

# **Technical Information Manual**

Revision n. 6  
27 February 2009

**MOD. V1495**  
*GENERAL PURPOSE*  
*VME BOARD*

**NPO:**  
**00117/04:V1495.MUTx/06**

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# 1. General description

## 1.1. Overview

The Mod. V1495 is a VME 6U board, 1U wide, suitable for various digital Gate/Trigger/Translate/Buffer/Test applications, which can be directly customised by the User, and whose management is handled by two FPGA's:

FPGA "Bridge", which is used for the VME interface and for the connection between the VME interface and the 2nd FPGA (FPGA "User") through a proprietary local bus. FPGA "Bridge" manages also the programming via VME of the FPGA "User".

FPGA "User", which manages the front panel I/O channels. FPGA "User" is provided with a basic firmware which allows to perform coincidence matrix, I/O register and asynchronous timers functions.

FPGA "User" can be also free reprogrammed by the user with own custom logic function (see § 5.1). It is connected as slave to the FPGA "Bridge" via CAEN Local Bus, whose protocol shall be used in order to communicate with the FPGA "Bridge" and thus with the VME bus.

The I/O channel digital interface is composed by four sections (A, B, C, G) placed on the motherboard (see § 1.2). The channel interface can be expanded in the D, E, F sections by using up to 3 mezzanine boards (see § 2.6 and § 2.7), which can be added, choosing between the four types developed in order to cover the I/O functions and the ECL, PECL, LVDS, NIM, TTL electrical standard (see § 1.2). The maximum number of channels can be expanded up to 194.

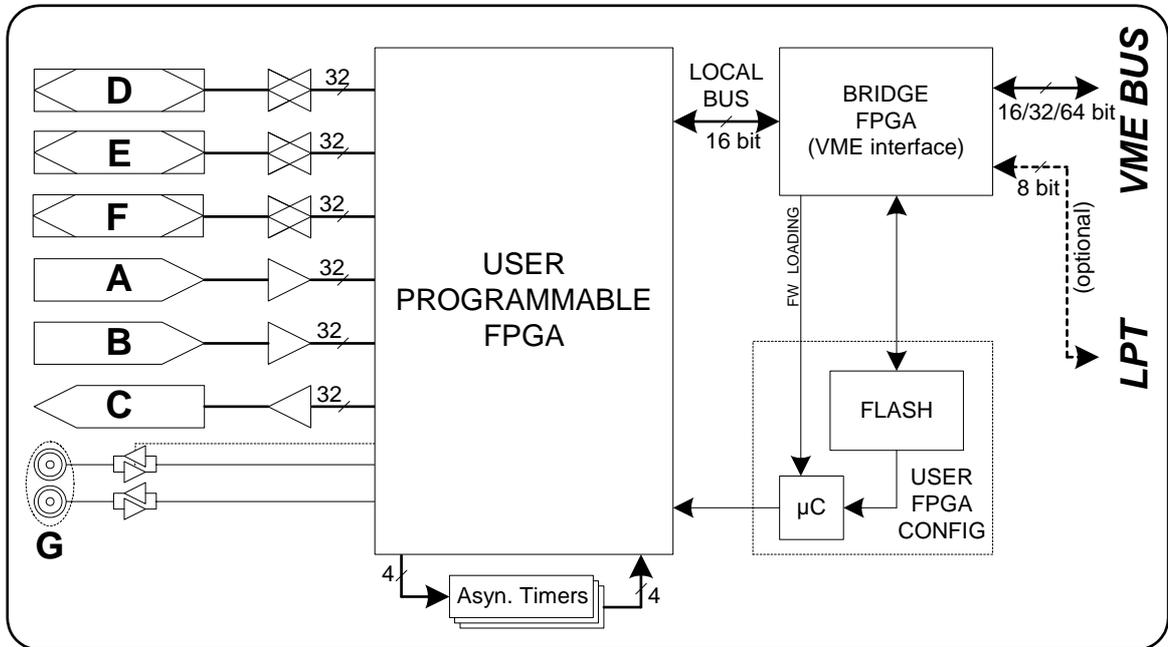
The FPGA "User" can be programmed "on the fly" directly via VME, without external hardware tools, without disconnecting the board from the set up, without resetting it or turning the crate off, allowing quick debug operations by the developer with his own firmware. A flash memory on the board can store the different programming file, which can be loaded to the FPGA "User" at any moment.

Four independent digital programmable asynchronous timers are available for Gate/Trigger applications. It is possible to chain them for generating complex Gate/Trigger pulse.

**Table 1.1: Available items**

Code	Description
WV1495XAAAAA	V1495 - General Purpose VME Board
WA395XAAAAAA	A395A - 32 LVDS/ECL/PECL input channels
WA395XBAAAAA	A395B - 32 LVDS output channels
WA395XCAAAAA	A395C - 32 ECL output channels
WA395XDAAAAA	A395D - 8 NIM/TTL input/output channels
WPERS0149501	V1495 - Customization - 3 A395C Mounting Option
WA967XAAAAAA	A967 - 32 Channel Cable Adapter (1x32 to 2x16)

## 1.2. Block Diagram



**Fig. 1.1: Mod. V1495 Block Diagram**

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## 2. Technical specifications

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### 2.1. Packaging

The module is housed in a 6U-high, 1U-wide VME unit. The board is provided the VME P1, and P2 connectors and fits into both VME standard and V430 backplanes.

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### 2.2. Power requirements

The power requirements of the modules are as follows:

**Table 2.1: Model V1495 and mezzanine boards power requirements**

Power supply	Mod. V1495	Mod. A395A	Mod. A395B	Mod. A395C	Mod. A395D
+5 V	1 A	0.1 A	0.1 A	1.4 A	1.1 A

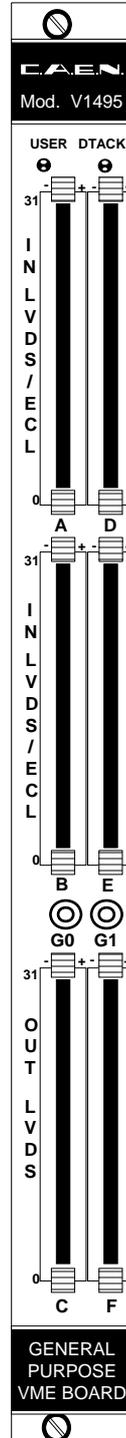
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### 2.3. Front panel displays

The front panel (refer to § 2.4) hosts the following LEDs:

<b>DTACK:</b>	<i>Colour:</i> green. <i>Function:</i> it lights up green whenever a VME read/write access to the board is performed.
<b>USER:</b>	<i>Colour:</i> green / orange / red. <i>Function:</i> programmable.

## 2.4. Front Panel



**Fig. 2.1: Model V1495 front panel (with A395A/B/C piggy back boards)**

## 2.5. Motherboard Specifications

The Mod. V1495 Motherboard is composed by four I/O sections (see § 1.2), described in the following table:

**Table 2.2: V1495 Motherboard I/O sections**

Board	No. of Ch.	Direction	Logic	Signal	Bandwidth	Front panel connector
<b>A</b>	32	Input	Direct	LVDS/ECL/PECL (single ended TTL optional) 110ohm Rt. Extended Common Mode input range -4V to +5V; Fail Safe input feature.	200MHz	Robinson Nugent P50E-068-P1-SR1-TG type, (34+34) pins
<b>B</b>	32	Input	Direct	LVDS/ECL/PECL (single ended TTL optional) 110ohm Rt. Extended Common Mode input range -4V to +5V; Fail Safe input feature.	200MHz	Robinson Nugent P50E-068-P1-SR1-TG type, (34+34) pins
<b>C</b>	32	Output	Direct	LVDS 100ohm RI	250MHz	Robinson Nugent P50E-068-P1-SR1-TG type, (34+34) pins
<b>G</b>	2	I/O selectable	TTL IN=Direct TTL OUT=Direct NIM IN=Invert NIM OUT=Direct	NIM/TTL selectable Open/50ohm Rt selectable	250MHz	LEMO 00

## 2.6. Mezzanine Specifications

The four I/O Mezzanine boards developed so far are described in the following table:

**Table 2.3: V1495 Mezzanine boards**

Board	No. of Ch.	Direction	Logic	Signal	Bandwidth	Front panel connector
<b>A395A</b>	32	Input	Direct	LVDS/ECL/PECL (single ended TTL optional) 110ohm Rt. Extended Common Mode input range -4V to +5V; Fail Safe input feature.	200MHz	Robinson Nugent P50E-068-P1-SR1-TG type, (34+34) pins
<b>A395B</b>	32	Output	Direct	LVDS 100ohm RI	250MHz	Robinson Nugent P50E-068-P1-SR1-TG type, (34+34) pins
<b>A395C</b>	32	Output	Direct	ECL	300MHz	Robinson Nugent P50E-068-P1-SR1-TG type, (34+34) pins
<b>A395D</b>	8	I/O selectable	TTL IN=Direct TTL OUT=Direct NIM IN=Invert NIM OUT=Direct	NIM/TTL selectable Open/50ohm Rt selectable	250MHz	LEMO 00

## 2.7. Mezzanine boards installation

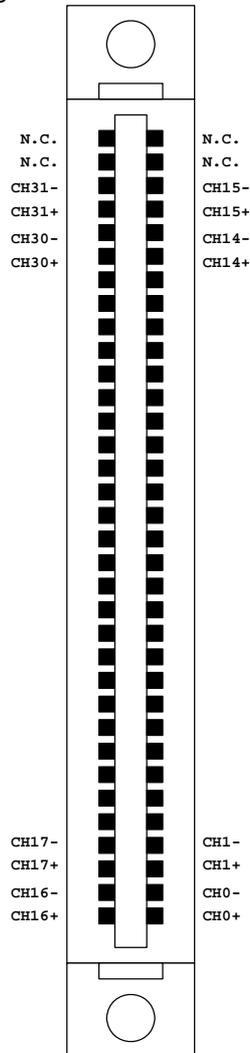
In order to install one A395x-series mezzanine board on the V1495 motherboard it is necessary to follow these steps:

- Remove (unscrew) the metal cover (one at will)
- Plug the mezzanine board into the 100 pin connector on the motherboard
- Fix the mezzanine board with the screws

**WARNING! A Mounting Option is necessary in order to install three A395C mezzanine boards on the V1495 (see table 1.1)**

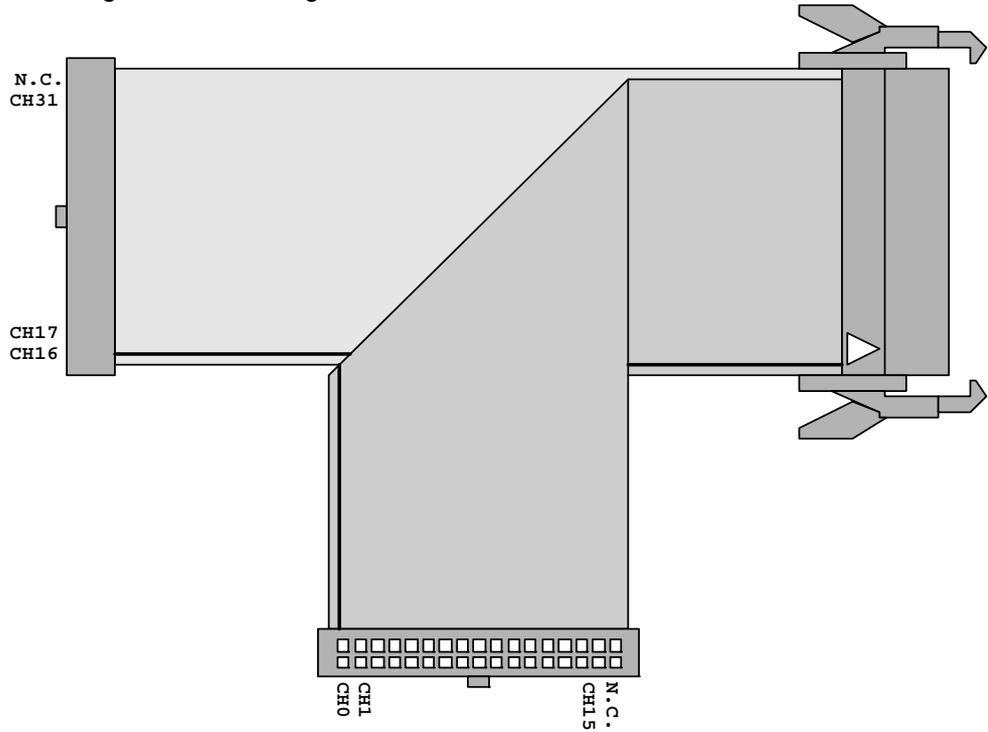
## 2.8. Front panel connector cabling

Motherboard I/O sections A, B, C and A395A, A395B and A395C Mezzanine boards feature the Robinson Nugent P50E-068-P1-SR1-TG multipin connector, whose pin set is shown in the following figure:



**Fig. 2.2: Multipin connector pin assignment**

The CAEN Mod. A967 Cable Adapter allows to adapt each Robinson Nugent Multipin Connector into two 1" 17+17-pin Header-type male connectors (3M, 4634-7301) with locks through two 25 cm long flat cables.



