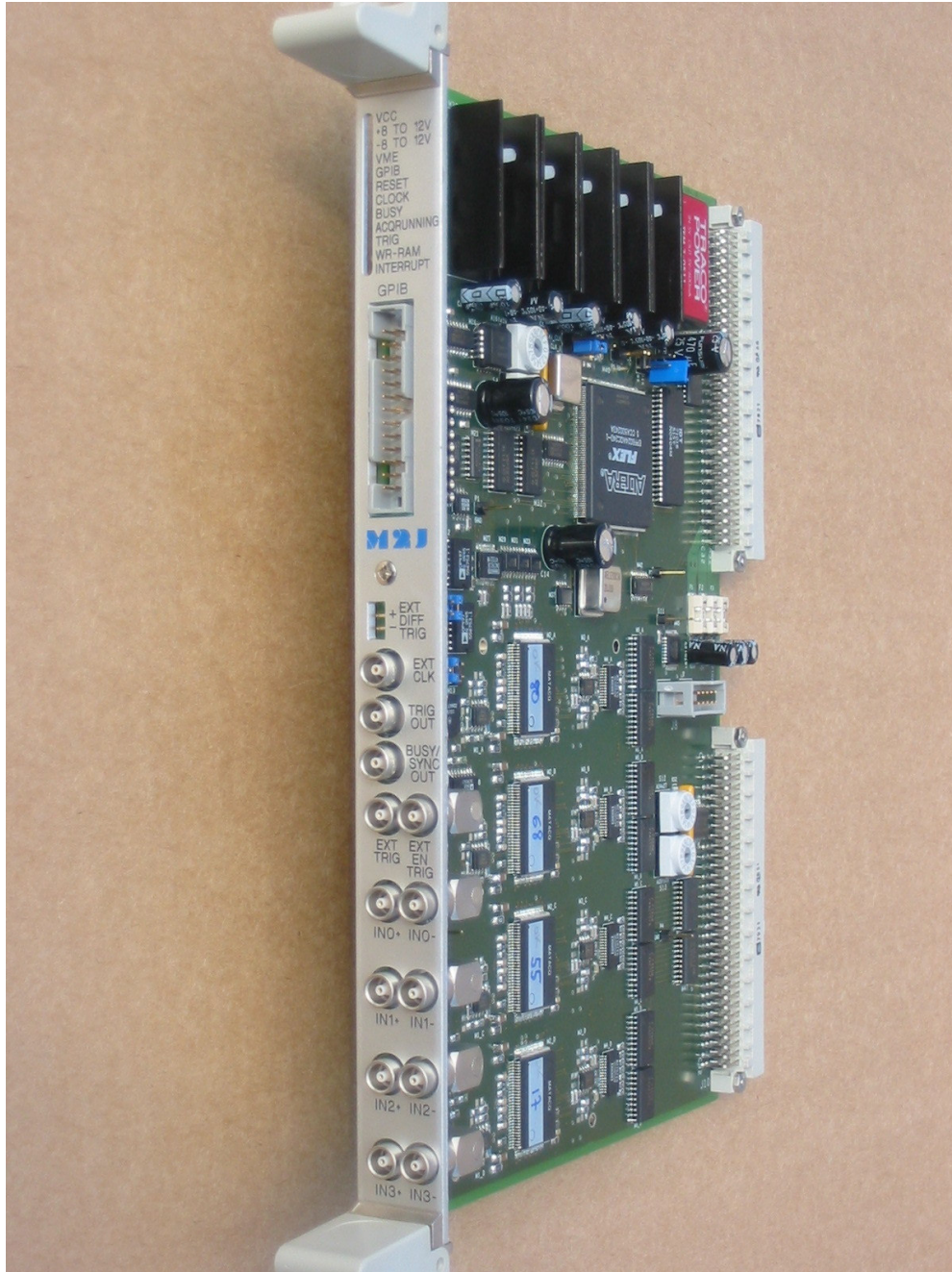




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| Date : 12/12/2006 | Object : Documentation of the MATAcq32 board. |
| By : E. DELAGNES + D. BRETON | V/Ref. : 1.8 |

N O T E : Documentation of the MATAcq32 board.



M2J

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EVOLUTIONS OF THE DOCUMENT.

Rev1.0 : translation from French by Layla Seirafi-Najar.

Rev1.1 :

* IV.2.a : ADDRESS MODIFIERS supported by the board.

Rev 1.2 :

* In all the document (where necessary) :

- POSTRIG replaced by POSTTRIG.
- The INTERRUPT register is reset by the START_ACQ command.

* II.1 : figure 1. Update of the maximum data transfer rates on the acquisition busses.

* II.1.d : figure 3b. Update to clarify it without change in the principle.

* II.4.b : correction of the ROT formula.

* III.3.a : put NB_OF_COL_TO_READ to 1 to calibrate the interpolator.

* IV.1.c : description of the front panel leds.

* IV.4 : no readback of the TRIGGER THRESHOLD DAC registers in GPIB. Clearer redefinition of TRIG_REC.

* V : update of the event acquisition rates.

Rev 1.3 :

* TRIG_REC instead of REC_CP everywhere (there were some remaining).

* II.4.b : correction of equation (1).

* IV.1.a : update of figure 8.

* IV.1.e : JTAG connector for the E2PROM.

* IV.1.f : update of the array.

* IV.1.g : correction of the implementation for using differential inputs.

* IV.1.h : using a shifted input range.

* IV.4 : adding of 2 new bits (ISA et IRQP) in MAT CTRL REGISTER at sub-address 0x11.

Suppression of sub-address 0x25. Correction of sub-address 0x81.

Rev 1.4 :

* Some little corrections.

* I.2 : details about EXT_CLK.

* II.1.a and II.1.e : introduction of the trigger validation signal.

* IV.4 : introduction of the POST STOP LATENCY and POST LATENCY PRETRIG registers.

Rev 1.5 :

* II.1.e : validation of the trigger by a second subsequent signal. New writing.

* II.2 : minimal values of PRETRIG modified.

* III.1.a : synchronisation of the channels from the same board. New writing.

* V : update of the specifications.

* VI : bibliography. Introduction of the US patent.

Rev 1.6 :

* IV.1.h : inversion of « positive » and « negative » in the shift direction and correction of the array.

Rev 1.7 :

* II.1.d : update of figure 3b.

* IV.4 : adding of 2 new bits (6 & 7) in TRIGGER TYPE at sub-address 0x1D.

Rev 1.8 :

* No modification (correction only on French version).

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I. DESCRIPTION OF THE FUNCTIONALITIES OF THE MATAQ32 BOARD.

I.1. Generalities. Description of the overall functionality.

The MATAQ32 board is suited for acquisition of fast analog signals based on the MATAQ (analog matrix) chip developed by collaboration of the CEA/DAPNIA and the I'IN2P3/LAL [1].

The MATAQ32 board, in the mechanical format VME double Europe, is compatible with several standards of acquisition (VME A32/D32, A24/D16, and GPIB).

This board performs the coding of 4 analog channels of bandwidth up to 300MHz over 12 bits at a sampling frequency (F_e) reaching up to 2GHz and over a depth of 2520 usable points.

This operation is realized in three phases (see Fig 1) :

- **Acquisition** :

the analog signal is continuously sampled at the frequency F_e in a circular analog memory. The arrival of a trigger signal initiates the stopping phase of the sampling (II.1.a). At the end of this phase, the state of the memory is set : it then contains the last 2560 points sampled (of which 2520 are valid).

- **Numerization and storage** :

after a stopping order of the acquisition, the samples stored under analog form in the MATAQ chips are rapidly ($650\mu\text{s}$) re-read and coded into digital data over 12 bits, then stored in a digital memory buffer. The acquisition is informed of the end of the coding phase either by scrutation of an internal register, or by an interruption.

- **Reading** :

the memory buffer can then be re-read by the acquisition system. For an acquisition system of VME A24-D16 standard, the latter operation lasts a few ms for the full readout of a 4-channel board, which permits attaining an acquisition frequency of a few hundred Hz for the acquisition of 2500 points per channel. With a high performance A32-D32 system, one should reach 1 kHz.

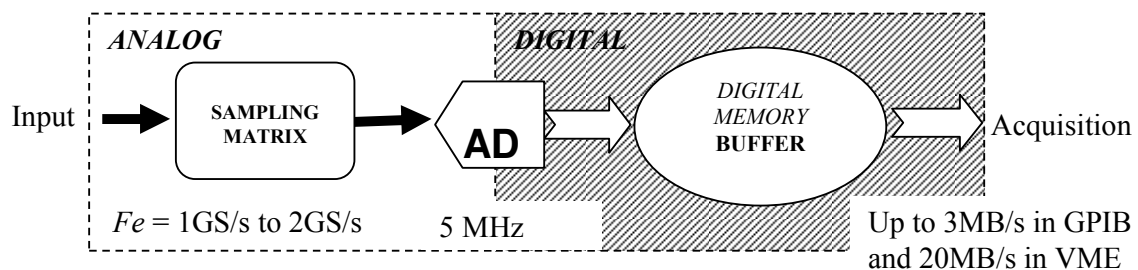


Fig 1 : data flow in the board.

I.2. Sampling frequency.

The MATACQ32 board is sequenced by an oscillator at a frequency of 100MHz. No greater frequency signal exists on the board. This is what explains the low consumption of the system. The sampling at a very high frequency (F_e) in the MATACQ chip is in fact realized by virtual multiplication of frequency inside the chip by a factor up to 20.

The MATACQ chip functions with a pilot frequency of 50MHz or 100MHz programmable on the board by software, which corresponds to a sampling frequency $F_e (= 20 \cdot F_p)$ of 1 or 2 GHz.

The EXT_CLK input may possibly be used to inject a very clean external pilot clock comprised between 50MHz and 100MHz. **Caution** : the MATACQ chip cannot work properly with a pilot frequency F_p lower than 50MHz.

