Board Aggregate Data Format scheme.

BOARD AGGREGATE SIZE: total size of the aggregate

BOARD ID: corresponds to the GEO address of the board. In case of VME64X boards this number is automatically set for each board. In case of VME boards this value is by default = 0 for all boards. It is possible to set the GEO address of the boards using register 0xEF08, which is quite useful in case of concatenate BLT (CBLT) read.

BF: Board Fail flag. This bit is set to "1" after a hardware problem, as for example the PLL unlocking, or over-temperature condition. The user can investigate the problem checking the error monitor register 0x8178, or contacting CAEN support (refer to **3).**

Note: BF bit is meaningful only for ROC FPGA firmware revision greater than 4.5. It is reserved for previous releases.

PATTERN: is the value read from the LVDS I/O (VME only);

CHANNEL MASK: corresponds to those channels participating to the Board Aggregate;

BOARD AGGREGATE COUNTER: counts the board aggregate. It increases with the increase of board aggregates;

BOARD AGGREGATE TIME TAG: is the time of creation of the aggregate (this does not correspond to any physical quantity);

Data Block

The readout of the digitizer is done using the Block Transfer (BLT, refer to **[RD1]**); for each transfer, the board gives a certain number of Board Aggregates, consisting in the Data Block. The maximum number of aggregates that can be transferred in a BLT is defined by the READOUT_BTL_AGGREGATE_NUMBER. In the final readout each Board Aggregate comes successively. In case of n Board Aggregates, the Data Block is as in Fig. **2.6**

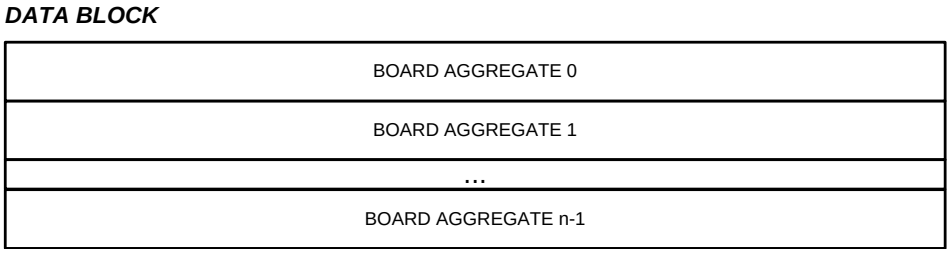

Fig. 2.6: Data Block scheme.

3 Technical Support

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

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

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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UM5407 - 724-781 DPP-PHA Legacy User Manual rev. 3 - July 13th, 2020

00117-10-DGT28-MUTX