**Fig. 2.3: Mod. A967 Cable Adapter**

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## 3. Operating modes

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### 3.1. Timers

Gate/Trigger applications require the production of an output signal with programmable width (Gate), whenever an input signal (Trigger) occurs.

Gates can be produced in several ways, according to the system set up, which can be either synchronous or asynchronous.

Synchronous systems:

Input signals are referred to a system clock: they can be sampled by the clock itself and the output is a gate signal (obtained with a counter) whose width (and delay) is a multiple of the clock period. If the application requires a width (and delay) of the Gate signal synchronous but with step resolution higher than the system clock period, this can be achieved by enabling the PLL in the USER FPGA and enter the reference clock on channel G0.

Asynchronous systems:

Input signals are not referred to a system clock. As a consequence the gate signal will be generated without any time reference. It is possible to use the implementation described above, with the freedom of choosing the clock source between external or 40MHz internal. The resulting Gate signal will have stable duration, but with maximum position jitter equal to one clock period.

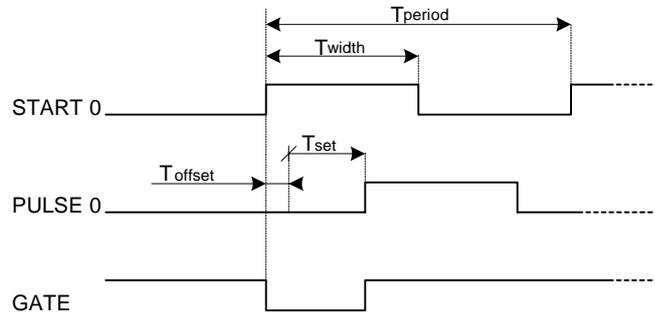
Such position jitter can be rejected by using the asynchronous timers present on the V1495, which allow to generate references synchronous with the occurred trigger.

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#### 3.1.1. *Timer0, Timer1*

Each timer is based on a programmable delay line. FPGA USER drives a STARTx pulse and, after the programmed delay, it receives the return signal PULSEx. The time difference between transmission and reception (logic implementation inside the FPGA USER) can be used to drive a gate signal. The programming of the delay time can be done manually as binary value either via 8 bit dip switches (SW4 and SW5) or via VME register, with a 1ns step resolution (max step delay = 255ns). The software setting has higher priority with respect to the dip switches.

The following figure shows a diagram of the timers usage:



$$T_{dly} = T_{offset} + T_{set}$$

$$T_{offset} = 30 \pm 2ns$$

$$T_{set} = SETBINARY * 1ns$$

$$START_x-WIDTHMIN = 320ns \text{ recommended } (22ns \text{ absolute min.})$$

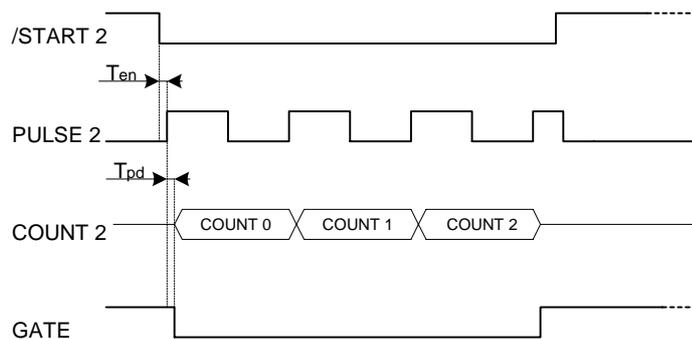
$$START_x-PERIODMIN = 640ns \text{ recommended } (46ns \text{ absolute min.})$$

**Fig. 3.1: Timers diagram**

The use of START<sub>x</sub> signals with timing shorter than those recommended is possible, although the linearity on the set delay scale is no longer guaranteed.

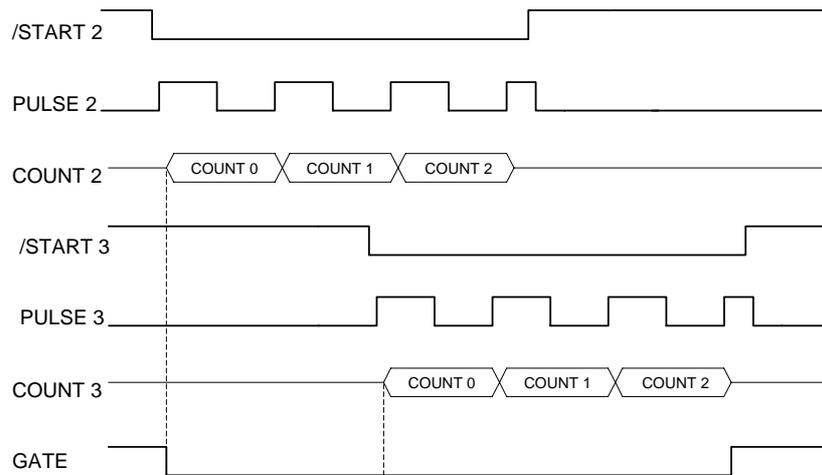
### 3.1.2. Timer2, Timer3

Each timer is made up of one digital circuit which produces a typical fixed time base with 10ns period and 50% duty cycle. These timers are proposed for generating any Gate pulse > 10ns with a 10ns step. The following figure shows an example of a Gate generation made with Timer2 and n.3 PULSE width.



**Fig. 3.2: Gate pulse example**

FPGA USER drives a /START<sub>x</sub> pulse and after T<sub>EN</sub> time FPGA USER will receive a PULSE<sub>x</sub> clock signal. A counter with clock = PULSE<sub>x</sub> implemented in the FPGA USER, allows to generate a pulse with programmable duration. It is possible to reduce to one half (5ns) the counter step by advancing the counter on both sides of PULSE<sub>x</sub>. Since the circuit is completely digital, no recovery time is necessary between one stop and the following start: it is thus possible to generate multiple gate pulses with very high rate. Timer2 and Timer3 can be used together for handling one single Gate pulse from multiple overlapped triggers.



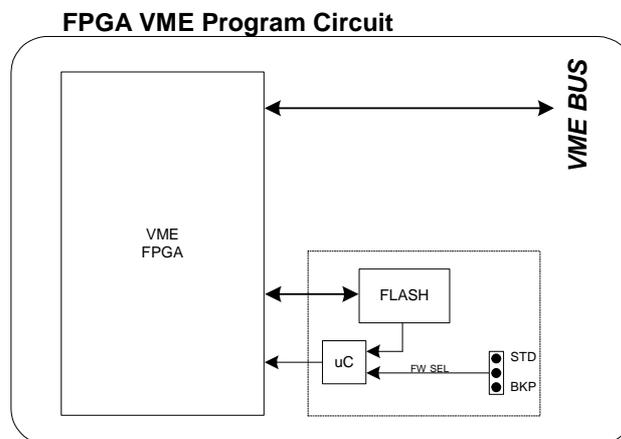
**Fig. 3.3: Timer2 and Timer3 used together for handling a Gate pulse**

## 3.2. FPGA Programming

The programming of FPGA VME and FPGA USER are handled by two independent microcontrollers + flash memory. The updating of the firmware contained in the flash memories does not require the use of external tools and can be executed via VME. The flash related to FPGA VME contains the firmware dedicated to the interface of the board with the FPGA USER and the VME bus; such firmware is developed by CAEN. The flash related to the FPGA USER contains the firmware developed by the User according to his own application requirements.

### 3.2.1. FPGA VME

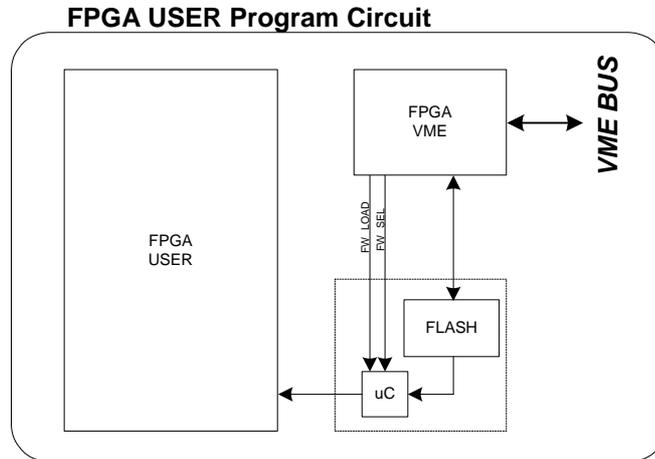
The microcontroller provides the firmware uploading at board's power on. The flash memory contains two versions of the firmware, which can be selected manually via jumper (Standard or Backup).



**Fig. 3.4: FPGA VME diagram**

### 3.2.2. *FPGA USER*

The microcontroller provides the firmware uploading at board's power on. The flash memory contains one firmware image only (Standard).



**Fig. 3.5: FPGA USER diagram**

FPGA VME aim is to handle the operation of FPGA USER, which can be programmed on the fly, i.e. without turning off the system, thus allowing quick debug operations by the Developer.

Register implemented on FPGA VME allows the following operations:

- FPGA USER flash memory programming.
- FPGA USER updating.

## 4. VME Interface

### 4.1. Register address map

The Address map for the Model V1495 is listed in Table 4.1. All register addresses are referred to the Base Address of the board, i.e. the addresses reported in the Tables are the offsets to be added to the board Base Address.