I.3. Input signals, Dynamic range.

The MATACQ32 board integrates 4 analog channels. The inputs of these channels are connected through double LEMO plugs (IN0+/- à IN3+/-).

The inputs are by default unipolar and terminated on 50 Ohms. However, the input levels of the board can be very easily modified (through displacing a few resistors and mounting new ones) in such a way as to permit the input in differential mode (from which the double LEMO plugs). For this purpose, free CMS-805 resistor footprints are indeed implemented on the MATACQ32 board (see IV.1.g).

The analog to digital conversion is made on 12 bits with a maximum dynamic range of 1V, or an LSB of $250\mu\text{V}$. This range is centered on 0V ($\pm 0.5\text{V}$). However, free CMS-805 footprints are implemented on the MATACQ32 board for shifting the dynamic range in the interval $\pm 0.5\text{V}$ in order to be able to optimize the system for unipolar signals (see IV.1.h).

The measured noise referred to input is less than $200\mu\text{V}$ RMS (i-e below the lsb of the ADC), and the non-linearity remains below 1 per 1000 over the whole dynamic range.

II. MODE OF OPERATION.

II.1. Definition of the acquisition window. Trigger modes.

II.1.a) Principle, PRETRIG, POSTTRIG.

During the acquisition, the analog signal is continuously sampled in the analog memory which is comparable to a circular buffer with a depth of 2560 points (time depth = $2560/F_e$). The stopping of sampling is initiated by the arrival of a trigger signal T_a (*asynchronous trigger*) which is common to all the channels of a board. This signal is only authorized to be produced following a programmable delay named *PRETRIG* after the triggering of the acquisition sequence.

The effective stopping of the sampling will occur following a pre-defined number (named *POSTTRIG*) of clock periods (50MHz or 100MHz) after the trigger (cf Fig 2).

The *POSTTRIG*, programmable by the user, permits defining and displacing the position of the trigger signal in the acquisition window. It is adjustable in the $1/F_p$ to $65535/F_p$ range by steps of $1/F_p$ ($= 20\text{ns}$ or 10ns), to which a fixed extra offset of $3/F_p$ has to be added. This is illustrated in Fig 3a.

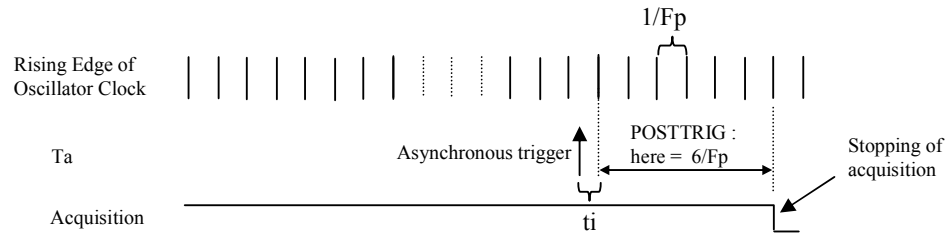


Fig 2 : chronogram of the stopping of the acquisition.

In the example illustrated by Fig2, the total POSTTRIG is fixed at $6/F_p$. The acquisition will be stopped $6/F_p + t_i$ after the arrival of the trigger signal (t_i corresponds to the time measured by the vernier between the T_a and the next rising edge of the clock – see II.4.b). The analog memory will then contain the 2560 last samples (of which only 2520 will be exploited).



Fig 3a : centering of the Trigger in the acquisition window for two POSTTRIG cases.

Thus, a POSTTRIG value close to 64 assures the centering of the trigger in the middle of the acquisition window. For the values of $POSTTRIG > 127$, the trigger is no longer in the acquisition window.

II.1.b) Trigger sources.

There exist four possible sources for the trigger signal T_a . They are selectable by the user (see IV.4) :

- **Trigger on signal** : this is the result of the logic « OR » of the discriminators on the analog signals of one or several channels of the board by choice of the user. The common threshold of the discriminators is programmable by steps of 0.25mV over a range of $\pm 0.5V$ (which corresponds to the integrality of the usable input range of the board). The user can also define the type of discrimination (signal higher than or inferior to the threshold) via the choice of the trigger edge.
- **External trigger** : external trigger signal entering on a LEMO plug (EXT_TRIG signal at the NIM level). This signal can be either used as any other trigger source with choice of its edge, or exploited directly as an asynchronous trigger (rising edge only) in cases where one uses discriminators from several boards in order to produce at the exterior of the boards (via their output TRIG_OUT) a trigger which will be sent back to them in a synchronous way (see figure 3b). This mode is selected by the bit 4 of the TRIG_TYPE register (see IV.4).

- **Auto trigger** : triggered by a software command issued from the acquisition. It permits the generation of a random trigger. This corresponds to the automatic trigger mode.
- **« Auto + normal » trigger** : result of a logic « OR » between the trigger on signal and the automatic trigger.
- **Internal random trigger** : this internal periodic signal is asynchronous from the clock. When it is selected and the trigger mode chosen is « auto », this signal serves as a source for the automatic trigger. One uses it for the fast calibration of the verniers of the MATAcq chips (see III.3.a).

II.1.c) Trigger edge.

The trigger edge (rising or falling) can be selected in all modes (except the direct external trigger which uses only the rising edge).

II.1.d) TRIGOUT signal.

A copy of the pre-trigger signal (positive pulse) generated by the MATAcq32 board is available at the output on a LEMO plug on the front panel (TRIG_OUT output on the NIM level). It can in particular permit synchronization of trigger for several boards.

A simplified summary of the trigger modes of the board is presented in figure 3b.

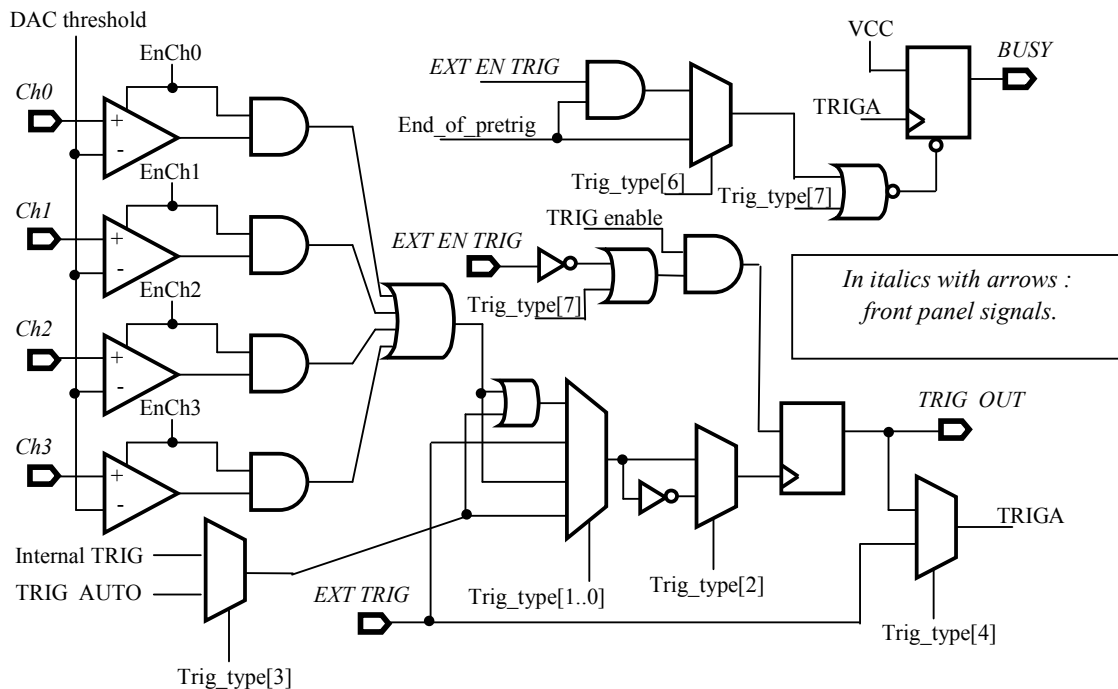


Fig 3b : simplified description of the trigger selection chain.

II.1.e) Validation of the trigger by a second subsequent signal.

In the case where one would like to validate the data stored in the MATAcq chips before their transfer towards the RAM, it is possible to make use of the *EXT_EN_TRIG* input to introduce

therethrough a validation signal (see figure 3c). This is particularly useful if the system produces such a signal with a delay greater than the maximum sampling depth ($2560/F_p$ i-e $1.25\mu\text{s}$ at 2GS/s and $2.5\mu\text{s}$ at 1GS/s) and smaller than the transfer time towards the RAM ($650\mu\text{s}$). This can thus permit a big decrease of the potential dead-time linked to the readout. In this case, the usual use of the *EXT_EN_TRIG* signal (which permits inhibiting the trigger as described on figure 3b) is inhibited.

In order to perform the validation, a programmable 8-bit latency counter (called *POST_STOP_LATENCY*) with steps of $2.5\mu\text{s}$ is started at the end of the *POSTTRIG*, and if the external validation signal hasn't arrived before the end of that delay, the Matacq chips switch back into the analog input signal writing mode thus waiting for the next trigger. If on the other hand the validation signal did arrive, the waiting data is digitized then stored into the RAM. This mode is validated thanks to the bit 5 of the *TRIGGER_TYPE* register (see IV.4). Moreover, a second 8-bit register (called *POST_LATENCY_PRETRIG*) with the same steps of $2.5\mu\text{s}$ permits the programming of the time to wait before enabling the trigger again if the validation didn't occur. The minimum time for refilling is of $1.25\mu\text{s}$ at 2GS/s and of $2.5\mu\text{s}$ at 1GS/s. The minimum value in that register is thus 1.

