



Class: VME

Function: RF2TTC

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USER MANUAL

User Manual V5.1

RF to TTC VMEbus Interface Card and S/W

Summary:

This document describes the functionality of the RF2TTC card as well as the generic S/W that has been developed for it.
Document Revision 5.1 –

- o 12.03.07: the CR/CSR space has been transposed to the User Space.
- o 16.05.07 (rev 4): geographical address modified, information on orbit period counter results, initialisation procedure (section 2.7.1), last firmware version, output signals amplitude adjustments (section 2.6), etc...
- o 24.06.09 (rev 5.0):
 - Information about DAC registers for clock input has been removed (does not exist since V1 of the board)
 - BSET and BCLEAR register definition changed to allow individual resetting of QPLLs
 - Last firmware version is 19052009
 - Default values of QPLL modes
 - If an error occurs, the QPLL_status remains at '1' until having been read
- o Precisions about orbit delays
- o Correction on TTCrx read control register example
- o 25.06.09 (rev 5.1): Modification on orb length: now, all the orbits are 25ns pulses by default.

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1. INTRODUCTION

The RF2TTC (RF to TTC VMEbus Interface Card) is an interface card between the optical receiver modules (receiving timing signals coming from the SR4 building in Echevex), and the TTC electronics within the experiments.



The timing signals treated by the RF2TTC are the three 40.078MHz Bunch Clocks (BC1, BC2 and BCref) and the two orbit signals (Orb1 and Orb2) necessary to drive the 2 beam lines of the LHC. The RF2TTC module converts them into ECL signals, and performs various adjustments on each signal before making them available for the in-detector TTC electronics.

The three Bunch Clocks (represented on the top part of the following diagram) are all treated in the following way: A comparator with an adjustable threshold first converts the input signal into a PECL signal, before being multiplexed with an internal 40.078MHz clock in case of absence of the Bunch Clock on the front panel. The signal is then shifted by an adjustable delay with 0.5ns precision, before being cleaned by a QPLL and transmitted on the front panel via an ECL 50 Ohm coaxial cable driver with an AC-coupled output.

A global multiplexer allows selection between the three Bunch Clocks and the internal clock to generate a fourth Bunch Clock output, called Main BC, which can also be delayed.

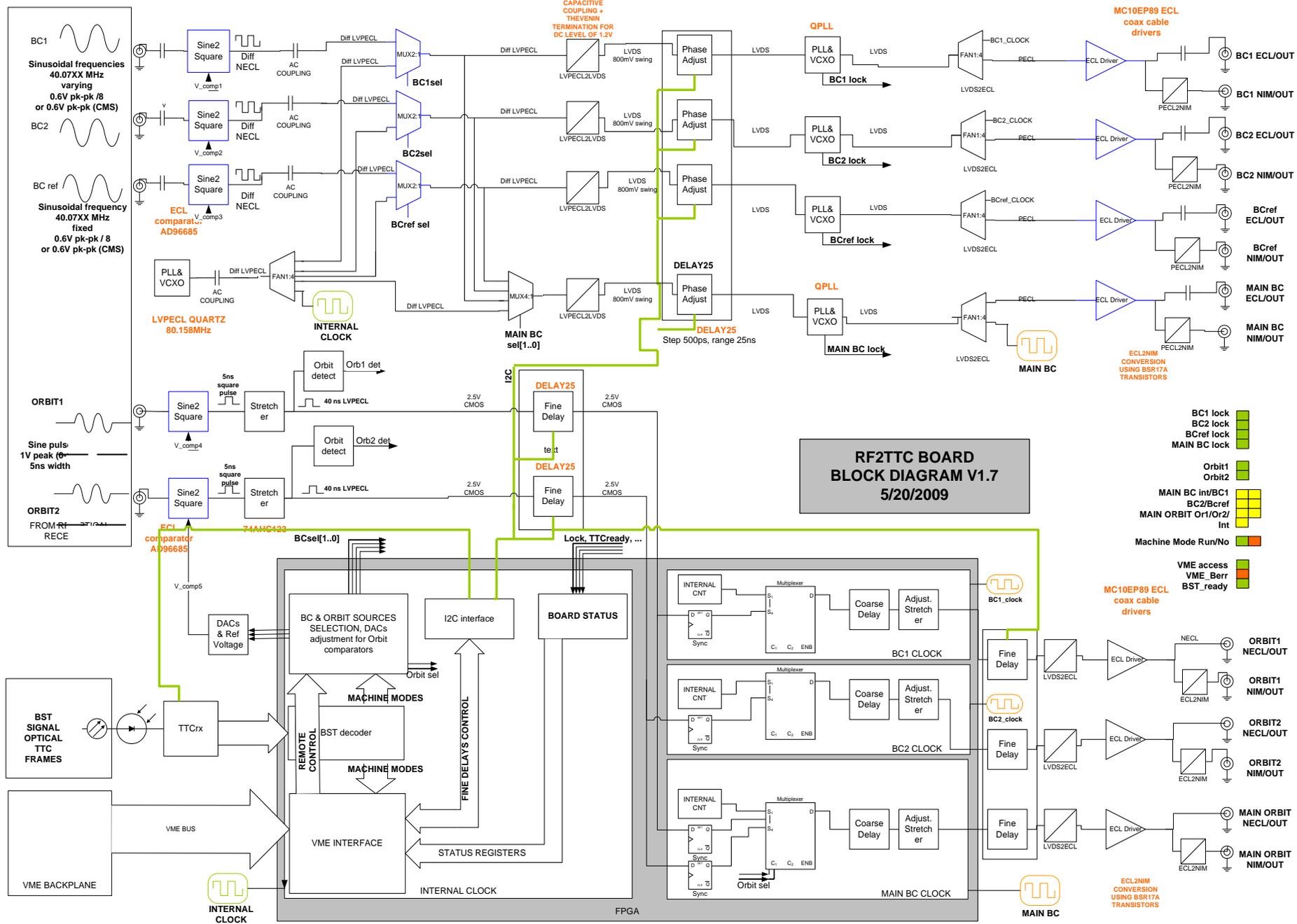
The two orbit signals (middle and bottom right parts of the diagram) are first converted using the same adjustable comparator stage as for the Bunch Clocks. They are then lengthened to more than 25ns, finely delayed with 0.5ns steps, before going into an FPGA (grey block of the diagram), where they are synchronized to their corresponding clock, multiplexed with an internal orbit, and coarse delayed. Their length and polarity can be adjusted, and they are then again finely delayed before being transmitted by the ECL drivers.

A global multiplexer also allows selection between the two orbits and an internal one, synchronized to the Main Bunch Clock. This orbit signal is called Main Orbit and can as well be finely delayed before being transmitted.

The BST (Beam Synchronous Timing) optical signal (on the bottom left part of the diagram) is received, decoded and analyzed to recover the machine mode. This mode is useful to know when the timing signals are stable and can be used. In deed, neither the Bunch Clocks nor the Orbit signals are fully guaranteed out of the physics modes (flat top of the LHC energy curve). It is thus advised to use internal signals when the machine mode indicates that there is no beam.

All the adjustments are done using VME registers. Many status registers are available, as well as special configurations, for stand-alone or debugging work.

This document contains a description of all accessible registers of the RF2TTC card as well as description of the generic S/W that has been developed for this card. At the end of this document, some basic examples of configuration procedures are proposed.



RF2TTC module diagram

2. RF2TTC HARDWARE

2.1. STANDARDS AND POWER SUPPLIES

The RF2TTC board is a VME64x 6U board. It requires the following power supplies:

- +3V3: 2.5A
- +5V: 0.3A
- -12V: 1.4A

Total power : 26W

2.2. VMEBUS INTERFACE

The VMEbus interface of the RF2TTC cards is implemented in its FPGA and based on the VME interface developed by Peter Lichard for the TRT-TTC board (ATLAS). It provides 2 types of VMEbus addressable resources as described in Table 1.

| Resource | VMEbus access mode | Description |
|-------------------------------------|-------------------------------------|---|
| Control and status registers | A32/D32 with A19=0 and AM-code 0x09 | These are the registers that control the behaviour of a RF2TTC card and provide information about its current status. |
| EPROM | A32/D32 with A19=1 and AM-code 0x09 | The access to the EPROM is reserved for in-crate reconfiguration. |

Table 1: VMEbus resources of the RF2TTC

All the registers of the board are accessible using 0x09 AM (A32, D32). The board address is the geographical address of the module if the manual rotary switches are set to 0x00. The address used to access the user space is hence defined as follows:

| ADDRESS SWITCHES | A31-A28 | A27-A24 | A23-A20 |
|-----------------------------|---------|-----------------|-----------------|
| SW1=SW2=0x00 | 0 | GEOG ADD | |
| SW1≠0x00 or SW2≠0x00 | 0 | SW2[3..0] (MSB) | SW1[7..4] (LSB) |



SW1=LSB

SW2=MSB

This picture shows a board numbered: 0xF000000

2.2.1. Reset registers

| Register | Offset | Purpose | Access |
|----------|---------|---------------------|--------|
| BSET | 0x00010 | Set reset actions | R/W |
| BCLEAR | 0x00014 | Clear reset actions | W |

BSET: Board Set Register assignment

Description:

This register is declared in the VME64x as a User-defined Bset register. It is used here to define partial reset functions (QPLL only, Delay25 chips only, TTCrx only). The bit definition is as follows:

| Bit | Value | Write | Read |
|-----|-------|--------------------------------------|------------------------------------|
| 0 | 1 | place Delay25 chips in reset mode | Delay25 chips in reset mode |
| | 0 | no effect | Delay25 chips not in reset mode |
| 1 | 1 | x | x |
| | 0 | x | x |
| 2 | 1 | place BC1-QPLL chip in reset mode | BC1 -QPLL chip in reset mode |
| | 0 | no effect | BC1-QPLL chip not in reset mode |
| 3 | 1 | place BC2-QPLL chip in reset mode | BC2 -QPLL chip in reset mode |
| | 0 | no effect | BC2-QPLL chip not in reset mode |
| 4 | 1 | place BCref-QPLL chip in reset mode | BCref -QPLL chip in reset mode |
| | 0 | no effect | BCref-QPLL chip not in reset mode |
| 5 | 1 | place BCmain-QPLL chip in reset mode | BCmain -QPLL chip in reset mode |
| | 0 | no effect | BCmain-QPLL chip not in reset mode |
| 6 | 1 | place TTCrx chips in reset mode | TTCrx chips in reset mode |
| | 0 | no effect | TTCrx chips not in reset mode |
| 7 | 1 | place board in reset mode | Board in reset mode |
| | 0 | no effect | Board not in reset mode |

Note: When the QPLL are reset using bits 2 to 5, the BCx_QPLL_MODE registers are NOT reset. So the QPLLs are remaining in the mode to which they were previously configured (ie: autorestart or relock after reset).