**Table 4.1: Address Map for the Model V1495**

ADDRESS	REGISTER/CONTENT	ADDR	DATA	Read/Write
Base + 0x0000÷0x7FFC	USER FPGA Access	A24/A32	D16	R/W (*)
Base + 0x8000	Control Register	A24/A32	D16	R/W
Base + 0x8002	Status Register	A24/A32	D16	R
Base + 0x8004	Interrupt Level	A24/A32	D16	R/W
Base + 0x8006	Interrupt Status-ID	A24/A32	D16	R/W
Base + 0x8008	Geo Address_Register	A24/A32	D16	R
Base + 0x800A	Module Reset	A24/A32	D16	W
Base + 0x800C	Firmware revision	A24/A32	D16	R
Base + 0x800E	Select VME FPGA Flash(**)	A24/A32	D16	R/W
Base + 0x8010	VME FPGA Flash memory(**)	A24/A32	D16	R/W
Base + 0x8012	Select USER FPGA Flash(**)	A24/A32	D16	R/W
Base + 0x8014	USER FPGA Flash memory(**)	A24/A32	D16	R/W
Base + 0x8016	USER FPGA Configuration(**)	A24/A32	D16	R/W
Base + 0x8018	Scratch16	A24/A32	D16	R/W
Base + 0x8020	Scratch32	A24/A32	D32	R/W
Base + 0x8100÷0x801FE	Configuration ROM(**)	A24/A32	D16	R

(\*) Read/Write capability depends on USER FPGA implementation.

(\*\*) See § 5.7

#### 4.1.1. Configuration ROM

The following registers contain some module's information according to the Table 3.2, they are D16 accessible (read only):

- **OUI:** manufacturer identifier (IEEE OUI)
- **Version:** purchased version
- **Board ID:** Board identifier
- **Revision:** hardware revision identifier
- **Serial MSB:** serial number (MSB)
- **Serial LSB:** serial number (LSB)

**Table 4.2: ROM Address Map for the Model V1495**

Description	Address	Content
checksum	0x8100	
checksum_length2	0x8104	
checksum_length1	0x8108	
checksum_length0	0x810C	
constant2	0x8110	

Description	Address	Content
constant1	0x8114	
constant0	0x8118	
c_code	0x811C	
r_code	0x8120	
oui2	0x8124	0x00
oui1	0x8128	0x40
oui0	0x812C	0xE6
vers	0x8130	
board2	0x8134	0x00
board1	0x8138	0x05
board0	0x813C	0xD7
revis3	0x8140	
revis2	0x8144	
revis1	0x8148	
revis0	0x814C	
sernum1	0x8180	
sernum0	0x8184	

These data are written into one Flash page; at Power ON the Flash content is loaded into the Configuration ROM.

## 4.2. Control Register

(Base Address + 0x8000, read/write, D16)

This register allows performing some general settings of the module.  
Not used for VME FPGA Rev 0.0. Foreseen for future development

## 4.3. Status Register

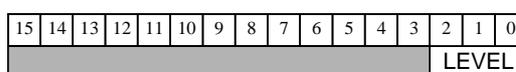
(Base + 0x8002, read only, D16)

This register contains information on the status of the module.  
Not used for VME FPGA Rev 0.0. Foreseen for future development

## 4.4. Interrupt Level Register

(Base Address + 0x8004, read/write, D16)

The 3 LSB of this register contain the value of the interrupt level (Bits 3 to 15 are meaningless). Default setting is 0x0. In this case interrupt generation is disabled.  
Not implemented in VME FPGA Rev 0.0. Available in next releases

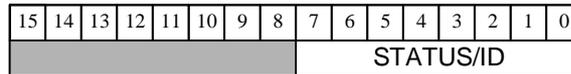


**Fig. 4.1: Interrupt Level Register**

## 4.5. Interrupt Status-ID Register

(Base Address + 0x8006, read/write, D16)

This register contains the STATUS/ID that the V1495 places on the VME data bus during the Interrupt Acknowledge cycle (Bits 8 to 15 are meaningless). Default setting is 0xDD. Not implemented in VME FPGA Rev 0.0. Available in next releases

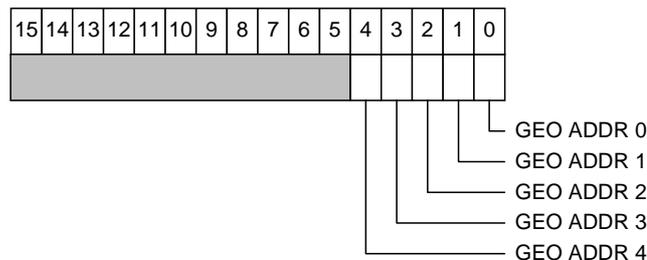


**Fig. 4.2: Interrupt Vector Register**

## 4.6. GEO Address Register

(Base Address + 0x8008, read, D16)

The register content is the following:



**Fig. 4.3: Geographical address register**

This register allows readback of the level of GEO pins for the selected board. The register content is valid only for the VME64X board version. The register content for the VME64 version is 0x1F.

## 4.7. Module Reset Register

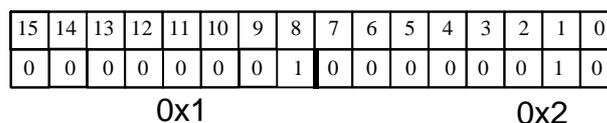
(Base Address + 0x800A write only, D16)

A dummy access to this register allows to generate a single shot RESET of the module.

## 4.8. Firmware Revision Register

(Base Address + 0x800C, read only, D16)

This register contains the firmware revision number coded on 8 bit. For instance, the REV. 1.2 register content is:



**Fig. 4.4: Firmware Revision Register**

---

## 4.9. Scratch16 Register

(Base Address + 0x8018, D16, read/write)

This register allows to perform 16 bit test accesses for test purposes.

---

## 4.10. Scratch32 Register

(Base Address + 0x8020, D32, read/write)

This register allows to perform 32 bit test accesses for test purposes.

---

## 4.11. Select VME FPGA Flash Register

(Base Address + 0x800E, read/write, D16)

This register allows the VME FPGA configuration update (stored into on-board flash memory) via VMEBUS.

The configuration can be updated by the user by means of the V1495Upgrade software (developed and distributed by CAEN), see § 5.7.

---

## 4.12. Select USER FPGA Flash Register

(Base Address + 0x8012, read/write, D16)

This register allows USER FPGA configuration update (stored into on-board flash memory) via VMEBUS.

The configuration can be updated by the user by means of the V1495Upgrade software (developed and distributed by CAEN), see § 5.7.

---

## 4.13. VME FPGA Flash Memory

(Base Address + 0x8010, read/write, D16)

This register allows the VME FPGA configuration update (stored into on-board flash memory) via VMEBUS.

The configuration can be updated by the user by means of the V1495Upgrade software (developed and distributed by CAEN), see § 5.7.

---

## 4.14. USER FPGA Flash Memory

(Base Address + 0x8014, read/write, D16)

This register allows the USER FPGA configuration update (stored into on-board flash memory) via VMEBUS.

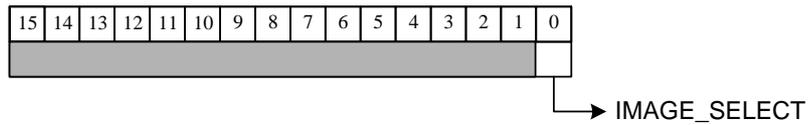
The configuration can be updated by the user by means of the V1495Upgrade software (developed and distributed by CAEN), see § 5.7.

## 4.15. USER FPGA Configuration Register

(Base Address + 0x8016, read/write, D16)

This register allows the update of the USER FPGA configuration. A write access to this register generates a configuration reload. The configuration image (Standard) will be uploaded into the USER FPGA as the IMAGE\_SELECT bit is set to 1:

IMAGE\_SELECT = 1 Standard image (default).

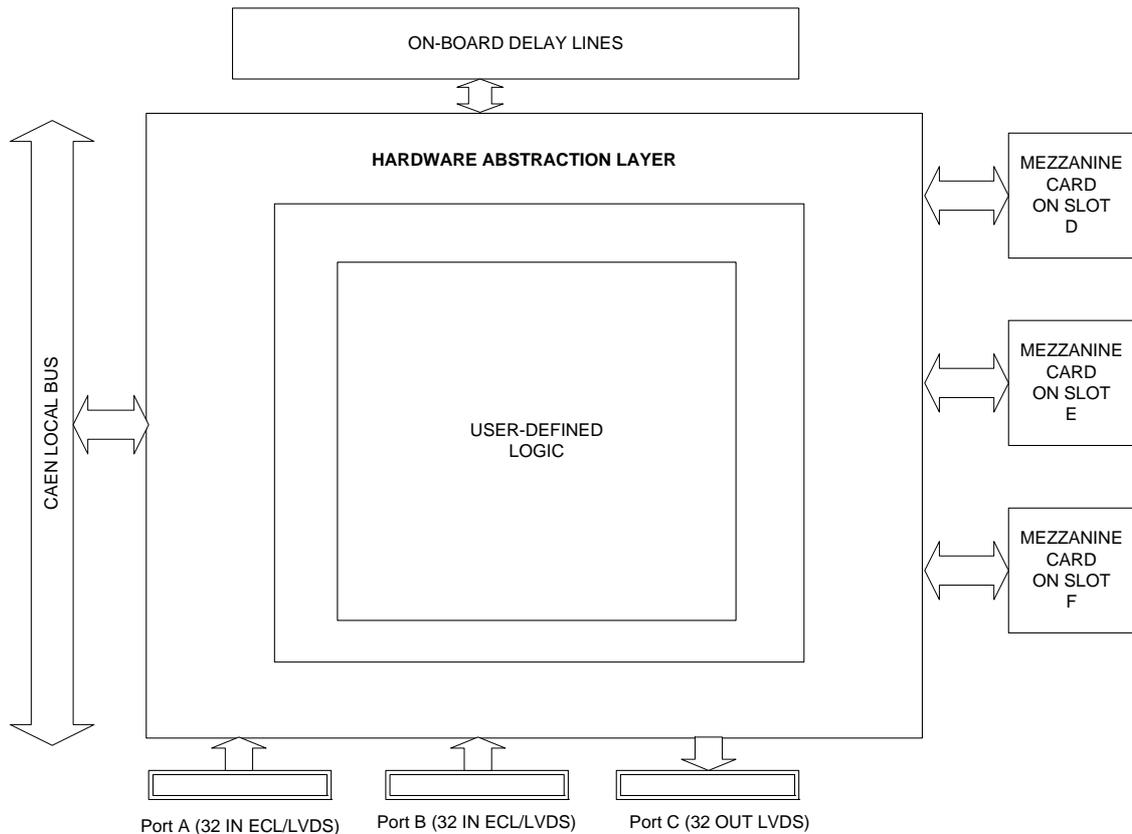


**Fig. 4.5: USER FPGA Configuration Register**

## 5. V1495 USER FPGA Reference Design Kit

### 5.1. Introduction

The CAEN V1495 board provides a user-customizable FPGA (called USER FPGA). The COIN\_REFERENCE reference design illustrates how to use the USER FPGA to implement a Coincidence Unit & I/O Register Unit. This design can be customised by the user in order to adapt its functionality to his own needs.



**Fig. 5.1: USER FPGA block diagram**

### 5.2. Design Kit

#### 5.2.1. V1495HAL

The V1495 Hardware Abstraction Layer (V1495HAL) is a HDL module provided, in Verilog format at netlist level, in order to help the hardware interfacing.