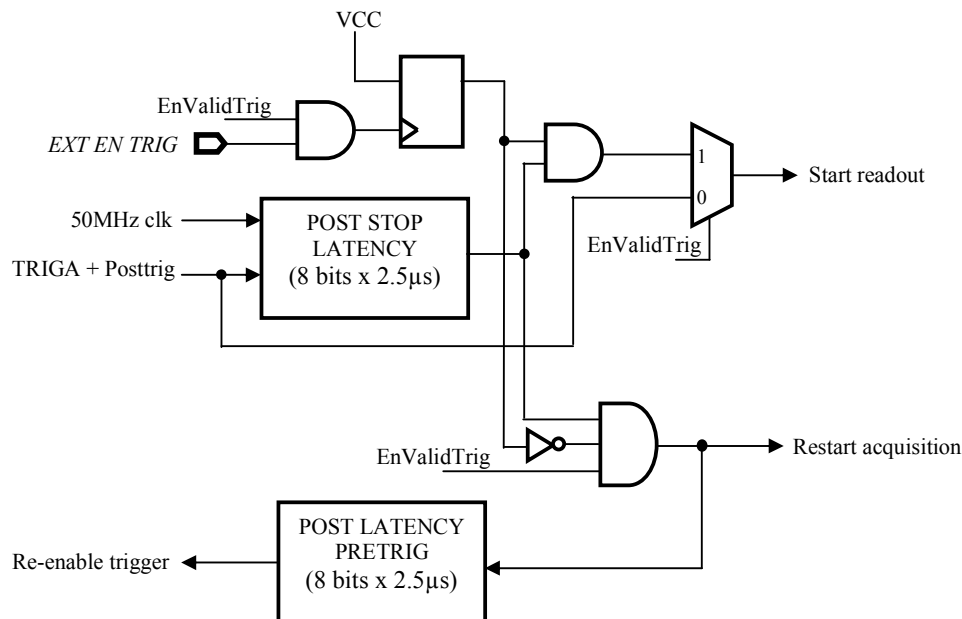


Fig 3c : simplified description of the trigger validation system.

II.2. Dead time at the start of the acquisition; Pretrig.

The frequency of the clock present on the board is relatively low (50MHz or 100MHz). In order to be able to sample at a rate equal to or greater than the Giga-sample per second, the MATACQ chips realize a virtual multiplication of frequency. This multiplication requires a servo of which the control loop is interrupted at the time of the data read cycle. At the time of the start of the acquisition, this servo has to get locked again. This implicates a typical waiting of 150 μ s before being able to reach the optimum of the sampling performances.

For this reason, at each restarting of the acquisition, the board must automatically generate a dead time during which the triggers are not accepted.

This dead time is adjustable by the PRETRIG, from 1 to 65535 times the period of the main clock. The minimal recommended PRETRIG values are therefore :

- 7500 (decimal) for a clock frequency of $F_p = 50\text{MHz}$.
- 15000 (decimal) for a clock frequency of $F_p = 100\text{MHz}$.

II.3. Standard acquisition sequence.

Fig 4 shows the standard course of an acquisition :

- The sequence begins with the initialization of the board by a *RESET* order.
- Next, the different parameters which are not used with their default value must be programmed (PRETRIG, POSTTRIG, TRIGGER TYPE, TRIGGER EDGE, MASK, NB OF COL TO READ, FP FREQUENCY, ...).
- The starting order of the acquisition is next sent.
- The user if necessary sends a software trigger (in the case of an automatic trigger) having taken care to wait at least the time necessary for the PRETRIG.
- The program then waits for a request emitted by the MATACQ32 board when the data are ready to be read. For this, there exist two possibilities illustrated by Fig 5 :
 - Waiting and handling of an interruption (SRQ in GPIB, IRQ3 in VME).
 - Regular scanning of the LSB of the interruption register (INTERRUPT h80).

In both cases, the user should acknowledge the request by writing a 0 in the *INTERRUPT* register, but the latter is anyhow reset by the *START_ACQ* command. The first solution has the big advantage of being less noisy for the front-end of the board.

- The user can then partially or wholly read the data stored in the board. This includes :
 - the values of the vernier and of the samples (cf IV.3)
 - the value of TRIG_REC which permits determination of the position of the trigger in the acquisition window (cf II.4.b) and IV.4)
- The user must correct the data before using it (cf II.4):
 - By subtracting the pedestals (cf II.1.a).
 - By reordering the data (cf II.4.b).

These operations can be executed on-line or off-line according to the context.

II.4. Correction of data.

The raw data extracted from the board must be treated before really being usable. This treatment consists of two operations :

- Correction of the pedestals.
- Reordering and time alignment of the data.

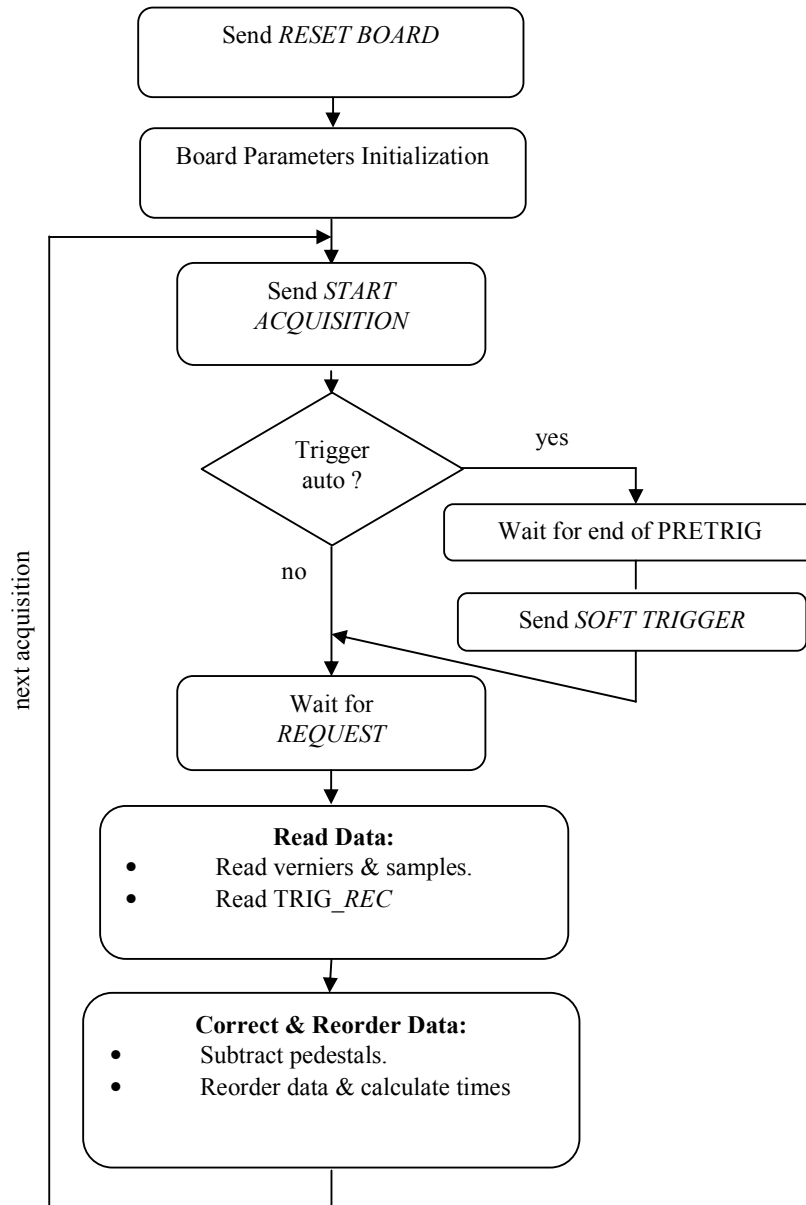


Fig 4 : block diagram of a standard acquisition.

II.4.a) Correction of the pedestals.

The analog memories of the MATAQ chips present by design dispersions of pedestal from cell to cell which can reach several tens of mV. On the other hand, the pedestal of a data cell is extremely reproducible (250 μ V RMS). Due to the structure of the chip, the dispersion of the

pedestals presents a principal periodicity of 20 cells, followed by a tiny individual distribution. If not compensated, this dispersion will appear as a noise at the reconstruction of the signal because of the random position of the trigger in the matrix.

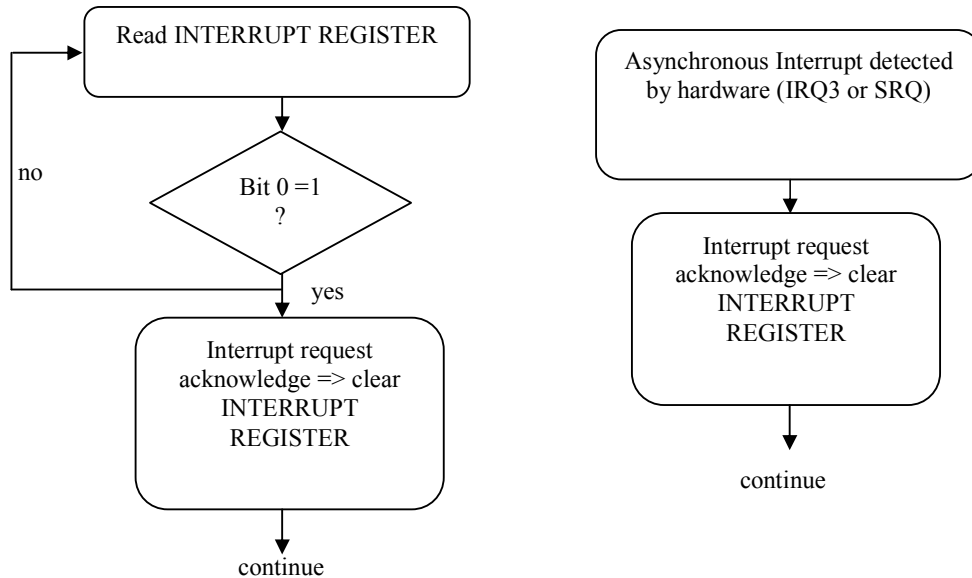


Fig 5 : two possibilities for detection and for treatment of the request : scanning of the interruption register or treatment of the asynchronous interruption.