BCLEAR (User-defined BCLEAR) Register assignment

Description:

This register is declared in the VME64x as a User-defined Bclear register. It is used here to remove partial reset functions (QPLL only, Delay25 chips only, TTCrx only). The bit definition is as follows:

| Bit | Value | Write | Read |
|-----|-------|--------------------------------------|-----------------------------------|
| 0 | 1 | remove Delay25 chips from reset mode | Delay25 chips in reset mode |
| | 0 | no effect | Delay25 chips not in reset mode |
| 1 | 1 | | |
| | 0 | | |
| 2 | 1 | remove BC1-QPLL from reset mode | BC1-QPLL chip in reset mode |
| | 0 | no effect | BC1-QPLL chip not in reset mode |
| 3 | 1 | remove BC2-QPLL from reset mode | BC2-QPLL chip in reset mode |
| | 0 | no effect | BC2-QPLL chip not in reset mode |
| 4 | 1 | remove BCref-QPLL from reset mode | BCref-QPLL chip in reset mode |
| | 0 | no effect | BCref-QPLL chip not in reset mode |
| 5 | 1 | remove BCmain-QPLL from reset mode | BCmain-QPLL chip in reset mode |
| | 0 | no effect | BCmainQPLL chip not in reset mode |
| 6 | 1 | remove TTCrx chips from reset mode | TTCrx chips in reset mode |
| | 0 | no effect | TTCrx chips not in reset mode |
| 7 | 1 | remove Board from reset mode | Board in reset mode |
| | 0 | no effect | Board not in reset mode |

2.2.2. Board Identification read only registers

| Register | Address | Value | Access |
|-----------------|---------|---|--------|
| MANUFACTURER ID | 0x00000 | 0x00080030 (CERN) | R |
| BOARD ID | 0x00004 | 0x0000016B | R |
| REVISION ID | 0x00008 | Hardware version Prototype = 0x2, Production = 0x3 | R |
| PROGRAM ID | 0x0000C | Firmware date number Last 19052009 (19 May 2009) | R |

2.2.3. Board configuration registers

BCx_MAN_SELECT, BCx_BEAM_SELECT & BCx_NOBEAM_SELECT

| Name | Offset | Size | Access |
|----------------------|---------|--------|--------|
| BC1_MAN_SELECT | 0x7FBFC | 1 bit | R/W |
| BC2_MAN_SELECT | 0x7FBCC | | |
| BCref_MAN_SELECT | 0x7FBAC | | |
| BC1_BEAM_SELECT | 0x7FBF8 | | |
| BC2_BEAM_SELECT | 0x7FBC8 | | |
| BCref_BEAM_SELECT | 0x7FBA8 | | |
| BC1_NOBEAM_SELECT | 0x7FBF4 | | |
| BC2_NOBEAM_SELECT | 0x7FBC4 | | |
| BCref_NOBEAM_SELECT | 0x7FBA4 | | |
| BCmain_MAN_SELECT | 0x7FB8C | 2 bits | |
| BCmain_BEAM_SELECT | 0x7FB88 | | |
| BCmain_NOBEAM_SELECT | 0x7FB84 | | |

Description:

These registers select the sources of the BC outputs. Only one set of registers is active at a time.

- The BCx_MAN_SELECT registers are active when the BCx is operating in manual mode (defined in WORKING_MODE register).
- The BCx_BEAM_SELECT registers are active when BCx is defined (by WORKING_MODE register) to be ‘automatic’, and the current LHC beam mode (decoded in BST_BEAM_MODE) is declared by BEAM_NO_BEAM_DEF to be “**with** beam”.
- The BCx_NOBEAM_SELECT registers are active when BCx is defined (by WORKING_MODE register) to be ‘automatic’, and the current LHC beam mode (decoded in BST_BEAM_MODE) is declared by BEAM_NO_BEAM_DEF to be “**without** beam”.

- The BCx_MAN_SELECT and the BCx_NOBEAM_SELECT registers are set to INTERNAL (=0) by default, and the BCx_BEAM_SELECT register to EXTERNAL (=1).

Bit definition for BC1, BC2 and BCref registers

| Value | Description |
|-------|---|
| 0 | Output taken from internal 40.078MHz clock (INTERNAL) |
| 1 | Output follows the respective BC input (EXTERNAL) |

Bit definition for BCmain registers

| Value | Description |
|-------|--|
| 0 | Output taken from internal 40.078MHz clock |
| 1 | Output follows BCref input |
| 2 | Output follows BC2 input |
| 3 | Output follows BC1 input |

BCx_QPLL_MODE

| Name | Offset | Size | Access |
|------------------|---------|-------|--------|
| BC1_QPLL_MODE | 0x7FBF0 | 1 bit | R/W |
| BC2_QPLL_MODE | 0x7FBC0 | | |
| BCref_QPLL_MODE | 0x7FBA0 | | |
| BCmain_QPLL_MODE | 0x7FB80 | | |

Description:

These registers define the QPLL locking mode.

| Value | Description |
|-------|---|
| 0 | Re-lock only after a reset |
| 1 | Re-lock automatically if the lock gets lost (autorestart) |

Qpills are all set to autorestart (1) by default. More information about the QPLL locking procedure and how to handle it within an experiment: http://ttc-upgrade.web.cern.ch/ttc-upgrade/Study_for_QPLL_on_RF2TTC_during_RF_resynchronization.pdf

BCx_QPLL_STATUS

| Name | Offset | Size | Access |
|--------------------|---------|--------|--------|
| BC1_QPLL_STATUS | 0x7FBE8 | 2 bits | R |
| BC2_QPLL_STATUS | 0x7FBB8 | | |
| BCref_QPLL_STATUS | 0x7FB98 | | |
| BCmain_QPLL_STATUS | 0x7FB7C | | |

Description:

These registers contain the status of the QPLLs of the BC channels. Bit 1 indicates that the QPLL detected an error and bit 0 indicates the locking status. These error and unlocked bits are latched and, if an error or a loss-of-sync briefly occurs, will remain at '1' until the register has been read.

| Bit 1 | Description |
|-------|----------------|
| 0 | QPLL OK |
| 1 | QPLL has error |

| Bit 0 | Description |
|-------|-----------------|
| 0 | QPLL not locked |
| 1 | QPLL locked |

ORBx_MAN_SELECT, ORBx_BEAM_SELECT & ORBx_NOBEAM_SELECT

| Name | Offset | Size | Access |
|-----------------------|---------|--------|--------|
| ORB1_MAN_SELECT | 0x7FB6C | 1 bit | R/W |
| ORB2_MAN_SELECT | 0x7FB2C | | |
| ORB1_BEAM_SELECT | 0x7FB68 | | |
| ORB2_BEAM_SELECT | 0x7FB28 | | |
| ORB1_NOBEAM_SELECT | 0x7FB64 | | |
| ORB2_NOBEAM_SELECT | 0x7FB24 | | |
| ORBmain_MAN_SELECT | 0x7FAEC | 2 bits | |
| ORBmain_BEAM_SELECT | 0x7FAE8 | | |
| ORBmain_NOBEAM_SELECT | 0x7FAE4 | | |

Description:

These registers select the sources of the orbit outputs. Only one set of registers is active at any time. The ORBx_MAN_SELECT registers are active when the RF2TTC is operating in manual mode. If the card is in automatic mode and the beam is on the orbit outputs are controlled by the ORBx_BEAM_SELECT registers. The ORBx_NOBEAM_SELECT registers control the orbit outputs when the RF2TTC is in automatic mode and the beam absent. The MAN_SELECT and NO_BEAM registers are set to INTERNAL by default. The BEAM register to EXTERNAL.

Bit definition for ORB1 and ORB2 registers

| Value | Description |
|-------|--|
| 0 | Output follows the respective orbit input (EXTERNAL) |
| 1 | Output from internal BC synchronized orbit generator |

Bit definition for ORBmain registers

| Value | Description |
|-------|---|
| 0 | Output follows the orbit 1 input |
| 1 | Output follows the orbit 2 input |
| 2 | Output from internal orbit generator synchronized to BCmain |

ORBx_POLARITY

| Name | Offset | Size | Access |
|------------------|---------|-------|--------|
| ORB1_POLARITY | 0x7FB60 | 1 bit | R/W |
| ORB2_POLARITY | 0x7FB20 | | |
| ORBmain_POLARITY | 0x7FAE0 | | |

Description:

If set, this bit inverts the polarity of the orbit output with respect to the orbit input (i.e. the orbit output is negative active).