## 5.2.2. COIN\_REFERENCE Design

The COIN\_REFERENCE design VHDL entity is the interface to the V1495HAL. If the User wishes to use V1495HAL to develop his own application on the V1495 platform, the VHDL entity must not be modified: this means that signals names and function of the COIN\_REFERENCE entity must be used, as shown in the following table:

**Table 5.1: COIN\_REFERENCE signals**

PORT NAME	DIRECTION	WIDTH	DESCRIPTION
<b>GLOBAL SIGNALS</b>			
NLBRES	IN	1	Async Reset (active low)
LCLK	IN	1	Local Bus Clock (40 MHz)
<b>REGISTER INTERFACE</b>			
REG_WREN	IN	1	Write pulse (active high)
REG_RDEN	IN	1	Read pulse (active high)
REG_ADDR	IN	16	Register address
REG_DIN	IN	16	Data from CAEN Local Bus
REG_DOUT	OUT	16	Data to CAEN Local Bus
USR_ACCESS	IN	1	Current register access is at user address space(Active high)
<b>V1495 Front Panel Ports (PORT A,B,C,G) INTERFACE</b>			
A_DIN	IN	32	In A (32 x LVDS/ECL)
B_DIN	IN	32	In B (32 x LVDS/ECL)
C_DOUT	OUT	32	Out C (32 x LVDS)
G_LEV	OUT	1	Output Level Select (0=>TTL; 1=>NIM)
G_DIR	OUT	1	Output Enable (0=>Output, 1=>Input)
G_DOUT	OUT	2	Out G - LEMO (2 x NIM/TTL)
G_DIN	IN	2	In G - LEMO (2 x NIM/TTL)
<b>V1495 Mezzanine Expansion Ports (PORT D,E,F) INTERFACE</b>			
D_IDCODE	IN	3	D slot mezzanine Identifier
D_LEV	OUT	1	D slot Port Signal Level Select (the level selection depends on the mezzanine expansion board mounted onto this port)

PORT NAME	DIRECTION	WIDTH	DESCRIPTION
D_DIR	OUT	1	D slot Port Direction
D_DIN <sup>1</sup>	IN	32	D slot Data In Bus
D_DOUT	OUT	32	D slot Data Out Bus
E_IDCODE	IN	3	E slot mezzanine Identifier
E_LEV	OUT	1	E slot Port Signal Level Select (the level selection depends on the mezzanine expansion board mounted onto this port)
E_DIR	OUT	1	E slot Port Direction
E_DIN	IN	32	E slot Data In Bus
E_DOUT	OUT	32	E slot Data Out Bus
F_IDCODE	IN	3	F slot mezzanine Identifier
F_LEV	OUT	1	F slot Port Signal Level Select (the level selection depends on the mezzanine expansion board mounted onto this port)
F_DIR	OUT	1	F slot Port Direction
F_DIN	IN	32	F slot Data In Bus
F_DOUT	OUT	32	F slot Data Out Bus
<b>PDL CONFIGURATION INTERFACE</b>			
PDL_WR	OUT	1	Write Enable
PDL_SEL	OUT	1	PDL Selection (0=>PDL0, 1=>PDL1)
PDL_READ	IN	8	Read Data
PDL_WRITE	OUT	8	Write Data
PDL_DIR	OUT	1	Direction (0=>Write, 1=>Read)
<b>DELAY LINES AND OSCILLATORS I/O</b>			
PDL0_OUT	IN	1	Signal from PDL0 Output
PDL1_OUT	IN	1	Signal from PDL1 Output
DLO0_OUT	IN	1	Signal from DLO0 Output
DLO1_OUT	IN	1	Signal from DLO1 Output

<sup>1</sup> The I/O channels of the A395D Mezzanine board are mapped on the 8 LSB of D\_DIN, D\_DOUT, E\_DIN, E\_DOUT, F\_DIN, F\_DOUT signals

PORT NAME	DIRECTION	WIDTH	DESCRIPTION
PDL0_IN	OUT	1	Signal to PDL0
PDL1_IN	OUT	1	Signal to PDL1 Input
DLO0_GATE	OUT	1	Signal to DLO0 Input
DLO1_GATE	OUT	1	Signal to DLO1 Input
<b>SPARE INTERFACE</b>			
SPARE_OUT	OUT	12	SPARE Data Out
SPARE_IN	IN	12	SPARE Data In
SPARE_DIR	OUT	1	SPARE Direction
<b>LED INTERFACE</b>			
RED_PULSE	OUT	1	RED Led Pulse (active high)
GREEN_PULSE	OUT	1	GREEN Led Pulse (active high)

## 5.3. Interface description

### 5.3.1. Global Signals

The nLBRES must be used as an asynchronous reset signal by the user. An active low pulse will be generated when a write is done at the Module Reset register address (see § 4.1).

The LBCLK is a 40 MHz clock. It is the FPGA main clock.

### 5.3.2. REGISTER INTERFACE

The signals of the Register Interface allows to read/write into the USER FPGA registers, which can be accessed via VMEbus. The COIN\_REFERENCE module shows how to implement a set of registers.

The following table shows the registers map as it is provided. Each register address is coded via constants in V1495pkg.vhd file. This file allows to modify the registers map; all registers allow D16 accesses (write only, read only or read/write). Registers default value is the value after a reset for write only and read/write registers; read only registers return the status of the signals read by the FPGA and have no default value.

The Register Interface allows to abstract the VME registers access. The User can access a simple register interface: two signals (REG\_WREN e REG\_RDEN) are pulses with a one clock cycle duration which enables respectively a write or a read access to a register. REG\_ADDR signal represents the register address.

Writing into a register:

In case of a write operation into a register via VME, the 16 bit datum is available through the REG\_DIN signal. The datum is guaranteed stable on the CLK leading edge where REG\_WREN is active. The register access is valid only when USR\_ACCESS is at logic level = 1.

Reading from a register:

In case of a read operation from a register via VME, the datum to be returned must drive the REG\_DOUT and be stable on the CLK leading edge, where REG\_RDEN is active. The register access is valid only when USR\_ACCESS is at logic level = 1.

### 5.3.3. V1495 Front Panel Ports (PORT A,B,C,G) INTERFACE

These signals allows to handle the interface with the motherboard ports A, B, C, G. A\_DIN and B\_DIN signals show the logic level of A and B ports (32 bit, input only). The output logic level on port C can be set via C\_DOUT signal. The logic level on port G (LEMO connectors) can be set via G\_LEV signal; the direction via G\_DIR, the datum to be written via G\_DOUT or to be read via G\_DIN.

### 5.3.4. V1495 Mezzanine Expansion Ports (PORT D,E,F) INTERFACE

These signals allows to handle the interface with the piggy back board ports D, E, F. The following table explains the available signals:

**Table 5.2: V1495 Mezzanine Expansion Ports signals**

Port:	Signal:	Function:	Applies to:
D	D_DIR	Selects direction	Bidirectional port
	D_DIN	Read the logic level	Input/Bidirectional
	D_DOUT	Set the logic level	Output/Bidirectional
	D_IDCODE	Read IDCODE for piggy back identification	All
	D_LEV	Set the logic level	Output/Bidirectional
E	E_DIR	Selects direction	Bidirectional port
	E_DIN	Read the logic level	Input/Bidirectional
	E_DOUT	Set the logic level	Output/Bidirectional
	E_IDCODE	Read IDCODE for piggy back identification	All
	E_LEV	Set the logic level	Output/Bidirectional
F	F_DIR	Selects direction	Bidirectional port
	F_DIN	Read the logic level	Input/Bidirectional
	F_DOUT	Set the logic level	Output/Bidirectional
	F_IDCODE	Read IDCODE for piggy back identification	All
	F_LEV	Set the logic level	Output/Bidirectional

### 5.3.5. PDL Configuration Interface

PDL Configuration Interface signals are as follows:

**Table 5.3: PDL Configuration Interface signals**

PDL_WR	OUT	1	Write Enable
PDL_SEL	OUT	1	PDL Selection (0=>PDL0, 1=>PDL1)
PDL_READ	IN	8	Read Data
PDL_WRITE	OUT	8	Write Data

PDL_DIR	OUT	1	Direction (0=>Write, 1=>Read)
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### 5.3.6. Delay Lines and Oscillators I/O

Delay Lines and Oscillators signals are as follows (see also § 5.5.5 and § 5.5.6):

**Table 5.4: Delay Lines and Oscillators signals**

PDL0_OUT	IN	1	Signal from PDL0 Output
PDL1_OUT	IN	1	Signal from PDL1 Output
DLO0_OUT	IN	1	Signal from DLO0 Output
DLO1_OUT	IN	1	Signal from DLO1 Output
PDL0_IN	OUT	1	Signal to PDL0
PDL1_IN	OUT	1	Signal to PDL1 Input
DLO0_GATE	OUT	1	Signal to DLO0 Input
DLO1_GATE	OUT	1	Signal to DLO1 Input

### 5.3.7. SPARE Interface

These signals allow to set and read the status of SPARE pin present on the board.

**Table 5.5: SPARE Interface signals**

SPARE_OUT	OUT	12	SPARE Data Out
SPARE_IN	IN	12	SPARE Data In
SPARE_DIR	OUT	1	SPARE Direction

### 5.3.8. LED Interface

These signals, when active for one clock cycle, allow to generate a blink of the relevant Led.

**Table 5.6: LED Interface signals**

RED_PULSE	OUT	1	RED Led Pulse (active high)
GREEN_PULSE	OUT	1	GREEN Led Pulse (active high)

## 5.4. Reference design description

The reference design preloaded into the USER FPGA is given as a design guide. It is a full functional application of the usage of the board as a coincidence and/or I/O register unit. This reference design give access to A,B,C,G ports. So no mezzanine expansion cards are needed in order to use this design.

The MODE register can be used to set the preferred operating mode. When the board is switched on, the default operating mode is I/O Register mode.

In I/O Register Mode, C port is directly driven by the C\_CONTROL register. The coincidence is anyway still active so that a pulse is generated on G port when a coincidence event is detected.

In Coincidence Mode, the C port is used to report the coincidence operator on A and B port. In this case the C port can be masked through a mask register (C\_MASK).

A gate pulse is generated on G port when data patterns on input ports A and B satisfy a trigger condition.

The trigger condition implemented in this reference design is true when a bit-per-bit logic operation on port A and B is true. The logic operator applied to Port A and B is selectable by means of a register bit (MODE Register Bit 4).

If MODE bit 4 is set to '0', an AND logic operation is applied to corresponding bits in Port A and B (i.e. A(0) AND B(0), A(1) AND B(1) etc.).

In this case, a trigger is generated if corresponding A and B port bits are '1' at the same time.

