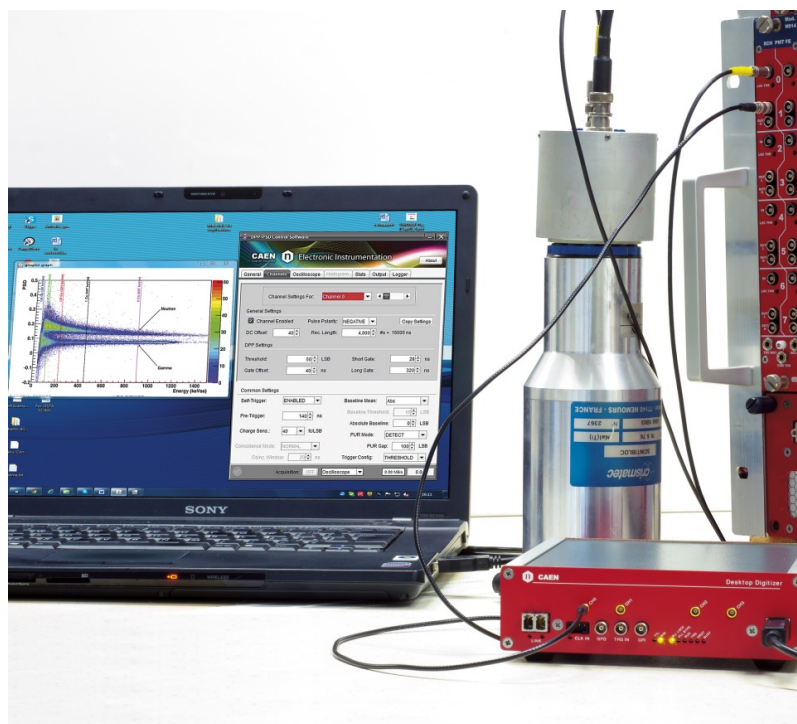




Rev. 3 - December 21st, 2023

751 DPP-PSD

Register Description and Data Format



Purpose of this Manual



The User Manual contains the full description of the DPP-PSD firmware registers for 751 family series. The description is compliant with the DPP-PSD firmware revision **4.23_132.09 (Legacy)** and **4.25_132.38**. For future release compatibility check in the firmware history files.

Change Document Record

Date	Revision	Changes
Sept 26 th , 2016	00	Initial Release
Jan 25 th , 2017	01	Modified registers CFD Settings, Front Panel I/O Control, Front Panel LVDS I/O New Features .
May 4 th , 2020	02	Added registers: Trigger Latency, Buffer Occupancy Gain, Extended Veto Delay . Modified registers: Acquisition Control, Acquisition Status, Run/Start/Stop Delay, Board Failure Status, Readout Status, Aggregate Number per BLT . Added Chap. DPP-PSD Memory Organization
Dec 21 st , 2023	03	Revised layout and improved text. Added register: Baseline Timeout . Modified registers: Baseline Threshold, Shaped Trigger Width, DPP Algorithm Control, Board Configuration, Acquisition Control, Front Panel TRG-OUT (GPO) Enable Mask, Run/Start/Stop Delay, Board Failure Status, Front Panel LVDS I/O New Features .

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
ROC	ReadOut Controller
USB	Universal Serial Bus

Reference Documents

- [RD1] UM1935 - CAEN Digitizer User & Reference Manual.
- [RD2] GD2827 - How to make coincidences with CAEN digitizers.
- [RD3] UM5960 - CoMPASS User Manual.

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

Manufacturer Contacts



CAEN S.p.A.
Via Vetraia, 11 55049 Viareggio (LU) - ITALY
Tel. +39.0584.388.398 Fax +39.0584.388.959
www.caen.it | info@caen.it
©CAEN SpA – 2023

Limitation of Responsibility

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

Disclaimer

No part of this manual may be reproduced in any form or by any means, electronic, mechanical, recording, or otherwise, without the prior written permission of CAEN SpA.

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

Made in Italy

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



Index

Purpose of this Manual	1
Change document record	1
Symbols, abbreviated terms and notation	1
Reference Documents	1
1 Registers and Data Format	5
Register Address Map	5
Record Length	8
Number of Events per Aggregate	9
Pre Trigger	10
CFD Settings	11
Short Gate Width	12
Long Gate Width	13
Gate Offset	14
Trigger Threshold	15
Fixed Baseline	16
Baseline Threshold	17
Baseline Timeout	18
Trigger Latency	19
Shaped Trigger Width	20
Trigger Hold-Off Width	21
Threshold for the PSD cut	22
DPP Algorithm Control	23
Channel n Status	25
AMC Firmware Revision	26
DC Offset	27
Channel ADC Configuration	28
Channel n ADC Temperature	29
Read Data from ADC	30
Board Configuration	31
Aggregate Organization	33
Data Flush	34
Acquisition Control	35
Acquisition Status	37
Software Trigger	38
Global Trigger Mask	39
Front Panel TRG-OUT (GPO) Enable Mask	40
LVDS I/O Data	41
Front Panel I/O Control	42
Channel Enable Mask	44
ROC FPGA Firmware Revision	45
Voltage Level Mode Configuration	46
Software Clock Sync	47
Board Info	48
Analog Monitor Mode	49
Event Size	50
Time Bomb Downcounter	51
Fan Speed Control	52
Run/Start/Stop Delay	53
Board Failure Status	54