ORBx_COARSE_DELAY

| Name | Offset | Size | Access |
|----------------------|---------|---------|--------|
| ORB1_COARSE_DELAY | 0x7FB5C | 12 bits | R/W |
| ORB2_COARSE_DELAY | 0x7FB1C | | |
| ORBmain_COARSE_DELAY | 0x7FADC | | |

Description:

This register allows the orbit output signal to be shifted by multiples of 25 ns with respect to the input. It is set to 0 by default.

If set to 0 or 1, the output is shifted by the minimum intrinsic delay induced by the board itself (about 194ns if the orbit_out fine delay is 0 too).

If the coarse delay is set to C and the orbit out fine delay is set to F, the total delay will be

$$\text{Total orbit delay} = [194 + (C-1)*25 + F*0.5] \text{ ns.}$$

Values above 0xDEB (3563) are illegal because they would result in a shift longer than the LHC orbit period (88.93 μ s).

ORBx_LENGTH

| Name | Offset | Size | Access |
|----------------|---------|--------|--------|
| ORB1_LENGTH | 0x7FB58 | 8 bits | R/W |
| ORB2_LENGTH | 0x7FB18 | | |
| ORBmain_LENGTH | 0x7FAD8 | | |

Description:

This register allows the orbit pulse to be stretched in steps of 25 ns. It is set to 0 by default. If set to 0 or 1, the width of the orbit pulse is 25 ns.

If set to L, the width of the output pulse will be:

$$\text{Orbit length} = [25 + (L-1)25] \text{ ns}$$

The largest pulse width (with all 8 bits set to 1) is 6.4 μ s. The default width of the internally generated orbit pulse is 25ns.

ORBx_INT_PERIOD_SET

| Name | Offset | Size | Access |
|------------------------|---------|---------|--------|
| ORB1_INT_PERIOD_SET | 0x7FB54 | 12 bits | R/W |
| ORB2_INT_PERIOD_SET | 0x7FB14 | | |
| ORBmain_INT_PERIOD_SET | 0x7FAD4 | | |

Description:

This register allows setting the period of the internally generated orbit signal in units of 25 ns. The default value is 0xDEC, which corresponds to 3564 bunch clocks between two orbits.

ORBx_INT_PERIOD_COUNTER

| Name | Offset | Size | Access |
|----------------------------|---------|---------|--------|
| ORB1_INT_PERIOD_COUNTER | 0x7FB50 | 12 bits | R |
| ORB2_INT_PERIOD_COUNTER | 0x7FB10 | | |
| ORBmain_INT_PERIOD_COUNTER | 0x7FAD0 | | |

Description:

This register is provided for debugging purposes. It holds the value of the BC counter that is used to generate the internal orbit signal. This can be reset by the ORB_INT_RESET register.

ORBx_COUNTER

| Name | Offset | Size | Access |
|-----------------|---------|---------|--------|
| ORB1_COUNTER | 0x7FB4C | 32 bits | R |
| ORB2_COUNTER | 0x7FB0C | | |
| ORBmain_COUNTER | 0x7FACC | | |

Description:

This register holds the number of orbit pulses that have been received since the counter was reset/enabled. At an orbit period of 89 μ s this counter will overflow after approximately 106 hours, and will be reset.

ORBx_PERIOD_RD

| Name | Offset | Size | Access |
|-------------------|---------|---------|--------|
| ORB1_PERIOD_RD | 0x7FB48 | 12 bits | R |
| ORB2_PERIOD_RD | 0x7FB08 | | |
| ORBmain_PERIOD_RD | 0x7FAC8 | | |

Description:

This register holds the time, in units of 25 ns BC ticks, that has elapsed between the last two orbit output pulses. The number of steps given is always 1 more than the real number of steps between 2 orbits

ORBx_PERIOD_FIFO_STATUS

| Name | Offset | Size | Access |
|----------------------------|---------|--------|--------|
| ORB1_PERIOD_FIFO_STATUS | 0x7FB44 | 2 bits | R |
| ORB2_PERIOD_FIFO_STATUS | 0x7FB04 | | |
| ORBmain_PERIOD_FIFO_STATUS | 0x7FAC4 | | |

Description:

This register holds the status of the FIFO that contains the most recent 256 orbit periods of the respective orbit output channel. Bit definitions:

| Bit | Value | Description |
|-----|-------|----------------|
| 0 | 0 | Fifo not empty |
| | 1 | Fifo empty |
| 1 | 0 | Fifo not full |
| | 1 | Fifo full |

Note: Bit 14 of the ORBx_PERIOD_FIFO_RD register also gives the empty flag of the fifo.

ORBx_PERIOD_FIFO_RD

| Name | Offset | Size | Access |
|------------------------|---------|---------|--------|
| ORB1_PERIOD_FIFO_RD | 0x7FB40 | 16 bits | R |
| ORB2_PERIOD_FIFO_RD | 0x7FB00 | | |
| ORBmain_PERIOD_FIFO_RD | 0x7FAC0 | | |

Description:

These registers provide access to three 256 word deep FIFOs which contain the most recent 256 orbit periods of the respective orbit output channel in bits 0..13. Reading the last period stored in the FIFO, or from an empty FIFO results in reading a 1 in bit 14 (FIFO empty) . For the moment it is not possible to read these FIFOs with a constant address block transfer. The first value stored in the Fifo immediately after a reset or an enable is not significant, because the counter does not begin with an orbit pulse, but with an 'enable' or a 'reset' command.

If the fifo is read with a period smaller than 89us, it is possible to have a continuous monitoring of the orbit period.

ORBx_DAC

| Name | Offset | Size | Access |
|----------|---------|--------|--------|
| ORB1_DAC | 0x7FB3C | 8 bits | R/W |
| ORB2_DAC | 0x7FAFC | | |

Description:

These registers allow setting the threshold voltage of the orbit input comparator in a range from -1.25 V to +1.25 V. The threshold is linked to the value of the register by the formula:

$$\text{Threshold}(V) = -1.25 + \text{value} * 2.5 / 255$$

The default value of the threshold is 0xAA.

TTCrx_status

| Name | Offset | Size | Access |
|--------------|---------|-------|--------|
| TTCrx_status | 0x7FAA0 | 1 bit | R |

Description:

This register reflects the status of the on-board TTCrx chip. Bit definitions:

| Value | Description |
|-------|---|
| 0 | TTCrx not ready |
| 1 | TTCrx ready – the BST message is correctly decoded (at least a 40MHz clock is sent over the optical fibre connected to the TTCrx) |

BST_Beam_Mode

| Name | Offset | Size | Access |
|---------------|---------|---------|--------|
| BST_Beam_Mode | 0x7FA9C | 32 bits | R |

Description:

This register holds the LHC machine mode as decoded from the BST messages received by the TTCrx. Each number corresponds to one machine mode, as transmitted by the BST:

| Value (Dec) | Value (Hex) | Description |
|-------------|-------------|------------------------|
| 1 | 1 | No mode |
| 2 | 2 | Setup |
| 3 | 3 | Injection probe beam |
| 4 | 4 | Injection setup beam |
| 5 | 5 | Injection physics beam |
| 6 | 6 | Prepare ramp |
| 7 | 7 | Ramp |
| 8 | 8 | Flat top |
| 9 | 9 | Squeeze |
| 10 | A | Adjust |
| 11 | B | Stable beams |
| 12 | C | Unstable beams |
| 13 | D | Beam dump |
| 14 | E | Ramp down |
| 15 | F | Recovery |
| 16 | 10 | Inject and dump |
| 17 | 11 | Circulate and dump |
| 18 | 12 | Abort |
| 19 | 13 | Cycling |
| 20 | 14 | Beam dump Warning |
| 21 | 15 | No beam |

BEAM_NO_BEAM_DEF

| Name | Offset | Size | Access |
|------------------|---------|---------|--------|
| BEAM_NO_BEAM_DEF | 0x7FA7C | 32 bits | R/W |

Description:

The BST system is sending every orbit an update of the beam mode (between 1 and 21). This mode is decoded in the previous register BST_BEAM_MODE. For each mode, the BEAM_NO_BEAM_DEF registers defines if it is considered as a mode “with beam” (1) or “without beam” (0).

If, for example, the BC1 selection is in “automatic mode” (set in WORKING_MODE register):

- all the beam modes “with beam” will apply the “BC1_BEAM_SELECT” settings
- all the modes “without beam” will apply the “BC1_NOBEAM_SELECT” settings

If the BC1 is in “manual mode”, this register is ignored and “BC1_MAN_SELECT” settings are being applied.