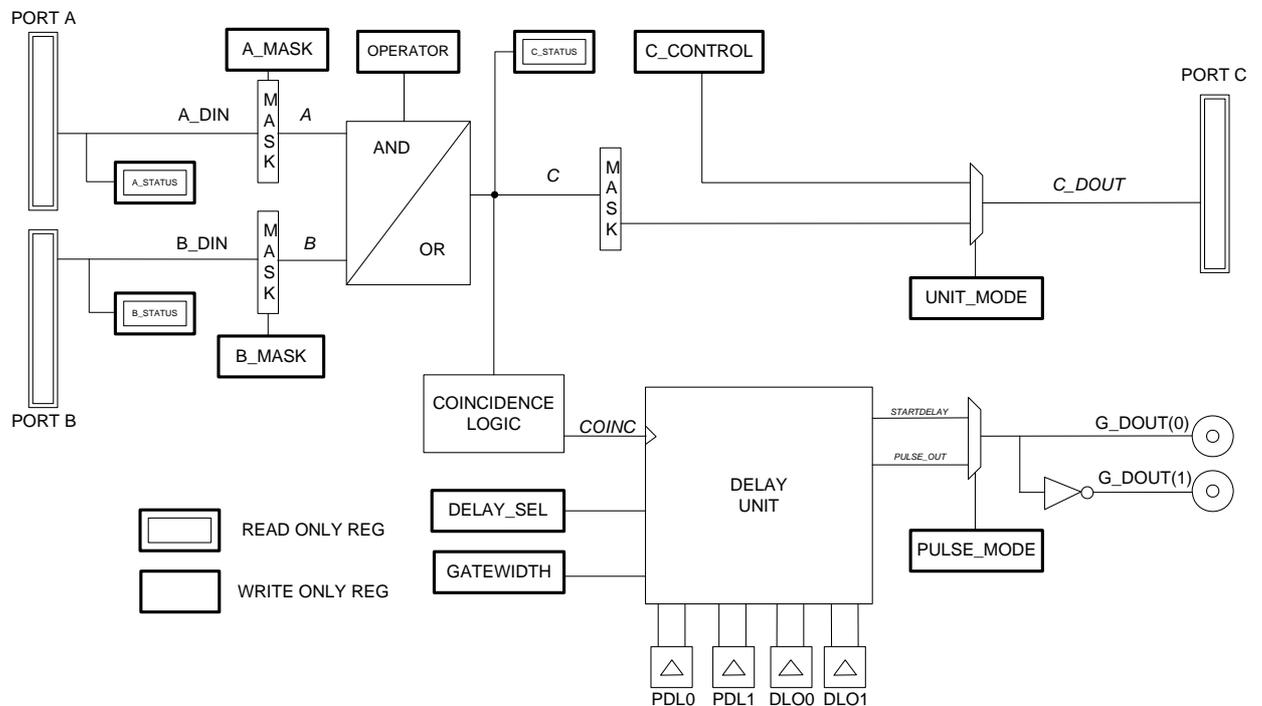
If MODE bit 4 is set to '1', an OR logic operation is applied to corresponding bits in Port A and B (i.e. A(0) OR B(0), A(1) OR B(1) etc.).

In this case, a trigger is generated if there is a '1' on one bit of either port A or B.

Port A and B bits can be singularly masked through a register, so that a '1' on that bit doesn't generate any trigger.

Expansion mezzanine cards can be directly controlled through registers already implemented in this design.

The expansion mezzanine is identified by a unique identification code that can be read through a register.



**Fig. 5.2: Front Panel Ports Interface Diagram**

The following table illustrates the the register map of the USER FPGA reference design (COIN\_REFERENCE).

**Table 5.7: COIN\_REFERENCE register map**

NAME	ADDRESS	DATA SIZING	ACCESS	NOTES	DEFAULT
A_STATUS_L	0x0000	D16	RO	Port A status. This register reflects A[15:0] bit status.	
A_STATUS_H	0x0002	D16	RO	Port A status. This register reflects A[31:16] bit status.	
B_STATUS_L	0x0004	D16	RO	Port B status. This register reflects B[15:0] bit status.	
B_STATUS_H	0x0006	D16	RO	Port B status. This register reflects B[31:16] bit status.	
C_STATUS_L	0x0008	D16	RO	Port C status. This register reflects C[15:0] bit status.	
C_STATUS_H	0x000A	D16	RO	Port C status. This register reflects C[31:16] bit status.	
A_MASK_L	0x000C	D16	WO	Port A mask. This register masks A[15:0]. Mask bit is active low.	X"FFFF"
A_MASK_H	0x000E	D16	WO	Port A mask. This register masks A[31:16]. Mask bit is active low.	X"FFFF"
B_MASK_L	0x0010	D16	WO	Port B mask. This register masks B[15:0]. Mask bit is active low.	X"FFFF"
B_MASK_H	0x0012	D16	WO	Port B mask. This register masks B[31:16]. Mask bit is active low.	X"FFFF"
C_MASK_L	0x0014	D16	WO	Port C mask. This register masks C[15:0]. Mask bit is active low.	X"FFFF"
C_MASK_H	0x0016	D16	WO	Port C mask. This register masks C[31:16]. Mask bit is active low.	X"FFFF"
GATEWIDTH	0x0018	D16	WO	Gate signal width. This number represents a multiple of the	X"0004"

NAME	ADDRESS	DATA SIZING	ACCESS	NOTES	DEFAULT
				selected delay line period (see detailed description)	
C_CONTROL_L	0x001A	D16	WO	Port C control. When the port C is configured to be an output under register control (see MODE register), the status of C[15:0] is controlled by this register.	X"0000"
C_CONTROL_H	0x001C	D16	WO	Port C control. When the port C is configured to be an output under register control (see MODE register), the status of C[31:16] is controlled by this register.	X"0000"
MODE	0x001E	D16	WO	It configures the behaviour of the system:  MODE[1:0]: DELAY SEL  MODE[3]: UNIT_MODE  '0': Coincidence Unit  '1': I/O Register  MODE[4]: OPERATOR  '0': C = A AND B;  '1': C = A OR B;  MODE[5]: PULSE_MODE  See Description	X"0008"; -- Default : I/O Register Mode.
SCRATCH	0x0020	D16	RW	This register is available to test read and write to a register.	X"5A5A"
G CONTROL	0x0022	D16	W	Only Bit 0 (G_CONTROL(0)) is used in this reference design. It can be used to select G output level:  '0': TTL  '1': NIM	X"0000"
D_CONTROL_L	0x0024	D16	RW		X"0000"
D_CONTROL_H	0x0026	D16	RW		X"0000"
D_DATA_L	0x0028	D16	RW		X"0000"
D_DATA_H	0x002A	D16	RW		X"0000"

NAME	ADDRESS	DATA SIZING	ACCESS	NOTES	DEFAULT
E_CONTROL_L	0x002C	D16	RW		X"0000"
E_CONTROL_H	0x002E	D16	RW		X"0000"
E_DATA_L	0x0030	D16	RW		X"0000"
E_DATA_H	0x0032	D16	RW		X"0000"
F_CONTROL_L	0x0034	D16	RW		X"0000"
F_CONTROL_H	0x0036	D16	RW		X"0000"
F_DATA_L	0x0038	D16	RW		X"0000"
F_DATA_H	0x003A	D16	RW		X"0000"
REVISION	0x003C	D16	RW	Firmware revision . For example, the register content for release 1.0 is X"0100".	X"XXYY"
PDL_CONTROL	0x003E	D16	RW	It allows to either set the PDL delay through either on-board switches or via VMEbus.	X"0001"; Default : PDL delay is set by on-board dip-switches
PDL_DATA	0x0040	D16	RW		X"0000"
D_IDCODE	0x0042	D16	RO	Read Slot D mezzanine ID Code. ID Code is X"0007" if no mezzanine is plugged.	
E_IDCODE	0x0044	D16	RO	Read Slot E mezzanine ID Code. ID Code is X"0007" if no mezzanine is plugged	
F_IDCODE	0x0046	D16	RO	Read Slot F mezzanine ID Code. ID Code is X"0007" if no mezzanine is plugged	

## 5.5. REGISTER DETAILED DESCRIPTION

### 5.5.1. V1495 Front Panel Ports Registers (PORT A,B,C,G)

The Front Panel ports (A,B,C,G) can be configured and accessed using a set of registers:

The x\_MASK\_y (x can be A,B,C; y can be L or H) registers can be used to selectively mask a bit of a port. Each status register is split into two 16 bit register (MASK\_L corresponds to MASK[15:0], while MASK\_H corresponds to MASK[31:16]). There is not a

MASK register associated with G port. Each bit of the input ports (A,B) mask registers are internally used in a logic AND operation with the corresponding bit of the port, so it is an active low mask bit. For instance, when A\_MASK\_L[0] is set to '0', the A[0] bit is internally masked (logic '0').

Each bit of the output port (C) mask register is internally used in a logic AND operation with the corresponding bit of the internal signal, so it is an active low mask bit. For instance, when C\_MASK\_L[0] is set to '0', the C[0] bit is masked (output bit is stuck at '0').

The x\_STATUS\_y (x can be A,B,C; y can be L or H) registers can be used to read back each port bit. Each status register is split into two 16 bit register (STATUS\_L corresponds to STATUS[15:0], while STATUS\_H corresponds to STATUS[31:0]). There is not a STATUS register associated with G port. The x\_STATUS\_y register reflects the status of the unmasked input and output ports.

A control register (C\_CONTROL) is available to set the C port when the board is configured in I/O register mode.

### 5.5.2. V1495 Mezzanine Expansion Ports Registers (PORT D,E,F)

The mezzanine expansion ports (D,E,F) can be configured and accessed using a set of registers:

In this reference design, no mask register is implemented for the expansion ports.

The x\_DATA\_y (x can be D,E,F; y can be L or H) registers can be used to read back each port bit. Each status register is split into two 16 bit register (D\_DATA\_L corresponds to D[15:0], while D\_DATA\_H corresponds to D[31:16]). The expansion ports can be bidirectional. In case the port is configured as an output, the register value set the port value. In case the port is configured as an input, the register content reflects current port value.

A x\_CONTROL register (x can be D,E,F) is available to set the corresponding port direction and logic level selection.

### 5.5.3. Delay Selection

The selection of the asynchronous timer is made through the MODE register by means of the DELAY\_SEL bit (MODE[1:0]).

The selection of the delay line is made according to the following table:

**Table 5.8: Selection of the delay line**

MODE[1]	MODE[0]	DELAY LINE
0	0	PDL0
0	1	PDL1
1	0	DLO0
1	1	DLO1

### 5.5.4. PDL DELAY VALUE SETTING AND READBACK

The programmable delay lines chip available on board can be programmed with a specific delay using :

on-board 8 bit dip-switch (SW6 for Delay 0 and SW5 for Delay1 on motherboard)  
via VMEbus

Two registers are available to configure PDLs:

PDL\_CONTROL

PDL\_DATA

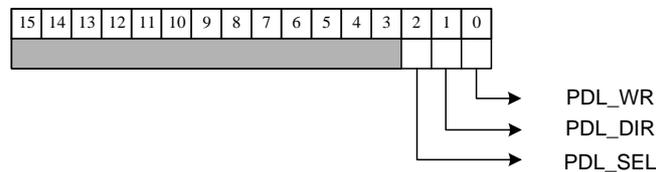
PDL\_CONTROL is used to:

Select target PDL for read/write operations

Enable delay update

Select programming mode (via VME register or by on-board switches)

The PDL\_CONTROL bit fields are shown in the following figure:



**Fig. 5.3: PDL\_CONTROL bit fields**

PDL\_WR = '1' enables the updating of the PDL delay value: in this way, the delay value set either via dip switch or via PDL\_DATA register is automatically loaded. By setting this bit to 0, the delay value cannot be changed.

PDL\_DIR allows to select the source of data for PDL programming:

0: the selected PDL has as delay value on its parallel programming bus the dip switch value.

1: the selected PDL has as delay value on its parallel programming bus the PDL\_DATA register 8 LSB

PDL\_SEL allows to select one of the PDL's (PDL0 and PDL1) for read/write operations.

PDL\_DATA register is used to:

Write the delay value for the next delay update via VMEbus

Read the on-board switch status

Examples:

updating of PDL0 delay via switch: the default value in the PDL\_CONTROL allows to update the delay directly via dip switch just after the board turning ON; each change in the dip switch status set immediately a new delay value.