In order to obtain the nominal noise performances (signal to noise ratio of 73 to 74dB), the pedestals, which are stable in time and with temperature, must be removed by the acquisition software individually cell by cell. As discussed above, it is also possible to subtract 128 times a pattern of 20 cells. This makes it possible to store only 20 pedestals, and the loss of the signal over noise ratio remains minor (approximately 1 to 2dB) even though it is not negligible.

Since the pedestal of a cell is linked to its physical location and not to its position in relation to the Trigger, **it is necessary to realize this removal BEFORE reordering the data.**

A method of calibration of the pedestals is demonstrated in section III.3.b).

II.4.b) Temporal corrections.

The signal is sampled in a circular memory. The first operation necessary for the treatment of the data is therefore to « unfold » the circular memory of every channel in order to obtain tables of 2560 temporally ordered data (cf Fig 6). This can be done, by example, by realizing a rotation of :

$$(1) \text{ ROT} = (\text{TRIG_REC} - \text{POSTTRIG}) * 20$$

cells towards the left of the data tables issued from the RAM and formerly sorted channel by channel (see IV.3).

Or, equivalently through a calculation of a new index number for each data :

$$(2) \text{ NEW}_i = (\text{2560} + \text{OLD}_i - \text{END_CELL}) \text{ modulo } \text{2560}$$

where **END_CELL** is the index of the last written cell :

$$\text{END_CELL} = 20 * (\text{POSTTRIG} + \text{TRIG_REC}) \text{ modulo } 128$$

The trigger signal (asynchronous trigger) T_a is the absolute reference which serves to temporally realign the data (cf Fig 2). In order to find its position, one uses the information provided by a temporal interpolator (vernier) measuring t_i , time interval separating the arrival of T_a from the next rising edge of the F_p clock.

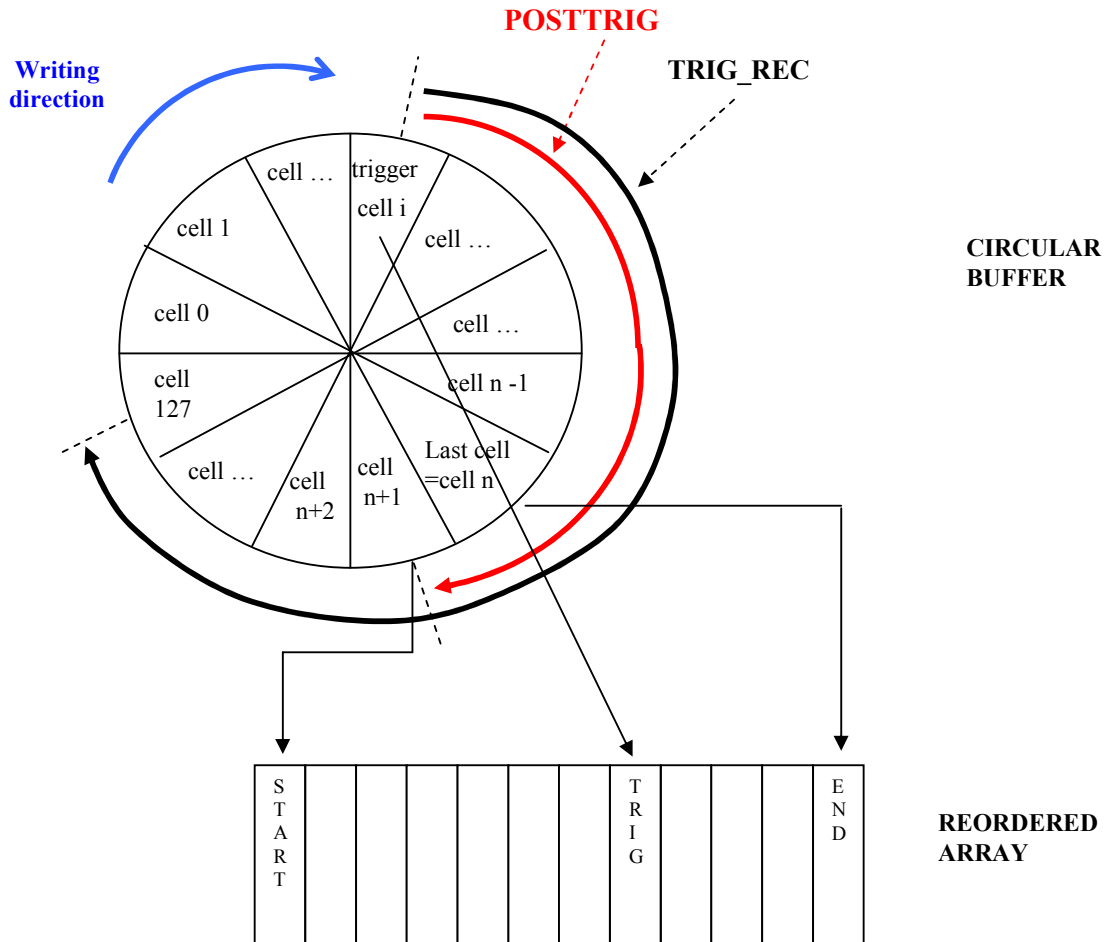


Fig 6 : unfolding of the circular memory

This information associated with the *MINVER* and *MAXVER* calibration constants (cf III.3.a) permits determination of the position of the Trigger and therefore realignment of the data with a typical maximum precision in the region of 50ps RMS. This realignment is unnecessary if the user simply desires to study the signal shape and in this case, the curve acquired will present a jitter of a period of F_p . The information of the 4 verniers from the same board being redundant in order to realize the temporal adjustment, it is therefore possible :

- to use solely the vernier from the channel 0.
- to use the vernier i for the channel i .
- to calculate the mean of the 4 verniers in order to refine the time precision.

The following formula permits determination of the time of each point of the reordered table, with by convention a time origin (Time = 0) at the arrival of the Trigger.

$$(3) \text{Time}[\text{NEW}_i] = \text{DT0} + \{\text{NEW}_i - 20 * [128 - \text{POSTTRIG} + \text{Correc_Ver}]\} * \text{dT}$$

$$\text{With (4) Correc_Ver} = (\text{VERNIER} - \text{MINVER}) / (\text{MAXVER} - \text{MINVER})$$

Where :

- dT is the sampling period (500ps or 1ns)
- DT0 is a fixed temporal offset, close to 0, due to signal propagation times in the board (of which the calibration is described in III.1.a)

An alternative but equivalent solution, consists in generating the reordered table through a rotation towards the left of the data of :

$$(1b) \text{ROT} = (\text{TRIG_REC} - \text{POSTTRIG}) * 20 - \text{INT}(\text{Correc_Ver} * 20) \text{ cells}$$

where INT corresponds to rounding off to the nearest whole number.

The trigger is then situated at a time

$$(5) tT = [\text{Correc_Ver} * 20 - \text{INT}(\text{Correc_Ver} * 20)] * \text{dT}$$

before the cell numbered 20(128-POSTTRIG) (plus the offset DT0).*

III. SYNCHRONIZATIONS, CALIBRATIONS.

III.1. Synchronization between the channels.

III.1.a) Channels from the same board.

A single trigger signal is used for all of the channels from the same board. The acquisition of these channels will therefore naturally be synchronous, with a typical jitter of only 20ps RMS. The possible temporal offset dT0, constant, between the channels (principally due to the propagation of the trigger signal on the board, but also to the different lengths of cables at the inputs) will be calibrated once for all. This calibration is executed by sending a same signal on all of the inputs and by looking for the fine position of the trigger on each of the channels.

In the case where the board is triggered on one of the input signals, a fine synchronisation method consists of interpolating by software the crossing of the signal through the trigger threshold on the given channel, this permitting the fine datation of all the measured channels.

III.1.b) Channels situated on different boards.

The synchronization is only possible if the trigger source is common to the different boards. For this, several possibilities can be envisaged :

- to use an external trigger signal common to all of the boards.
- to generate the trigger signal on a fixed board (master) which triggers itself and to send its TRIG_OUT signal output to the external trigger input of the other boards (via a NIM buffer if there is more than one target board).
- to generate the trigger signal on any one of the boards. The TRIG_OUT outputs of all of the boards will then be connected on an external NIM logic then the result will be redistributed in a

synchronous fashion to all the boards via their EXT_TRIG input. It is this latter input which will then be programmed as the source of the asynchronous trigger via the bit 4 of the TRIGGER_TYPE register on all the boards.

In all cases a calibration of the temporal offset between the boards is necessary. This calibration, similar to that which is necessary to align the channels from the same board, will be dependent upon the set-up (length of the cables...).

III.2. SYNC OUT and BUSY signals. Partial reading of the matrices.

One of the NIM outputs of the front panel can be configured either as a SYNC_OUT, or as a BUSY respectively with the help of the S4 and S2 straps. SYNC_OUT is a synchronization signal corresponding to the writing in the first cell of the second column of the circular analog memory, and which can be made available on the front panel. For certain applications, this signal can permit triggering of the source analog signals and thus guaranties their fixed position in the memory. Thus, if the temporal occupation of the signals to acquire is low, the user will have the possibility to only re-read the beginning of the depth of the analog memory and to thus limit the dead time linked to the acquisition.

BUSY is a signal destined to inform the external world that the board is not ready to receive a signal (it is either idle, or in the process of transferring data between the MATAQ chips and the RAM, or at the beginning of the acquisition phase). Its transition to 0 indicates then that the board is now ready to record a signal.

III.3. Calibrations.

In order to attain the optimal metrological performance, the MATAQ32 board requires calibrations. These remain valid for several weeks, even several months.

III.3.a) Calibration of the interpolator.

