

Using the FADC250 V3 PRAD Module

(V8a – 4/30/25)

1.1 Controlling the Module

Communication with the module is by standard VME bus protocols. All registers and memory locations are defined to be 4-byte entities. The VME slave module has three distinct address ranges.

A24 – The base address of this range is set by a 12-element DIP switch on the board. It occupies 4 Kbytes of VME address space, organized in 1 K 32-bit words. Relative to the base address, this space is divided as follows:

000-0FF – Register space to control and monitor the module (64 long words)

100-2FF – ADC data processing registers (256 short words)

300-3FF – SCALER registers (64 long words)

400-4FF – SYSTEM TEST registers (64 long words)

500-5FF – AUXILIARY registers (64 long words)

600-FFF – Reserved (640 long words)

In addition to registers that are directly mapped to a VME address (Primary Address), the module supports Secondary Addressing in the A24 address space. These registers are accessed through an address mapping register (Secondary Address Register). Each secondary address is associated with a primary address. A Primary Address may have up to 64 K secondary addresses associated with it. A VME cycle loads the mapping register with data which is the internal (secondary) address of the target register. A VME cycle with the associated primary address accesses (read/write) the chosen internal register. Important registers are assigned primary addresses, allowing them to be directly accessible in a single VME cycle. Setup tables are assigned secondary addresses. This allows for a large internal address space, while maintaining a small VME footprint.

A32 - The base address of this range is programmed into register ADR32. It occupies 8 Mbytes of VME address space, organized in 2 M 32-bit words. A read of any address in this range will yield the next FADC data word from the module. Even though the module is logically a FIFO, the expanded address range allows the VME master to increment the address during block transfers. This address range can participate in single cycle, 32-bit block, and 64-bit block reads. The only valid write to this address range is

the data value 0x80000000 which re-enables the module to generate interrupts (after one has occurred). The address range must be enabled by setting ADR32[0] = 1.

A32 - The lower and upper limits of this address range are programmed into register ADR_MB. This common address range for a set of FADC modules in the crate is used to implement the Multiblock protocol. By means of token passing FADC data may be read out from multiple FADC modules using a single logical block read. The board possessing the token will respond to a read cycle in this address range with the next FADC data word from that module. The token is passed along a private daisy chain line to the next module when it has transferred all data from a programmed number of events (register BLOCK SIZE). The address range must be enabled: set ADR_MB[0] = 1.

1.3 Module Registers

VERSION – board/firmware revision (0x0)

[7...0] – (R) – firmware revision

[15...8] – (R) – board revision

[31...16] – (R) – board type (“FADC”)

CSR – Control/Status (0x4)

0 – (R) – Event Accepted

1 – (R) – Block of Events Accepted

2 – (R) – Block of Events ready for readout

3 – (R) – BERR Status (1 = BERR asserted)

4 – (R) – Token Status (1 = module has token)

5 – (R) – Compression Algorithm ERROR

[6...9] – (reserved)

10 – (R) – DAC serialization status (1 = active)

11 – (R) – Data FIFO Empty Flag Asserted

12 – (R) – Data FIFO Almost Empty Flag Asserted

- 13 – (R) – Data FIFO Half Full Flag Asserted
- 14 – (R) – Data FIFO Almost Full Flag Asserted
- 15 – (R) – Data FIFO Full Flag Asserted
- 16 – (R) – ADC Processing FPGA high temperature alarm flag
- 17 – (R) – CTRL FPGA high temperature alarm flag
- [18...19] – (reserved)
- 20 – (W) – Pulse Soft **Trigger 2** (if CTRL[7] = 1 and CTRL[6..4] = 5)
(delayed **Trigger 1** follows; delay in TRIG21_DELAY register)
(R) – Trigger 2 -> Trigger 1 sequence active
- 21 – (W) – Pulse Clear Module – soft reset + clear data pipelines
(R) – Clear Module process active
- 22 – (W) – ENABLE SCALERS INTO DATA STREAM with FORCED
BLOCK TRAILER INSERTION (write ‘1’ to bits 22, 23)
- 23 – (W) – FORCE BLOCK TRAILER INSERTION – will be successful only
if there are NO triggers waiting to be processed
- 24 – (R) – Last FORCE BLOCK TRAILER INSERTION Successful
- 25 – (R) – Last FORCE BLOCK TRAILER INSERTION Failed
- 26 – (R) – Local Bus Time Out – target AK or DK timed out (5 us);
- 27 – (R/W) – Local Bus Error – target protocol violation;
(write ‘1’ clears latched bits 26, 27)
- 28 – (W) – Pulse Soft **Sync Reset** (if CTRL[11] = 1 and CTRL[10..8] = 6)
- 29 – (W) – Pulse Soft **Trigger 1** (if CTRL[7] = 1 and CTRL[6..4] = 6)
- 30 – (W) – Pulse Soft Reset – initialize counters, state machines, memory
- 31 – (W) – Pulse Hard Reset – initialize module to power-up state

CTRL1 – Control 1 (0x8)

- [1...0] – (R/W) – Sampling Clock Source Select

- 0 = Internal Clock
- 1 = Front Panel connector
- 2 = P0 connector (VXS)
- 3 = P0 connector (VXS)

2 – (not used)

3 – (R/W) – Enable Internal Clock

[6...4] – (R/W) – Trigger Source Select

- 0 = Front Panel Connector (**Trigger 1**)
- 1 = Front Panel Connector (**Trigger 1**; synchronized)
- 2 = P0 Connector (VXS) (**Trigger1, Trigger 2**)
- 3 = P0 Connector (VXS) (**Trigger1, Trigger 2**; synchronized)
- 4 – (not used)
- 5 – Software Generated (**Trigger 2** + delayed **Trigger 1**)
- 6 = Software Generated (**Trigger 1**)
- 7 = Module Internal Logic

7 – (R/W) – Enable Soft Trigger

[10...8] – (R/W) – Sync Reset Source Select

- 0 = Front Panel Connector
- 1 = Front Panel Connector (synchronized)
- 2 = P0 Connector (VXS)
- 3 = P0 Connector (VXS) (synchronized)
- 4 – (not used)
- 5 – (not used)
- 6 = Software Generated
- 7 = no source

11 – (R/W) – Enable Soft Sync Reset

12 – (R/W) – Select Live Internal Trigger to Output (otherwise, Module Trigger).

13 – (R/W) – Enable Front Panel Trigger Output

14 – (R/W) – Enable P0 (VXS) Trigger Output

15 – (R/W) – Insert ADC parameter word into data stream. The data word appears as a block header continuation word and has the following format:

- [31...29] – 0
- [28...18] – PL (see ADC data processing address map below)
- [17...9] – NSB
- [8...0] – NSA

- 16 – (R/W) – Suppress both trigger time words from data stream
- 17 – (R/W) – Suppress trigger time word 2 from data stream
(most significant bytes)
- 18 – (R/W) – Enable Event Level Interrupt
- 19 – (reserved)
- 20 – (R/W) – Enable BERR response
- 21 – (R/W) – Enable Multiblock protocol
- 22 – (R/W) – FIRST board in Multiblock system
- 23 – (R/W) – LAST board in Multiblock system
- 24 – (reserved)
- 25 – (R/W) – Enable Debug Mode
- [27...26] – (R/W) – Readout Data Format (see **Appendix 1**)
 - 0 = Standard format (default)
 - 1 = Intermediate compression format
 - 2 = Full compression format
 - 3 = Full compression format
- 28 – (R/W) – Multiblock Token passed on P0
- 29 – (R/W) – Multiblock Token passed on P2
- 30 – (reserved)
- 31 – (R/W) – System Test Mode (0 = normal, 1 = test mode enabled)

CTRL2 – Control 2 (0xC)

- 0 – (R/W) – GO (allow data transfer from external FIFOs to input FIFOs)
- 1 – (R/W) – Enable **Trigger (1 & 2)** to Module (source = CTRL1[6...4])
- 2 – (R/W) – Enable **Sync Reset** to Module (source = CTRL1[10...8])
- 3 – (R/W) – Enable Internal Trigger Logic

4 – (R/W) – Enable Streaming mode (NO event build)
5 – (R/W) – Use pulse derived from leading edge of **Sync Reset** signal as module Sync Reset

[7...6] – Hall B data compression mode
0 = NO compression
1 = Verify (raw + compressed)
2 = Compression ON

8 – (R/W) – Enable Test Event Generation (for debug)

9 – (R/W) – HALL B user (for data compression)

10 – (R/W) – data output mode select
0 = VME (default)
1 = VXS

[14...11] – VXS data output control bits

15 – (reserved)

Bits 16 – 31 are functional only in Debug Mode (CTRL1[25] = 1)

16 – (reserved)

17 – (R/W) – Transfer data: build FIFO → output FIFO

[18...31] – (reserved)

BLOCK SIZE (0x10)

[15...0] – (R/W) – number of events in a BLOCK.
Stored Event Count ≥ BLOCK SIZE → CSR[3] = 1.

[31...16] – (reserved)

INTERRUPT (0x14)

[7...0] – (R/W) – Interrupt ID (vector)

[10...8] – (R/W) – Interrupt Level [2..0]. Valid values = 1,...,7.