The sequence to be followed is:

Step 1: write 0x1 in the PDL\_CONTROL register

Step2: update the dip switches value

B) updating of PDL1 delay via switch:

Step 1: write 0x5 in the PDL\_CONTROL register

Step 2: update the dip switches value

C) updating of PDL0 delay via VMEbus:

Step 1: write 0x3 in the PDL\_CONTROL register

Step2: write the delay value in the PDL\_DATA register

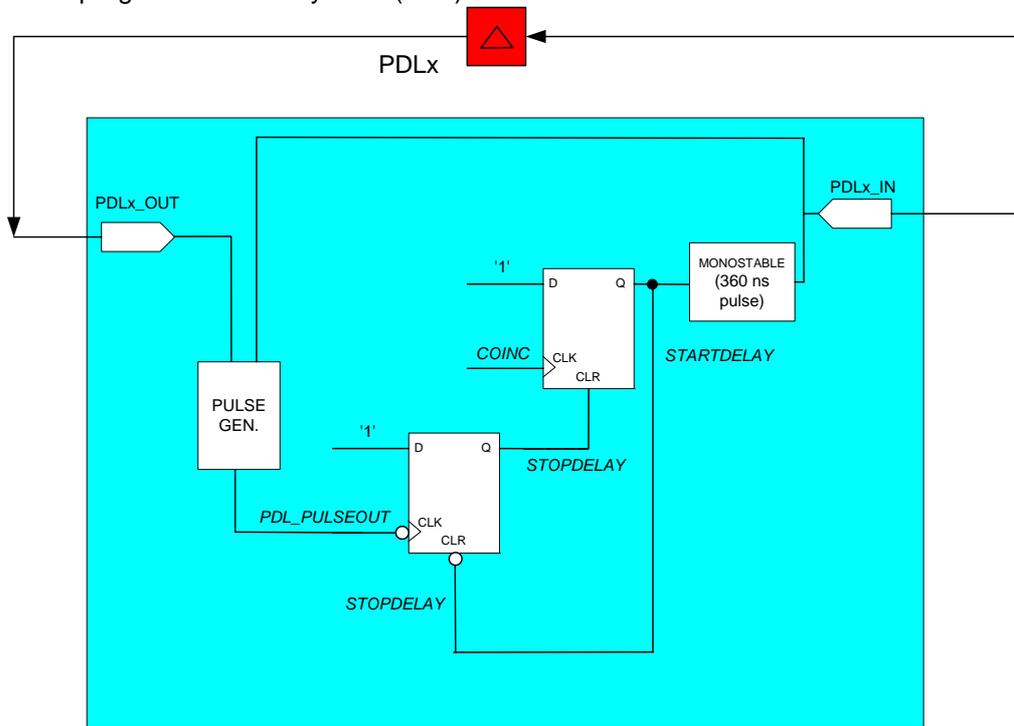
- D) updating of PDL1 delay via VMEbus:  
 Step 1: write 0x7 in the PDL\_CONTROL register  
 Step 2: write the delay value in the PDL\_DATA register

**GATE WIDTH (USING Delay Line Oscillators)**

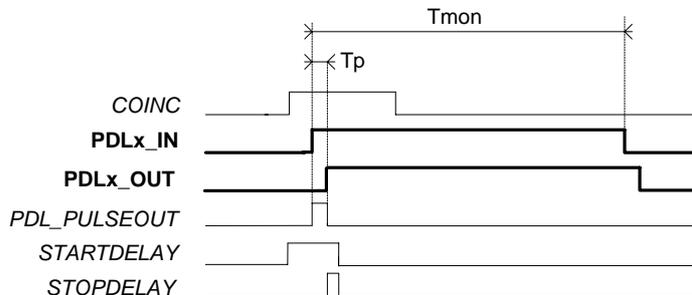
The GATEWIDTH register can be used to set the gate signal width on the G port (see Delay Unit using DLOs, see § 5.5.6).

**5.5.5. Delay Unit using PDLs**

The following diagram shows the implementation of the DELAY\_UNIT using the one of the two programmable delay lines (PDL) available on the boards.



**Fig. 5.4: Delay Unit with PDLs**



**Fig. 5.5: PDLs Delay line timing**

The pulse width generated using PDLs ( $T_p$ ) can be adjusted setting the PDL delay using either on-board dip switches or through register.

When a coincidence occurs (leading edge of COINC signal) the STARTDELAY signal becomes active (high). STARTDELAY triggers a monostable in order to generate a pulse with a duration large enough to ensure maximum linearity performance of the. This value should be more than 320 ns PDL (see 3D3428 component datasheet). The selected value in the reference design is 360 ns.

The PDL\_PULSEOUT internal signal is generated as the logic OR of PDL\_IN and PDL\_OUT, so generating a pulse whose width is proportional to the PDL actual delay. The PDL\_PULSEOUT signal falling edge is used to reset the flip-flop state.

The pulse width ( $T_p$ ) is:

$$T_p = T_{pd} + T_{pf}$$

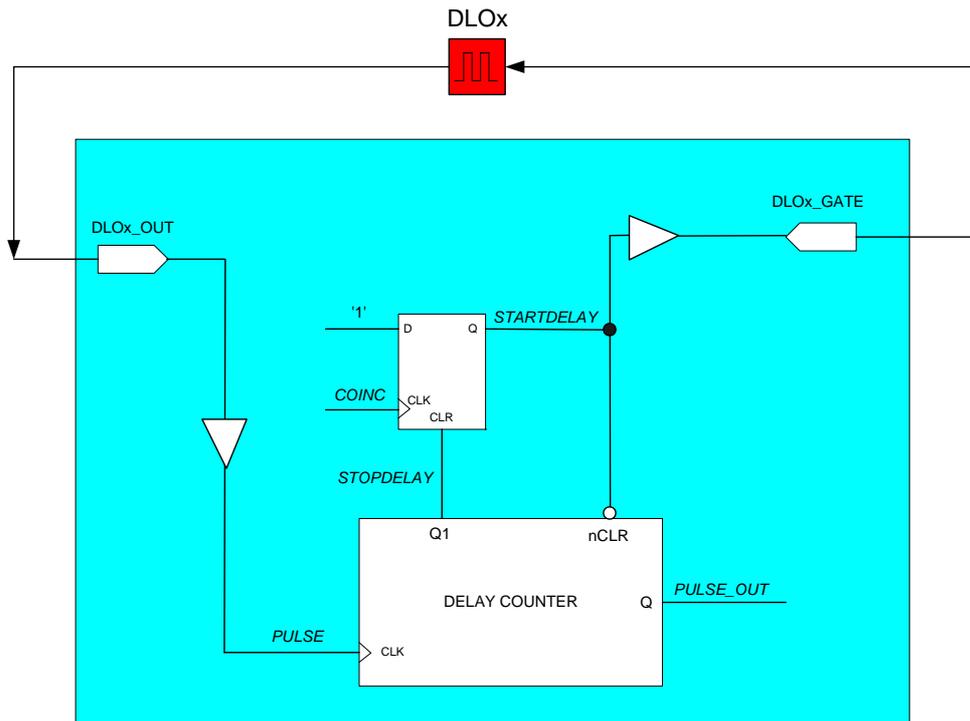
Where  $T_{pd}$  is the delay of the selected PDL. (programmable via VME or by on-board dip-switches, whichever mode is enabled).

$T_{pf}$  is the delay introduced by the FPGA pad and internal logic.

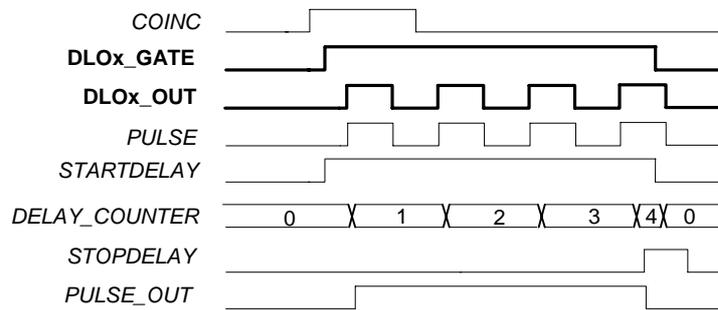
The maximum pulse width is limited by the PDL maximum delay, in this case.

### 5.5.6. Delay Unit using DLOs

The following diagram shows the implementation of the DELAY\_UNIT using two oscillators based on delay lines (DLO) present on the board.



**Fig. 5.6: Delay Unit with DLOs**



**Fig. 5.7: DLOs Delay line timing**

When a coincidence occurs (leading edge of COINC signal) the STARTDELAY signal becomes active (high).

STARTDELAY enables the oscillator on external delay line (DLOx) selected via MODE register. At the same time the DELAY\_COUNTER is enabled. The PULSE signal leading edge increases the counter until the value set via GATEWIDTH register is reached. The PULSE signal corresponds, in this reference, with the selected PDL output. On the first PULSE leading edge after the coincidence, PULSE\_OUT is activated high and is kept high until a time = GATEWIDTH times the period of the selected DLO. The period in this case is constant.

The maximum pulse width is limited by the GATEWIDTH counter: in the case of this reference design the GATEWIDTH register is 16 bit wide, so a maximum width of  $65536 \cdot T_d$  ( $T_d$  is the intrinsic delay of the selected DLO).

## 5.6. Quartus II Web Edition Project

The freely available Altera Quartus II (it can be downloaded from the Altera Web site) software must be used in order to generate a user firmware for the USER FPGA. It includes the source of VHDL reference design, which can be modified according to the description provided with the manual, in order to modify the card functionalities.

The tool provides a complete pinout of the FPGA; it is also enabled to generate the file type of programming (RBF format) used for the flash programming.

This software tool requires the Quartus II Web Edition rel. 5.1 (and newer) and can be freely downloaded at:

[http://www.caen.it/nuclear/software\\_download.php](http://www.caen.it/nuclear/software_download.php)

Quartus II manual is available at: [www.altera.com/literature/hb/qts](http://www.altera.com/literature/hb/qts)

The following figure shows the typical project flow for generating the firmware for an ALTERA FPGA, through the following steps:

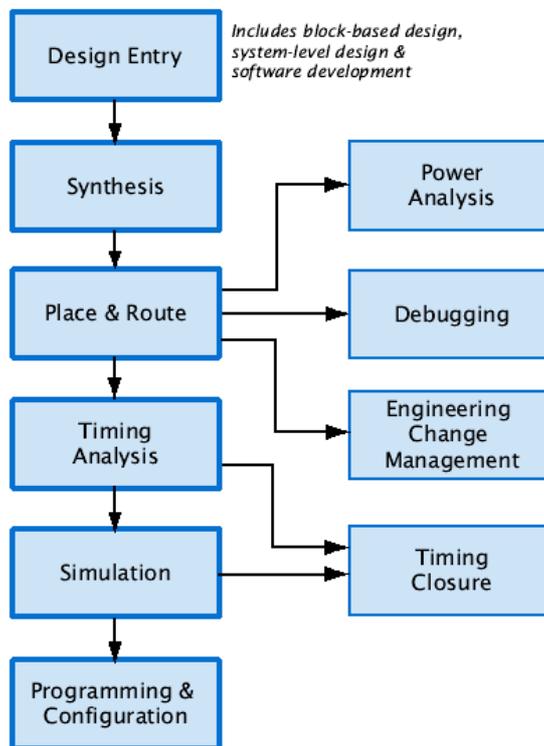
Design Entry is the functional description of the circuit; it could be either a description of the hardware (VHDL, Verilog, AHDL) or a scheme made with the tool provide by Quartus. The reference design provided is developed through VHDL; a VHDL knowledge is required in order to modify this design. A different description can be developed with a different language among those allowed by the Quartus tool.

Synthesis translates the description into a format compatible with the subsequent place&route step.

Place&route, starting from the netlist, performs the placing (place) and the subsequent interconnection (route) of the FPGA capabilities.