Disable External Trigger	55
Trigger Validation Mask	56
Front Panel LVDS I/O New Features	57
Buffer Occupancy Gain	58
Extended Veto Delay	59
Readout Control	60
Readout Status	61
Board ID	62
MCST Base Address and Control	63
Relocation Address	64
Interrupt Status/ID	65
Interrupt Event Number	66
Aggregate Number per BLT	67
Scratch	68
Software Reset	69
Software Clear	70
Configuration Reload	71
Configuration ROM Checksum	72
Configuration ROM Checksum Length BYTE 2	73
Configuration ROM Checksum Length BYTE 1	74
Configuration ROM Checksum Length BYTE 0	75
Configuration ROM Constant BYTE 2	76
Configuration ROM Constant BYTE 1	77
Configuration ROM Constant BYTE 0	78
Configuration ROM C Code	79
Configuration ROM R Code	80
Configuration ROM IEEE OUI BYTE 2	81
Configuration ROM IEEE OUI BYTE 1	82
Configuration ROM IEEE OUI BYTE 0	83
Configuration ROM Board Version	84
Configuration ROM Board Form Factor	85
Configuration ROM Board ID BYTE 1	86
Configuration ROM Board ID BYTE 0	87
Configuration ROM PCB Revision BYTE 3	88
Configuration ROM PCB Revision BYTE 2	89
Configuration ROM PCB Revision BYTE 1	90
Configuration ROM PCB Revision BYTE 0	91
Configuration ROM FLASH Type	92
Configuration ROM Board Serial Number BYTE 1	93
Configuration ROM Board Serial Number BYTE 0	94
Configuration ROM VCXO Type	95
2 DPP-PSD Memory Organization	96
751 series	96
Event Data Format	97
Channel Aggregate Data Format for 751 series	97
Board Aggregate Data Format	100
Data Block	101
3 Technical Support	102

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
Record Length	0x1n20, 0x8020	R/W	I
Number of Events per Aggregate	0x1n34, 0x8034	R/W	I
Pre Trigger	0x1n38, 0x8038	R/W	I
CFD Settings	0x1n3C, 0x803C	R/W	I
Short Gate Width	0x1n54, 0x8054	R/W	I
Long Gate Width	0x1n58, 0x8058	R/W	I
Gate Offset	0x1n5C, 0x805C	R/W	I
Trigger Threshold	0x1n60, 0x8060	R/W	I
Baseline Threshold	0x1n64, 0x8064	R/W	I
Fixed Baseline	0x1n64, 0x8064	R/W	I
Baseline Timeout	0x1n68, 0x8068	R/W	I
Trigger Latency	0x1n6C, 0x8n6C	R/W	I
Shaped Trigger Width	0x1n70, 0x8070	R/W	I
Trigger Hold-Off Width	0x1n74, 0x8074	R/W	I
Threshold for the PSD cut	0x1n78, 0x8078	R/W	I
DPP Algorithm Control	0x1n80, 0x8080	R/W	I
Channel n Status	0x1n88	R	I
AMC Firmware Revision	0x1n8C	R	I
DC Offset	0x1n98, 0x8098	R/W	I
Channel ADC Configuration	0x1n9C, 0x809C	W	I
Channel n ADC Temperature	0x1nA8	R	I
Read Data from ADC	0x1nFC	R	I
Board Configuration	0x8000, 0x8004 (BitSet), 0x8008 (BitClear)	R/W	C
Aggregate Organization	0x800C	R/W	C
Data Flush	0x803A	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
Extended Veto Delay	0x81C4	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

Record Length

Sets the record length for the waveform acquisition

Address 0x1n20, 0x8020
 Mode R/W
 Attribute I

Bit	Description
[15:0]	Number of samples in the waveform according to the formula $N_s = N * 12$, where N_s is the record length and N is the register value. For example, write $N = 3$ to acquire 36 samples. Each sample corresponds to 1 ns
[31:16]	Reserved

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 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]	Defines the number of pre trigger samples according to the formula $N_s = N * 8$, where N_s is the pre trigger and N is the register value. For example, write $N = 2$ to set 16 samples of pre trigger. Each sample corresponds to 1 ns. Bit[9] corresponds to the Pre Trigger sign, i.e. also negative values are allowed. In this case the waveform is acquired starting N_s samples after the trigger. NOTE: the Pre Trigger value must be greater than the Gate Offset value by at least 8 ns
[31:10]	Reserved

CFD Settings

Sets the Constant Fraction Discrimination (CFD) delay and fraction parameters.

Note: this register is valid for 751 DPP-PSD firmware greater than 132.32. In case of smaller firmware revisions this register is reserved.

Address 0x1n3C, 0x803C
 Mode R/W
 Attribute I

Bit	Description
[7:0]	Set the CFD delay in ns
[9:8]	Set the CFD fraction. Options are: 00 : fraction = 25%; 01 : fraction = 50%; 10 : fraction = 75%; 11 : fraction = 100%
[12:10]	Sets the Interpolation Points, corresponding to the n-th sample before and after the zero crossing that are used for the linear interpolation. These bits can be used both in case of CFD and LED (Leading Edge Discrimination). Options are: 000: the sample before and after the zero crossing; 001: second sample before and after the zero crossing; 010: third sample before and after the zero crossing; 011: fourth sample before and after the zero crossing; 100: fifth sample before and after the zero crossing; 101: sixth sample before and after the zero crossing; 110: seventh sample before and after the zero crossing; 111: eighth sample before and after the zero crossing
[31:13]	Reserved

Short Gate Width

Sets the Short Gate width for the charge integration of the fast component in the Pulse Shape Discrimination

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

Bit	Description
[9:0]	Number of samples for the Short Gate width. Each sample corresponds to 1 ns for 751 series
[31:10]	Reserved

Long Gate Width

Sets the Long Gate width for the charge integration of the slow component in the Pulse Shape Discrimination. The Long integration Gate is also used for the energy spectra calculation

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

Bit	Description
[13:0]	Number of samples for the Long Gate width. Each sample corresponds to 1 ns for 751 series
[31:14]	Reserved

Gate Offset

To correctly integrate the input pulse, the integration Gate starts before the trigger position. The Gate Offset defines how many samples the Gate starts before the trigger.

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

Bit	Description
[7:0]	Number of samples of the Gate Offset. Each sample corresponds to 1 ns
[31:8]	Reserved

Trigger Threshold

Sets the Trigger Threshold value for the Leading Edge discrimination

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

Bit	Description
[9:0]	Set the number of LSB counts for the Trigger Threshold, where 1 LSB = 0.97 mV for 751 series. The threshold is referred to the baseline level and can be used to trigger on Leading Edge Discrimination or to arm the digital Constant Fraction Discrimination
[31:10]	Reserved

Fixed Baseline

The baseline calculation can be performed either dynamically or statically. In the first case the user can set the samples of the moving average window through register 0x1n80. In the latter case the user must disable the automatic baseline calculation through bits[22:20] of register 0x1n80 and set the desired value of fixed baseline through this register. The baseline value then remains constant for the whole acquisition.