The temporal interpolator (vernier) requires a calibration. This calibration, based on a statistical measure, will require the acquisition of several thousand events and can last from one second to a couple of minutes depending on the type of bus and on the software used. It can be done with the inputs connected to any source, but the trigger must be asynchronous in relation to the clock. The result of this calibration will be a “square” histogram, of which the sides correspond to two successive rising edges of Fp. The corresponding value on the left side (*MINVER*) will be the « zero » of the vernier, and the one on the right side (*MAXVER*) will correspond to a vernier of 1/Fp (in other words 10 or 20ns). The intermediate values will next be deduced at the time of the acquisitions by a simple proportional calculation.

The most precise but the longest calibration method consists in putting the system in the mode (TRIGGER_TYPE, PRETRIG, POSTRIG) which will be used for real measurements, and in accumulating a few thousands of events until the edges of the vernier distribution be well drawn. The precision obtained will then be the highest but many minutes might be necessary.

If a lower precision is sufficient, faster modes do exist. The diagram in Fig 7, which follows from that in Fig 4, indeed shows the sequencing of such a calibration, optimized so as to be the fastest possible. In particular :

- The PRETRIG and POSTTRIG are fixed at their minimal value.

- NB_OF_COL_TO_READ has to be set to 1.
- Only the vernier values are read in the RAM. In other words, if NCH channels are read, only the 2*NCH first data are read and only the NCH+1 to 2*NCH words are conserved (cf IV.3).

After a certain number of acquisitions (at least 10000), the boundaries of the vernier *MINVER* and *MAXVER* can be calculated.

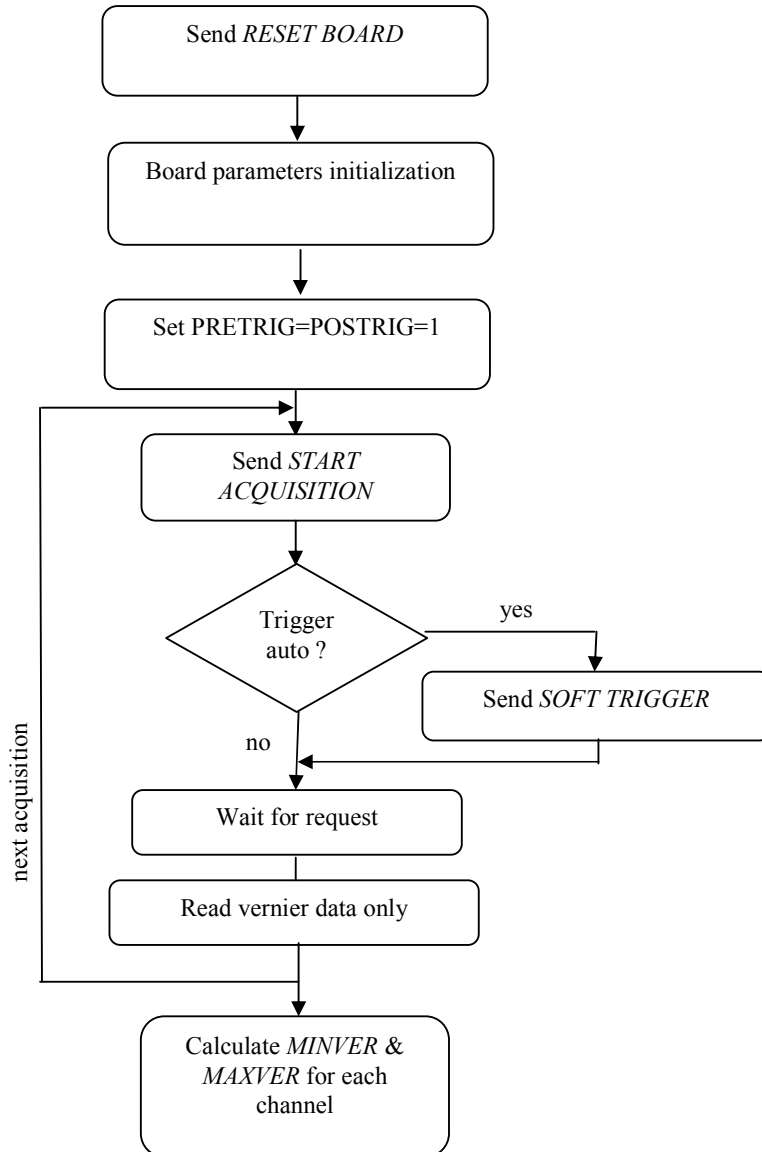


Fig 7 : diagram of the calibration of the verniers.

At first approximation, it is possible to simply use the minimal and maximal values of the vernier for *MAXVER* and *MINVER*. This method is sufficient to obtain temporal resolutions in the region of 70ps RMS.

To get greater precision, one must in order to find the two sides fix a threshold corresponding to half the mean number of ADC counts in the « square » distribution.

To obtain even more precision, it is possible to use more complex methods.

A second, much faster method of calibration is available. For this :

- Charge NB_OF_COL_TO_READ at 0.
- Position the trigger in auto mode.
- Validate the internal random trigger.
- Launch a Start_ACQUISITION.

The RAM is then filled with 65536 vernier values corresponding to 16384 random triggers. For each trigger one finds only 4 values, arranged in the following order :

Channel 3 vernier, channel 2 vernier, channel 1 vernier, channel 0 vernier.

At the end of this calibration, an interruption is generated in order to permit the user to launch a reading. This reading can be realized in block mode, which permits realization of the calibration of the vernier in less than one second if the PRETRIG and POSTRIG are short.

One must note that for this particular method of calibration, the distributions obtained are not necessarily uniform. Nevertheless, the MAXVER and MINVER boundaries are extremely well-defined and therefore perfectly exploitable for corrections. If ever this weren't the case, it would be necessary to run the calibration again but with a different value of PRETRIG.

Our experience showed us that this calibration remains valid several weeks, even several months. The boundaries can nevertheless be updated in real time from the readout event data if their triggering is random relatively to the board pilot clock.

III.3.b) Calibration of the pedestals.

For this, a calibration of the baselines is necessary. This operation will be necessary following **all changes** either in the frequency of sampling, or in the bandwidth of the write amplifier (BWL), or in the read modes (FAST READ MODES). It will consist in realizing a mean measurement over a few tens of raw acquisitions of the baselines for all of the cells (**disconnected or grounded inputs**). The trigger must then be either automatic, or external.

The acquisition procedure is the same as for a standard acquisition, but the reading of TRIG_REC can nevertheless be skipped. Of course not the least temporal correction is made on the data. At each acquisition, the table of the means will be computed and finally recorded for an eventual subtraction by software from the unaligned raw data. This calibration operation lasts less than one second.

In cases where the input is connected to unlikely physical signals, it is also possible to realize this calibration without disconnecting the input. However, it will then probably be necessary to increase the number of acquisitions in order to diminish the effect of the induced additional noise.

Our experience shows us that this calibration remains valid several weeks.

III.3.c) Temporal calibration between different channels.

Cf III.1

IV. TECHNICAL DESCRIPTION.

IV.1. Mechanical and electrical standards.

IV.1.a) Mechanical standard.

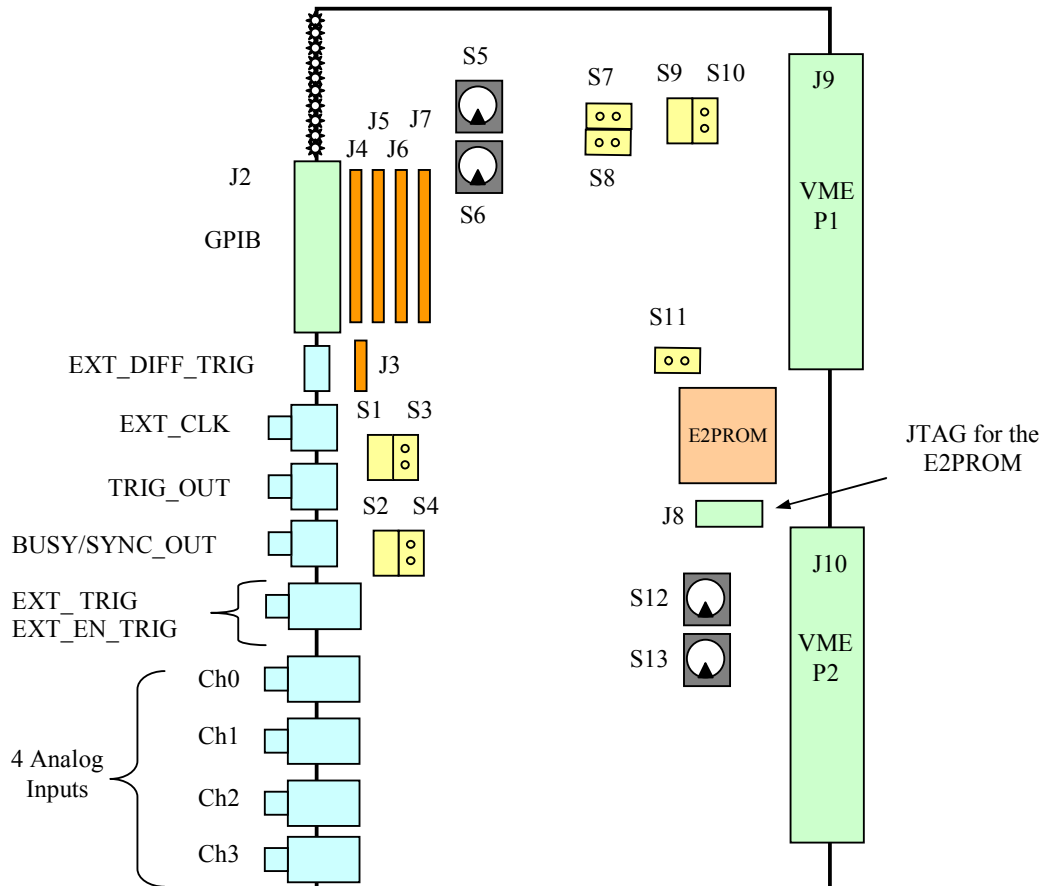


Fig 8 : implementation of the connectors and of the configuration elements on the MATAQ32 board.