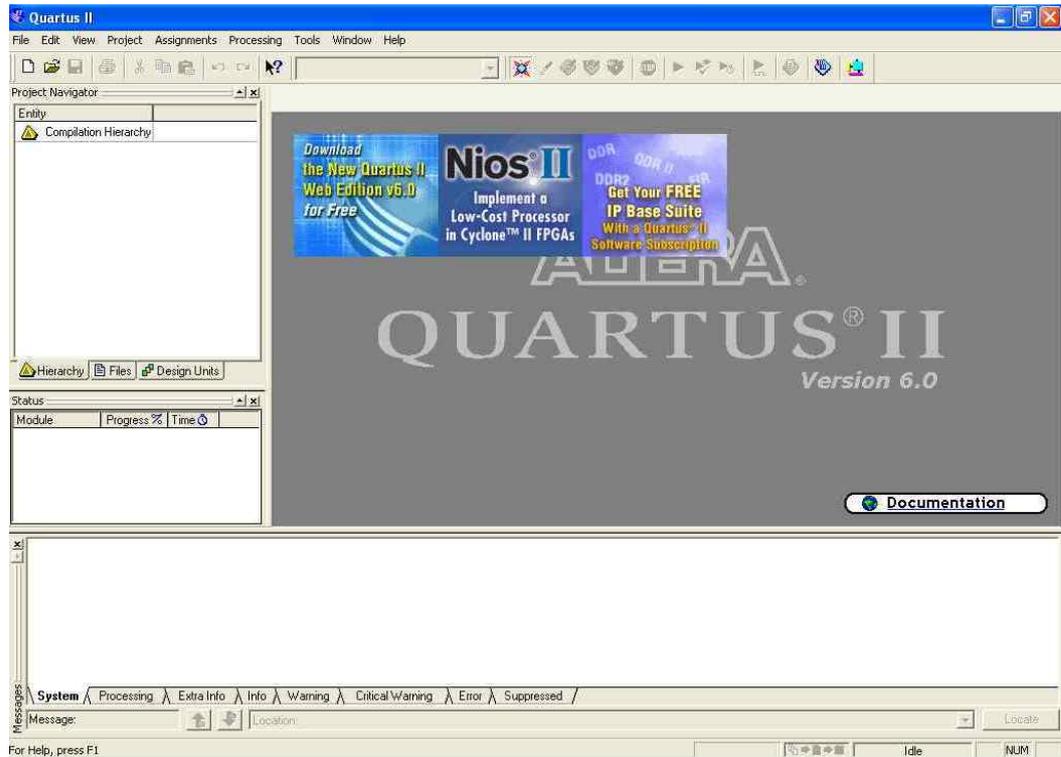
Simulation and timing analysis allow to verify the functionality of the project. The reference design includes a minimum set of constraints in order to allow the design to perform the foreseen function.

The last important step is the generation of the programming file. Quartus allows to generate different formats: the RBF format is the one used to program the FPGA USER via VME. The provided reference project produces automatically this format in the project directory under the filename v1495usr\_demo.rbf.



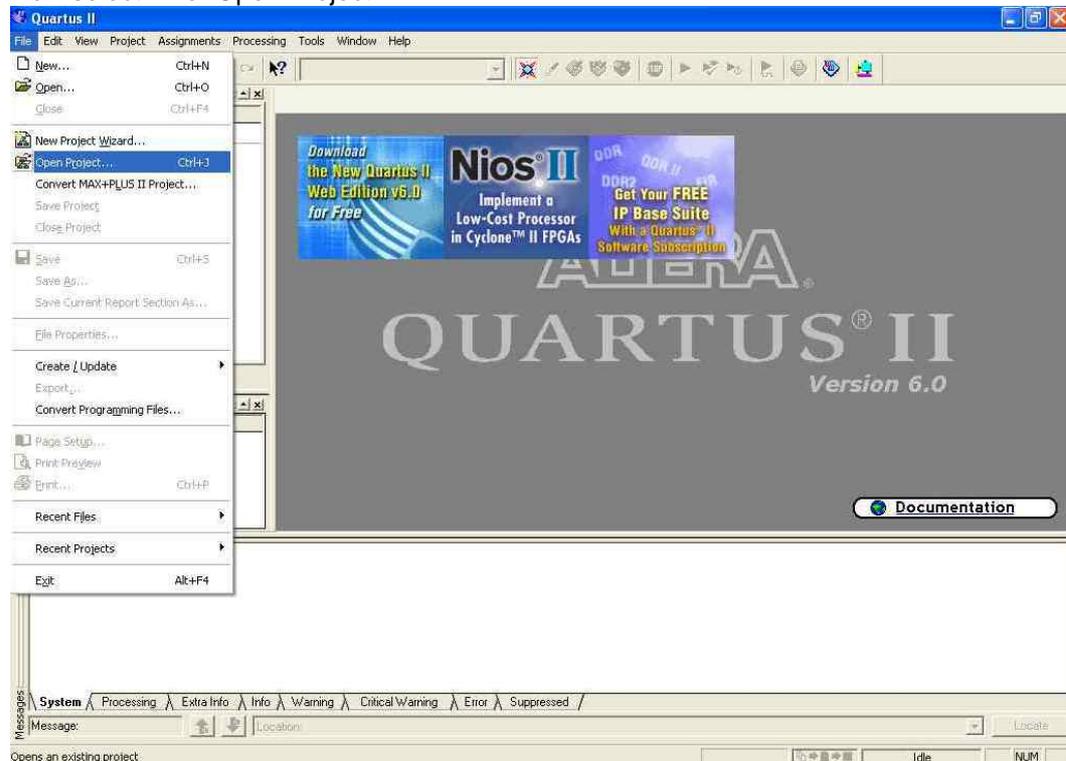
**Fig. 5.8: Quartus II project flow**

The following screenshot shows the main menu of Quartus II:



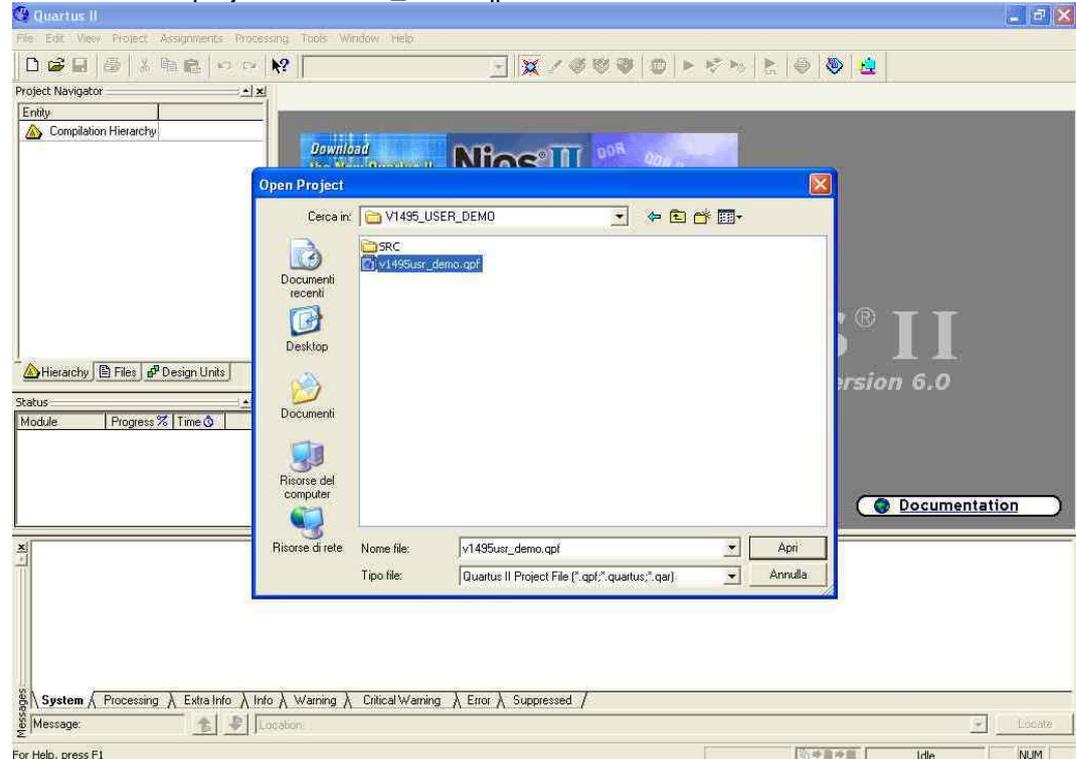
**Fig. 5.9: Quartus II main menu**

Now select File>Open Project...



**Fig. 5.10: Quartus II file menu**

browse the file project v1495usr\_demo.qpf



**Fig. 5.11: Quartus II project browser**

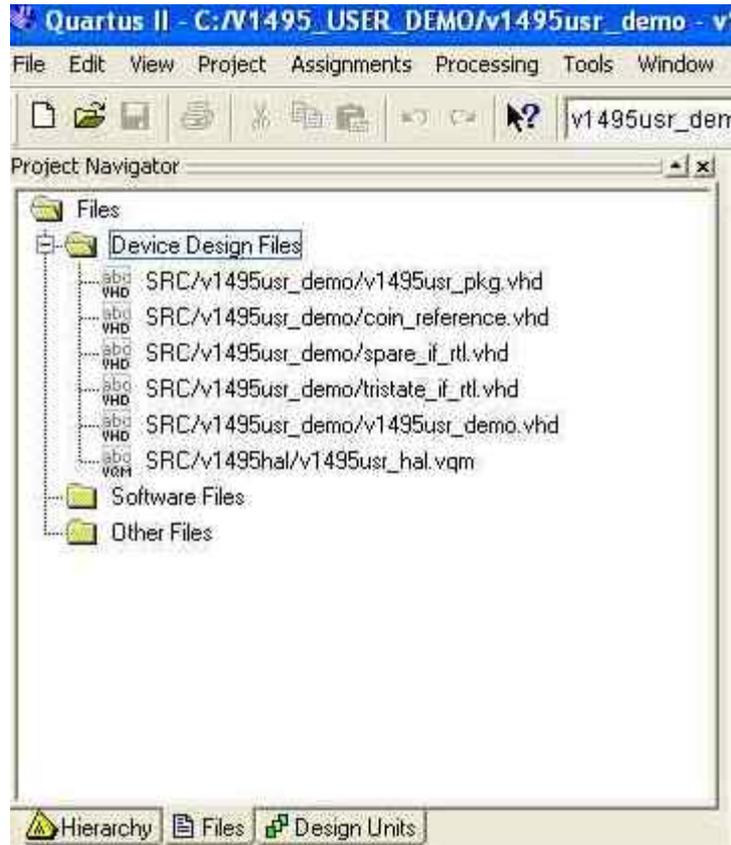
Once the project is open, the Project Navigator shows the following information:

There are 5 VHDL files (*filename.vhd*) and a Verilog netlist (*listname.vqm*):

The reference design is included in the coin\_reference.vhd file.

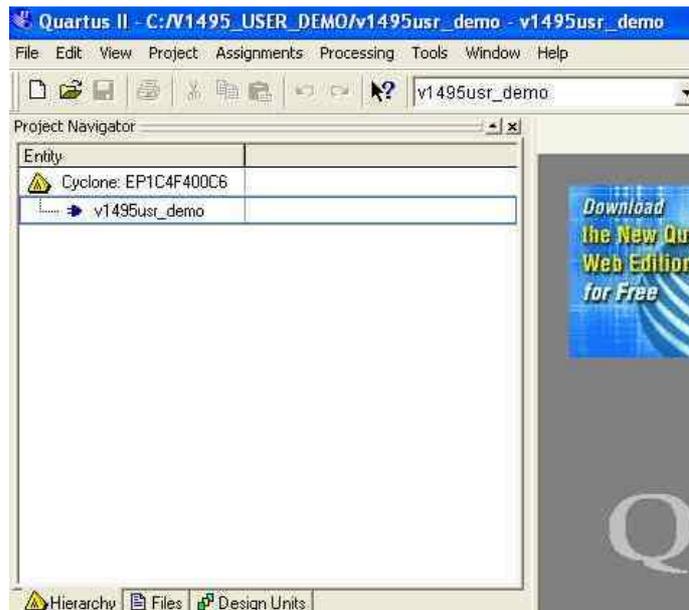
The other files provide support to the project and shall not be modified by the developer.

