OptoHybrid Modules & Functionalities

Thomas Lenzi ([thomas.lenzi@cern.ch](mailto:thomas.lenzi@cern.ch))

This document describes how to interact with the OptoHybrid (OH) modules and how to parameterize and use the various functionalities integrated in the firmware.

# Contents

[Contents 1](#_Toc431542656)

[VFAT2 I2C 2](#_Toc431542657)

[VFAT2 I2C Extended 3](#_Toc431542661)

[Threshold & Latency Scans 4](#_Toc431542665)

[T1 Controller 6](#_Toc431542670)

[DAC Scans (in development) 8](#_Toc431542679)

[ADC (in development) 10](#_Toc431542684)

[Clocking (not available for test beam, use system registers to control clocking options) 11](#_Toc431542688)

[Counters 12](#_Toc431542690)

[System Registers 13](#_Toc431542692)

[Status Registers 14](#_Toc431542694)

# VFAT2 I2C

This module handles I2C transactions with a single VFAT2 hybrid.

## Addressing

Module ID 0

Address 0x4000XXYY

0b 0100 0000 0000 0000 000X XXXX YYYY YYYYY

|  |  |  |
| --- | --- | --- |
| Y register | Mode | Function |
| VFAT2 registers | | |
| 0 - 150 | Read / write | Read or write the register on VFAT2 n°X (5 bit chip identifier)  5 MSBits are constant 0s  1 next bit is set when an error occurred  1 next bit is set when the transaction is valid  1 next bit is the read/not write bit of the transaction  8 next bits hold the id of the addressed VFAT2  8 next bits hold the id of the addressed register  8 LSBits hold the response from the VFAT2 |

## Errors

The module returns an error if the parameters are not in spec or if the VFAT2 is not accessible.

## Errors to avoid

* The VFAT2 number must be in the range 0 to 23.
* The register ID must be in the range 0 to 150.

# VFAT2 I2C Extended

This module broadcasts I2C requests to all the VFAT2s that are not masked by the *mask* register.

## Addressing

Module ID 1

Address 0x41000YYY

0b 0100 0001 0000 0000 0000 000Y YYYY YYYYY

|  |  |  |
| --- | --- | --- |
| Y register | Mode | Function |
| VFAT2 registers | | |
| 0 - 150 | Read / write | Read or write the register on all VFAT2s not masked by the *mask* register |
| Parameters | | |
| 256 | Read / write | *mask* - 24 bits  Asserting a bit in this register will remove the corresponding VFAT2 from the broadcast list |
| Results | | |
| 257 | Read only | FIFO holding the results of a request. This register will return the response of each individual request made to the VFAT2s:  8 MSBits are constant 0s  8 next bits hold the status of the transaction  8 next bits are the VFAT2 id (0 to 23)  8 LSBits hold response from the VFAT2  If no data is present, an error is returned. |
| Reset | | |
| 258 | Write only | Local reset of the module |

## Errors

The module returns an error if the parameters are not in spec. The errors related to individual VFAT2s are stored in the FIFO.

## Errors to avoid

* The register ID must be in the range 0 to 150 or 256 to 258.

# Threshold, Latency, and S-Curve Scans

This module performs a threshold, threshold by channel, latency, or s-curve scan on (channel *channel* of) VFAT2 *vfat2* by varying its threshold/latency/calibration pulse from a minimum value *min* to a maximum value *max* by steps of *step* and by counting the number of events where the SBits/strips are fired in a set of *N* events.

## Addressing

Module ID 2

Address 0x4200000Y

0b 0100 0010 0000 0000 0000 0000 0000 YYYY

|  |  |  |
| --- | --- | --- |
| Y register | Mode | Function |
| Control | | |
| 0 | Write only | Start the scan. This will also empty the FIFO holding the data of the previous scan. |
| Parameters | | |
| 1 | Read / write | *mode* - 2 bits - [0, 2]  0 = threshold scan  1 = threshold scan by channel  2 = latency scan  3 = s-curve |
| 2 | Read / write | *VFAT2* - 5 bits - [0, 23] |
| 3 | Read / write | *channel* – 8 bits - [0x0, 0xFF]  Only used for a threshold scan by channel |
| 4 | Read / write | *min -* 8 bits - [0x0, *max*] |
| 5 | Read / write | *max -* 8 bits - [*min*, 0xFF]  Default: 0 = 0xFF |
| 6 | Read / write | *step -* 8 bits - [0x0, 0xFF]  Default: 0 = 0x1 |
| 7 | Read / write | *N -* 24 bits - ]0x0, 0xFFFFFF]  Default: 0 = 0xFFFFFF |
| Results | | |
| 8 | Read only | FIFO holding the results of the scan. This register will return the data points collected by the scan using the following data format:  8 MSBits hold the threshold/latency value of the point  24 LSBits hold the number of events that have fired  If no data is present, an error is returned. |
| Monitoring | | |
| 9 | Read only | *Status* - 3 bits - [0, 4]  0 = nothing running  1 = threshold scan running  2 = threshold scan by channel running  3 = latency scan running  4 = s-curve scan running |
| Reset | | |
| 10 | Write only | Local reset of the module |