11 - 15 – (reserved)

[20...16] – (R) – Geographic Address (slot number) in VME64x chassis.

21 – 22 – (reserved)

23 – (R) – Parity Error in Geographic Address.

24 – 31 – (reserved)

ADR32 – Address for data access (0x18)

0 – (R/W) – Enable 32-bit address decoding

1 – 6 – (reserved – read as 0)

[15...7] – (R/W) – Base Address for 32-bit addressing mode (8 Mbyte total)

ADR_MB – Multiblock Address for data access (0x1C)

0 – (R/W) – Enable Multiblock address decoding

1 – 6 – (reserved – read as 0)

[15...7] – (R/W) – Lower Limit address (ADR_MIN) for Multiblock access

16 – 22 – (reserved – read as 0)

[31...23] – (R/W) – Upper Limit address (ADR_MAX) for Multiblock access

The board that has the TOKEN will respond with data when the VME address satisfies the following condition:

$$\text{ADR_MIN} \leq \text{Address} < \text{ADR_MAX}.$$

SEC_ADR – Secondary Address (0x20)

[15...0] – (R/W) – Secondary Address for 24-bit addressing mode

16 – (R/W) – Enable auto-increment mode (secondary address increments by 1 after each access of the associated primary address)

DELAY – Trigger/Sync Reset Delay (0x24) (NOT USED)

[21...16] – (R/W) – Sync reset delay

[5...0] – (R/W) – Trigger delay

INTERNAL TRIGGER CONTROL (0x28)

[23...16] – (R/W) – trigger width (4 ns per count; max = 1024 ns)

[11...0] – (R/W) – trigger hold off delay (4 ns per count; max = 16,384 ns)

RESET CONTROL (0x2C)

0 – (W) – Hard reset – Control FPGA

1 – (W) – Hard reset – ADC processing FPGA

[2...3] – (reserved)

4 – (W) – Soft reset – Control FPGA

5 – (W) – Soft reset – ADC processing FPGA

[6...7] – (reserved)

8 – (W) – Reset – ADC data FIFO

[9...10] – (reserved)

10 – (W) – Reset – HITSUM FIFO

11 – (W) – Reset – DAC (all channels)

12 – (W) – Reset – EXTERNAL RAM Read & Write Address Pointers

[13...15] – (reserved)

16 – (W) – Take Token – return token to 1st board of multiboard set

[17...31] – (reserved)

TRIGGER COUNT (0x30)

[31...0] – (R) – total trigger count

31 – (W) – reset count

EVENT COUNT (0x34)

[23...0] – (R) – number of events on board (non-zero → CSR[0] = 1).

[31...24] – (reserved)

BLOCK COUNT – (0x38)

[31...20] – reserved

[19...0] – (R) - number of event BLOCKS on board (non-zero → CSR[2] = 1).

BLOCK FIFO COUNT – (0x3C)

[31...6] – reserved

[5...0] – (R) - number of entries in BLOCK WORD COUNT FIFO

BLOCK WORD COUNT FIFO – (64 deep FIFO) (0x40)

[31...25] – reserved (read as ‘0’)

24 – (R) – count not valid (word count FIFO empty)

[23...20] – reserved (read as ‘0’)

[19...0] – (R) - number of words in next event BLOCK

INTERNAL TRIGGER COUNT (0x44)

[31...0] – (R) – internal live trigger count

31 – (W) – reset count

EXTERNAL RAM WORD COUNT (0x48)

[31...22] – reserved (read as ‘0’)

21 – (R) – RAM empty

20 – (R) – RAM full (1,048,576 eight byte words)

[19...0] – (R) – data word count (eight byte words)

DATA FLOW STATUS (0x4C) (for debug)

DAC CSR (Control/Status) (0x50)

31 – (W) – DAC initialize

30 – (R) – DAC initialization complete

29 – (W) – Clear latched status bits for DAC (bits 18-19)

[28...20] – (reserved – read as 0)

19 – (R) – DAC timeout on access since last status Clear (bit 29)

18 – (R) – DAC not ready on access since last status Clear (bit 29)

17 – (R) – Last DAC access successful

16 – (R) – DAC ready – current state

[15...4] – (reserved – read as 0)

[3...0] – (R/W) – DAC channel (0-15) to access with DAC DATA register

DAC DATA (0x54)

[31...22] – (reserved – read as 0)

21 – (R) – register A,B select (valid for DAC read only)

20 – (R) – 1 (valid for DAC read only)

19 – (R) – 0 (valid for DAC read only)

18 – (R) – 0 (valid for DAC read only)

[17...14] – (R) – channel accessed (valid for DAC read only)

[13...12] – (R) – DAC register select [REG1,REG0] (valid for DAC read only)

[11...0] – (R/W) – DAC data to write or read (channel selected in DAC CSR)

[To write or read DAC:

1 – Set channel to access by writing DAC_CSR register

2 – DAC write: write 12-bit value to DAC_DATA register

3 – DAC read: read 12-bit value from DAC_DATA register]

CONFIG ROM CONTROL 0 (0x58)

[7...0] – (R/W) – Configuration CMD

8 – (R/W) – Configuration HostEndOfCmd

9 – (R/W) – Configuration Host_Exec

10 – (R/W) – Configuration ThreBytesAdr

11 – (R/W) – Reboot FPGA from Config ROM. Write 1 to Reboot.

[12-31] – reserved

See VME_Program_FADCV3_Config_ROM.docx and
FADC250V3_Firmware_ver_4100_Description_Instructions.docx located at M:\FE\
fADC-250V3\document

CONFIG ROM CONTROL 1 (0x5C)

[31...0] – (R/W) – Configuration Rom_Address

CONFIG ROM CONTROL 2 (0x60)

[31...0] – (R/W) – Configuration DataToROM

CONFIG ROM STATUS 0 (0x64)

[31...0] – (R) – Configuration DataReadFromROM

CONFIG ROM STATUS 1 (0x68)

0 – (R) – Configuration NotValidOpCode

1 – (R) – Configuration ReadyForCmd

[2...31] – reserved

RESERVED (0x6C)

STATUS 1 – Input Buffer Status (0x70)

31 – (R) – data buffer ready for input

30 – (R) – data buffer input paused

29 – (R) – reserved (read as ‘0’)

28 – (R) – data buffer empty

27 – (R) – data buffer full

[26...16] – (R) – data buffer word count

[15...11] – (reserved)

[10...2] – latched compression buffer full flags (should always be ZERO)

1 – (R) – compression buffer full

0 – (R) – compression buffer empty

STATUS 2 – Build Buffer Status (0x74)

[31...29] – reserved (read as ‘0’)

28 – (R) – data buffer ‘A’ empty

27 – (R) – data buffer ‘A’ full

[26...16] – (R) – data buffer ‘A’ word count

- [15...13] – reserved (read as ‘0’)
- 12 – (R) – data buffer ‘B’ empty
- 11 – (R) – data buffer ‘B’ full

- [10...0] – (R) – data buffer ‘B’ word count

STATUS 3 – Output Buffer Status (0x78)

- [31...30] – reserved (read as ‘0’)
- 29 – (R) – data buffer ‘A’ empty
- 28 – (R) – data buffer ‘A’ full
- [27...16] – (R) – data buffer ‘A’ word count
- [15...14] – reserved (read as ‘0’)
- 13 – (R) – data buffer ‘B’ empty
- 12 – (R) – data buffer ‘B’ full
- [11...0] – (R) – data buffer ‘B’ word count

STATUS 4 – (spare) (0x7C)

- [31...0] – reserved

AUXILIARY 1 – (spare) (0x80)

- [31...0] – reserved

TRIGGER CONTROL (0x84) – Under normal conditions, a trigger received by the module is counted and sent to the ADC Processing FPGA. A trigger is considered acknowledged when data associated with it has been transferred to the Control FPGA. To ensure that data buffers in the ADC Processing FPGA are not overrun, the number of unacknowledged triggers is continuously compared to levels (MAX1, MAX2) set by the user. These levels are based on the parameters (processing mode, # samples in window) loaded into the ADC Processing FPGA. Two module based methods to avert buffer overflow and the resulting data corruption are available to the user.

In the first method, module BUSY is asserted when the number of unacknowledged triggers \geq MAX1. BUSY propagates back to the Trigger Supervisor. The Trigger Supervisor does not deliver triggers to the system while BUSY is asserted. Level MAX1 is based on the BUSY propagation delay, ADC Processing parameters, and the minimum trigger interval parameter of the Trigger Supervisor.

In the second method, triggers received by the module are not sent to the ADC Processing FPGA when the number of unacknowledged triggers \geq MAX2. Level MAX2 is based on the ADC Processing parameters. Not sending triggers to the FPGA Processing FPGA can cause a loss of synchronization among system components, but will prevent data corruption within the module. (See Auxiliary Scaler 2 for a count of lost triggers.)

Both methods can be applied together, with $\text{MAX2} \geq \text{MAX1}$.