HAL (Hardware Abstraction Layer) is implemented on the netlist Verilog v1495usr\_hal.vqm.



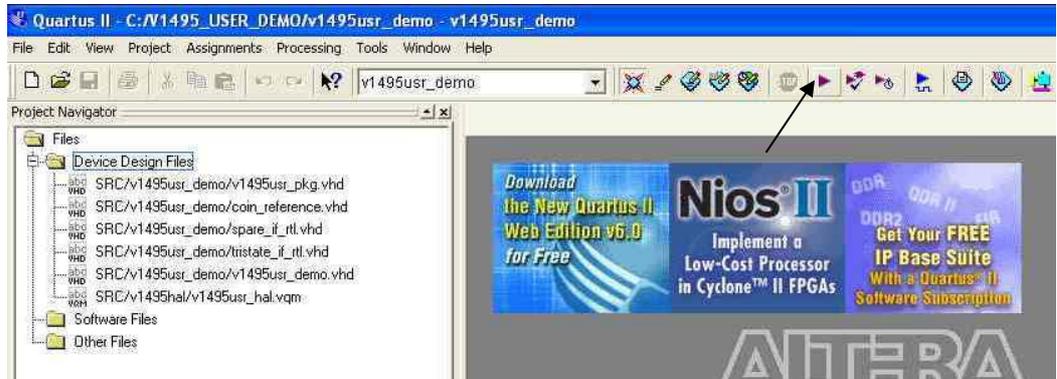
**Fig. 5.12: Quartus II netlist**

The first time the project is launched the hierarchy includes only the name of the head of the project (v1495usr\_demo). At the end of the project flow the whole hierarchical structure of the project is shown.



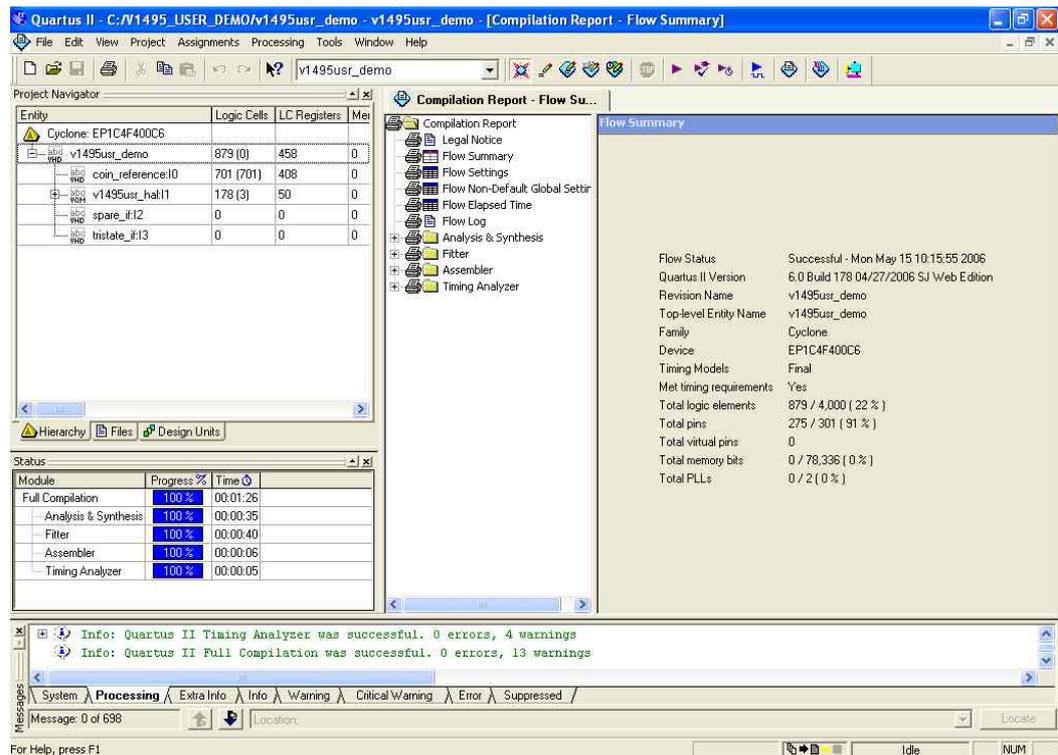
**Fig. 5.13: Quartus II hierarchical structure**

In order to generate a new programming file it is necessary to launch the compiler, by clicking on the red “play” button on the tool bar.



**Fig. 5.14: Quartus II compiler launching**

Quartus at this point launches in sequence the steps of the flow chart (synthesis, fitting, place&route), then shows the correct compiling and the following screen:



**Fig. 5.15: Quartus II compiling summary**

At this point an updated RBF file is generated in the project directory. This file can be used for updating the firmware as described in § 5.7.

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## 5.7. Firmware upgrade

It is possible to upgrade the board firmware via VME, by writing the Flash: for this purpose, download the software package available at:

[http://www.caen.it/nuclear/software\\_download.php](http://www.caen.it/nuclear/software_download.php)

The program is provided as executable, source code and Microsoft Visual C++ 2005 project.

The executable file is the pre-compiled program for Windows platform.

The program is based on the CAENVMElib library (available both for Windows and Linux).

The program must be launched as follows:

```
V1495Upgrade FileName BaseAdd [TargetFPGA] [image]
```

These are the options available and defaults:

<i>Filename:</i>	the RBF filename (V1495vme01.rbf for instance)
<i>BaseAdd:</i>	hex value of base address of the 1495 (32100000 is the module is mapped has a base address equal to 0x32100000)
<i>[TargetFPGA]:</i>	vme or user (user is default option if not specified)
<i>[image]:</i>	/standard or /backup (/standard is default option if not specified)

---

### 5.7.1. USER FPGA Upgrade

In order to update the flash memory of the USER FPGA, the program must be launched as follows:

```
V1495Upgrade FileName BaseAdd user /standard
```

*With:*

*FileName:* the path to be followed of the RBF file generated with Quartus II (see § 5.6)

*BaseAdd:* the base address (Hex 32 bit) of the V1495 board

For example, in order to update the firmware of a V1495 with base address 32100000, it is necessary to launch:

```
V1495Upgrade V1495.rbf 32100000 user /standard
```

If the upgrading is successful, the number of transferred bytes is reported and the program is exited

If the upgrading fails, then an error message is reported.

In case of successful upgrading, the new firmware can be loaded, without turning the board (and the crate) off, by performing a write access on the USER FPGA Configuration register (Base Address 0x8016): it is necessary to write 1 in order to reload the FPGA configuration. The Flash Memory programming algorithm flow-chart is reported below (see source code for details).

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### 5.7.2. VME FPGA Upgrade

VME FPGA flash memory can be updated in a similar way to the USER FPGA; the board can store two firmware versions, called STD and BKP respectively; at Power On, a microcontroller reads the Flash Memory and programs the module with the firmware version selected via the SW9 jumper on the motherboard, which can be placed either on the STD position, or in the BKP position. The program to be launched is:

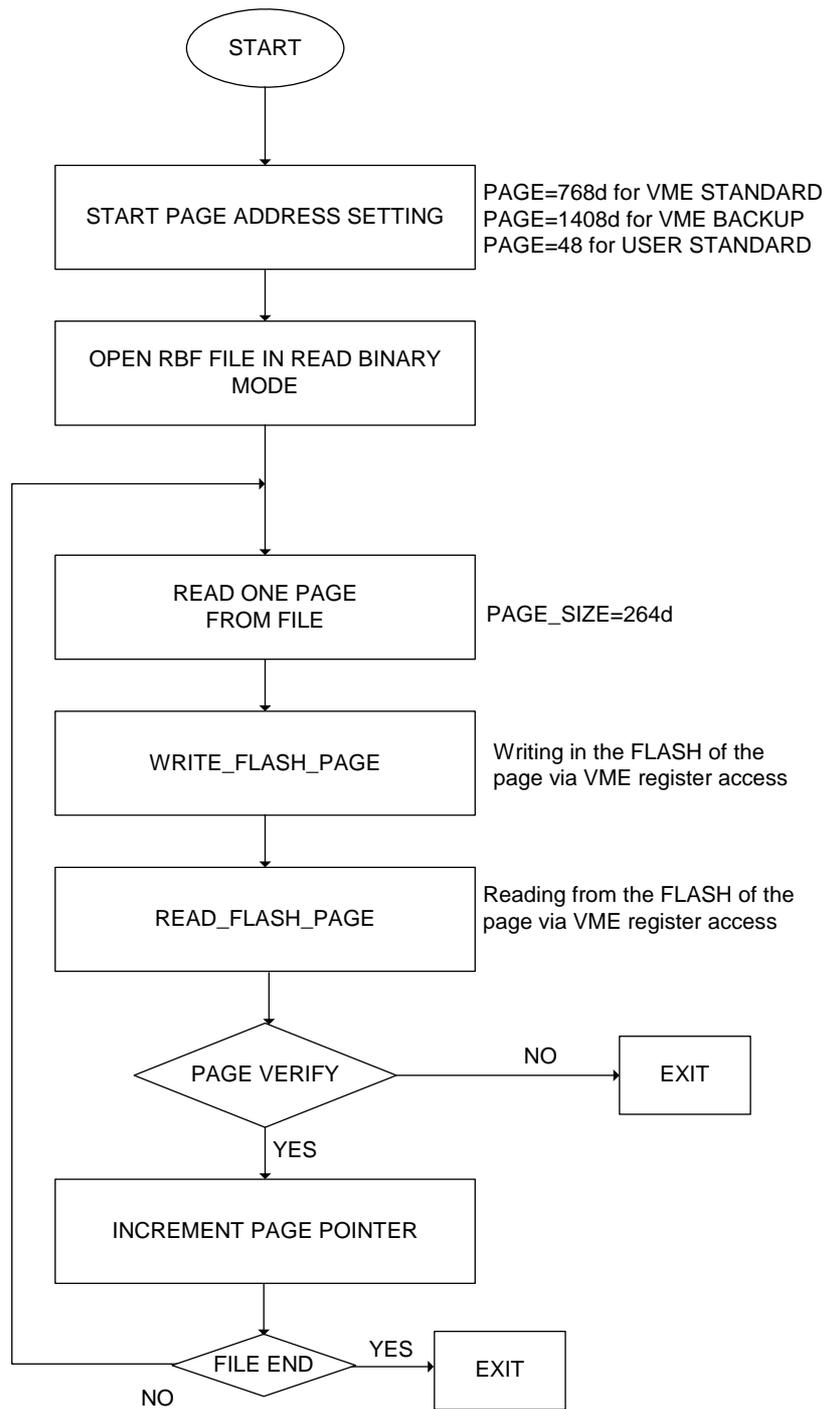
V1495Upgrade *FileName BaseAdd* vme [*image*]

*With:*

*FileName*: the path to be followed of the RBF file generated with Quartus II (see § 5.6)

*BaseAdd*: the base address (Hex 32 bit) of the V1495 board

*Image*: /Standard or Backup (default: /standard)



**Fig. 5.16: Flash programming algorithm flow-chart**