Note: This register is ignored in case of dynamic calculation.

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

Bit	Description
[9:0]	Value of Fixed Baseline in LSB counts
[31:10]	Reserved

Baseline Threshold

The absolute baseline value can be defined if bits[22:20] of register 0x1n80 are set to 0x0. In all the other cases, this register value defines the acceptance band: when the input signal goes outside the baseline threshold (blthr) interval, the correspondent samples are not included in the input signal baseline mean calculation. In other words, when $\text{abs}(\text{baseline} - \text{signal}) < \text{blthr}$, the baseline mean is calculated.

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

Bit	Description
[9:0]	Value of Fixed Baseline/ Acceptance band in LSB counts
[31:10]	Reserved

Baseline Timeout

This register is used to define the maximum time in which the input signal stays outside the acceptance band for the baseline mean calculation (refer to register 0x1n64) . During this time the baseline mean is kept frozen. After that time, the baseline value is initialized (is forced) to the input signal value and the baseline starts to be calculated again but it might take some time (depending on the number of samples for the baseline mean) to recover.

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

Bit	Description
[7:0]	Maximum time value in number of 125 MHz clock cycles
[31:8]	Reserved

Trigger Latency

This register allows the user to set a time window (latency) to be added to the Shaped Trigger Width (i.e. the length of the correlation window) required to take into account the latency in the trigger propagation from the piggyback to the motherboard when setting coincidence/anticoincidence between the digitizer channels.

Mandatory values are:

- 0x9 for the x720 (DT5790) and x751 series
- 0x2 for the x725 and x730 series when setting coincidence/anticoincidence within the same channel couple
- 0x9 for the x725 and x730 series when setting coincidence/anticoincidence between channels belonging to different couples.

Address	0x1n6C, 0x8n6C
Mode	R/W
Attribute	I

Bit	Description
[9:0]	Value of the latency in trigger clock cycles, 8 ns step
[31:10]	Reserved

Shaped Trigger Width

The Shaped Trigger is a logic signal of programmable width generated by a channel in correspondence to its local self-trigger (that is the output of the leading edge discriminator). 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 0x1n70, 0x8070
Mode R/W
Attribute I

Bit	Description
[9:0]	Shaped Trigger width in steps of 8 ns. Minimum allowed value 2 clock cycles (16 ns)
[31:10]	Reserved

Trigger Hold-Off Width

The Trigger Hold-Off is a logic signal of programmable width generated by a channel in correspondence with its local self-trigger (that is the output of the leading edge discriminator). Other triggers are inhibited for the overall Trigger Hold-Off duration

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

Bit	Description
[9:0]	Set the Trigger Hold-Off width in steps of 8 ns
[31:10]	Reserved

Threshold for the PSD cut

Sets the PSD threshold to online select events according to their PSD value. PSD ranges from 0 to 1.

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

Bit	Description
[9:0]	Set the PSD threshold value. The desired value has to be multiplied by 1024. For example for a PSD threshold of 0.12, write 122 (= 0.12 * 1024). Set bits[28:27] of register 0x1n80 to enable the cut on gamma or neutron respectively
[31:10]	Reserved

DPP Algorithm Control

Management of the DPP algorithm features.

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

Bit	Description
[2:0]	Charge Sensitivity: defines how many fC of charge correspond to one channel of the energy spectrum. Options are: 000: 20 fC; 001: 40 fC; 010: 80 fC; 011: 160 fC; 100: 320 fC; 101: 640 fC
[3]	Reserved
[4]	Charge Pedestal: when enabled a fixed value of 1024 is added to the charge. This feature is useful in case of energies close to zero
[5]	Reserved
[6]	Discrimination mode for the event selection. Options are: 0 (default value): leading edge discrimination (LED); 1: digital constant fraction discrimination (CFD). Note: This bit is valid for 751 DPP-PSD firmware greater than 132.32. In case of smaller firmware revisions this bit is reserved
[10:7]	Reserved
[13:11]	Extras Word options. The channel aggregate data format has a 32 bit word, called EXTRAS word which can be configured to have the following information. Options are: 000: bits[31:16] = Extended Time Stamp, bits[15:0] = Baseline * 8; 001: bits[31:16] = Extended Time Stamp, bits[15:0] = Flags; 010: bits[31:16] = Extended Time Stamp, bits[15:10] = Flags, bits[9:0] = Fine Time Stamp; 011: bits[31:26] = Flags, bits[25:16] = Fine Time Stamp, bits[15:0] = Baseline * 8; 100: Reserved; 101: bit[31] = Discrimination Mode, bit[30] = Pulse Polarity, bit[29:20] = Sample Before Zero Crossing, bit[19:10] = Sample After Zero Crossing, bit[9:0] = Mid- Scale Value (CFD) or Threshold (LED); 110: Reserved; 111: Fixed value = 0x12345678 (debug use only). To enable the EXTRAS word set bit[17]=1 of register 0x8000. Note: This bit is valid for 751 DPP-PSD firmware greater than 132.32. In case of smaller firmware revisions this bit is reserved.
[15:14]	Reserved
[16]	Pulse Polarity. Options are: 0: positive pulse; 1: negative pulse
[17]	Shaped Trigger Duration. Options are: 0: programmable width according to register 0x1n74; 1: over-threshold duration
[19:18]	Trigger Mode. Options are: 00: Normal mode. Each channel can self-trigger independently from the other channels; 01: Coincidence mode. Each channel saves the event only when a validation signal occurs inside the shaped trigger coincidence window; 10: Reserved; 11: Anti-coincidence mode. Each channel saves the event only when no validation signal occurs inside the shaped trigger coincidence window