31 – (R/W) – enable trigger stop when number of unacknowledged triggers \geq MAX2

[23...16] – (R/W) – level MAX2

15 – (R/W) – enable module busy assertion when number of unacknowledged triggers \geq MAX1

[7...0] – (R/W) – level MAX1

TRIG21 DELAY (0x88)

[31...12] – reserved

[11...0] – (R/W) – Delay from soft TRIG2 to generated TRIG1 (4 ns/count)

RAM Address Register (0x8C) – The RAM is organized as two 36-bit words with a common address. Auxiliary VME access (R/W) to the RAM is provided through a pair of 32 bit data registers (RAM 1, RAM 2). Note that bits 35 – 32 of each RAM word are not accessible through VME. During data flow operations, these bits carry event marker tags (header, trailer).

31 – increment address after access (R/W) of RAM 1 Data Register

30 – increment address after access (R/W) of RAM 2 Data Register

[29...21] – reserved (read as 0)

[19...0] – RAM address

RAM 1 Data Register (0x90)

[31...0] – RAM data word bits 67 – 36 (32 bits)

RAM 2 Data Register (0x94)

[31...0] – RAM data word bits 31 – 0 (32 bits)

(PROM Registers 1 and 2 are used for FPGA configuration over VME.)

PROM Register 1 (0x98)

31 – READY – (R) – configuration state machine is available to accept command
(i.e. no configuration process is currently executing).

[30...8] – reserved (read as 0)

[7...0] – configuration OPCODE

PROM Register 2 (0x9C)

[31...0] – PROM ID – (R) response to specific OPCODE write to PROM reg 1.

BERR Module Count (0xA0)

[31...0] – BERR count (driven by module to terminate data transmission)

BERR Total Count (0xA4)

[31...0] – BERR count (as detected on bus)

Auxiliary Scaler 1 (0xA8)

[31...0] – Total word count from ADC Processing FPGA

Auxiliary Scaler 2 (0xAC)

[31...0] – Count of triggers lost because number of unacknowledged triggers ≥ MAX2. (See TRIGGER CONTROL register.)

Auxiliary Scaler 3 (0xB0)

[31...0] – Event header word count from ADC Processing FPGA

TRIGGER 2 SCALER (0xB4)

[31...0] – (R) – **Trigger 2** count

31 – (W) – write ‘1’ to reset count

Auxiliary Scaler 5 (0xB8)

[31...0] – Event trailer word count from ADC Processing FPGA

SYNC RESET SCALER (0xBC)

[31...0] – (R) – **Sync Reset** count

31 – (W) – write ‘1’ to reset count

Module Busy Level (0xC0)

[31] – Force module busy

[30...20] – reserved

[19...0] – Busy Level (eight-byte words)

(External RAM word count > Busy Level → module busy = 1)

NOTE: At the system level, an asserted module busy signal should be used to prevent further triggers from being sent to the modules. By setting the Busy Level well below the memory capacity (1,048,576 eight-byte words), triggers already in the distribution pipeline can still be accepted by the module.

To prevent data corruption in the module if this global trigger control is NOT in place, the module itself will BLOCK input triggers when the number of 8-byte words in memory is within 12K (1.2%) of memory capacity (i.e. 1,036,288).

When global trigger control IS in place, it is important to set Busy Level significantly LESS than 1,036,288 so that local trigger blocking will NEVER

occur. (Local trigger blocking will result in a loss of system synchronization.) The safe maximum Busy Level depends on data size per trigger (i.e. mode of ADC processing), but a Busy Level equal to ~87.5% of memory capacity (i.e. 917,504 = 0xE0000) should be adequate for all circumstances.

Generate Event Header Word (0xC4) (for debug)

[31...0] – (W) – Event Header Word

Generate Event Data Word (0xC8) (for debug)

[31...0] – (W) – Event Data Word

Generate Event Trailer Word (0xCC) (for debug)

[31...0] – (W) – Event Trailer Word

MGT STATUS (0xD0)

0 – (R) – lane 1 up (GTX1)

1 – (R) – lane 2 up (GTX1)

2 – (R) – channel up (GTX1)

3 – (R) – hard error (GTX1)

4 – (R) – soft error (GTX1)

5 – (R) – lane 1 up (GTX2)

6 – (R) – lane 2 up (GTX2)

7 – (R) – channel up (GTX2)

8 – (R) – hard error (GTX2)

9 – (R) – soft error (GTX2)

10 – (R) – SUM DATA VALID

11 – (R) – MGT RESET ASSERTED

[31...12] – (R) - Reserved

MGT CONTROL (0xD4)

0 – **RELEASE MGT RESET** (0 = reset MGT, 1 = release reset)

1 – Data Type to CTP (0 = counting sequence, 1 = front-end data)

2 – Enable Data Alignment on Sync Reset occurrence

[31...3] – Reserved

RESERVED (2 registers) (0xD8 – 0xDC)

SCALER CONTROL (0xE0) – See SCALERS (0x300 – 0x340)

0 – (R/W) – Enable all scalers to count (1 = enable, 0 = disable)

1 – (W) – Latch all scalers. Write ‘1’ to simultaneously transfer all 17 scaler counts to registers for readout.

2 – (W) – Reset all scalers. Write ‘1’ to simultaneously reset all 17 scaler counts to zero.

[3 – 31] – (reserved)

BOARD SERIAL NUMBER 0 (0xE4)

[31...24] – (R) – board serial number byte 0

[23...16] – (R) – board serial number byte 1

[15...8] – (R) – board serial number byte 2

[7...0] – (R) – board serial number byte 3

BOARD SERIAL NUMBER 1 (0xE8)

[31...24] – (R) – board serial number byte 4

[23...16] – (R) – board serial number byte 5

[15...8] – (R) – board serial number byte 6

[7...0] – (R) – board serial number byte 7

BOARD SERIAL NUMBER 2 (0xEC)

[31...24] – (R) – board serial number byte 8

[23...16] – (R) – board serial number byte 9

[15...8] – (R) – board serial number byte 10

[7...0] – (R) – board serial number byte 11

SCALER INSERTION INTERVAL (0xF0) - Data from the SCALERS defined below (0x300 – 0x340) may be inserted into the readout data stream at regular event count intervals. The interval is specified in multiples of the event BLOCK SIZE. When the interval is ZERO (the default condition), there is NO insertion of scaler data into the data stream. When programmed for a non-zero interval, the current scaler values are appended to the last event of the appropriate BLOCK of events. The current Trigger 1 count is also inserted as the 18th scaler. Note that the scalers are **NOT** reset after their values are captured.

Example: Interval = 10 means that every 10th block of events will have the integrated scaler data appended to it.

(See the document FADC V2 Data Format for information on identifying scaler data words in an event.)

The scalers may ALSO be inserted into the data stream when a FORCE BLOCK TRAILER is done by the user. A simultaneous write of ‘1’ to bit 22 and bit 23 of the CSR (0x4) accomplishes this. The scaler values are those at the time of the last trigger’s occurrence.

[15...0] - (R/W) – N (in BLOCKS of events); every Nth block of events has integrated scaler data appended to the last event in the block.

[31...16] – (reserved)

SUM THRESHOLD (History buffer) (0xF4)

31 – (R) – sum data READY for readout if value = ‘1’

[30...16] – (R/W) – reserved (read as ‘0’)

[15...0] – (R/W) – sum threshold value for data capture

SUM DATA (History buffer) (0xF8)

31 – (W) – writing a ‘1’ ARMs History buffer for data capture

[30...16] – (R) – reserved (read as ‘0’)

[15...0] – (R) – sum data sample

SYSTEM MONITOR (0xFC)

[31...22] – (R) – FPGA auxiliary voltage (2.5V) (common)

$\text{vaux} = (((\text{float})(\text{reg_value} \gg 22) \& 0x3FF)) / 1024.0) * 3.0;$

21 – (R) – reserved (read as ‘0’)

[20...11] – (R) – FPGA core voltage (1.0V) (common)

$\text{vint} = (((\text{float})(\text{reg_value} \gg 11) \& 0x3FF)) / 1024.0) * 3.0;$

10 – (R) – reserved (read as ‘0’)

[9...0] – (R) – CTRL_FPGA temperature (°C)

$\text{temp_ctrl} = (((\text{float})(\text{reg_value} \& 0x3FF)) * 503.975 / 1024.0) - 273.15;$

SCALER Registers (0x300 – 0x340) (R)

SCALER[0] – (0x300) - input channel 0 count

SCALER[1] – (0x304) - input channel 1 count

SCALER[2] – (0x308) - input channel 2 count

SCALER[3] – (0x30C) - input channel 3 count

SCALER[4] – (0x310) - input channel 4 count

SCALER[5] – (0x314) - input channel 5 count

SCALER[6] – (0x318) - input channel 6 count

SCALER[7] – (0x31C) - input channel 7 count

SCALER[8] – (0x320) - input channel 8 count

SCALER[9] – (0x324) - input channel 9 count

SCALER[10] – (0x328) - input channel 10 count

SCALER[11] – (0x32C) - input channel 11 count

SCALER[12] – (0x330) - input channel 12 count

SCALER[13] – (0x334) - input channel 13 count

SCALER[14] – (0x338) - input channel 14 count

SCALER[15] – (0x33C) - input channel 15 count

TIME COUNT – (0x340) - timer (each count represents 2048 ns)

SYSTEM TEST Registers (0x400 – 0x410)

TEST BIT REGISTER (0x400)

- 0 – (R/W) – trigger_out_p0 (1 = asserted, 0 = not asserted)
- 1 – (R/W) – busy_out_p0 (1 = asserted, 0 = not asserted)
- 2 – (R/W) – sdlink_out_p0 (1 = asserted, 0 = not asserted)
- 3 – (R/W) – token_out_p0 (1 = asserted, 0 = not asserted)
- [4 – 7] – (R/W) – spare out test bits
- 8 – (R) – status_b_in_p0 state (1 = asserted, 0 = not asserted)
- 9 – (R) – token_in_p0 state (1 = asserted, 0 = not asserted)
- [10 - 14] – (R) – reserved (read as ‘0’)
- 15 – (R) – clock_250 counter status (1 = counting, 0 = not counting)
- [16 - 31] – (R) – reserved (read as ‘0’)

CLOCK 250 COUNT REGISTER (0x404)

- 0 – (W) – Write ‘0’ resets the counter. Write ‘1’ initiates 20us counting interval.
- [31 - 0] – (R) – CLK_250 counter value. (Should be 5000 after count interval.)