## 

## Description

The module will store the value of the register before the scan and reapply the later after the end of the operation.

## Errors

When starting the scan, the returned status of the write operation informs the user about the validity of the parameters. Invalid parameters will return an error and prevent the scan from starting. Other errors related to the VFAT2s are stored in the FIFO.

Two types of errors are stored in the FIFO when running the scan: global errors and local errors.

A global error occurs if the VFAT2 is not present or running at the start of the scan. In that case, a single 32 bits word is stored in the FIFO. No other read operations of the FIFO should occur afterwards:

* 0xF0000000 means that the VFAT2 is not running ;
* 0xFF000000 means that the current value of the register could not be saved.

A local error occurs if one of the I2C operations used to change the value did not succeed. In that case, the value of the 24 LSBits of that particular point is 0xFFFFFF. Other data points will still be saved and be present in the FIFO.

## Errors to avoid

* The VFAT2 number must be in the range 0 to 23.
* The maximum value of the register to scan must be higher than the minimum value.
* The register ID must be in the range 0 to 10.

## Note

When performing a threshold scan by channel or an s-curve scan, the user should provide a source of triggers in order to generate tracking data.

# T1 Controller

This module sends T1 commands to the VFAT2s according to different operation modes defined by *mode*.

## Addressing

Module ID 3

Address 0x4300000Y

0b 0100 0011 0000 0000 0000 0000 0000 YYYY

|  |  |  |
| --- | --- | --- |
| Y register | Mode | Function |
| Control | | |
| 0 | Write only | Toggle the module on and off. |
| 1 | Read / write | *mode* - 2 bits - [0, 2] |
| Mode 0 & 1 parameters | | |
| 2 | Read / write | *type*  - 2 bits - [0, 3] 0 = LV1A  1 = Calpulse  2 = Resync  3 = BC0 |
| 3 | Read / write | *N -* 32 bits – [0, 0xFFFFFFFF] Default: 0 = infinite |
| 4 | Read / write | *interval* – 32 bits – [3, 0xFFFFFFFF] |
| 5 | Read / write | *delay* - 32 bits – [*3*, interval - 3] |
| Mode 2 parameters | | |
| 7 & 6 | Read / write | *lv1a\_sequence* – 64 bits |
| 9 & 8 | Read / write | *calpulse\_sequence –* 64 bits |
| 11 & 10 | Read / write | *resync\_sequence -* 64 bits |
| 13 & 12 | Read / write | *bc0\_sequence* - 64 bits |
| Monitoring | | |
| 14 | Read only | *Status* - 2 bits - [0, 3]  0 = nothing running  1 = MODE 0 running  2 = MODE 1 running  3 = MODE 2 running |
| Reset | | |
| 15 | Write only | Local reset of the module |

## Errors

When starting the module, the returned status of the write operation informs the user about the validity of the parameters. Invalid parameters will return an error and prevent the module from starting.

## Operation modes

### Mode 0

Send *N* T1 commands of type *type* with an interval of *interval* BXs. Note that *interval* cannot be smaller than 3 BXs which is the time needed to encode a T1 command on the wire. Example with an *interval* of 4 BXs:

CLK \_|‾|\_|‾|\_|‾|\_|‾|\_|‾|\_|‾|\_|‾|\_|‾|\_|‾|\_|‾|\_|‾|\_|‾|\_|‾|\_|‾|\_|‾|\_

T1 \_|‾|\_\_\_\_\_\_\_\_\_\_\_\_\_|‾|\_\_\_\_\_\_\_\_\_\_\_\_\_|‾|\_\_\_\_\_\_\_\_\_\_\_\_\_|‾|\_\_\_\_\_\_\_\_\_

### Mode 1

Send *N* packets composed of a Calpulse followed by an LV1A separated by *delay* BXs. The packets are spaced by *interval* BXs. Note that *interval* cannot be smaller than 3 BXs which is the time needed to encode a T1 command on the wire and that *delay* must be in the range [3, *interval* – 3] BXs. Example with a *delay* of 4 BXs and an *interval* of 10 BXs:

CLK \_|‾|\_|‾|\_|‾|\_|‾|\_|‾|\_|‾|\_|‾|\_|‾|\_|‾|\_|‾|\_|‾|\_|‾|\_|‾|\_|‾|\_|‾|\_

LV1A \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_|‾|\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_|‾|\_

CAL \_|‾|\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_|‾|\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

### Mode 2

Send T1 commands according to a pattern defined by the sequence registers: *lv1a\_sequence, calpulse\_sequence, resync\_sequence,* and *bc0\_sequence*. Every 4 BXs, the module reads a bit in each of the registers and sets/resets the T1 line according to the asserted bits. This operation mode allows the user to create custom patterns of T1 commands. The module will loop over the registers *N*  times. Example of a generated pattern using the *lv1a\_sequence* and *calpulse\_sequence* registers.

CLK \_|‾|\_|‾|\_|‾|\_|‾|\_|‾|\_|‾|\_|‾|\_|‾|\_|‾|\_|‾|\_|‾|\_|‾|\_|‾|\_|‾|\_

SEQ\_LV1A \_\_1\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_1\_\_\_\_\_\_

SEQ\_BC0 \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_1\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

LV1A \_|‾|\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_|‾|\_\_\_\_\_

BC0 \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_|‾|\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

## Notes

The module will stop automatically once all the signals are sent.

## Errors to avoid

* The interval must have a value higher than 3 (not checked when sending only 1 command).
* The delay must have a value higher than interval + 3.
* The register ID must be in the range 0 to 15.

# DAC Scans (in development)

This module performs a scan of a DAC register *dac* on a single VFAT2 *vfat2* by varying its value from a minimum value *min* to a maximum value *max* by steps of *step* and by averaging the value on 2^*N* readouts.

## Addressing

Module ID 4

Address 0x4400000Y

0b 0100 0100 0000 0000 0000 0000 0000 YYYY

|  |  |  |
| --- | --- | --- |
| Y register | Mode | Function |
| Control | | |
| 0 | Write only | Start the scan. This will also empty the FIFO holding the data of the previous scan. The written value is ignored. |
| Parameters | | |
| 1 | Read / write | *dac* - 4 bits - [0, 9]  0 = IPreampIn  1 = IPreampFeed  2 = IPreampOut  3 = IShaper  4 = IShaperFeed  5 = IComp  6 = VThreshold1  7 = VThreshold2  8 = VCal  9 = CalOut |
| 2 | Read / write | *VFAT2* - 5 bits - [0, 23] |
| 3 | Read / write | *min -* 8 bits - [0x0, *max*] |
| 4 | Read / write | *max -* 8 bits – [*min*, 0xFF]  Note: 0 = 0xFF |
| 5 | Read / write | *step -* 8 bits - [0x0, 0xFF]  Note: 0 = 0x1 |
| 6 | Read / write | *N -* 4 bits – [0, 15]  Events = 2^N |
| Results | | |
| 7 | Read only | FIFO holding the results of the scan. This register will return the data points collected by the scan using the following data format:  8 MSBits hold the DAC value of the point  24 LSBits hold the mean of the ADC values  If no data is present, an error is returned. |
| Monitoring | | |
| 8 | Read only | *Status* - 1 bits - {0, 1}  0 = nothing running  1 = DAC scan running |
| Reset | | |
| 9 | Write only | Local reset of the module |

## Description

The module will store the value of the register before the scan and reapply the later after the end of the operation. It will also set the “Control Register 1” of all the VFAT2s to 0 in order to avoid conflicting scans.

## Errors

When starting the scan, the returned status of the write operation informs the user about the validity of the parameters. Invalid parameters will return an error and prevent the scan from starting. Other errors related to the VFAT2s are stored in the FIFO.

Two types of errors are stored in the FIFO when running the scan: global errors and local errors.

A global error occurs if the VFAT2 is not present or running at the start of the scan. In that case, a single 32 bits word of value 0xFF000000 is stored in the FIFO. No other read operations of the FIFO should occur afterwards.

A local error occurs if one of the I2C operations used to change the value did not succeed. In that case, the value of the 24 LSBits of that particular point is 0xFFFFFF. Other data points will still be saved and be present in the FIFO.

## Errors to avoid

* The DAC number must be in the range 0 to 9.
* The VFAT2 number must be in the range 0 to 23.
* The maximum value of the register to scan must be higher than the minimum value.
* The register ID must be in the range 0 to 9.