The BEAM_NO_BEAM_DEF is set by default to 0x1F00

| Bit | Mode description | Default |
|---------|------------------------|-------------|
| 0 | XXXXXXXXXXXXXX | 0 |
| 1 | No mode | 0 = no beam |
| 2 | Setup | 0 |
| 3 | Injection probe beam | 0 |
| 4 | Injection setup beam | 0 |
| 5 | Injection physics beam | 0 |
| 6 | Prepare ramp | 0 |
| 7 | Ramp | 0 |
| 8 | Flat top | 1 = beam |
| 9 | Squeeze | 1 |
| 10 | Adjust | 1 |
| 11 | Stable beams | 1 |
| 12 | Unstable beams | 1 |
| 13 | Beam dump | 0 |
| 14 | Ramp down | 0 |
| 15 | Recovery | 0 |
| 16 | Inject and dump | 0 |
| 17 | Circulate and dump | 0 |
| 18 | Abort | 0 |
| 19 | Cycling | 0 |
| 20 | Beam dump Warning | 0 |
| 21 | No beam | 0 |
| 22...30 | x...x | 0 |

WORKING_MODE

| Name | Offset | Size | Access |
|--------------|---------|--------|--------|
| WORKING_MODE | 0x7FA78 | 7 bits | R/W |

Description:

The bits in this register control the operational modes of the outputs of the RF2TTC. Each bit corresponds to one signal.

| Bit number | Related output | Bit value | Selected mode |
|------------|----------------|-----------|---------------|
| 0 | BC1 | 0 | Manual |
| | | 1 | Automatic |
| 1 | BC2 | 0 | Manual |
| | | 1 | Automatic |
| 2 | BCref | 0 | Manual |
| | | 1 | Automatic |
| 3 | BCmain | 0 | Manual |
| | | 1 | Automatic |
| 4 | ORB1 | 0 | Manual |
| | | 1 | Automatic |
| 5 | ORB2 | 0 | Manual |
| | | 1 | Automatic |
| 6 | ORBmain | 0 | Manual |
| | | 1 | Automatic |

ORB_INT_ENABLE

| Name | Offset | Size | Access |
|----------------|---------|--------|--------|
| ORB_INT_ENABLE | 0x7FA6C | 3 bits | R/W |

Description:

This register controls the status of the BC counters that generate the internal orbit pulses.

| Bit number | Related orbit | Bit value | Counter mode |
|------------|----------------------------------|-----------|--------------|
| 0 | Orbit 1 (counts BC1 ticks) | 0 | Disabled |
| | | 1 | Enabled |
| 1 | Orbit 2 (counts BC2 ticks) | 0 | Disabled |
| | | 1 | Enabled |
| 2 | Main orbit (counts BCmain ticks) | 0 | Disabled |
| | | 1 | Enabled |

ORB_COUNTER_ENABLE

| Name | Offset | Size | Access |
|--------------------|---------|--------|--------|
| ORB_COUNTER_ENABLE | 0x7FA68 | 3 bits | R/W |

Description:

This register controls the status of the orbit pulse counters. Once a channel has been enabled the registers ORBx_COUNTER count the orbit pulses of that channel

| Bit number | Related orbit | Bit value | Counter mode |
|------------|---------------|-----------|--------------|
| 0 | Orbit 1 | 0 | Disabled |
| | | 1 | Enabled |
| 1 | Orbit 2 | 0 | Disabled |
| | | 1 | Enabled |
| 2 | Main orbit | 0 | Disabled |
| | | 1 | Enabled |

PERIOD_COUNTER_ENABLE

| Name | Offset | Size | Access |
|-----------------------|---------|--------|--------|
| PERIOD_COUNTER_ENABLE | 0x7FA64 | 3 bits | R/W |

Description:

This register controls the status of the orbit period counters. Once a channel has been enabled the FIFOs and ORBx_PERIOD_FIFO_RD start measuring and storing the duration of orbit signals.

| Bit number | Related orbit | Bit value | Counter mode |
|------------|---------------|-----------|--------------|
| 0 | Orbit 1 | 0 | Disabled |
| | | 1 | Enabled |
| 1 | Orbit 2 | 0 | Disabled |
| | | 1 | Enabled |
| 2 | Main orbit | 0 | Disabled |
| | | 1 | Enabled |

COUNTERS' RESET registers

| Name | Offset | | Function |
|----------------------|---------|---|--|
| ORB_INT_RESET | 0x7FA4C | W | Reset the three counters that generate the internal orbits 1, 2 and Main. One bit per counter. Same definition than the ORB_INT_ENABLE register. |
| PERIOD_COUNTER_RESET | 0x7FA48 | | Reset the counters that measure the period of the orbit pulses 1, 2 and Main. At the same time the period FIFOs are cleared. One bit per counter. Same definition than the PERIOD_COUNTER_ENABLE register. |
| ORB_COUNTER_RESET | 0x7FA44 | | Reset the orbit pulse counters 1, 2 and Main |

Description:

A reset is triggered by writing a 1 to the address of the respective register. The 3 bits of the counter_reset register can reset the counters of ORB1, ORB2 and/or ORBmain, by writing various patterns:

| Bit number | Related orbit counter | Bit value | Counter mode |
|------------|-----------------------|-----------|--------------|
| 0 | Orbit 1 | 0 | No effect |
| | | 1 | reset |
| 1 | Orbit 2 | 0 | No effect |
| | | 1 | reset |
| 2 | Main orbit | 0 | No effect |
| | | 1 | reset |

DELAY25_REG, TTCrx_REG

| Name | Offset | Size | Access |
|-------------|---------|--------|--------|
| DELAY25_REG | 0x7D200 | 8 bits | R |
| TTCrx_REG | 0x7E200 | | |

Description:

These registers are required to read values from the TTC and Delay25 registers described below. Due to delays introduced by the I2C bus it is not possible to read these registers directly. Instead a sequence of three steps is required.

- 1) Read a dummy data word from the address of the TTC or Delay25 register that is to be read out
- 2) Wait for at least 2 ms
- 3) Read the data value from the DELAY25_REG or TTCrx_REG (FIFO contents of the read access to delay25 and TTCrx chips)

If multiple registers are to be read one can group the dummy reads (step 1) and data reads (step 3) such that they are only separated by one 2 ms delay. This pipelining however works for up to 256 read requests.

BC_DELAY25_x

| Name | Offset | Used | Size | Access |
|-------------------|---------|------|--------|--------|
| BC_DELAY25_GCR | 0x7D014 | Yes | 8 bits | (R)/W |
| BC_DELAY25_BCmain | 0x7D00c | Yes | | |
| BC_DELAY25_BCref | 0x7D008 | Yes | | |
| BC_DELAY25_BC2 | 0x7D004 | Yes | | |
| BC_DELAY25_BC1 | 0x7D000 | Yes | | |

Description:

These registers control the configuration of the Delay25 chips for the BC signals. These chips ensure the BC signal to be shifted by steps of 0.5ns with a jitter lower than 19ps rms. For details about the read protocol see above. Bit definition (from Delay25 manual):

BC_DELAY25_BCx registers:

The bit allocation of each channel control register is as given in the following table. Bits Del<5:0> control the delay for each channel and the *Enable bit enables the channel output. Upon a reset, bit Enable and bits Del<5:0> are cleared. The delay chip must be manually re-enabled!! At power-up, however, an internal routine in the RF2TTC fpga enables all the delay25 chips.*

Control registers (CR0 to CR4) bit allocation, with their state after reset.

| B7 | B6 | B5 | B4 | B3 | B2 | B1 | B0 | |
|------|---------------|--------|--------|--------|--------|--------|--------|-------------|
| n.u. | Enable | Del<5> | Del<4> | Del<3> | Del<2> | Del<1> | Del<0> | Function |
| n.u. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | Reset State |

BC_DELAY25_GCR register:

The general control register GCR controls the operation of the Delay-Locked Loop (DLL) and allows to reset the DLL or the ASIC via the I2C interface. The bit allocation for this register is given in Table 4:

General Control Register (GCR) bit allocation, with their state after reset:

| B7 | B6 | B5 | B4 | B3 | B2 | B1 | B0 | |
|----------|------|------|------|------|------|-------------|-------------|-------------|
| reserved | IDLL | n.u. | n.u. | n.u. | n.u. | M<1> | M<0> | Function |
| 0 | 0 | - | - | - | - | Not cleared | Not cleared | Reset State |

The ASIC can operate with for different clock frequencies (32, 40, 64 and 80 MHz). For this application, the M<0> and M<1> bits must be set to 0 (40MHz).

IDLL: bit IDLL is used to force the resynchronization of the DLL without resetting the chip. Writing a “1” to this bit forces the resynchronization of the DLL. This bit always reads as a “0”. *At power-up, an internal routine in the RF2TTC fpga sets M<1> and M<0> to 0.*

ORBIN_DELAY25_x

| Name | Offset | Used | Size | Access |
|--------------------|---------|------|--------|--------|
| ORBIN_DELAY25_GCR | 0x7D034 | yes | 8 bits | (R)/W |
| ORBIN_DELAY25_ORB2 | 0x7D024 | Yes | | |
| ORBIN_DELAY25_ORB1 | 0x7D020 | Yes | | |

Description:

These registers control the configuration of the Delay25 chips for the orbit input signals. Finely adjusting the delay of the orbit inputs (with steps of 0.5ns) allows moving the rising edge of the orbit pulse away from the rising edge of the corresponding bunch clock to ensure a good synchronisation of the 2 signals (basically to avoid the metastability generated if the rising edge of the orbit is in the setup time or hold time of the latch). The window in which the orbit will be stably synchronized is of the order of 20ns out of 25.

The way to choose the good value for these registers is described in *2.3 Calibration Procedures*.

For details about the read protocol see above. Bit definition: see BC_DELAY_x register.

ORBOUT_DELAY25_x

| Name | Offset | Used | Size | Access |
|------------------------|---------|------|--------|--------|
| ORBOUT_DELAY25_GCR | 0x7D054 | Yes | 8 bits | (R)/W |
| ORBOUT_DELAY25_ORBmain | 0x7D048 | Yes | | |
| ORBOUT_DELAY25_ORB2 | 0x7D044 | Yes | | |
| ORBOUT_DELAY25_ORB1 | 0x7D040 | Yes | | |

Description:

These registers control the configuration of the Delay25 chips for the orbit output signals. This adjustment is to allow the experiments fine tuning the orbit for its use in their trigger electronics. For details about the read protocol see above. Bit definition: see BC_DELAY_x register.