SYNC IN P0 COUNT REGISTER (0x408)

- 0 – (W) – Write ‘0’ resets the counter.
- [31 - 0] – (R) – SYNC_IN_P0 counter value.

TRIG1 IN P0 COUNT REGISTER (0x40C)

- 0 – (W) – Write ‘0’ resets the counter.

[31 - 0] – (R) – TRIG1_IN_P0 counter value.

TRIG2_IN_P0 COUNT REGISTER (0x410)

0 – (W) – Write '0' resets the counter.

[31 - 0] – (R) – TRIG2_IN_P0 counter value.

AUXILIARY Registers (0x500 – 0x5FF)

DEBUG (0x500 – 0x518) – for VME transfers

Three registers enable the tracking of the state machine used for 2eSST VME data transmission from the module. State values are saved in a FIFO buffer when recording is enabled and a change in the state value occurs. While enabled the buffer is continuously updated so that the last ‘N’ state values are present in the buffer; ‘N’ is programmed by the user. Recording must be disabled before user readout of the state value buffer (FIFO) can begin. The actual number of valid saved state values is available to the user.

STATE LEVEL (0x500) (AUX 0)

[31...16] – (R) – reserved (read as ‘0’)

[15...9] – (R/W) – reserved

[8...0] – (R/W) – number of state values to capture (up to 511). Default value is 500 (loaded on power up or hard reset of module).

STATE CSR (0x504) (AUX 1)

31 – (R/W) – ‘1’ - buffer armed for state value capture; ‘0’ – buffer not armed

[30...28] – (R) – reserved (read as ‘0’)

[27] – (R) – state buffer full

[26] – (R) – state buffer empty

[25...9] – (R) – reserved (read as ‘0’)

[8...0] – (R) – number of valid state values stored in buffer

STATE VALUE (0x508) (AUX 2)

[31...17] – (R) – reserved (read as ‘0’)

[16...0] – (R) – next 2eSST state value

SPARE DEBUG REGISTER 1 (0x50C) (AUX 3)

[31...17] – (R/W) – reserved

BERR DRIVEN COUNT (0x510) (AUX 4)

[31...0] – (R) – count of BERR driven by the module

RETRY DRIVEN COUNT (0x514) (AUX 5)

[31...0] – (R) – count of RETRY driven by the module

SPARE DEBUG REGISTER 2 (0x518) (AUX 6)

[31...17] – (R/W) – reserved

VXS OUTPUT STATUS REGISTER (0x51C) (AUX 7)

[31...0] – (R) – status of VXS data output

SPARSIFY CONTROL REGISTER (0x520) (AUX 8)

0 – (R/W) – Bypass sparsification (1 = no sparsification (default on hard reset))

[3 – 1] – (R/W) – sparsification mode (000 on hard reset)

[31...4] – (R/W) – reserved

SPARSIFY STATUS REGISTER (0x524) (AUX 9)

0 – (R) – wait channel mask

1 – (R) – sparsification active

[30 – 2] – (R) – reserved (read as 0)

31 – (W) – clear sparsification status (pulse)

FIRST TRIGGER NUMBER MISMATCH REGISTER (0x528) (AUX 10)

[31...0] – (R) – trigger number at mismatch

MISMATCH TRIGGER NUMBER COUNTER (0x52C) (AUX 11)

[31...0] – (R) – mismatched trigger count

NUMBER OF TRIGGERS PROCESSED COUNTER (0x530) (AUX 12)

[31...0] – (R) – processed trigger count

SPARE DEBUG REGISTER 3 (0x534) (AUX 13)

[31...17] – (R/W) – reserved

SPARE DEBUG REGISTER 4 (0x538) (AUX 14)

[31...17] – (R/W) – reserved

SPARE DEBUG REGISTER 5 (0x53C) (AUX 15)

[31...17] – (R/W) – reserved

IDELAY CONTROL 1 (0x540) (AUX 16)

[31...0] – (R/W) – idelay1

[8...0] – (R/W) – Idelay Count Value to be loaded into Idelay array

[12...9] – (R/W) – Select ADC channel to load Idelay Count Value

[15..13] – (R/W) – Select ADC channel Idelay Count Value to be at idelay_status1[28..11]

[16] – (R/W) – Rising edge load all values in Idelay array into Idelay

[17] – (R/W) – 1 allows changing Idelay Count Value.) enable VTC

[18] -- (R/W) – Rising edge reset IDELAY Control.

*** See Appendix C for description of bit 16

IDELAY CONTROL 2 (0x544) (AUX 17)

[31...0] – (R/W) – idelay2

[3...0] – (R/W) – Select ADC Channel Idelay Value in pico Second stored in ROM to be at idelay_status1[10..0]

IDELAY STATUS 1 (0x548) (AUX 18)

[31...0] – (R) – current idelay1

[10..0] – (R) – Idelay Value in picosecond from ADC chanel select by IDELAYCONTROL2 [3..0]

[19..11] – (R) – Idelay Count Value from ADC channel 0-8 select from IDELAYCONTROL1[15..13]

[28..20] - Idelay Count Value from ADC channel 0-8 select from IDELAYCONTROL1[15..13]

[29] – Done Loading Idelay Count Value (Success)

[30] – Failed to Load Idelay Count Value

[31] – Done Load Idelay Count Value

*** See Appendix C for description of bit 29,30,31

IDELAY STATUS 2 (0x54C) (AUX 19)

[31...0] – (R) – current idelay2

Appendix A - Hall D FADC250 Data Format (9/16)

Data Type List

- 0 – block header
- 1 – block trailer
- 2 – event header*
- 3 – trigger time
- 4 – window raw data
- 5 – 8 – (reserved)
- 9 – pulse parameters**
- 10 – 11 – (reserved)
- 12 – scaler data
- 13 – (reserved)
- 14 – data not valid (empty module)
- 15 – filler (non-data) word

* reformatted data type

** new data type – information from previous data types 7, 8, 10
(data types not marked with * or ** remain unchanged)

Data Word Categories

Data words from the module are divided into two categories: Data Type Defining (bit 31 = 1) and Data Type Continuation (bit 31 = 0). Data Type Defining words contain a 4-bit data type tag (bits 30 - 27) along with a type dependent data payload (bits 26 - 0). Data Type Continuation words provide additional data payload (bits 30 - 0) for the *last defined data type*. Continuation words permit data payloads to span multiple words and allow for efficient packing of raw ADC samples and pulse parameters. Any number of Data Type Continuation words may follow a Data Type Defining word. The scaler data type is an exception. It specifies the number of 32-bit data words that follow.

Data Types

Block Header (0) – Word 1 indicates the beginning of a block of events. Optional continuation Word 2 contains ADC processing parameters.

Word 1:

- (31) = 1
- (30 – 27) = 0
- (26 – 22) = slot number (set by VME64x backplane)
- (21 – 18) = module ID ('1' for FADC250)
- (17 – 8) = event block number
- (7 – 0) = number of events in block

Word 2:

- (31) = 0
- (30 – 29) = 0
- (28 – 18) = PL (# samples before trigger point for processing to begin)
- (17 – 9) = NSB (# samples before threshold crossing to include in processing)
(pulse modes)
- (8 – 0) = NSA (# samples after threshold crossing to include in processing)
(pulse modes)

Block Trailer (1) – indicates the end of a block of events.

- (31) = 1
- (30 – 27) = 1
- (26 – 22) = slot number (set by VME64x backplane)
- (21 – 0) = total number of words in block of events

Event Header (2) – indicates the start an event.

- (31) = 1
- (30 – 27) = 2
- (26 – 22) = slot number (set by VME64x backplane)
- (21 – 12) = trigger time (bits 9 – 0 (see below))
- (11 – 0) = trigger number

Trigger Time (3) – time of trigger occurrence relative to the most recent global reset. Time in the ADC data processing chip is measured by a 48-bit counter that is clocked by the 250 MHz system clock. The six bytes of the trigger time

$$\text{Time} = T_A T_B T_C T_D T_E T_F$$

are reported in two words (Type Defining + Type Continuation). (Both Words or Word 2 alone may be suppressed from readout by the user.)