[22:20]	Baseline Mean. Sets the number of events for the baseline mean calculation. Options are: 000: Fixed: the baseline value is fixed to the value set in register 0x1n64; 001: 8 samples; 010: 16 samples; 011: 32 samples; 100: 64 samples; 101: 128 samples; 110: 256 samples; 111: 512 samples
[23]	Reserved
[24]	Disable Self Trigger. When disabled, the self-trigger 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]	Pile-Up Retriggering, when a second pulse arrives within the long gate (and after the end of the short gate) of a first pulse, the charge integration is stopped prematurely. A new event is created, by opening a short and long gate again. See the CoMPASS User Manual for additional details. Options are: 0: disabled (default); 1: enabled
[26]	Pile-Up Rejection, when an event recognized as pile-up, it is completely rejected by the firmware. See the CoMPASS User Manual for additional details. Options are: 0: disabled (default); 1: enabled
[27]	Enable PSD cut below threshold (to cut on gammas)
[28]	Enable PSD cut above threshold (to cut on neutrons)
[31:29]	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
[4:3]	Reserved
[5]	Aggregate Free error flag. Options are: 0: no error; 1: trying to free a number of aggregates too large
[6]	ADC Calibration flag. Options are: 0: calibration in progress; 1: calibration done
[7]	Power Down flag. Options are: 0: Ch Power OK; 1: Ch Power Down
[8]	Over Temperature flag. Options are: 0: Ch temperature OK; 1: Ch Over temperature
[31:9]	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 $2^{N_{\text{Bit}}} - 1$, where N_{Bit} 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 N_{Bit} 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

Channel ADC Configuration

This register manages the channel n ADC calibration and power mode. x751 digitizers require a channel calibration to achieve the best performance. A calibration of the ADCs is automatically performed by the firmware at the power-on, but the user is recommended to manually execute the calibration after the ADCs have stabilized their operating temperature (see the register 0x1nA8). Do not perform the calibration for each acquisition run, unless the operating temperature varies significantly, or clock settings are modified (e.g. switching from internal to external clock).

WARNING: before writing this register, it is necessary to check that bit[2] = 0 of register 0x1n88, otherwise the writing process cannot run properly.

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

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

Address 0x1n9C, 0x809C
Mode W
Attribute I

Bit	Description
[0]	ADC power down configuration. In case of broadcast write to address 0x809C this bit should always be equal to 0. Options are: 0: channel ADC power OK; 1: channel ADC power down
[1]	ADC calibration. Enable this bit to perform the ADC calibration. Options are: 0: the board does not perform the ADC calibration; 1: the board performs the ADC calibration
[31:2]	Reserved

Channel n ADC Temperature

This register monitors the temperature of the ADC chips.

Note: if the temperature varies significantly during the digitizer operation, the user is recommended to perform a new channel calibration procedure (see register 0x809C) to restore the board performance. This is not true in case of 725S and 730S as these models do not require any calibration.

Address	0x1nA8
Mode	R
Attribute	I

Bit	Description
[7:0]	ADC Chip Temperature (expressed in °C). Values are signed, ranging from -64°C to 127°C
[31:8]	Reserved

Read Data from ADC

Read data directly from the ADC of channel n

Address 0x1nFC
Mode R
Attribute I

Bit	Description
[9:0]	Data from the ADC
[31:10]	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]	Test Mode (default value is 0). When the test pattern is enabled, the input samples are replaced by a sawtooth test signal. Options are: 0 = Test Mode disabled; 1 = Test Mode enabled
[4]	Reserved: must be 1
[7:5]	Reserved: must be 0
[8]	Individual trigger: must be 1
[9]	Pulse Polarity. Options are: 0: the input pulses are positive with respect to the baseline; 1: the input pulses are negative with respect to the baseline. Note: This bit affects all channels. To individual set the channel polarity set this bit to 0 and modify bit[16] of register 0x1n80
[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. According to the Analog Probe selection (see bits[13:12]) the following selections are available: Dual Trace = 0, Analog Probe = 0 => Trace 1 = Input, Trace 2 = N/A; Dual Trace = 0, Analog Probe = 1 => Trace 1 = CFD, Trace 2 = N/A; Dual Trace = 1, Analog Probe = 0 => Trace 1 = Input, Trace 2 = Baseline; Dual Trace = 1, Analog Probe = 1 => Trace 1 = CFD, Trace 2 = Baseline; Dual Trace = 1, Analog Probe = 2 => Trace 1 = Input, Trace 2 = CFD. Note: This bit is valid for 751 DPP-PSD firmware greater than 132.32. In case of smaller firmware revisions this bit is reserved
[13:12]	Analog Probe selection: selects which signal is associated to the analog probes. According to the Dual Trace value (see bit[11]) the following selections are available: Dual Trace = 0, Analog Probe = 0 => Trace 1 = Input, Trace 2 = N/A; Dual Trace = 0, Analog Probe = 1 => Trace 1 = CFD, Trace 2 = N/A; Dual Trace = 1, Analog Probe = 0 => Trace 1 = Input, Trace 2 = Baseline; Dual Trace = 1, Analog Probe = 1 => Trace 1 = CFD, Trace 2 = Baseline; Dual Trace = 1, Analog Probe = 2 => Trace 1 = Input, Trace 2 = CFD. Note: These bits are valid for 751 DPP-PSD firmware greater than 132.32. In case of smaller firmware revisions these bits are reserved.
[15:14]	Reserved: must be 0
[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]	<p>Extras Recording: when enabled the EXTRAS word is saved into the event data. Refer to the "Channel Aggregate Data Format" chapter below for more details about the EXTRAS word.</p> <p>Options are:</p> <p>0: disabled;</p> <p>1: enabled.</p> <p>Note: In case of DPP-PSD Legacy, if EXTRAS word is enabled, the only available option is EXTRAS[9:0] = BASELINE.</p>
[18]	<p>Time Stamp Recording: enables the recording of the time stamp in the Channel Aggregate Data format. Options are:</p> <p>0: disabled;</p> <p>1: enabled</p>
[19]	<p>Charge Recording: enables the recording of the charges Qlong and Qshort in the Channel Aggregate Data format. Options are:</p> <p>0: disabled;</p> <p>1: enabled</p>
[22:20]	<p>Digital Virtual Probe 1: when the mixed or oscilloscope mode are enabled, the following digital virtual probes can be selected:</p> <p>000 = "Long Gate";</p> <p>001 = "Over Threshold", digital signal that is 1 when the input signal is over the requested threshold;</p> <p>010 = "Shaped TRG", logic signal of programmable width 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;</p> <p>011 = "TRG Val. Acceptance Win.", logic signal corresponding to the time window where the coincidence validation is accepted. The validation enables the event dump into the memory;</p> <p>100 = "Pile Up", logic pulse set to 1 when a pile up event occurred;</p> <p>101 = "Coincidence", logic pulse set to 1 when a coincidence occurred;</p> <p>110 = Reserved;</p> <p>111 = Reserved</p>
[25:23]	<p>Digital Virtual Probe 4: when the mixed or oscilloscope mode are enabled, the following digital virtual probes can be selected:</p> <p>000 = "Short Gate";</p> <p>001 = "Over Threshold", digital signal that is 1 when the input signal is over the requested threshold;</p> <p>010 = "TRG Validation", digital signal that is 1 when a coincidence validation signal comes from the mother board FPGA;</p> <p>011 = "TRG HoldOff", logic signal of programmable width generated by a channel in correspondence with its local self- trigger. Other triggers are inhibited for the overall Trigger Hold-Off duration;</p> <p>100 = "Pile-up", logic pulse set to 1 when a pile up event occurred;</p> <p>101 = "Coincidence", logic pulse set to 1 when a coincidence occurred;</p> <p>110 = Reserved;</p> <p>111 = Reserved</p>
[26]	<p>Enable Digital Virtual Probes. When this option is enabled, two bits of the Analog Probe samples are used for the Digital Probes. In this case, the Analog Probe samples are represented into 8 bits, rather than 10 bits. When disabled, the Analog Probe samples are represented into 10 bits. Options are:</p> <p>0: disabled;</p> <p>1: enabled</p>
[30:27]	Reserved
[31]	<p>Enable second word of Format in the Channel Aggregate data format. Refer to the "Channel Aggregate Data Format" chapter below for more details.</p> <p>Note: This bit is valid for 751 DPP-PSD firmware greater than 132.32. In case of smaller firmware revisions this bit is reserved. Options are:</p> <p>0: disabled;</p> <p>1: enabled</p>