TTCrx REGISTERS

| Name | Offset | Size | Access |
|-------------------------------|---------|--------|--------|
| TTCrx_pointer to the register | 0x7E000 | 8 bits | R/W |
| TTCrx_pointer to the data | 0x7E004 | 8 bits | W |

Description:

These are the two registers used to read and write all the internal registers of the TTCrx used to receive the BST message (see TTCrx user manual). Only one register requires to be accessed for the purpose of receiving the BST message: the control register (internal address= 0x03). Its value should be 0xB3 instead of 0x93 (its default value). The '1' added on bit 5 allows enabling the Dout bus of the TTCrx, which contains the broadcast data, and hence the Machine Mode.

Register access protocol:

The TTCrx chip needs to be ready (ie, the optical fibre needs to deliver a correct encoded 40MHz clock), in order to access the internal registers.

The way to access the TTCrx registers is described in the TTCrx manual, p30:

“I2C_pointer register and the I2C_data register. The I2C_pointer register is five bits wide and contains the address of the internal register as defined in Table 3 (page 16). When reading the I2C_data register, the content of the TTCrx register *being addressed by the pointer register* is transferred. Conversely, writing a byte to the I2C_data register in fact writes to the TTCrx register *addressed by the I2C_pointer* register. Hence, each I2C access is performed in two steps:

- 1) Write the register number in the I2C_pointer register
- 2) Read or write the I2C_data register

According to the I2C bus specification, each device on the bus is addressed by a 7-bit wide I2C device address. Each TTCrx chip occupies two consecutive positions in the 7-bit I2C address space. Hence, it is possible to address 64 devices in the system. The 7-bit I2C address is derived from the content of the ID_I2C<5:0> base address register in the following way:

| I2C access register name | Resulting 7 bit I2C address |
|--------------------------|-----------------------------|
| I2C_pointer | ID_I2C<5:0> * 2 |
| I2C_data | ID_I2C<5:0> * 2 + 1 |

Table 12 I2C address calculation.”

The registers accessible via I2C are the following:

| I2C reg. address (decimal) | Register name | Default content (After reset) |
|----------------------------|--------------------------------|-------------------------------|
| 0 | Fine Delay 1 | 00000000 |
| 1 | Fine Delay 2 | 00000000 |
| 2 | Coarse Delay | 00000000 |
| 3 | Control | 10010011 |
| 8 | Single error count<7:0> | 00000000 |
| 9 | Single error count<15:8> | 00000000 |
| 10 | Double error count<7:0> | 00000000 |
| 11 | SEU error count <15:8> | 00000000 |
| 16 | ID<7:0> | 00000000 |
| 17 | MasterModeA<1:0>, ID<13:8> | 00000000 |
| 18 | MasterModeB<1:0>, I2C_ID <5:0> | 00000000 |
| 19 | Config 1 | 00011010 |
| 20 | Config 2 | 10000100 |
| 21 | Config 3 | 10100111 |
| 22 | Status | 11100000 |
| 24 | Bits <7:0> | 00000000 |

| | | |
|----|--------------|----------|
| 25 | Bits <15:8> | 00000000 |
| 26 | Bits <7:0> | 00000000 |
| 27 | Bits <15:8> | 00000000 |
| 28 | Bits <23:16> | 00000000 |

Example of registers read and write via VME access:

Read control register (I2C address 3):

- 1- VME WRITE, AM=0x09, RegOFFSET=0xE000, Data=0x3 (register I2C address)
- 2- VME READ, AM=0x09, RegOFFSET=0xE000, (the Data read has no meaning)
- 3- VME READ, AM=0x09, RegOFFSET=0xE200, Data should be 0x000000FF after initialisation

Write Fine Delay Register (I2C address 1):

- 1- VME WRITE, AM=0x09, RegOFFSET=0xE000, Data=0x1 (register I2C address)
- 2- VME WRITE, AM=0x09, RegOFFSET=0xE004 (offset of the data register), 0x0000YOURDATA

Read fine delay register (I2C address 1):

- 1- VME WRITE, AM=0x09, RegOFFSET=0xE000, Data=0x1
- 2- VME READ, AM=0x09, RegOFFSET=0xE000, (the Data read has no meaning)
- 3- VME READ, AM=0x09, RegOFFSET=0xE200, Data should be 0x000XYOURDATA, with X=0 if the FIFO is not empty, X=1 if you are reading the last word stored in a FIFO

Successively read fine delay registers 1 and 2 (I2C address 1 and 2):

- 4- VME WRITE, AM=0x09, RegOFFSET=0xE000, Data=0x1
- 5- VME READ, AM=0x09, RegOFFSET=0xE000, (the Data read has no meaning)
- 6- VME WRITE, AM=0x09, RegOFFSET=0xE000, Data=0x2
- 7- VME READ, AM=0x09, RegOFFSET=0xE000, (the Data read has no meaning)
- 8- VME READ, AM=0x09, RegOFFSET=0xE200, Data should be 0x0000YOURDATA
- 9- VME READ, AM=0x09, RegOFFSET=0xE200, Data should be 0x0001YOURDATA

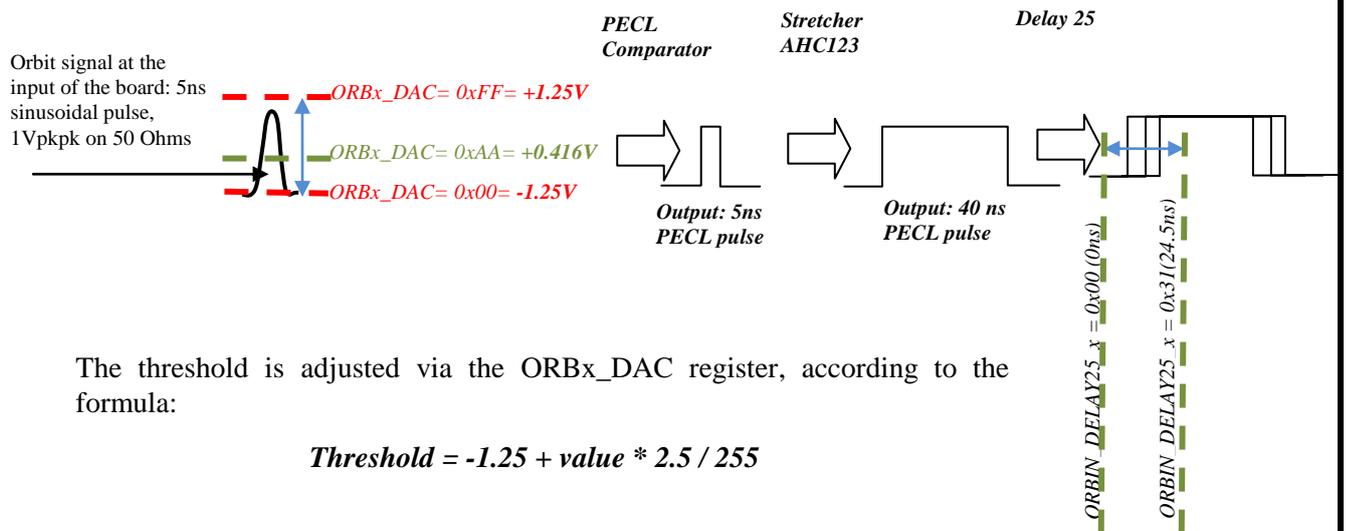
2.3. CALIBRATION PROCEDURES

For a proper operation of the RF2TTC in its environment, a number of registers have to be tuned by the user (delays, thresholds, length). The purpose of adjusting the delay of the Bunch Clock outputs is easy to understand, as well as delaying the orbit output signals (finely with 0.5ns steps or coarsely with 25ns steps).

However, finding the right values for the orbit_in delay and threshold registers is not so easy. The following calibration procedure may help you to optimize these settings.

2.3.1. Threshold adjustment (ORBx_DAC)

The orbit is arriving at the board input as a 5ns sinusoidal pulse, with 1V amplitude on 50 Ohm termination. To be converted to a digital pulse, it is first compared to an adjustable threshold (set by the ORBx_DAC register), then stretched to 40ns, and then finally latched by one of the Bunch Clocks.



The threshold is adjusted via the ORBx_DAC register, according to the formula:

$$\text{Threshold} = -1.25 + \text{value} * 2.5 / 255$$

The ORBx_DAC registers are set to 0xAA by default (which corresponds to 0.416V). This value should match perfectly with the level of the input signals. However, if you have any doubt or you want to adjust it better, we advise you to respect the following procedure. 'x' = '1' or '2'.

1. Set your board to receive BCx and Orbx from a reliable external source (synchronised BC and Orbit, with orbit period= 3564BC)
2. Set the ORBx_DAC to 0
3. Reset the Orbx fifo
4. Read 100 times ORBx_PERIOD_FIFO_RD.
5. While ORBx_DAC < 0xFF, ORBx_DAC <= ORBx_DAC +1 and go back to 3),
6. You should get a window of threshold values of, for example, [0x09;0xF0], for which the 100 periods are all 2564 (0xDEC). Then pick-up one value in the middle of the range and set the ORBx_DAC with it.