# ADC (in development)

This module handles the read out of the ADC.

## Addressing

Module ID 8

Address 0x4800000Y

0b 0100 1000 0000 0000 0000 0000 0000 YYYY

|  |  |  |
| --- | --- | --- |
| Y register | Mode | Function |
| ADC registers | | |
| 0 - 15 | Read only | Returns the conversion value of a given channel |

## Errors

The module returns an error if the parameters are not in spec.

## Errors to avoid

* The register ID must be in the range 0 to 15.

# Clocking (not available for test beam, use system registers to control clocking options)

Registers that control and monitor various clocking parameters

## Addressing

Module ID 9

Address 0x4900000Y

0b 0100 1001 0000 0000 0000 0000 0000 YYYY

|  |  |  |
| --- | --- | --- |
| Y register | Mode | Function |
| VFAT2 readout clock | | |
| 0 - 2 | Read / write | *phase shift* - 8 bits - [0, 255]  Controls the phase shift between the VFAT2 clock and the data readout clocks (for each column) on the FPGA in order to minimize data corruption |

# Counters

This module holds all the counters of the OptoHybrid. Writing to a given register will reset its value.

## Addressing

Module ID 10

Address 0x4A0000YY

0b 0100 1010 0000 0000 0000 0000 0000 YYYY

|  |  |  |
| --- | --- | --- |
| Y register | Mode | Function |
| Wishbone | | |
| 0 - 3 | Read | *Wishbone masters strobe*  Order: GTX, Extended I2C, Scan, DAC |
| 4 - 7 | Read | *Wishbone masters acknowledgments* |
| 8 - 21 | Read | *Wishbone slaves strobe*  Order: I2C 0, I2C 1, I2C 2, I2C 3, I2C 4, I2C 5, Extended I2C, Scan, T1, DAC, ADC, Clocking, Counters, System |
| 22 - 35 | Read | *Wishbone slaves acknowledgments* |
| VFAT2 |  |  |
| 36 - 59 | Read | *VFAT2 tracking data valid CRC*  For each VFAT2 counts the number of data packets that come with a valid CRC |
| 60 - 83 | Read | *VFAT2 tracking data incorrect CRC*  For each VFAT2 counts the number of data packets that come with an incorrect CRC |
| T1 commands | | |
| 84 - 87 | Read | *T1 from AMC13*  Order: LV1A, Calpulse, Resync, BC0 |
| 88 - 91 | Read | *T1 from firmware* |
| 92 - 95 | Read | *T1 from external source* |
| 96 - 99 | Read | *T1 from loopback* |
| 100 - 103 | Read | *T1 sent to the VFAT2* |
| GTX | | |
| 104 | Read | *Tracking link error* |
| 105 | Read | *Trigger link error* |
| 106 | Read | *Data packets sent* |

# System Registers

List of system registers

## Addressing

Module ID 11

Address 0x4B0000YY

0b 0100 1011 0000 0000 0000 0000 0000 YYYY

|  |  |  |
| --- | --- | --- |
| Y register | Mode | Function |
| VFAT2 | | |
| 0 | Read / write | *VFAT2 tracking data mask* - 24 bits  Allows to mask individual VFAT2s for tracking data readout over the optical link |
| 1 | Read / write | *VFAT2 T1 source select* - 3 bits  0 : T1 from AMC13  1 : T1 from OptoHybrid  2 : T1 from external source  3 : Internal loopback on SBits  4 : Logical OR of all sources |
| 2 | Read / write | *T1 loopback SBit select -* 5 bits |
| 3 | Write only | *VFAT2 reset* - 1 bit  This register automatically returns to a 0 state |
| Clocking | | |
| 4 | Read / write | *Reference clock source* - 2 bits  0 : allow clock switch to GTX recovered clock  1 : GTX recovered clock  2 : external clock  3 : on board oscillator |
| Misc | | |
| 5 | Read / write | *TDC SBits selects* - 30 bits |

# Status Registers

List of status registers

## Addressing

Module ID 12

Address 0x4C0000YY

0b 0100 1011 0000 0000 0000 0000 0000 YYYY

|  |  |  |
| --- | --- | --- |
| Y register | Mode | Function |
| Global | | |
| 0 | Read only | *OH firmware version* |
| Clocking | | |
| 1 | Read only | *FPGA clock PLL locked* |
| 2 | Read only | *External clock PLL locked* |
| 3 | Read only | *CDCE locked* |
| 4 | Read only | *Recovered clock locked* |
| 5 | Read only | *Clock switch operated* |