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 $N_{aggr} = 2^{N_b}$. The corresponding values of N_b and N_{aggr} are: N_b : 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

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 0x803A
Mode W
Attribute C

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

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). Acquisition must be armed by setting bit[2] = 1, then the run can optionally START/STOP ON LEVEL or START ON EDGE according to bit[11] (NOTE: the START ON EDGE option is implemented from ROC FPGA fw revision 4.22 on); 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-In Enable (VME only). Default value is 0. This bit must be enabled to let the board accept the Busy signal as input on the LVDS I/Os. 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), the LVDS I/O mode is set to nBusy/nVeto (see register 0x81A0), and the LVDS I/Os are set as inputs (see register 0x811C)
[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]	<p>LVDS I/O RunIn Enable Mode (VME only) and START ON EDGE Enable for S-IN/GPI CONTROLLED Mode.</p> <p>- If LVDS CONTROLLED MODE is set (bit[1:0] = 11) and acquisition is armed (bit[2] = 1), this bit let the LVDS I/Os be set to accept a RunIn signal to control the acquisition upon two options. One is start/stop on level, where the start of the RUN is given at RunIn signal level high and the stop at RunIn signal level low. The other is start on edge, where the start of the RUN is given on the rising edge of the RunIn signal, while the Stop must be only on software command.:</p> <p>0 = starts on RunIn level (default); 1 = starts on RunIn rising edge.</p> <p>Note: this bit is meaningful only if the LVDS new features are enabled (bit[8]=1 of register 0x811C). Register 0x81A0 must also be configured for nBusy/nVeto.</p> <p>Note: this register is valid from ROC FPGA fw revision 4.16 on.</p> <p>- If S-IN/GPI CONTROLLED Mode is set (bit[1:0] = 01) and acquisition is armed (bit[2] = 1):</p> <p>0 = Start/Stop run on S-IN/GPI level (default); 1 = Start run on S-IN/GPI rising edge (stop must be by software command: bit[2] = 0).</p> <p>Note: options bit[11] = 1 is valid from ROC FPGA fw revision 4.22 on</p>
[12]	<p>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.</p> <p>Options are:</p> <p>0 = VetoIn not used (default); 1 = VetoIn used for TRG-OUT inhibit</p> <p>Note: this bit is reserved in case of Desktop and NIM digitizers or ROC FPGA firmware rel. < 4.16</p>
[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 drives the front panel 'RUN' LED. Options are: 0 = acquisition is stopped ('RUN' is off); 1 = acquisition is running ('RUN' lites)
[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 logical level on S-IN (GPI) front panel connector
[16]	TRG-IN Status. Reads the 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 for the majority coincidence in units of the Trigger Clock (8 ns). 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 bits [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). LVDS connectors programmed as inputs (according to registers 0x811C and 0x81A0) can participate in the TRG-OUT (GPO) signal generation, 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]	<p>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</p>
[10]	<p>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</p>
[11]	<p>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</p>
[13:12]	Reserved
[14]	<p>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</p>
[15]	<p>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]</p>
[17:16]	<p>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</p>
[19:18]	<p>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]</p>
[20]	<p>According to bits[19:18], this bit selects the probe to be propagated on TRG-OUT . If bits[19:18] = 00, then bit[20] options are: 0 = RUN, the signal is active when the acquisition is running and it is synchronized with the start run. This option must be used to synchronize the start/stop of the acquisition through the TRG-OUT->TR-IN or TRG-OUT->S-IN (GPI) daisy chain; 1 = delayedRUN. This option can be used to debug the synchronization when the start/stop is propagated through the LVDS I/O (VME boards). If bits[19:18] = 11, then bit[20] options are: 0 = Board BUSY; 1 = PLL Lock Loss. Note: this bit is reserved in case of ROC FPGA firmware rel. 4.5 or lower. Note: this bit corresponds to BUSY/UNLOCK for ROC FPGA firmware rel. less than 4.12</p>
[22:21]	<p>Pattern Configuration. Configures the information given by the 16-bit PATTERN field in the header of the event format (VME only). Options are: 00 = PATTERN: 16-bit pattern latched on the 16 LVDS signals as one trigger arrives (default); Other options are reserved</p>
[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 Ω .