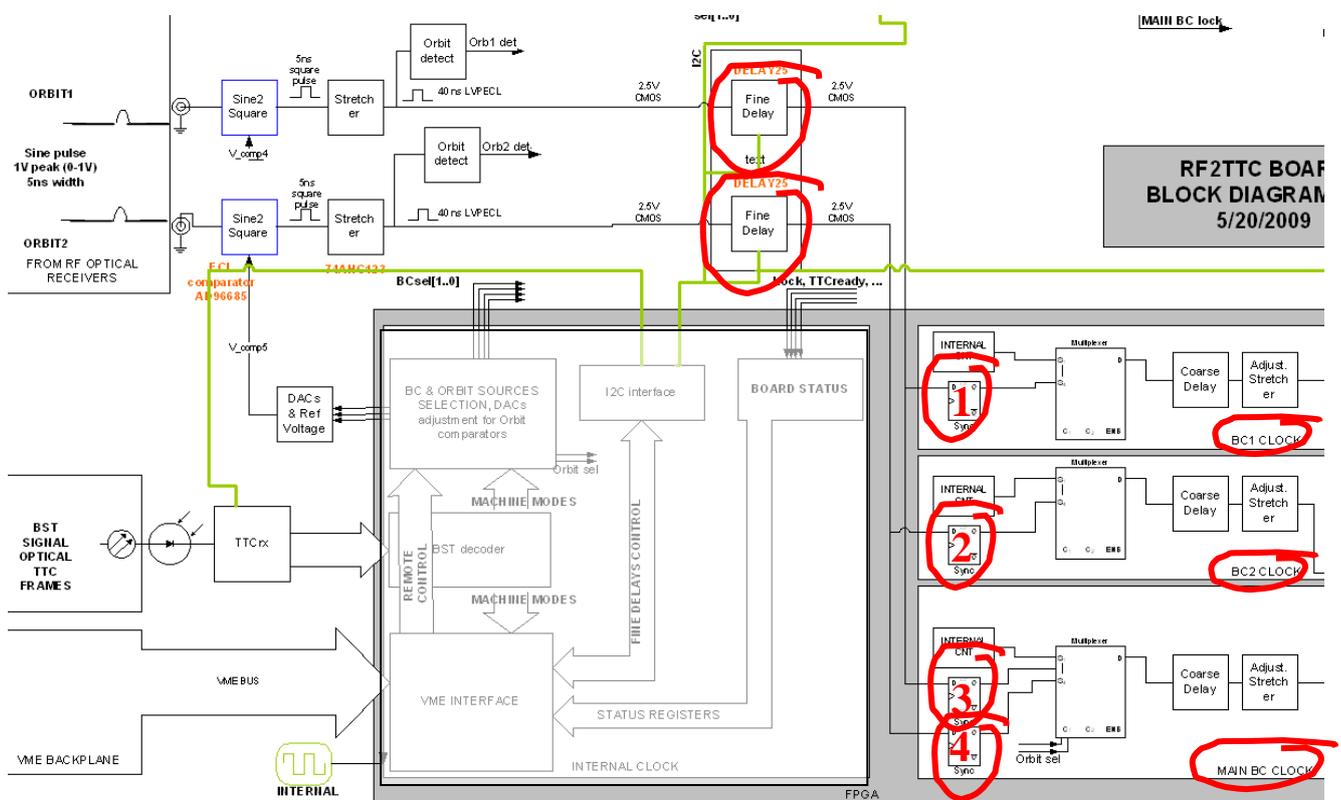
2.3.2. Orbit inputs delay adjustment

The ORBIN_DELAY25_ORBx are 2 registers configuring the Delay25 chips on orb1 and orb2 inputs. They are set to 0x40 by default, which means that they are enabled (bit6) with a delay of 0x00. The delay can go from 0 (=0ns) to 0x3F (31.5ns), by steps of 0.5ns.

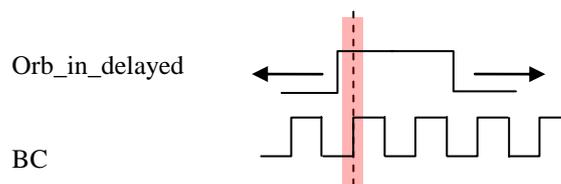
As you can see on the diagram below, the orbit, once stretched to a 40ns pulse, is latched by its corresponding Bunch Clock:

- BC1 for orb1,
- BC2 for orb2, and
- BCmain for orbmain (with BCmain = BC1, BC2 or BCref).

We do not consider the case of internal bunch clocks, as it wouldn't make much sense latching an external orbit with an internal (ie not synchronous) clock.



As the phase between the orbit and its relative BC is not known when it enters the latch in the FPGA, we may face a problem of metastability if the rising edge of the orbit pulse occurs close to the rising edge of the BC. This metastability window is in a range of [-setup time; +hold time] of internal FPGA flipflops, which should be of the order of max [-1ns; +1ns] (see graph below). Although very unlikely to happen, this situation must be avoided, and a calibration is recommended.



Thereby,

- a) Orb1 must be calibrated to match BC1 (Dflipflop 1 on the diagram)
- b) Orb2 must be calibrated to match BC2 (Dflipflop 2).

But it is not enough! You have also to ensure that your Orbmain is matching BCmain. The duo Orbmain/BCmain can be made of:

- c) Orb1/BC1: Dflipflop3 (if Orbmain=Orb1 and BCmain=BC1), or
- d) Orb1/BCref: Dflipflop3 (if Orbmain=Orb1 and BCmain=BCref), or
- e) Orb2/BC2: Dflipflop4 (if Orbmain=Orb2 and BCmain=BC2), or
- f) Orb2/BCref: Dflipflop4 (if Orbmain=Orb2 and BCmain=BCref), or

Note that, if c) and e) look similar to a) and b), the flipflop is different and the clock is following another path, so the phase between Orb and BC may be different.

A minimal calibration procedure would include at least 3 of the above points.

- The two first ones, a) and b), are mandatory
- The, according to the choice you made for the orbmain/bcmain, you have to pick-up one of the 4 :c) or d) or e) or f). If you plan to use several configurations, you have to calibrate for example c) AND d). This is not a problem, as the working window is very large. To be conservative, you may do the 6 cycles of calibration (3 per orbit input), and you will be sure they will always be safely latched.

The calibration procedure is similar to the threshold adjustment described above:

1. Connect your board to the RF_Rx modules outputs
2. Adjust the phase of the clocks (BC1, BC2, BCref and BCmain) according to your detector requirements. (use the BCdelay25 registers).
3. **ORB1_out**: Calibrate case a) (mandatory):
 - a. Set your board to have BC1_MAN_SELECT=BC1 and ORB1_MAN_SELECT=external
 - b. Set ORBIN_DELAY25_ORB1 to 0x40 (enabled, 0 delay)
 - c. Reset the Orb fifo (PERIOD_COUNTER_RESET)
 - d. Read 1000 times ORB1_PERIOD_FIFO_RD.
 - e. While ORBIN_DELAY25_ORB1[5,0] < 0x4F, ORBIN_DELAY25_ORB1<= ORBIN_DELAY25_ORB1+1 and go back to c), Pay attention to keep the ORBIN_DELAY25_ORB1[6]=1 (chip enabled).
 - f. You should get a window (called here Orb1_Wa) of about 40 consecutive steps for which the 1000 periods are all 2564 (0xDEC).

4. **ORB2_out**: Calibrate case b)

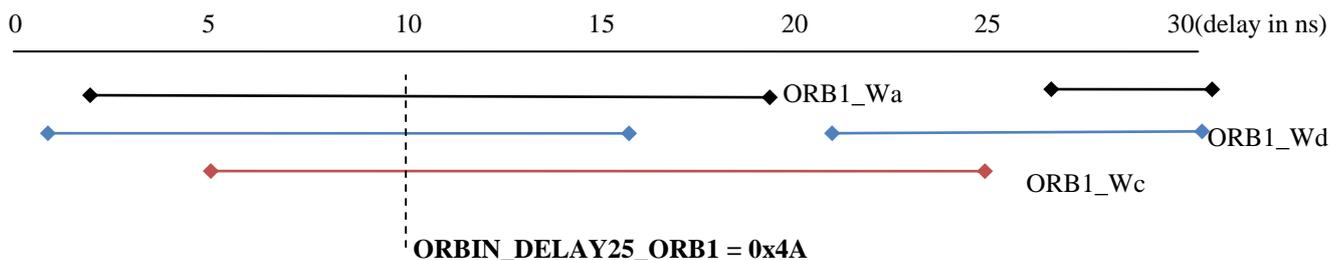
- a. Set your board to have `BC2_MAN_SELECT=BC2` and `ORB2_MAN_SELECT=external`
- b. Set `ORBIN_DELAY25_ORB2` to 0x40 (enabled, 0 delay)
- c. Reset the Orb fifo (`PERIOD_COUNTER_RESET`)
- d. Read 1000 times `ORB2_PERIOD_FIFO_RD`.
- e. While `ORBIN_DELAY25_ORB2[5,0] < 0x4F`, `ORBIN_DELAY25_ORB2 <= ORBIN_DELAY25_ORB2+1` and go back to c),
- f. You should get a window (called here `Orb2_Wb`) of about 40 consecutive steps for which the 1000 periods are all 2564 (0xDEC).

5. **ORBmain_out**: Calibrate case c) or/and d) or/and e) or/and f). Example of case c) below:

- a. Set your board to have `BCmain_MAN_SELECT=BC1` and `ORBmain_MAN_SELECT=ORB1`
- b. Set `ORBIN_DELAY25_ORB1` to 0x40 (enabled, 0 delay)
- c. Reset the Orb fifo (`PERIOD_COUNTER_RESET`)
- d. Read 1000 times `ORBmain_PERIOD_FIFO_RD`.
- e. While `ORBIN_DELAY25_ORB1[5,0] < 0x4F`, `ORBIN_DELAY25_ORB1 <= ORBIN_DELAY25_ORB1+1` and go back to c),
- f. You should get a window (called here `Orb1_Wc`) of about 40 consecutive steps for which the 1000 periods are all 2564 (0xDEC).
- g. Do the same procedure for d, e and f. You will get `Orb1_Wd`, `Orb2_We` and `Orb2_Wf`.