Word 1:

- (31) = 1
- (30 – 27) = 3
- (26 – 24) = T_C bits 2 – 0 (duplicated in Word 2)
- (23 – 16) = T_D
- (15 – 8) = T_E
- (7 – 0) = T_F

Word 2:

- (31) = 0
- (30 – 24) = reserved (read as 0)
- (23 – 16) = T_A

$$\begin{aligned}(15 - 8) &= T_B \\ (7 - 0) &= T_C\end{aligned}$$

Window Raw Data (4) – raw ADC data samples for the trigger window. The first word identifies the channel number and window width. Multiple continuation words contain two samples each. The earlier sample is stored in the most significant half of the continuation word. Strict time ordering of the samples is maintained in the order of the continuation words. A *sample not valid* flag may be set for any sample; e.g. the last reported sample is not valid when the window consists of an odd number of samples.

Word 1:

$$\begin{aligned}(31) &= 1 \\ (30 - 27) &= 4 \\ (26 - 23) &= \text{channel number (0 - 15)} \\ (22 - 12) &= \text{reserved (read as 0)} \\ (11 - 0) &= \text{window width (in number of samples)}\end{aligned}$$

Words 2 - N:

$$\begin{aligned}(31) &= 0 \\ (30) &= \text{reserved (read as 0)} \\ (29) &= \text{sample } x \text{ not valid} \\ (28 - 16) &= \text{ADC sample } x \text{ (includes overflow bit)} \\ (15 - 14) &= \text{reserved (read as 0)} \\ (13) &= \text{sample } x + 1 \text{ not valid} \\ (12 - 0) &= \text{ADC sample } x + 1 \text{ (includes overflow bit)}\end{aligned}$$

Pulse Parameters (9) – computed pulse parameters for detected pulses in a channel. The first word identifies the channel number, event number within the block, and pedestal information for the window. Multiple continuation word *pairs* contain information about the pulses detected. For a channel with hits detected:

Word 1: Channel ID and Pedestal information (reported *once* for a channel with hits)

$$\begin{aligned}(31) &= 1 \\ (30 - 27) &= 9 \\ (26 - 19) &= \text{event number within block (1 - 255)} \\ (18 - 15) &= \text{channel number (0 - 15)} \\ (14) &= \text{pedestal quality} \\ (13 - 0) &= \text{pedestal sum}\end{aligned}$$

Word 2: Integral of first pulse in window

$$\begin{aligned}(31) &= 0 \\ (30) &= 1 \\ (29 - 12) &= \text{18-bit sum of raw samples that constitute the pulse data set} \\ (11 - 9) &= \text{integral quality}\end{aligned}$$

(8 – 0) = number of samples within NSA that the pulse is above threshold

Word 3: Time of first pulse in window

(31) = 0

(30) = 0

(29 – 21) = coarse time (4 ns/count)

(20 – 15) = fine time (0.0625 ns/count)

(14 – 3) = pulse peak

(2 – 0) = time quality

Words 2 and 3 are repeated for *each additional pulse* found in the window for the channel.

Scaler Header (12) – indicates the beginning of a block of scaler data words. The number of scaler data words that will immediately follow it is provided in the header. The scaler data words are 32 bits wide and so have no bits available to identify them. Currently there are 18 scaler words reported: 16 from individual channels, a timer, and a trigger count. The scalers and time represent values recorded at the indicated trigger count. Scaler data must be enabled into the data stream by the user.

(31) = 1

(30 – 27) = 12

(26 – 6) = reserved (read as 0)

(5 – 0) = number of scaler data words to follow (18 = current)

Data Not Valid (14) – module has no valid data available for read out.

(31) = 1

(30 – 27) = 14

(26 – 22) = slot number (set by VME64x backplane)

(21 – 0) = undefined

Filler Word (15) – non-data word appended to the block of events. Forces the total number of 32-bit words read out of a module to be a multiple of 2 or 4 when 64-bit VME transfers are used. **This word should be ignored.**

(31) = 1

(30 – 27) = 15

(26 – 22) = slot number (set by VME64x backplane)

(21 – 0) = undefined

Processing Modes

Two processing modes are supported.

Mode 9: reports pulse parameters (type 9) for hits

Mode 10: reports raw window samples (type 4) and pulse parameters (type 9) for hits

Readout Format

Standard: For a block of N events

```
Block Header
  Event 1 Header
    Trigger Time 1
    Trigger Time 2
    Data words (event 1)
  Event 2 Header
    Trigger Time 1
    Trigger Time 2
    Data words (event 2)
  -----
  -----
  Event  $N$  Header
    Trigger Time 1
    Trigger Time 2
    Data words (event  $N$ )
Block Trailer
```

Intermediate compression: For a block of N events and data in events I, J, K

```
Block Header
  Event 1 Header (always)
  Event  $I$  Header
    Data words (event  $I$ )
  Event  $J$  Header
    Data words (event  $J$ )
  Event  $K$  Header
    Data words (event  $K$ )
Block Trailer
```

Full compression: For a block of N events and data in events I, J, K

Block Header
 Event 1 Header
 Data words (event I)
 Data words (event J)
 Data words (event K)
Block Trailer

Notes about the Readout Format

For the *Full compression* readout format the trigger time in the Event 1 Header enables the detection of synchronization loss among modules. If synchronization is lost (e.g. module misses a trigger), it will likely not be discovered until the next *Sync Event* (TS pauses triggers and test for synchronization). Synchronization loss thus requires that multiple blocks of events be discarded. Since the *Standard* and *Intermediate compression* readout formats have the trigger time available for each event (within the Event Header for *Intermediate compression* format), the exact point of synchronization loss can be discovered in off-line analysis. Events can be re-aligned, with a loss of only one event for each trigger missed by a module.

For simplicity of design the ADC Processing FPGA always transmits data to the Control FPGA in *Standard* format (less Block Header or Trailer words). Based on the readout format selected by the user, the Control FPGA suppresses data words that are not required to be read out.

When using processing mode 10, raw window samples (type 4 words) will precede pulse parameters (type 9 words) for a given channel. This is done for performance reasons. Because type 4 words do not have an event number in their definition, it is recommended that the *Standard* or *Intermediate compression* readout formats be used for this mode.

Appendix B: Example of Data Format for Production Mode 9

1st Trigger Occurred at Time 0x123456
Channel 1 and 15 has 1 good pulse each

Event Header (2) – indicates the start an event.

Word 1:

(35 – 32) = 0001
(31) = 1
(30 – 27) = 2
(26 – 22) = 00000
(21 – 12) = “00” & x”56” (trigger time (bits 9 –))
(11 – 0) = x”0001”

Trigger Time

Word 2:

(35 – 32) = 0000
(31) = 1
(30 – 27) = 3
(26 – 24) = “011” T_C bits 2 – 0 (duplicated in Word 2)
(23 – 16) = x”4”
(15 – 8) = x”5”
(7 – 0) = x”6”

Word 3:

(35 – 32) = 0000
(31) = 0
(30 – 24) = 0
(23 – 16) = x”1”
(15 – 8) = x”2”
(7 – 0) = x”3”

Pulse Parameters

Channel 1 data

Word 4: Channel ID and Pedestal information (reported *once* for a channel with hits)

(35 – 32) = 0000
(31) = 1
(30 – 27) = 9
(26 – 19) = 00000000 event number within block (0 – 255)
(18 – 15) = 0001
(14) = 0
(13 – 0) = pedestal sum

0xC800----

Word 5: Integral of first pulse in window

(35 – 32) = 0000

(35 – 32) = 0000

(31) = 0

(30) = 1

(29 – 12) = 18-bit sum of raw samples that constitute the pulse data set

(11 – 9) = 000

(8 – 0) = number of samples within NSA that the pulse is above threshold

Word 6: Time of first pulse in window

(35 – 32) = 0000

(35 – 32) = 0000

(31) = 0

(30) = 0

(29 – 21) = coarse time (4 ns/count)

(20 – 15) = fine time (0.0625 ns/count)

(14 – 3) = pulse peak

(2 – 0) = time quality

Channel 15 data

Word 7: Channel ID and Pedestal information (reported *once* for a channel with hits)

(35 – 32) = 0000

(31) = 1

(30 – 27) = 9

(26 – 19) = 00000000 event number within block (0 – 255)

(18 – 15) = 1111

(14) = 0

(13 – 0) = pedestal sum

Word 8: Integral of first pulse in window

(35 – 32) = 0000

(31) = 0

(30) = 1

(29 – 12) = 18-bit sum of raw samples that constitute the pulse data set

(11 – 9) = 000

(8 – 0) = number of samples within NSA that the pulse is above threshold

Word 9 Time of first pulse in window

(35 – 32) = 0000

(31) = 0

(30) = 0

(29 – 21) = coarse time (4 ns/count)

(20 – 15) = fine time (0.0625 ns/count)

(14 – 3) = pulse peak

(2 – 0) = time quality

Event Trailer: Indicate the end of an event.