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.

Note: if a Sync command is intentionally issued, the user must consider that a new channels calibration procedure is needed for a correct board operating (see 0x809C).

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: 0x5 = 751 digitizer family
[15:8]	Channel Memory Size Code. Options are: 0x2: each channel is equipped with 1.8 MS acquisition memory; 0x10: each channel is equipped with 14.4 MS acquisition memory
[23:16]	Equipped Channels Number. Options are: 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

This register sets the delay in the Start Run of the board whether the command is issued by software, or by an input single-ended (via S-IN/GPI or TRG-IN connectors) or differential (via LVDS I/O connector) signal. This delay especially occurs in the daisy chain propagation of the run signal in a multi-board system. The latency, mainly due to the cable length and the board's internal circuitry, can be compensated by properly delaying the start of run for each board in the chain. The delay value to set is usually zero for the last board and rises going backwards along the chain.

Address 0x8170
Mode R/W
Attribute C

Bit	Description
[7:0]	Delay value in steps of 16 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]	Reserved
[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, 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 = reserved, 1 = reserved, 2 = reserved, 3 = nRun In) or as outputs (0 = reserved, 1 = reserved, 2 = reserved, 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
[31:16]	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 $0.976 \cdot 2^n$ 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

Extended Veto Delay

This register is valid for VME boards only and set the duration of the Extended VetoIn signal for trigger inhibit on TRG-OUT when bit[12]=1 of 0x8100 register. Such function is useful in particular cases of synchronization of a multi-board system.

Note: This register is valid from ROC FPGA fw revision 4.16 on.

Address 0x81C4
Mode R/W
Attribute C

Bit	Description
[15:0]	Extended VetoIn duration value in units of the Trigger Clock (8 ns)
[31:16]	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 - 0xFFFFFFF0 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 empty
[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 VME form factor are: V1751/VX1751: 0x60; V1751B/VX1751B: 0x61; V1751C/VX1751C: 0x62. Options for Desktop/NIM form factor are: DT5751/N6751: 0x60
[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-PSD 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” (N_b), address 0x800C: defines how many aggregates can be contained in the memory ($n_{aggr} = 2^{N_b}$).
- “Number of Events per Aggregate” (N_e), address 0x1n34: defines the number of events contained in one aggregate. The maximum allowed value is 1023.
- “Record Length” (N_s), address 0x1n20: defines the number of samples for the waveform acquisition, when enabled ($rec_len = N_s * 12$).
- “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 N_e 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 two charges Q_{short} and Q_{long} , and the Baseline/Extras information.

751 series

The following section describes the structure of the memory organization of 751 series. The physical memory of a board is made of memory locations, each of 120-bit (16B) In terms of location occupancy:

Trigger Time Stamp = 1 location;
Waveform (if enabled) = 1 location every 12 samples;
Charges (Q_L and Q_S) and 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 (N_e) and the number of buffers (2^{N_b}) accordingly. When the board runs in List Mode, the event memory contains only two locations, one for the Trigger Time Tag and one for the Charge and Baseline. Therefore it is very small and it is suggested to use a big value for N_e 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 N_e 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 N_e low (typically 1).

Example: suppose that the mixed mode is enabled and $N_s = 480$ samples:

Event size (in locations) = $1(\text{Time_Stamp}) + N_s/12(\text{Waveform}) + 1(\text{Charges_EXTRA}) = 42$. Suppose to have $N_e = 30$ (number of events per buffer), hence: buffer_size (in locations) = $42 * 30 = 1260$ loc. Supposing that the board memory is made of 128k loc./ch, the number of buffers will be: $128k/1260 = 102$ (buffers).

This value corresponds to the maximum number of buffers that the memory can contain. However, since the programmable value must be a power of two, the user has to choose the closest number smaller than 102 which can be represented as a power of two, that is $26 = 64$ (i.e. $N_b = 6$ has to be written in the Aggregate Organization register).

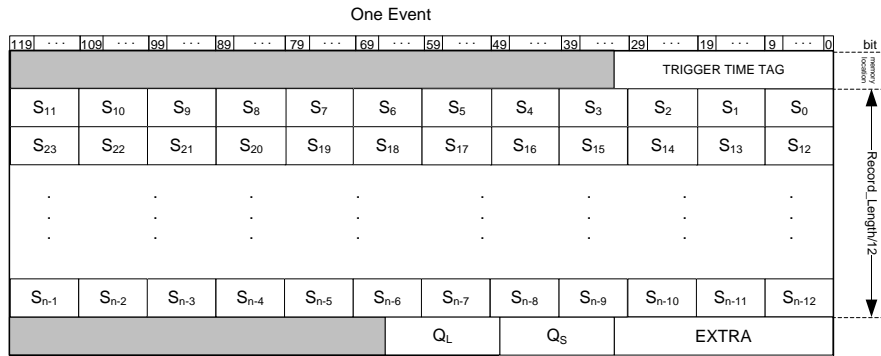


Fig. 2.1: Data organization into the Internal Memory of x751.

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 751 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) for series 751 is shown in Fig. 2.2, where:

“CHANNEL AGGREGATE” DATA FORMAT

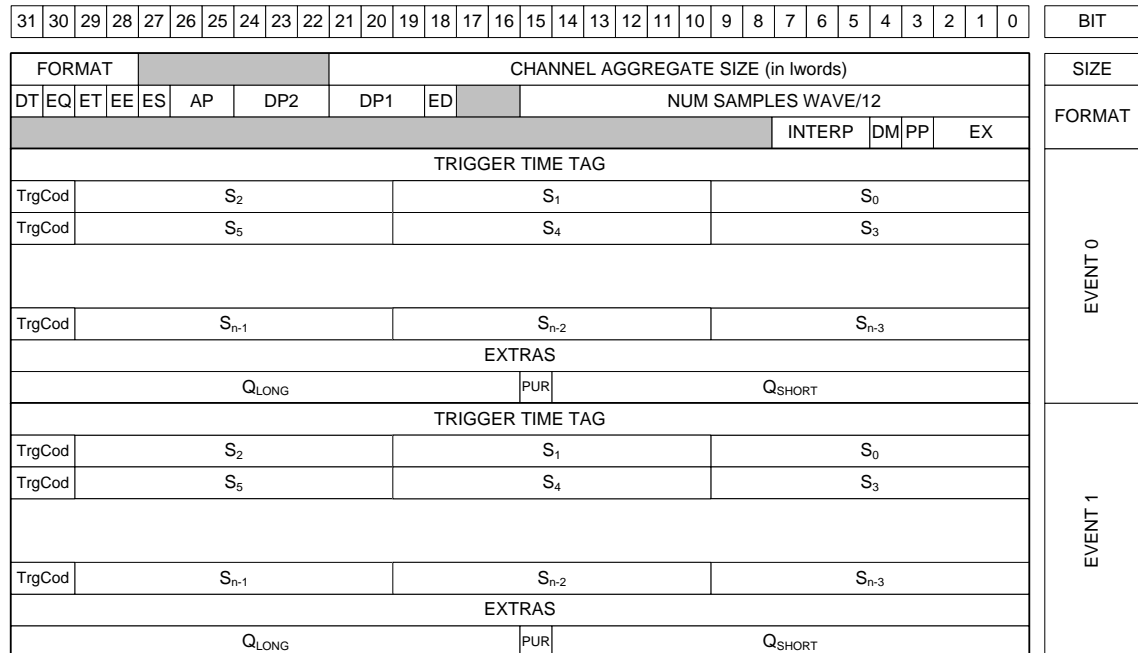


Fig. 2.2: Channel Aggregate Data Format scheme for 751 series.

FORMAT: defines the structure of the two consecutive words of FORMAT. Options are:

1000: format consistent with DPP-PSD firmware revision less than 132.32, where the second word of the FORMAT is not present, AP = 00, and EXTRAS[9:0] = BASELINE. This option is valid if bit[31] of register 0x8000 is equal to 0.

0100: format consistent with DPP-PSD firmware revision equal/greater than 132.32. The event data format is defined below. Enable this option by setting bit[31] = 1 of register 0x8000.

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

EQ: Charge enabled flag

ET: Time Tag enabled flag

EE: Extras enabled flag

ES: Waveform (samples) enabled flag

AP: Analog Probe selection. Possible selections are:

If DT = 0:

00 = "Input";

01 = "CFD";

If DT = 1:

00 = "Input" and "Baseline";

01 = "CFD" and "Baseline";

10 = "Input" and "CFD".

DP1: Digital Virtual Probe 1 selection among:

000 = "Long Gate";

001 = "Over Threshold", digital signal that is 1 when the input signal is over the requested threshold;

010 = "Shaped TRG", 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 (refer to [RD2]);

011 = "TRG Val. Acceptance Win.", logic signal corresponding to the time window where the coincidence validation is accepted. The validation enables the event dump into the memory (see [RD2]);

100 = "Pile Up", logic pulse set to 1 when a pile up event occurred (to be implemented);

101 = "Coincidence", logic pulse set to 1 when a coincidence occurred (refer to [RD2]);

DP2: Digital Virtual Probe 2 selection among:

000 = "Short Gate";

001 = "Over Threshold", digital signal that is 1 when the input signal is over the requested threshold;

010 = "TRG Validation", digital signal that is 1 when a coincidence validation signal comes from the mother board FPGA(refer to [RD2]);

011 = "TRG HoldOff", logic signal generated by a channel in correspondence with its local self- trigger. Other triggers are inhibited for the overall Trigger Hold-Off duration;

100 = "Pile Up", logic pulse set to 1 when a pile up event occurred (to be implemented);

101 = "Coincidence", logic pulse set to 1 when a coincidence occurred (refer to [RD2]);

ED: Digital Probe enabled flag.



Note:When ED ≠ 0, the analog trace sample is represented into 8 bits, rather than 10 bits. Indeed the two most significant bits of each samples are reserved for the two digital probes. Conversely, when ED = 0, each analog trace sample is represented into 10 bits.

INTERP: Interpolation Points used for the CFD or LED linear interpolation. The n-th sample before and after the zero crossing are defined according to the options:

000 = the sample before and after the zero crossing;

001 = second sample before and after the zero crossing;

010 = third sample before and after the zero crossing;

011 = fourth sample before and after the zero crossing;

100 = fifth sample before and after the zero crossing;

101 = sixth sample before and after the zero crossing;
 110 = seventh sample before and after the zero crossing;
 111 = eighth sample before and after the zero crossing.

DM: Discrimination Mode. Options are:

0 = Leading Edge Discrimination;
 1 = digital Constant Fraction Discrimination.

PP: Pulse Polarity identifies the pulse polarity and the trigger on the rising/falling edge.

0 = trigger on rising edge;
 1 = trigger on falling edge.

EX: Extras option enabled flag:



Note: to enable the “EXTRAS” word set bit[17] of register 0x8000.

000 = the word “EXTRAS” will be read as:

[31 : 16] = extended time stamp: those 16 bits become the most significant bits of the Time Stamp representation, which becomes a 32+16=48 bit number;
 [15 : 0] = the baseline value multiplied by 8.

001 = the word “EXTRAS” will be read as:

[31 : 16] = extended time stamp: those 16 bits become the most significant bits of the Time Stamp representation, which becomes a 32+16=48 bit number;
 [15 : 0] = flags, currently N.A.;

010 = the word “EXTRAS” will be read as:

[31 : 16] = extended time stamp – the trigger time stamp becomes a 32+16=48 bit number;
 [15 : 10] = flags, currently N.A.;
 [9 : 0] = fine time stamp (Tfine – see the definition in [RD3]).

011 = the word “EXTRAS” will be read as:

[31 : 26] = flags, currently N.A.;
 [26 : 16] = fine time stamp (Tfine – see the definition in [RD3]).
 [15 : 0] = the baseline value multiplied by 8.