6. Finally, find the best match:

- a. For **ORBIN_DELAY25_ORB1** : between `Orb1_Wa`, `Orb1_Wc` and `Orb1_Wd` (see example below)
- b. For **ORBIN_DELAY25_ORB2** : between `Orb2_Wb`, `Orb2_We` and `Orb2_Wf`



2.4. FIBRE / CABLE CONNECTIONS

| Connector name | To be connected to |
|-----------------------|---|
| BST | TTC encoded signal. One of the BST optical fibres (two are normally available, one per ring). The optical power level should be between -5dBm and -25dBm. |
| BC INPUTS – BC1 | ECL AC coupled signal. Should be connected to the BC1 output of the RF_Rx_D |
| BC INPUTS – BC2 | ECL AC coupled signal. Should be connected to the BC2 output of the RF_Rx_D |
| BC INPUTS – BC_REF | ECL AC coupled signal. Should be connected to the BCref output of the RF_Rx_D |
| ORB INPUTS – ORB1 | ECL AC coupled signal. Should be connected to the ORB1 output of the RF_Rx_D |
| ORB INPUTS – ORB2 | ECL AC coupled signal. Should be connected to the ORB2 output of the RF_Rx_D |
| BC OUTPUTS – BC1 | <ul style="list-style-type: none"> • ECL AC coupled signal. • a NIM copy is also available (for oscilloscope monitoring for example). |
| BC OUTPUTS – BC2 | <ul style="list-style-type: none"> • ECL AC coupled signal. • a NIM copy is also available |
| BC OUTPUTS – BC_REF | <ul style="list-style-type: none"> • ECL AC coupled signal. • a NIM copy is also available |
| BC OUTPUTS – BCmain | <ul style="list-style-type: none"> • ECL AC coupled signal. • a NIM copy is also available |
| ORB OUTPUTS – ORB1 | <ul style="list-style-type: none"> • ECL AC coupled signal. • a NIM copy is also available |
| ORB OUTPUTS – ORB2 | <ul style="list-style-type: none"> • ECL AC coupled signal. • a NIM copy is also available |
| ORB OUTPUTS – ORBmain | <ul style="list-style-type: none"> • ECL AC coupled signal. • a NIM copy is also available |

2.5. OUTPUT SIGNAL AMPLITUDE INFORMATION

The typical outputs ECL amplitude that we have after 2m of cables on 50Ohm terminated ends are:

- BC: 670mV amplitude
- POSITIVE ORBIT: 1.1V
- NEGATIVE ORBIT: 570mV

These values have been set to fit the various needs of all the users, but could need to be adjusted for a special need (ex: increase the negative orbit amplitude). *It is possible to increase or decrease all these amplitudes just by changing the value of one resistor per output. Please contact Stephane DETRAZ or Sophie BARON if you want to do it.*

2.6. FRONT-PANEL LEDES

| LED | Description |
|-------------|---|
| BC1_LOCK | Displays the state of the QPLL chip connected to the selected BC1 signal. (ON=locked/OFF=not locked). |
| BC2_LOCK | Displays the state of the QPLL chip connected to the selected BC1 signal. (ON=locked/OFF=not locked). |
| BCREF_LOCK | Displays the state of the QPLL chip connected to the selected BC1 signal. (ON=locked/OFF=not locked). |
| BCmain_LOCK | Displays the state of the QPLL chip connected to the selected BC1 signal. (ON=locked/OFF=not locked). |
| ORB1_OK | Monitors the presence of the external orbit after the comparator. (ON=signal present, OFF= no signal). When OFF, it can mean, either that the orbit is not present, or that the DAC setting the threshold at the input does not deliver an adapted threshold. |
| ORB2_OK | Monitors the presence of the external orbit after the comparator. (ON=signal present, OFF= no signal). When OFF, it can mean, either that the orbit is not present, or that the DAC setting the threshold at the input does not deliver an adapted threshold. |
| BEAM | Monitors if the current machine mode corresponds to a “BEAM” mode or a “NO BEAM” mode. (ON=BEAM/OFF=NO BEAM). |
| BST ready | Monitors the state of the TTCrx in charge of receiving and transmitting the BST message to the FPGA. (ON=TTCrx ready, received frame is consistent and can be decoded/ OFF=no consistent BST message). |
| BERR | Flashes when the RF2TTC generates a BERR. Not implemented yet. |
| VME | Flashes if the RF2TTC has replied to a VMEbus cycle |

2.7. IMPROVEMENTS MADE ON THE PRODUCTION VERSION (V3)

2.7.1. Initialisation procedure

The state of the Delay25 chips after a power-up was not satisfactory, as the outputs were all disabled. The same for the TTCrx, which does not allow by default the transmission of the broadcast words. Finally, the DAC in charge of the threshold adjustments are set to -1.25V by default after power-up. Hence, the Delay25, TTCrx and DAC chips need to be initialised first, and it requires using some internal protocols (I2C or other), controlled by VME accesses.

A solution was provided to ensure the board initialisation (after power up, sys reset or reconfiguration) without using a crate processor. This initialisation ensures that:

- All the delay25 chips are enabled (i.e. transmit the signals present at their inputs) (0x40 is written in all of their delay registers)
- All the DACs are configured correctly to allow latching the input orbits if any (set to 0xAA)
- The TTCrx chips is configured to transmit the BST message to the FPGA (control register is set to 0xFF)
- All the signals are set to INTERNAL by default

2.8. REGISTERS SUMMARY

| Name | Offset | Size (bits) | Access |
|-------------------------|---------|-------------|--------|
| BC1_MAN_SELECT | 0x7FBFC | 1 | R/W |
| BC1_BEAM_SELECT | 0x7FBF8 | 1 | R/W |
| BC1_NOBEAM_SELECT | 0x7FBF4 | 1 | R/W |
| BC1_QPLL_MODE | 0x7FBF0 | 1 | R/W |
| BC1_DAC | 0x7FBEC | 8 | R/W |
| BC1_QPLL_STATUS | 0x7FBE8 | 2 | R |
| BC2_MAN_SELECT | 0x7FBCC | 1 | R/W |
| BC2_BEAM_SELECT | 0x7FBC8 | 1 | R/W |
| BC2_NOBEAM_SELECT | 0x7FBC4 | 1 | R/W |
| BC2_QPLL_MODE | 0x7FBC0 | 1 | R/W |
| BC2_DAC | 0x7FBBC | 8 | R/W |
| BC2_QPLL_STATUS | 0x7FBB8 | 2 | R |
| BCref_MAN_SELECT | 0x7FBAC | 1 | R/W |
| BCref_BEAM_SELECT | 0x7FBA8 | 1 | R/W |
| BCref_NOBEAM_SELECT | 0x7FBA4 | 1 | R/W |
| BCref_QPLL_MODE | 0x7FBA0 | 1 | R/W |
| BCref_DAC | 0x7FB9C | 8 | R/W |
| BCref_QPLL_STATUS | 0x7FB98 | 2 | R |
| BCmain_MAN_SELECT | 0x7FB8C | 2 | R/W |
| BCmain_BEAM_SELECT | 0x7FB88 | 2 | R/W |
| BCmain_NOBEAM_SELECT | 0x7FB84 | 2 | R/W |
| BCmain_QPLL_MODE | 0x7FB80 | 1 | R/W |
| BCmain_QPLL_STATUS | 0x7FB7C | 2 | R/W |
| ORB1_MAN_SELECT | 0x7FB6C | 1 | R/W |
| ORB1_BEAM_SELECT | 0x7FB68 | 1 | R/W |
| ORB1_NOBEAM_SELECT | 0x7FB64 | 1 | R/W |
| ORB1_POLARITY | 0x7FB60 | 1 | R/W |
| ORB1_COARSE_DELAY | 0x7FB5C | 12 | R/W |
| ORB1_LENGTH | 0x7FB58 | 8 | R/W |
| ORB1_INT_PERIOD_SET | 0x7FB54 | 12 | R/W |
| ORB1_INT_PERIOD_COUNTER | 0x7FB50 | 12 | R |
| ORB1_COUNTER | 0x7FB4C | 32 | R |