Word 10

EVENT_TRAILER = "0010" & X"E8000000";

Appendix C: Control Bus Memory Map for Registers

Unused Bits are read back as zeroes

Failure to adhere to Min values can result in unpredictable results

Name [VME ADDRESS]	Width (Bits)	Quantity	Access	Primary Address (Secondary Address)	Power Up Values (hex)	Function
STATUS0 [0x100]	16	1	R	0x0000 (---)		Bits 14 to 0: Code Version Bit 15: 1= Command can be sent to AD4229
STATUS1 [0x102]	16	1	R	0x0001 (---)		15 : 1 Done all Trig received 11-0 : TRIGGER NUMBER
STATUS2 [0x104]	16	1	R	0x0002 (---)		Monitored Pedestal 15 → Sum is valid 14 → 0 Sum OK. 1 One or more is out of bound 13-0 → Sum
CONFIG1 [0x106]	16	1	R/W	0x0003 (---)	0040	Bit 0-2 (old code process mode): Bit 3: 1:Run (Collect On) Bit 5-4 : Max Number of Pulses in Mode 10 and 9 Bit 6: 1 Inverts ADC data output Bit 7: Test Mode (play Back). Bit 9-8: 00 → mode 9 (pulse parameters) 01 → mode 10 (pulse parameters & raw) 11 → mode 11 (raw) 11-10 NSAT 13-12 TNSAT 15→ Request Sum of Pedestal for monitoring purpose
CONFIG2 [0x108]			R/W	0x0004 (---)	0040	When 1 ADC values = 0 Bit 0 → ADC 0 Bit 1 → ADC 1 Bit 2 → ADC 2 Bit 3 → ADC 3 Bit 4 → ADC 4

						Bit 5 → ADC 5 Bit 6 → ADC 6 Bit 7 → ADC 7 Bit 8 → ADC 8 Bit 9 → ADC 9 Bit 10 → ADC 10 Bit 11 → ADC 11 Bit 12 → ADC 12 Bit 13 → ADC 13 Bit 14 → ADC 14 Bit 15 → ADC 15
CONFIG 4 [0x10A]	16	1	R/W	0x0005	0040	15..12=> Select which ADC receive- IDELAY control bits and read back- IDELAY comparator error 15..12 => Select which ADC Idelay Error Bits to monitor 11=> Idelay comparator reset 10=> Increment IDELAY N delay- value 9=> Decrement IDELAY P delay- value 8=> Reset IDELAY 11 => IDELAYE3_EN_VTC_D 10 => LdNextIdlyCh 9=> ConfigIdelay 8=> IDELAYCTRL_RST 7 => rising edge execute ADC command 6 => 1 write to all ADC 5 => 0 write to ADC 1 read from ADC. Data is at Stat 4 4 => 1 Reset ADC 3..0 => Select ADC to write to or read from
CONFIG5 [0x10C]	16	1		0x0006	0040	15..8 => Register inside ADC 7..0 => Data to write to register.
PTW [0x10E]	9	1	R/W	0x0007 (---)	0010	PTW + 1 number of ADC sample to include in trigger window. PTW = Trigger Window (ns) * 250 MHz. Minimum is 6.
PL [0x110]	11	1	R/W	0x0008 (---)	0000	Number of sample back from trigger point. PL = Trigger Window(ns) * 250MHz

NSB [0x112]	4	1	R/W	0x0009 (---)	0000	3..0: Read Back Path NSB Number of sample before trigger point to include in data processing. This include the trigger Point. When NSB bit 3 is 1: NSA has to be > NSB bits 1,0 by at least 4 => NSA – (NSB bits 1,0) ≥ 3
NSA [0x114]	15	1	R/W	0x000A (---)	0005	8..0: Read Back Path NSA Number of sample after trigger point to include in data processing. Minimum is 2 14..9: Trigger Path NSA
TET [0x116-134]	12	16	R/W	0x000B - 0x001A	0000	Trigger Read Out Energy Thredhold.
CONFIG6 (Monitored Pedestal Sum) [0x136]	16	1	R/W	0x001B	0000	13-10 MNPED : The number of ADC sample to sum up is MNPED + 1. Min is 4 9-0 PMaxPed : When an ADC Samples is greater than this, bit 14 of the 14 bits (13-0) Sum will be set.
CONFIG7 (Read Back Pedestal Sum) [0x138]	16	1	R/W	0x001C	0000	13-10 NPED : The number of ADC sample is NPED + 1 9-0 MaxPed
Test Wave Form [0x13A]	16	1	R/W	0x001D	0000	Write to PPG. Read should immediately follow write.
ADC Pedestal Subtract [0x13C-15A]	12	16	R/W	0x001E- 0x002D	0000	Subtract from ADC(0-15) Count before Summing
Config 3 [0x15C]	16	1	R/W	0x002E	0000	15 : Sync Disable (11..0) Trigger Path Processing Threshold
STATUS 3 [0x15E]	16	1	R	0x002F		FPGA core temp (DieTemp) 5 - DoneReadSeriallRomAt25040 4 - DoneLdIdelayCntVal 3 - Detect_ERROR_IDDR_P_CH8_15 2 - Detect_ERROR_IDDR_N_CH8_15 1 - Detect_ERROR_IDDR_P_CH0_7

						0 - Detect_ERROR_IDDR_N_CH0_7
STATUS 4 [0x160]	16	1	R	0x0030		14 – Vcc Aux is out of range 13 – Vcc Int is out of range 12 – FPGA over 85 degree C 11 – FPGA over 125 degree C 9-0 Result of ADC AD4229 register read back
Roque_PTW_Fall_Back [0x162]	16	1	R/W	0x0031		When 1 enable send raw data when any of the first 4 samples is above threshold. When 0 proceed to calculate SUM and TDC Bit 0 → ADC 0 Bit 1 → ADC 1 Bit 2 → ADC 2 Bit 3 → ADC 3 Bit 4 → ADC 4 Bit 5 → ADC 5 Bit 6 → ADC 6 Bit 7 → ADC 7 Bit 8 → ADC 8 Bit 9 → ADC 9 Bit 10 → ADC 10 Bit 11 → ADC 11 Bit 12 → ADC 12 Bit 13 → ADC 13 Bit 14 → ADC 14 Bit 15 → ADC 15
ConfigG 0 [0x164]	16	1	R/W	0x0032	0	15.. 0 - PRAD TRIG GAIN_REG ADC 0
ConfigG 1 [0x166]	16	1	R/W	0x0033	0	15.. 0 - PRAD TRIG GAIN_REG ADC 1
ConfigG 2 [0x168]	16	1	R/W	0x0034	0	15.. 0 - PRAD TRIG GAIN_REG ADC 2
ConfigG 3 [0x16A]	16	1	R/W	0x0035	0	15.. 0 - PRAD TRIG GAIN_REG ADC 3
ConfigG 4 [0x16C]	16	1	R/W	0x0036	0	15.. 0 - PRAD TRIG GAIN_REG ADC 4
ConfigG 5 [0x16E]	16	1	R/W	0x0037	0	15.. 0 - PRAD TRIG GAIN_REG ADC 5
ConfigG 6 [0x170]	16	1	R/W	0x0038	0	15.. 0 - PRAD TRIG GAIN_REG ADC 6
ConfigG 7 [0x172]	16	1	R/W	0x0039	0	15.. 0 - PRAD TRIG GAIN_REG ADC 7
ConfigG 8	16	1	R/W	0x003A	0	15.. 0 - PRAD TRIG GAIN_REG

[0x174]						ADC 8
ConfigG 9 [0x176]	16	1	R/W	0x003B	0	15.. 0 - PRAD TRIG GAIN_REG ADC 9
ConfigG 10 [0x178]	16	1	R/W	0x003C	0	15.. 0 - PRAD TRIG GAIN_REG ADC 10
ConfigG 11 [0x17A]	16	1	R/W	0x003D	0	15.. 0 - PRAD TRIG GAIN_REG ADC 11
ConfigG 12 [0x17C]	16	1	R/W	0x003E	0	15.. 0 - PRAD TRIG GAIN_REG ADC 12
ConfigG 13 [0x17E]	16	1	R/W	0x003F	0	15.. 0 - PRAD TRIG GAIN_REG ADC 13
ConfigG 14 [0x180]	16	1	R/W	0x0040	0	15.. 0 - PRAD TRIG GAIN_REG ADC 14
ConfigG 15 [0x182]	16	1	R/W	0x0041	0	15.. 0 - PRAD TRIG GAIN_REG ADC 15
ConfigG 16 [0x184]	16	1	R/W	0x0042	0	8..0 - PRAD TRIG DELAY_REG ADC 0
ConfigG 17 [0x186]	16	1	R/W	0x0043	0	8..0 - PRAD TRIG DELAY_REG ADC 1
ConfigG 18 [0x188]	16	1	R/W	0x0044	0	8..0 - PRAD TRIG DELAY_REG ADC 2
ConfigG 19 [0x18A]	16	1	R/W	0x0045	0	8..0 - PRAD TRIG DELAY_REG ADC 3
ConfigG 20 [0x18C]	16	1	R/W	0x0046	0	8..0 - PRAD TRIG DELAY_REG ADC 4
ConfigG 21 [0x18E]	16	1	R/W	0x0047	0	8..0 - PRAD TRIG DELAY_REG ADC 5
ConfigG 22 [0x190]	16	1	R/W	0x0048	0	8..0 - PRAD TRIG DELAY_REG ADC 6
ConfigG 23 [0x192]	16	1	R/W	0x0049	0	8..0 - PRAD TRIG DELAY_REG ADC 7
ConfigG 24 [0x194]	16	1	R/W	0x004A	0	8..0 - PRAD TRIG DELAY_REG ADC 8
ConfigG 25 [0x196]	16	1	R/W	0x004B	0	8..0 - PRAD TRIG DELAY_REG ADC 9
ConfigG 26 [0x198]	16	1	R/W	0x004C	0	8..0 - PRAD TRIG DELAY_REG ADC 10
ConfigG 27 [0x19A]	16	1	R/W	0x004D	0	8..0 - PRAD TRIG DELAY_REG ADC 11
ConfigG 28 [0x19C]	16	1	R/W	0x004E	0	8..0 - PRAD TRIG DELAY_REG ADC 12
ConfigG 29 [0x19E]	16	1	R/W	0x004F	0	8..0 - PRAD TRIG DELAY_REG ADC 13
ConfigG 30 [0x1A0]	16	1	R/W	0x0050	0	8..0 - PRAD TRIG DELAY_REG ADC 14
ConfigG 31	16	1	R/W	0x0051	0	8..0 - PRAD TRIG DELAY_REG