101 = the word “EXTRAS” will be read as:

[31] = Discrimination Mode. Options are the same of DM field;
 [30] = Pulse Polarity. Options are the same of PP field;
 [29 : 20] = n-th Sample Before the Zero Crossing (SBZC), according to bits[12:10] of register 0x8000 (see definition from [RD3]);
 [19 : 10] = n-th Sample After the Zero Crossing (SAZC), according to bits[12:10] of register 0x8000 (see definition from [RD3]);
 [9 : 0] = Mid-Scale value (= 512) in case of CFD, or Threshold Value in case of LED.

NUM SAMPLES WAVE/12 corresponds to the number of words to be read in the event related to the waveform / 4 (3 samples per word)

$S_{m'}$ ($m'=0, 2, 4, \dots, n-2$): Even Samples of input signal at time $t=m'$. (*)

$S_{m''}$ ($m''=1, 3, 5, \dots, n-1$): Odd Samples of input signal at time $t=m''$. If $DT=1$, $S_{m''}$ corresponds to the Baseline at time $t=m''-1$. (*)

Trg Cod: encodes on which sample (of the same word) the trigger fired

00 = no trigger
 01 = trigger on the first sample S0
 10 = trigger on the second sample S1
 11 = trigger on the third sample S2

$Q_{\text{short/long}}$: integrated charge value in the short/long gate



Note: when the “Dual Trace” option is enabled half of the samples are used to store the baseline. Therefore only the remaining half samples are used for the input waveform. In the plot visualization each input sample is duplicated to keep the same granularity. Those who need to acquire waveforms with full resolution should disable the dual trace option. In CoMPASS select the “NONE” option for “Analog Probe 2” (refer to [RD3] for more details).



Note: when the “Digital Probes” are enabled, the input is represented into 8 bits rather than 10 bits. This means that the input granularity in the plot visualization is four. Those who need to acquire waveforms with full resolution should select “NONE” for both Digital Trace 2 and 3 in the CoMPASS GUI (see [RD3] for further details).

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 sample 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. 2.3 for 751 series:

“BOARD AGGREGATE” DATA FORMAT for 751 series

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
1	0	1	0	BOARD AGGREGATE SIZE (in lwords)																								HEADER				
BOARD ID				BF	PATTERN														CHANNEL MASK						CH 0							
					BOARD AGGREGATE COUNTER																			CH 1								
					BOARD AGGREGATE TIME TAG																					...						
																											CH 7					
CHANNEL AGGREGATE CH0																																
CHANNEL AGGREGATE CH1																																
CHANNEL AGGREGATE CH7																																

Fig. 2.3: Board Aggregate Data Format scheme for 751 series.

BOARD AGGREGATE SIZE: total size of the aggregate

BOARD ID: corresponds to the GEO address of the board. In case of VX 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 Board ID through register 0xEF08. The GEO address is quite useful in case of concatenate BLT (CBLT) read.

BF: Board Fail flag. This bit is set to “1” because of a hardware problem, as for example the PLL unlock. The user can investigate the problem checking the Board Failure Status register 0x8178, or contacting CAEN support (refer to Chapter 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;

DUAL CHANNEL MASK: corresponds to the couple of channels participating to the Board Aggregate (725 and 730 only);

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. 2.4**

DATA BLOCK

BOARD AGGREGATE 0
BOARD AGGREGATE 1
...
BOARD AGGREGATE n-1

Fig. 2.4: Data Block scheme.

3 Technical Support

To contact CAEN specialists for requests on the software, hardware, and board return and repair, it is necessary a MyCAEN+ account on www.caen.it:

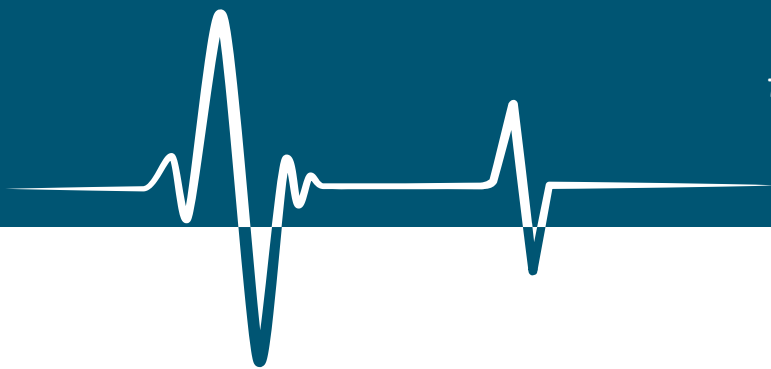
<https://www.caen.it/support-services/getting-started-with-mycaen-portal/>

All the instructions for use the Support platform are in the document:

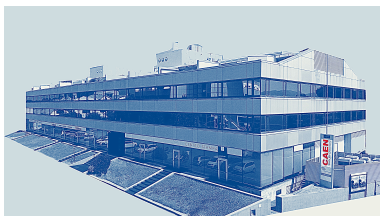


A paper copy of the document is delivered with CAEN boards.
The document is downloadable for free in PDF digital format at:

<https://www.caen.it/safety-information-product-support>

**CAEN S.p.A.**

Via Vetràia 11
55049 - Viareggio
Italy
Phone +39 0584 388 398
Fax +39 0584 388 959
info@caen.it
www.caen.it

**CAEN GmbH**

Brunnenweg 9
64331 Weiterstadt
Germany
Phone +49 212 254 40 77
Fax +49 212 254 40 79
info@caen-de.com
www.caen-de.com

CAEN Technologies, Inc.

1 Edgewater Street - Suite 101
Staten Island, NY 10305
USA
Phone: +1 (718) 981-0401
Fax: +1 (718) 556-9185
info@caentechnologies.com
www.caentechnologies.com

CAENspa INDIA Private Limited

B205, BLDG42, B Wing,
Azad Nagar Sangam CHS,
Mhada Layout, Azad Nagar, Andheri (W)
Mumbai, Mumbai City,
Maharashtra, India, 400053
info@caen-india.in
www.caen-india.in



UM5110 - 751 DPP-PSD - Register Description and Data Format rev. 3 - December 21st, 2023 00000-00-DGT28-MUTX

Copyright ©CAEN SpA. All rights reserved. Information in this publication supersedes all earlier versions. Specifications subject to change without notice.