The MATAQ32 board is of VME 6U (160x233,3mm²) mechanical format. The two connectors P1 and P2 of the VME crate are usable, both for the supply and the VME dialogue. However, these boards can completely be accessed via the GPIB bus out of a VME crate, or by only using the latter as mechanical and power supply support.

The plugs used for all the digital inputs/outputs are of female LEMO type. The analog inputs are either in double LEMO, simple LEMO, or in SMA, depending on the version.

IV.1.b) Electrical interfaces.

The MATAQ32 board is compatible with two acquisition buses :

- VME via the P1 connector of the VME (plus the P2 for the A32/D32 mode), 96 pin male connector DIN 41612 .
- GPIB via the HE10 connector located on the front panel (26 points male).

This board has an address coded over 8 or 16 bits, configurable through a set of hexadecimal rotary switches. For the GPIB and the VME A24/D16, one uses only the two rotary switches S5 and S6. For the VME A32/D32, one must also use the two rotary switches S10 and S11.

- In GPIB, the address is configurable from 1 to 29 (decimal).
- In VME, the address is configurable from h01 to hFF on the bits 16 to 23 for the A24/D16 mode, and from h0001 to hFFFF on the bits 16 to 31 for the A32/D32 mode.

The choice of the type of interface is determined by the S10 jumper. By default (without jumper), the bus used is the VME. When the jumper is mounted, it is the GPIB which is used.

IV.1.c) Summary of front panel signals.

The fast logical signals of input “EXT_TRIG” and of output “BUSY/SYNC_OUT” and “TRIG_OUT” of the MATAQ32 board use the NIM standard (-16mA in 50 Ohms for the logical state « 1 », no current for the logical state « 0 »).

| Plug name | Purpose | Connector | I/O | TYPE |
|------------------|--|----------------------------|-----|-------------------------------|
| IN0+ to IN3 + | Positive Analog Inputs | Half double LEMO or SMA | I | 50Ohm terminated |
| IN0- to IN3 - | <i>Negative Analog Inputs (option)</i> | Half double LEMO | I | 50Ohm terminated |
| EXT_EN_TRIG | External Trigger Enable | Half double LEMO | I | NIM |
| EXT_TRIG | External Trigger | Half double LEMO | I | NIM |
| EXT_DIFF_TRIG | External Trigger | Double pin | I | DIFF ECL (adaptable by J3) |
| EXT_CLK | External clock | LEMO | I | NIM |
| TRIG_OUT | Trigger Output | LEMO | O | NIM |
| BUSY/SYNC_OUT | Busy/Synchro Output | LEMO | O | NIM |

The front panel leds permit having an image of the current status of the board. The green ones shows the presence of the external power supplies ; the yellow ones that of the supplies realized on the board by the regulators. Finally, the red ones are linked to the internal signals via monostables which permit the visualization of very short pulses and to digital gates for the continuous levels.

| Led name | Type | Function |
|------------|-------------------|--|
| VME | Monostable + gate | VME access acknowledged by the board. |
| GPIB | Monostable + gate | GPIB access acknowledged. Remains ON if no EOI is sent by the controller at the end of a writing sequence. |
| RESET | Monostable + gate | Board reset. |
| CLOCK | Monostable only | The Altera FPGA is providing the main clock to the board. |
| BUSY | Monostable + gate | Displays the BUSY signal. |
| ACQRUNNING | Monostable + gate | Is set ON after a “start acquisition” command. Is set OFF at the end of the POSTTRIG. |
| TRIG | Monostable + gate | Image of the TRIGA signal. |
| WR-RAM | Monostable + gate | Write access to the data RAM. |
| INTERRUPT | Monostable + gate | Displays the INTERRUPT signal which is produced at |

| | | |
|--|--|--------------------------------------|
| | | the end of the acquisition sequence. |
|--|--|--------------------------------------|

IV.1.d) Supplies.

The MATACQ32 board uses the standard supplies of the VME : +/-12V and +5V.

It fabricates the -5V for the ECL logics starting from the +5V with the help of a DC-DC converter capable of delivering 600mA.

The intensities consumed on these different supplies are :

| | |
|--------------|---------------------|
| +12 V | 0.3A + X x Y x 0.7A |
| -12V | 0.2A + X x Y x 0.7A |
| +5V | 1.5A |

where X is the rate of acquisition = relation of time spent awaiting the event / total time .

X is worth 1 in the case of infrequent event acquisitions.

X is low (can fall to 1%) in the case of frequent events. In this case indeed, the dead time for readout is dominant in relation to the time spent awaiting the event.

Y depends on the bandwidth mode (cf control registers in IV.4) :

| | BWL0 | BWL1 | Bandwidth | Y |
|----------------------------|-------------|-------------|------------------|----------|
| Full bandwidth mode | 0 | 0 | 300 MHz | 1 |
| Normal mode | 1 | 0 | 230 MHz | 0,6 |
| Normal mode | 0 | 1 | 230 MHz | 0,6 |
| Low power mode | 1 | 1 | 180 MHz | 0,35 |

IV.1.e) Pinout of the non-standard connectors.

- GPIB Connector (HE10 26 pins male)

Reference : J2.

| | |
|-----------|----------|
| 1 : D1 | 2 : D5 |
| 3 : D2 | 4 : D6 |
| 5 : D3 | 6 : D7 |
| 7 : D4 | 8 : D8 |
| 9 : EOI | 10 : REN |
| 11 : DAV | 12 : GND |
| 13 : NRFD | 14 : GND |
| 15 : NDAC | 16 : GND |
| 17 : IFC | 18 : GND |
| 19 : SRQ | 20 : GND |
| 21 : ATN | 22 : GND |
| 23 : GND | 24 : GND |
| 25 : NC | 26 : NC |

The corresponding HE10 female connector can be directly pressed on a 24 wire flat cable equipped at the other extremity with a GPIB standard connector (CENTRONICS 24 points). Up to 18 HE10 female connectors can be mounted in parallel on the flat cable (be careful then to only mount the bus polarization networks on only one of the boards).

- JTAG connector (HE10 10 pins male)

Reference : J8.

Permits the reconfiguration of the E2PROM (EPC2) from an Altera file « .pof » thanks to JTAG.

IV.1.f) Straps and resistor network sockets.

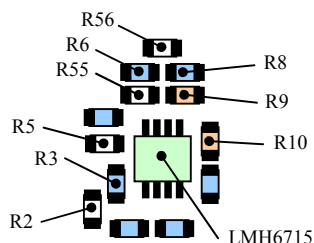
A certain number of sockets for straps and resistor networks are available on the board. These are their respective roles :

| Reference | Role |
|-------------|--|
| S1 | one utilizes the differential EXT_TRIG differential input (exclusive of S3) |
| S3 | one utilizes the unipolar EXT_TRIG input by Lemo (exclusive of S1) |
| S2 | the BUSY/SYNC_OUT output releases the BUSY signal (exclusive of S4) |
| S4 | the BUSY/SYNC_OUT output releases the SYNC_OUT signal (exclusive of S2) |
| S5 and S6 | address of the board (see IV.1.b) |
| S7 | one utilizes the EXT_CLK input for the main clock (exclusive of S8) |
| S8 | one utilizes the 100MHz oscillator for the main clock (exclusive of S7) |
| S9 | Do not use |
| S10 | choice of the acquisition data bus (see IV.1.b) |
| S11 | normally absent. Prevents the conf_done to rise which then permits not to validate the configuration of the Altera at power-up. |
| S12 and S13 | address of the board (see IV.1.b) |
| J3 | adaptation for the EXT_DIFF_TRIG input. Place 100 ohms between the pins 1 and 2 and between the pins 3 and 4 |
| J4 | pull-down for the GPIB. Place an 8 resistor network 6.8k with common pin |
| J5 | pull-up for the GPIB. Place an 8 resistor network 3.3k with common pin |
| J6 | pull-down for the GPIB. Place an 8 resistor network 6.8k with common pin |
| J7 | pull-up for the GPIB. Place an 8 resistor network 3.3k with common pin. Caution : only place these 4 networks once if the boards are linked. |

IV.1.g) Implementation of differential inputs.

The input signals are by default unipolar. In order to use differential inputs, one must make use of certain free CMS-805 resistor locations located close to the input amplifiers (LMH6715) and change some others. The equipment map of this zone of the board is presented below. The already present resistors appear in blue, whereas the free locations appear in white.

In order to wire a differential input (with both inputs adapted on 50 ohms), one must first remove the resistors R3, R6 and R8. Then one has to put 84.5 ohms on R2, 0 ohm on R5 (use the former R3), 121 ohms on R55 and 50 ohms on R56. Finally, R9 (750 ohms) has to be replaced by 237 ohms and R10 (30.9 ohms) by 10 ohms.



Implementation of the components around the differential amplifier located in the block, bottom left of the MATAcq chip.

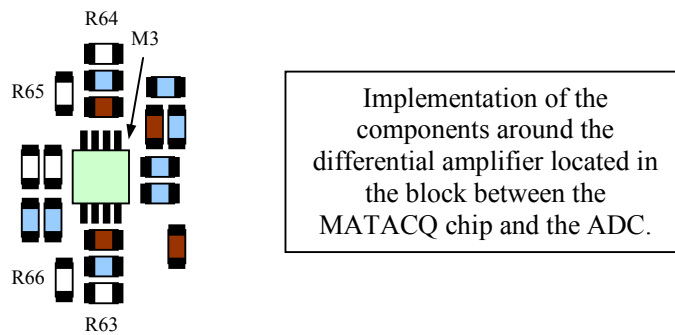
IV.1.h) Using a shifted input range.