[0x1A2]						ADC 15
ConfigG 32 [0x1A4]	16	1	R/W	0x0052	0	15..0 - PRAD LIVE TRIG MASK
ConfigG 33 [0x1A6]	16	1	R/W	0x0053	0	15..0 - PRAD LIVE TRIG WIDTH
ConfigG 34 [0x1A8]	16	1	R/W	0x0054	0	12..0 - PRAD HITBIT CONFIG
ConfigG 35 [0x1AA]	16	1	R/W	0x0055	0	Reserve 15..0 - PRAD LA RDEN
ConfigG 36 [0x1AC]	16	1	R/W	0x0056	0	0- PRAD LA CTRL REG
ConfigG 37 [0x1AE]	16	1	R/W	0x0057	0	12..0 - PRAD CMP MODE ADC 0
ConfigG 38 [0x1B0]	16	1	R/W	0x0058	0	12..0 - PRAD CMP MODE ADC 1
ConfigG 39 [0x1B2]	16	1	R/W	0x0059	0	12..0 - PRAD CMP MODE ADC 2
ConfigG 40 [0x1B4]	16	1	R/W	0x005A	0	12..0 - PRAD CMP MODE ADC 3
ConfigG 41 [0x1B6]	16	1	R/W	0x005B	0	12..0 - PRAD CMP MODE ADC 4
ConfigG 42 [0x1B8]	16	1	R/W	0x005C	0	12..0 - PRAD CMP MODE ADC 5
ConfigG 43 [0x1BA]	16	1	R/W	0x005D	0	12..0 - PRAD CMP MODE ADC 6
ConfigG 44 [0x1BC]	16	1	R/W	0x005E	0	12..0 - PRAD CMP MODE ADC 7
ConfigG 45 [0x1BE]	16	1	R/W	0x005F	0	12..0 - PRAD CMP MODE ADC 8
ConfigG 46 [0x1C0]	16	1	R/W	0x0060	0	12..0 - PRAD CMP MODE ADC 9
ConfigG 47 [0x1C2]	16	1	R/W	0x0061	0	12..0 - PRAD CMP MODE ADC 10
ConfigG 48 [0x1C4]	16	1	R/W	0x0062	0	12..0 - PRAD CMP MODE ADC 11
ConfigG 49 [0x1C6]	16	1	R/W	0x0063	0	12..0 - PRAD CMP MODE ADC 12
ConfigG 50 [0x1C8]	16	1	R/W	0x0064	0	12..0 - PRAD CMP MODE ADC 13
ConfigG 51 [0x1CA]	16	1	R/W	0x0065	0	12..0 - PRAD CMP MODE ADC 14
ConfigG 52 [0x1CC]	16	1	R/W	0x0066	0	12..0 - PRAD CMP MODE ADC 15
ConfigG 53 [0x1CE]	16	1	R/W	0x0067	0	12..0 - PRAD CMP THR ADC 0
ConfigG 54 [0x1D0]	16	1	R/W	0x0068	0	12..0 - PRAD CMP THR ADC 1
ConfigG 55 [0x1D2]	16	1	R/W	0x0069	0	12..0 - PRAD CMP THR ADC 2
ConfigG 56 [0x1D4]	16	1	R/W	0x006A	0	12..0 - PRAD CMP THR ADC 3
ConfigG 57 [0x1D6]	16	1	R/W	0x006B	0	12..0 - PRAD CMP THR ADC 4
ConfigG 58	16	1	R/W	0x006C	0	12..0 - PRAD CMP THR ADC 5

[0x1D8]						
ConfigG 59 [0x1DA]	16	1	R/W	0x006D	0	12..0 - PRAD CMP THR ADC 6
ConfigG 60 [0x1DC]	16	1	R/W	0x006E	0	12..0 - PRAD CMP THR ADC 7
ConfigG 61 [0x1DE]	16	1	R/W	0x006F	0	12..0 - PRAD CMP THR ADC 8
ConfigG 62 [0x1E0]	16	1	R/W	0x0070	0	12..0 - PRAD CMP THR ADC 9
ConfigG 63 [0x1E2]	16	1	R/W	0x0071	0	12..0 - PRAD CMP THR ADC 10
ConfigG 64 [0x1E4]	16	1	R/W	0x0072	0	12..0 - PRAD CMP THR ADC 11
ConfigG 65 [0x1E6]	16	1	R/W	0x0073	0	12..0 - PRAD CMP THR ADC 12
ConfigG 66 [0x1E8]	16	1	R/W	0x0074	0	12..0 - PRAD CMP THR ADC 13
ConfigG 67 [0x1EA]	16	1	R/W	0x0075	0	12..0 - PRAD CMP THR ADC 14
ConfigG 68 [0x1EC]	16	1	R/W	0x0076	0	12..0 - PRAD CMP THR ADC 15
ConfigG 69 [0x1EE]	16	1	R/W	0x0077	0	0 - PRAD_SCALER_LATCH
ConfigG 70 [0x1F0]	16	1	R/W	0x0078	0	For Future
ConfigG 71 [0x1F2]	16	1	R/W	0x0079	0	For Future
ConfigG 72 [0x1F4]	16	1	R/W	0x007A	0	For Future
ConfigG 73 [0x1F6]	16	1	R/W	0x007B	0	For Future
ConfigG 74 [0x1F8]	16	1	R/W	0x007C	0	For Future
ConfigG 75 [0x1FA]	16	1	R/W	0x007D	0	For Future
ConfigG 76 [0x1FC]	16	1	R/W	0x007E	0	For Future
ConfigG 77 [0x1FE]	16	1	R/W	0x007F	0	For Future
ConfigG 78 [0x200]0	16	1	R/W	0x0080	0	For Future
ConfigG 79 [0x202]	16	1	R/W	0x0081	0	For Future
ConfigG 80 [0x204]	16	1	R/W	0x0082	0	For Future
ConfigG 81 [0x206]	16	1	R/W	0x0083	0	For Future
ConfigG 82 [0x208]	16	1	R/W	0x0084	0	For Future
ConfigG 83 [0x20A]	16	1	R/W	0x0085	0	For Future
ConfigG 84 [0x20C]	16	1	R/W	0x0086	0	For Future
ConfigG 85	16	1	R/W	0x0087	0	For Future