| Name | Offset | Size (bits) | Access |
|----------------------------|---------|-------------|--------|
| ORB1_PERIOD_RD | 0x7FB48 | 12 | R |
| ORB1_PERIOD_FIFO_STATUS | 0x7FB44 | 2 | R |
| ORB1_PERIOD_FIFO_RD | 0x7FB40 | 16 | R |
| ORB1_DAC | 0x7FB3C | 8 | R/W |
| ORB2_MAN_SELECT | 0x7FB2C | 1 | R/W |
| ORB2_BEAM_SELECT | 0x7FB28 | 1 | R/W |
| ORB2_NOBEAM_SELECT | 0x7FB24 | 1 | R/W |
| ORB2_POLARITY | 0x7FB20 | 1 | R/W |
| ORB2_COARSE_DELAY | 0x7FB1C | 12 | R/W |
| ORB2_LENGTH | 0x7FB18 | 8 | R/W |
| ORB2_INT_PERIOD_SET | 0x7FB14 | 12 | R/W |
| ORB2_INT_PERIOD_COUNTER | 0x7FB10 | 12 | R |
| ORB2_COUNTER | 0x7FB0C | 32 | R |
| ORB2_PERIOD_RD | 0x7FB08 | 12 | R |
| ORB2_PERIOD_FIFO_STATUS | 0x7FB04 | 2 | R |
| ORB2_PERIOD_FIFO_RD | 0x7FB00 | 16 | R |
| ORB2_DAC | 0x7FAFC | 8 | R/W |
| ORBmain_MAN_SELECT | 0x7FAEC | 2 | R/W |
| ORBmain_BEAM_SELECT | 0x7FAE8 | 2 | R/W |
| ORBmain_NOBEAM_SELECT | 0x7FAE4 | 2 | R/W |
| ORBmain_POLARITY | 0x7FAE0 | 1 | R/W |
| ORBmain_COARSE_DELAY | 0x7FADC | 12 | R/W |
| ORBmain_LENGTH | 0x7FAD8 | 8 | R/W |
| ORBmain_INT_PERIOD_SET | 0x7FAD4 | 12 | R/W |
| ORBmain_INT_PERIOD_COUNTER | 0x7FAD0 | 12 | R |
| ORBmain_COUNTER | 0x7FACC | 32 | R |
| ORBmain_PERIOD_RD | 0x7FAC8 | 12 | R |
| ORBmain_PERIOD_FIFO_STATUS | 0x7FAC4 | 2 | R |
| ORBmain_PERIOD_FIFO_RD | 0x7FAC0 | 16 | R |
| TTCrx_status | 0x7FAA0 | 1 | R |
| BST_Beam_Mode | 0x7FA9C | 32 | R |
| BEAM_NO_BEAM_DEF | 0x7FA7C | 32 | R/W |

| Name | Offset | Size (bits) | Access |
|-------------------------------|---------|-------------|--------|
| WORKING_MODE | 0x7FA78 | 7 | R/W |
| ORB_INT_ENABLE | 0x7FA6C | 3 | R/W |
| ORB_COUNTER_ENABLE | 0x7FA68 | 3 | R/W |
| PERIOD_COUNTER_ENABLE | 0x7FA64 | 3 | R/W |
| ORB_INT_RESET | 0x7FA4C | 3 | W |
| PERIOD_COUNTER_RESET | 0x7FA48 | 3 | W |
| ORB_COUNTER_RESET | 0x7FA44 | 3 | W |
| TTCrx_REG (FIFO) | 0x7E200 | 8 | R |
| TTCrx_pointer to the data | 0x7E004 | 8 | (R)/W |
| TTCrx_pointer to the register | 0x7E000 | 8 | (R)/W |
| DELAY25_REG (FIFO) | 0x7D200 | 8 | R |
| ORBOUT_DELAY25_GCR | 0x7D054 | 8 | (R)/W |
| ORBOUT_DELAY25_ORBmain | 0x7D048 | 8 | (R)/W |
| ORBOUT_DELAY25_ORB2 | 0x7D044 | 8 | (R)/W |
| ORBOUT_DELAY25_ORB1 | 0x7D040 | 8 | (R)/W |
| ORBIN_DELAY25_GCR | 0x7D034 | 8 | (R)/W |
| ORBIN_DELAY25_ORB2 | 0x7D024 | 8 | (R)/W |
| ORBIN_DELAY25_ORB1 | 0x7D020 | 8 | (R)/W |
| BC_DELAY25_GCR | 0x7D014 | 8 | (R)/W |
| BC_DELAY25_BCmain | 0x7D00c | 8 | (R)/W |
| BC_DELAY25_BCref | 0x7D008 | 8 | (R)/W |
| BC_DELAY25_BC2 | 0x7D004 | 8 | (R)/W |
| BC_DELAY25_BC1 | 0x7D000 | 8 | (R)/W |
| BCLEAR | 0x00014 | 4 | R/W |
| BSET | 0x00010 | 4 | R/W |
| PROGRAM ID | 0x0000C | 32 | R |
| REVISION ID | 0x00008 | 32 | R |
| BOARD ID | 0x00004 | 32 | R |
| MANUFACTURER ID | 0x00000 | 32 | R |

3. LIST OF FIRMWARE UPDATES

| DATE | VERSION | AUTHOR | DESCRIPTION |
|------------|---------|--------|--|
| 03/10/06 | 0.01 | BARON | first VHDL entity definition clock selection feature |
| 27.02.07 | 0.1 | BARON | remove CR/CSR space and use only User space |
| 19.04.2007 | | | inversion of orb int/ext encoding in register to be like BC |
| 26.04.2007 | | BARON | initial value for DAC=AA. Initial value for TTCrx control register is 0xff |
| 30.04.07 | | BARON | V3 of the hardware => Manual LSB and MSB addresses are inverted |
| 08.05.07 | | BARON | signal tap removed after timing pbs with the delay25 read back data_o latched by clock in simple_I2C (was not sync before) |
| 29.10.2007 | | BARON | modif to have consistency between orbit period register, real orbit period and measured orbit period |
| 08.09.2008 | | BARON | modif of the BST decoding to follow the 2 bytes of machine modes according to LHC-OP-ES-0005 v.1.0 (bytes 26 and 27 - previously only 27. |
| 13.09.2008 | | BARON | compilation of files from may 08 for real time orbit reading and improvement of orbit length & delay |
| 16.09.2008 | 0.2 | BARON | modification of machine_mode_mgr: to have a latching of the Beam Mode register only after the 2 bytes have been transmitted to the TTCrx. Adding of the orbit reading modification to allow a real time reading and storage in the FIFO, plus an improvement of orbit length and delay |
| 08.10.2008 | 0.3 | BARON | correction on orb_sel_mgr: on period_fifo_wr_ena, modif per_fifo_status reg to memorize every full/empty until next read |
| 14.01.2009 | 0.4 | BARON | modif on 'mach_mode-mgr': on mmode_decode_process to sync it with clock40des1 instead of clock |
| 19.01.2009 | 0.5 | BARON | modif on QPLL_mgr: the qpll status registers keeps unlock and error active until next read action of the register |
| 13.02.2009 | 0.6 | BARON | modif on Orb_sel_mgr: following a request from Markus, the empty status given by a per_fifo_rd is now latched only when rdreq is active, to ensure that reading 0x4XXX means that the fifo is really empty! Previously, it meant that last word was being read. not very practical! |

| | | | |
|------------|-----|-------|---|
| 19.05.2009 | 0.7 | BARON | changes the definition of BSET and BCLEAR registers to allow individual reset of QPLL chips (bits 5..3). Change on the reset_n of the qpll registers (previously reset by qpll_reset. now by the general reset. |
| 24/06/09 | 0.8 | BARON | <p>init_ctrl: new constant (begin_init_delay = 1000000 x 25ns = 25ms)</p> <p>simple_I2C_sophie2: new version of simple_i2c_sophie with a corrected scl/sca (84 bits instead of 80 for scl and a new alignment of sda to have the edges in the middle of scl_low)</p> <p>rf2ttc_ctrl: update the WRn only when the iDTACK is released (to avoid a change of WR_n in the middle of a transaction (especially when the transaction is long as with the I2C).</p> |
| 25.06.2009 | 4.3 | BARON | orb_sel_mgr: modification of orb1 and mainorb lengths to match orb2 length adjustment: now the 3 orb_out are 25ns pulses by default. |

4. RF2TTC COMMON SOFTWARE

4.1. INTRODUCTION

Even though the RF2TTC performs the same task in each of the four LHC experiments it will be operated in H/W and S/W environments that are specific to the respective experiment. Therefore the common S/W is limited to the lowest level which consists of some diagnostic programs and a user library. This S/W is implemented in the rf2ttc package and can be found in CERN CVS repository at <http://isscvcs.cern.ch/cgi-bin/viewcvs-all.cgi/rf2ttc/?cvsroot=rf2ttc>. For direct access from Unix use (e.g.) “setenv CVSROOT :kserver:isscvcs.cern.ch:/local/refs/rf2ttc”

4.1.1. H/W Environment

In the ATLAS and ALICE experiments the RF2TTC is controlled by a VMEbus SBC from Concurrent Technologies (either a VP110 or a VP315). CMS uses a PCI-VMEbus link from CAEN and LHCb a USB-VMEbus link from the same manufacturer. In all four experiments the crate that houses the RF2TTC should be VME64X compatible as otherwise it is not possible use geographical addressing.

4.1.2. S/W Environment

On the low end ATLAS and ALICE will use the vme_rcc driver developed by ATLAS to communicate with the RF2TTC. CMS and LHCb will use S/W packages provided by CAEN for the respective interface. The common S/W will be programmed in a way that it is compatible with any of these bus access packages.

At the top end each experiment has to develop appropriate secondary libraries and applications to interface the RF2TTC to their respective control systems. The development of the interface to the DIP server is also up to the experiments.

4.2. TEST PROGRAMS

Currently there exists one program that comes in three flavours: rf2ttcscope_atlice (for ATLAS and ALICE), rf2ttcscope_cms and rf2ttcscope_lhcb. This interactive application can be used to read, decode and write any register of the RF2TTC in a (hopefully) intuitive way. If a users feels that some functionality is lacking he is welcome to contact the developer (M. Joos). It is e.g. possible to extend rf2ttcscope by additional command line parameters such that certain tests can be executed from scripts.

A tcltk graphical user interface (rf2ttc.tcl) is also available for test purpose. It has been written for SBCs from Concurrent Technologies (VP110 and VP315).

4.3. THE USER LIBRARY

This library consists of a common source file that implements the access to the registers of the RF2TTC in a generic way and a number of files to implement glue layers to the VMEbus access libraries from ATLAS and CAEN respectively.