The input signal range is defined by default to be $\pm 0.5V$. In order to shift it, one has to make use of free CMS-805 foot-prints located around the M3 amplifier (LM4130), itself located between the MATAcq chip and the ADC (ADS803E). The equipment map of this zone of the board is shown below.

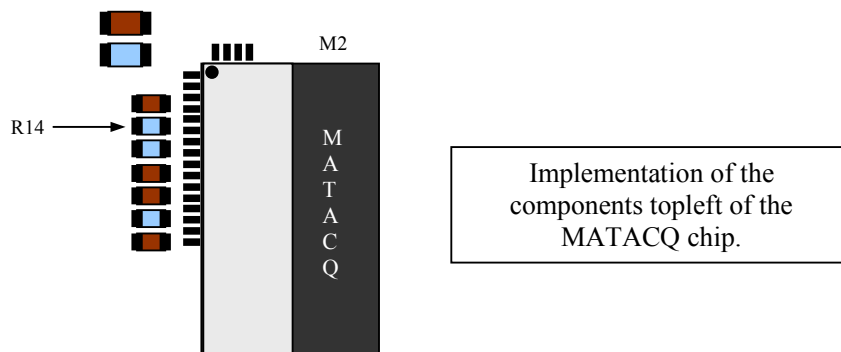
To shift the baseline downwards in order to deal with mainly positive pulses, mount R63 and R65.

To shift the baseline upwards in order to deal with mainly negative pulses, mount R64 and R66.

The values of those two 1%-precision resistors must be identical. The range is saturated with 2k: that is therefore the minimum value. The tabulation below displays the different resistor values necessary to obtain the targeted shifts.



It is also necessary to shift the fixed reference of the vernier (*VerRef2*) in order to compensate for the preceding operation at the level of the latter. Therefore, one has to modify the value of the resistor R14 (see figure below) which is 18k by default. It realizes a dividing bridge with R15 (20k) located just below. One has actually to shift the middle of that bridge with a voltage proportional to the shift aimed at on the signal itself. The values necessary for R14 thus also appear in the tabulation below.



| Input range neg - pos | Shift in V | Value of R64 & R66 | Value of R63 & R65 | Value of R14 |
|--------------------------|------------|--------------------|--------------------|--------------|
| 90% - 10% | +0,4V | 2,5k | X | 77k |
| 80% - 20% | +0,3V | 3,3k | X | 50k |
| 70% - 30% | +0,2V | 4,6k | X | 35k |

| | | | | |
|------------------|-------|----|------|------|
| 60% - 40% | +0,1V | 7k | X | 25k |
| 50% - 50% | 0V | X | X | 18k |
| 40% - 60% | -0,1V | X | 7k | 13k |
| 30% - 70% | -0,2V | X | 4,6k | 9k |
| 20% - 80% | -0,3V | X | 3,3k | 6k |
| 10% - 90% | -0,4V | X | 2,5k | 3,6k |

IV.2. Interfaces.

IV.2.a) VME interface.

The board is compatible with the A24-D16 and A32-D32 modes. It supports the h09, h0B, h0D, h0F, h39, h3B, h3D and h3F ADDRESS MODIFIERS, and therefore deals with the accesses in block mode. The sub-addresses are coded over the bits 08 to 15.

The base address is given by : switch_address x h10000 (0<switch_address<hFF for A24-D16 and 0<switch_address<hFFFF for A32-D32)

The offset is given by : sub_address x h100 (the sub-address list is given in *IV.2.d*)

The complete address is given by : base_address + offset

The IRQ3 is used to signal to the acquisition system the presence of data waiting in the RAM. This interruption should be released by any writing at the address of the INTERRUPT register, which sets it back to 0. It is anyhow also reset by the START_ACQ command.

The sending of IRQ3 can be inhibited by the positioning at 1 of the INH_IRQ bit (bit 1 of the CONTROL_REG register).

The presence of waiting data can be equally detected without treating the interruption, but by scanning the presence of a 1 in the same INTERRUPT register. However, it should be avoided because it is a source of noise during the data acquisition.

The reading of the data stored in the RAM is executed by realizing N successive readings at the address of RAM_DATA or by realizing series of readings in block mode at this same address (blocks of 128 16-bit words or 64 32-bit words maximum to comply with the VME standard).

IV.2.b) GPIB Interface.

The MATAcq32 boards can have an address set between 0 and 29 (decimal).

- **Writing**

The GPIB commands are carried out by writing a string of characters in the board situated at the address designated by the rotary switches.

The ASCII code of the first character corresponds to the sub-address of the order to be executed or of the register to be addressed.

The ASCII codes of the following characters correspond to the data (only one data byte except in the case of a writing to the sub-address hFF).

- **Reading**

A method of reading by block was implemented to accelerate the reading by GPIB. The reading of an element is thus executed in the following way :

* Writing operation of the 4 characters (#FF)(#LSB)(#MSB)(#REG) with

- (#FF) : ASCII hFF code character
- (#LSB) : ASCII code character corresponding to the 8 lowest significant bits of the number of bytes to read (nbyte).
- (#MSB) : ASCII code character corresponding to the 8 most significant bits of the number of bytes to read.
- (#REG) : ASCII code character corresponding to the sub-address of the register to read (h0C to read the data stored in the RAM for instance).

* Reading operation of nbyte characters.

In the general case (outside DATA RAM) nbyte =1.

In GPIB, the 16 bits of data converted by the ADC are read in two consecutive bytes in the order MSByte, LSByte.

- Interruption

At the end of the emptying of the data in the RAM, the MATAcq32 board generates a « Service Request (SRQ)» on the GPIB bus. The board is not compatible with the PARALLEL or SERIAL POLLING protocols. However the GPIB controller can identify the SRQ emitter by sequentially scanning the INTERRUPT registers of the different boards. It is not a source of noise because the acquisition is then already terminated.

Like in VME, the interruption (SRQ) is set back to 0 by any writing at the address of the INTERRUPT register, or by the START_ACQ command. In the same way, the presence of waiting data can equally be detected without treating the interruption, but by scanning the presence of a 1 in the same INTERRUPT register.

- Broadcast Mode.

A writing at the address 30 (decimal) permits realization of a writing in all the MATAcq32 boards present on the GPIB bus.

IV.3. Reading of the data in the RAM; mapping .

During the reading of the MATAcq chips, the data are digitized by the 12-bit ADC then transferred in the RAM. The sequence order is always the same : one starts by reading the first cell (upper left-hand) of the matrix, and one finishes with the last one (lower right-hand), this independently of the position of the trigger and of the stopping point of the acquisition.

One will therefore have to realign the data in relation to the trigger, which was explained in II.4.b). The channels are treated in parallel, and can be masked individually during the writing in RAM. This implicates that, in the case where NCH channels are validated by the mask (default value = h0F), the data are organized in 16-bit words by groups of NCH addresses corresponding to the NCH channels (**in the order 3 to 0, minus the masked channels**). The table below clarifies the arrangement of the words in the RAM (10252 words maximum).

The data in the table marked with an asterisk (*) are reserved for expert usage.

| RAM internal address (HEX) | Type of data |
|----------------------------|--------------------|
| 0000 to NCH-1 | First sample (*) |
| NCH to 2*(NCH)-1 | Vernier |
| 2*NCH to 3*(NCH)-1 | Reset baseline (*) |
| 3*NCH to 4*(NCH)-1 | 1st cell |

| | |
|---------------------------------|-------------------------|
| 4*NCH to 5*(NCH)-1 | 2 nd cell |
| 5*NCH to 6*(NCH)-1 | 3 rd cell |
| ... | ... |
| 2562*NCH to 2563*(NCH)-1 | 2559th cell |
| 2563*NCH to 2564*(NCH)-1 | 2560th cell (last cell) |

If the number of columns to read (register NB OF COLS TO READ) chosen is less than 128 (default value), the transfer in RAM will stop as soon as this number has been reached. In such a case, one must be sure that the useful data is located in the first part of the matrix. This is the role of the SYNC_OUT output which signals the passage into the beginning of the matrix. In order to validate it, the ESO bit must be placed at 1 in the control register (see IV.4), and one must displace the corresponding strap (S2).

The channel mask register furthermore permits validation of only the utilized channels, which will also permit reduction of the volume of data stored in the RAM. In this case indeed, only the data of the valid channels will be recopied in the RAM, all the while respecting the same storage order of the data.

The access to reading in the RAM is done by secondary addressing. Its internal address is indeed controlled by a 16-bit counter (RAM_INT_ADD) located in the controller placed on the board in the FPGA. This is not to be managed by the external interfaces, the acquisition sequencer generating its own address starting from zero for the writing in the RAM. This counter gets auto-incremented in the course of the addressing. It is systematically reset at zero at the end of the writing cycle, which permits not having to load it when one wants to read all of the memory. However, one can directly have access to an address or a group of addresses given in the RAM by pre-loading it.

Seen from the bus, the reading in the RAM is therefore always done at the same h0C (in GPIB) or h0D (in VME) address.

In GPIB, the 13 bits of data converted by the ADC and stored in the RAM (accessible by reading of 2 bytes at the 0C address) are read in order MSByte, LSByte. Only the 13 LSbits of the data issued from a conversion of the ADC have a significance : the bits from 0 to 11 correspond to the 12 encoded bits. The bit 12 is at 1 in cases of overflow. The 3 MSbits are fixed at 0 on the board, they can be masked at the reading.

IV.4. List of the sub-addresses.