[0x20E]						
StatG 0 [0x210]	16	1	R	0x0088	0	12..0 - PRAD LA DAT ADC 0
StatG 1 [0x212]	16	1	R	0x0089	0	12..0 - PRAD LA DAT ADC 1
StatG 2 [0x214]	16	1	R	0x008A	0	12..0 - PRAD LA DAT ADC 2
StatG 3 [0x216]	16	1	R	0x008B	0	12..0 - PRAD LA DAT ADC 3
StatG 4 [0x218]	16	1	R	0x008C	0	12..0 - PRAD LA DAT ADC 4
StatG 5 [0x21A]	16	1	R	0x008E	0	12..0 - PRAD LA DAT ADC 5
StatG 6 [0x21C]	16	1	R	0x008F	0	12..0 - PRAD LA DAT ADC 6
StatG 7 [0x21E]	16	1	R	0x0090	0	12..0 - PRAD LA DAT ADC 7
StatG 8 [0x220]	16	1	R	0x0091	0	12..0 - PRAD LA DAT ADC 8
StatG 9 [0x222]	16	1	R	0x0092	0	12..0 - PRAD LA DAT ADC 9
StatG 10 [0x224]	16	1	R	0x0093	0	12..0 - PRAD LA DAT ADC 10
StatG 11 [0x226]	16	1	R	0x0094	0	12..0 - PRAD LA DAT ADC 11
StatG 12 [0x228]	16	1	R	0x0095	0	12..0 - PRAD LA DAT ADC 12
StatG 13 [0x22A]	16	1	R	0x00596	0	12..0 - PRAD LA DAT ADC 13
StatG 14 [0x22C]	16	1	R	0x0097	0	12..0 - PRAD LA DAT ADC 14
StatG 15 [0x22E]	16	1	R	0x0098	0	12..0 - PRAD LA DAT ADC 15
StatG 16 [0x230]	16	1	R	0x0099	0	15..0 - PRAD ACC0 ADC 0
StatG 17 [0x232]	16	1	R	0x009A	0	15..0 - PRAD ACC0 ADC 1
StatG 18 [0x234]	16	1	R	0x009B	0	15..0 - PRAD ACC0 ADC 2
StatG 19 [0x236]	16	1	R	0x009C	0	15..0 - PRAD ACC0 ADC 3
StatG 20 [0x238]	16	1	R	0x009D	0	15..0 - PRAD ACC0 ADC 4
StatG 21 [0x23A]	16	1	R	0x009E	0	15..0 - PRAD ACC0 ADC 5
StatG 22 [0x23C]	16	1	R	0x009F	0	15..0 - PRAD ACC0 ADC 6
StatG 23 [0x23E]	16	1	R	0x00A0	0	15..0 - PRAD ACC0 ADC 7
StatG 24 [0x240]	16	1	R	0x00A1	0	15..0 - PRAD ACC0 ADC 8
StatG 25	16	1	R	0x00A2	0	15..0 - PRAD ACC0 ADC 9

[0x242]						
StatG 26 [0x244]	16	1	R	0x00A3	0	15..0 - PRAD ACC0 ADC 10
StatG 27 [0x246]	16	1	R	0x00A4	0	15..0 - PRAD ACC0 ADC 11
StatG 28 [0x248]	16	1	R	0x00A5	0	15..0 - PRAD ACC0 ADC 12
StatG 29 [0x24A]	16	1	R	0x00A6	0	15..0 - PRAD ACC0 ADC 13
StatG 30 [0x24C]	16	1	R	0x00A7	0	15..0 - PRAD ACC0 ADC 14
StatG 31 [0x24E]	16	1	R	0x00A8	0	15..0 - PRAD ACC0 ADC 15
StatG 32 [0x250]	16	1	R	0x00A9	0	15..0 - PRAD ACC1 ADC 0
StatG 33 [0x252]	16	1	R	0x00AA	0	15..0 - PRAD ACC1 ADC 1
StatG 34 [0x254]	16	1	R	0x00AB	0	15..0 - PRAD ACC1 ADC 2
StatG 35 [0x256]	16	1	R	0x00AC	0	15..0 - PRAD ACC1 ADC 3
StatG 36 [0x258]	16	1	R	0x00AD	0	15..0 - PRAD ACC1 ADC 4
StatG 37 [0x25A]	16	1	R	0x00AE	0	15..0 - PRAD ACC1 ADC 5
StatG 38 [0x25C]	16	1	R	0x00AF	0	15..0 - PRAD ACC1 ADC 6
StatG 39 [0x25E]	16	1	R	0x00B0	0	15..0 - PRAD ACC1 ADC 7
StatG 40 [0x260]	16	1	R	0x00B1	0	15..0 - PRAD ACC1 ADC 8
StatG 41 [0x262]	16	1	R	0x00B2	0	15..0 - PRAD ACC1 ADC 9
StatG 42 [0x264]	16	1	R	0x00B3	0	15..0 - PRAD ACC1 ADC 10
StatG 43 [0x266]	16	1	R	0x00B4	0	15..0 - PRAD ACC1 ADC 11
StatG 44 [0x268]	16	1	R	0x00B5	0	15..0 - PRAD ACC1 ADC 12
StatG 45 [0x26A]	16	1	R	0x00B6	0	15..0 - PRAD ACC1 ADC 13
StatG 46 [0x26C]	16	1	R	0x00B7	0	15..0 - PRAD ACC1 ADC 14
StatG 47 [0x26E]	16	1	R	0x00B8	0	15..0 - PRAD ACC1 ADC 15
StatG 48 [0x270]	16	1	R	0x00B9	0	15..0 - PRAD ACC2 ADC 0
StatG 49 [0x272]	16	1	R	0x00BA	0	15..0 - PRAD ACC2 ADC 1
StatG 50 [0x274]	16	1	R	0x00BB	0	15..0 - PRAD ACC2 ADC 2
StatG 51 [0x276]	16	1	R	0x00BC	0	15..0 - PRAD ACC2 ADC 3
StatG 52	16	1	R	0x00BD	0	15..0 - PRAD ACC2 ADC 4

[0x278]						
StatG 53 [0x27A]	16	1	R	0x00BE	0	15..0 - PRAD ACC2 ADC 5
StatG 54 [0x27C]	16	1	R	0x00BF	0	15..0 - PRAD ACC2 ADC 6
StatG 55 [0x27E]	16	1	R	0x00C0	0	15..0 - PRAD ACC2 ADC 7
StatG 56 [0x280]	16	1	R	0x00C1	0	15..0 - PRAD ACC2 ADC 8
StatG 57 [0x282]	16	1	R	0x00C2	0	15..0 - PRAD ACC2 ADC 9
StatG 58 [0x284]	16	1	R	0x00C3	0	15..0 - PRAD ACC2 ADC 10
StatG 59 [0x286]	16	1	R	0x00C4	0	15..0 - PRAD ACC2 ADC 11
StatG 60 [0x288]	16	1	R	0x00C5	0	15..0 - PRAD ACC2 ADC 12
StatG 61 [0x28A]	16	1	R	0x00C6	0	15..0 - PRAD ACC2 ADC 13
StatG 62 [0x28C]	16	1	R	0x00C7		15..0 - PRAD ACC2 ADC 14
StatG 63 [0x28E]	16	1	R	0x00C8		15..0 - PRAD ACC2 ADC 15
StatG 64 [0x290]	16	1	R	0x00C9		0 – 1: Logic Analyzer can be read out
StatG 65 [0x292]	16	1	R	0x00CA		For Future
StatG 66 [0x294]	16	1	R	0x00CB		For Future
StatG 67 [0x296]	16	1	R	0x00CC		For Future
StatG 68 [0x298]	16	1	R	0x00CD		For Future
StatG 69 [0x29A]	16	1	R	0x00CE		For Future
StatG 70 [0x29C]	16	1	R	0x00CF		For Future

Appendix B

Bias DAC Count	ADC Count With No Input (in hex)
4096	1000
4000	1000
3500	1000
3300	66
3100	173
3000	1FB
2900	281
2800	30A
2700	393
2600	419
2500	49E
2400	526
2300	5ae
2200	632
2100	6BA
2000	741
1900	7C6
1800	850
1700	8D5
1600	95B
1500	9E1
1400	A6B
1300	AF0
1200	B7B
1100	C00
1000	C86
900	D0E
800	D91
700	E19
600	EA1
500	F29
400	FAC
300	1FFF

Appendix D:

Idelay Values for FPGA ADC Input Pins:

Description:

ADC output data is Double Data Rate (data bits change on rising edge and falling edge of clock) at 250MHz. The FPGA clock has to be (approximately) at the center of the data bits. Due to a difference delay (when data and clock arrived at the FPGA) between the data and clock, the data have to be delayed. FPGA's delay circuit has 512 tap with each tap provided approximately 17.857 pS of delay. The tap's delay is varying with temperature and voltage. To accommodate this variation, the desired delay for each ADC is found at the current temperature and voltage and stored in on board serial ROM. The FPGA is compiled with a delay of 1000pS for all ADC channels. The tap values that provided this 1000pS at the current temperature and voltage are then load when FPGA is booting. These tap values are read by user to determine "tap per ps". The "tap per ps" is multiplied by the desired delay stored in ROM. The tap count is then loaded into the Idelay in the FPGA. The FPGA changes these count based on temperature and voltage to keep the desired delay (stored in ROM).

Loading Idelay values for FPGA's input circuit:

- 1) Run the Calc_Load_IdelayCntVal routine **AT POWER UP** in For_Coda_1.cpp file . The file is located at M:\FE\FADC-250V3\C_test_code_CPP2022\For_Coda. This routine does the following:
 - a) Read the deisre delays (in pSec from serial ROM on the FADCV3 board => IdelayValInRom
 - b) Read the present Idely Count Values (position of 512 taps) => InitIdelyCountValue
 - c) Tap delay resoulition; TapRes = 500 pS/InitIdelyCountValue
 - d) NewTapVal = TapRes * IdelayValInRom
 - e) Program NewTapVal into Idelay
- 2) Read IDELAY STATUS 1 (0x548) (**AUX 18**)
 - a) If bit 29 is a 1 then the count values are successfully loaded
 - b) If bit 30 is a 1 then the count values are not loaded. Something is wrong with the IDELAY circuit in the FPGA

Appendix F:

Rebooting the FPGA

The host can reboot the FPGA from configuration ROM by setting bit 11 of CONFIG ROM CONTROL 0 (0x58)