The table of the sub-addresses corresponding to the different commands is presented below. A certain number among them are reserved for expert usage. They are indicated by the word « RESERVED » in the « NAME » column. They will not be described in this document and **they should not be used**. In VME, the sub-addresses are coded over the bits A8 to A15, the bits A1 to A7 being unused. For more detail on the addressing in VME or GPIB, refer to IV.2.

| Subadd (HEX) | GPIB | VME | ACCES S | REG or COM. | NAME | bits of data | Default @ power on |
|-----------------|------|-----|------------|----------------|--|-----------------|--------------------------|
| 08 | YES | YES | W | Com | RESET BOARD | NO | - |
| 09 | YES | YES | W | Com | LOAD TRIGGER THRESHOLD DAC | NO | - |
| 12 | YES | YES | W | Com | RESERVED | NO | - |
| 13 | YES | YES | W | Com | RESERVED | NO | - |
| 14 | YES | YES | W | Com | RESERVED | NO | - |
| 15 | YES | YES | W | Com | RESERVED | NO | - |
| 16 | YES | YES | W | Com | RESERVED | NO | - |
| 17 | YES | YES | W | Com | START ACQUISITION | NO | - |
| 1C | YES | YES | W | Com | SOFTWARE TRIGGER | NO | - |
| 0A | YES | NO | W/R** | Reg | TRIGGER THRESHOLD DAC LSB (byte->GPIB) | 8 | 0 |
| 0B | YES | NO | W/R** | Reg | TRIGGER THRESHOLD DAC MSB (half byte->GPIB) | 4 | 0 |
| 0A | NO | YES | W/R | Reg | TRIGGER THRESHOLD DAC (word->VME) | 12 | 0 |
| 0C | YES | NO | R | Reg | RAM DATA MSB + LSB -> GPIB | 8 | - |
| 0D | NO | YES | R | Reg | RAM DATA ->VME | 16 | - |
| 0E | YES | YES | W/R | Reg | RAM_INT_ADD LSB | 8 | 0 |
| 0F | YES | YES | W/R | Reg | RAM_INT_ADD MSB | 8 | 0 |
| 10 | YES | YES | W/R | Reg | MAT CTRL REGISTER LSB | 8 | 0 |
| 11 | YES | YES | W/R | Reg | MAT CTRL REGISTER MSB | 8 | 0 |
| 18 | YES | YES | W/R | Reg | PRETRIG LSB | 8 | 0 |
| 19 | YES | YES | W/R | Reg | PRETRIG MSB | 8 | 40 |
| 1A | YES | YES | W/R | Reg | POSTTRIG LSB | 8 | 64 |
| 1B | YES | YES | W/R | Reg | POSTTRIG MSB | 8 | 0 |
| 1D | YES | YES | W/R | Reg | TRIGGER TYPE | 8 | 0 |
| 1E | YES | YES | W/R | Reg | TRIGGER CHANNEL SOURCE | 4 | 0 |
| 20 | YES | YES | R | Reg | TRIG_REC | 1 | - |
| 21 | YES | YES | W/R | Reg | FAST READ MODES | 2 | 0 |
| 22 | YES | YES | W/R | Reg | NB OF COLS TO READ | 7 | 128 |
| 23 | YES | YES | W/R | Reg | CHANNEL MASKS | 4 | h0F |
| 24 | YES | YES | W/R* | Reg | RESERVED | 8 | 64 |
| 30 | YES | YES | W/R* | Reg | POST STOP LATENCY | 8 | 4 |
| 31 | YES | YES | W/R* | Reg | POST LATENCY PRETRIG | 8 | 1 |
| 80 | YES | YES | W/R | Reg | INTERRUPT | 1 | 0 |
| 81 | YES | YES | W/R | Reg | FP_FREQUENCY | 2 | 1 |
| 82 | YES | YES | R | Reg | FPGA VERSION | 8 | - |
| 83 | YES | YES | W/R | Reg | EN_VME_IRQ | 1 | 0 |
| FF | YES | NO | W | Reg | NB OF BYTES TO READ IN BLOCK MODE (GPIB) | 24 (3x8) | 1 |

** : no readback of these registers in GPIB.

The sub-addresses are organized by type. For more detail on their specific use in VME or GPIB, refer to IV.2.

The functions of these different commands and registers are described below :

- **RESET BOARD** : reset of the board. Restores idle state. Does not modify the value loaded in the different registers.
- **LOAD TRIGGER THRESHOLD DAC** : permits transfer of the pre-loaded value in the register of the DAC towards the analog converter itself.
- **START ACQUISITION** : launches the data acquisition and resets the INTERRUPT register. When this is finished, the INTERRUPT signal will be validated and transmitted towards the bus interfaces. This latter signal will also be able to be read at the sub-address h80.
- **SOFTWARE TRIGGER** : permits generation of a trigger coming from a bus interface.
- **TRIGGER THRESHOLD DAC** : register of pre-loading of the DAC. This 12-bit register covers the range from $-0.5V$ (000) to $+0.5V$ (FFF). By GPIB, one has access to the MSBs and LSBs via 2 distinct sub-addresses. The access is necessarily made in the order MSB (0B) then LSB (0A). By VME, the access is made via a single sub-address (0A). After loading of this register, one must transfer the value in the analog converter via the LOAD_TRIGGER THRESHOLD DAC (09) command.
- **RAM DATA** : this is the memory where the data is stored. As above, the access to the data is made differently in GPIB and in VME (see NB OF BYTES TO READ IN BLOCK MODE). The addressing is indirect, the internal address of the RAM being defined by the RAM_INT_ADD counter located in the ALTERA. Data readout thus always makes use of the single 0D address in VME and of the 0E and 0F addresses in GPIB.
- **RAM INT ADD** : this 16-bit counter fixes the internal address of the RAM for the bus access in progress. It is set back to zero by the RESET_BOARD command and by the interruption at the end of the acquisition phase. For a direct access to an address or a given group of addresses, one must pre-load it.
- **MAT CTRL REGISTER** : this is a control register for the acquisition parameters. It covers 11 useful bits. The bits followed by an asterisk are reserved and must be left at zero.

| Bits | Name | Default | Function |
|------|---------|---------|---|
| 0 | BWL | 0 | Regulates the bandwidth of the input amplifiers with BWL1 (cf IV.1.d) |
| 1 | BWL1 | 0 | Regulates the bandwidth of the input amplifiers with BWL (cf IV.1.d) |
| 2 | EBP | 0 | At 1, authorizes the bypass of the input signal towards the ADC |
| 3 | ELD* | - | Reserved |
| 4 | ENVDLL* | 0 | Reserved |
| 5 | EIR* | 0 | Reserved |
| 6 | EPR | 0 | At 1, forces the permanent supply of the reading amplifiers |
| 7 | EPW | 0 | At 1, forces the permanent supply of the writing amplifiers |
| 8 | ESO | 0 | At 1, authorizes the SYNC_OUT signal to be output from the board (thanks to the corresponding strap S4) |
| 9 | ISA | 0 | At 1, inhibits the START_ACQUISITION command. |
| 10 | IRQP | 0 | At 1, inhibits the automatical RQP before the acquisition. |

- **PRETRIG** : this 16-bit register fixes the delay in periods of F_p between the START ACQUISITION and the internal authorization to validate a trigger, whatever the source of the latter. For proper functioning, it must be fixed at a minimum of 5000 for an F_p

frequency of 50MHz and at 10000 for a frequency of 100MHz. By default, its value is 10240.

- **POSTTRIG** : this 16-bit register fixes the delay in periods of F_p between the trigger and the stopping of the acquisition. It permits in practice choosing the useful position of the signal in the window of 2560 cells. By default, its value is 64.
- **TRIGGER TYPE** : this 6-bit register fixes the trigger's source and mode. The bits 6 and 7 permit dealing with the situation where a few cards have been interconnected to work together.

| Bits | Function |
|------|--|
| 0-1 | Val = 0 => SOFTWARE TRIGGER Val = 1 => trigger on discriminator (threshold fixed by the DAC) Val = 2 => external trigger from the TRIG_EXT input Val = 3 => logic "OR" of SOFTWARE TRIGGER and trigger on discriminator |
| 2 | Val = 0 => rising edge Val = 1 => falling edge |
| 3 | Val = 0 => Inhibites random internal trigger. Val = 1 => Authorizes random internal trigger. |
| 4 | Val = 0 => one uses the Trigger normally. Val = 1 => one uses the external Trigger directly and without masking. |
| 5 | Bit = EnValidTrig. Val = 0 => the Trigger directly launches the readout. Val = 1 => the Trigger has to be validated by the EN_EXT_TRIG input in order to launch the readout. |
| 6 | Selection of the reset mode of the BUSY signal: Val = 0 => one takes EN_EXT_TRIG into account. Val = 1 => one ignores EN_EXT_TRIG. |
| 7 | Permits inhibiting the BUSY signal: Val = 0 => the BUSY signal is performing in a usual way. Val = 1 => the BUSY signal is pulled at zero (inactive). |

- **TRIGGER CHANNEL SOURCE** : this 4-bit register fixes the channel(s) from which the discriminators will release the trigger. More than one channel can be validated at the same time because one realizes a logic «OR» of the outputs of the discriminators in the controller.

| Bits | Function |
|------|---|
| 0 | Val = 0 => Disables Trigger on channel 0. Val = 1 => Enables Trigger on channel 0. |
| 1 | Val = 0 => Disables Trigger on channel 1. Val = 1 => Enables Trigger on channel 1. |
| 2 | Val = 0 => Disables Trigger on channel 2. Val = 1 => Enables Trigger on channel 2. |
| 3 | Val = 0 => Disables Trigger on channel 3. Val = 1 => Enables Trigger on channel 3. |

- **TRIG_REC** : this 8-bit register gives the distance between the column where one finds the column pointer at the arrival time of the synchronous trigger and the last column (128). It permits in practice to roughly date the useful signal to the nearest clock rising edge. This dating will be refined with greater precision by the utilization of the vernier.

- **FAST READ MODES** : this 2-bit register permits realization of a faster reading of the MATAQ chips. Usage reserved for experts for it may have an influence on the noise level.

| Bits | Function |
|------|---|
| 0 | Val = 0 => sequence with reading of TRIG_REC (normal) Val = 1 => sequence without reading of TRIG_REC (short) |
| 1 | Val = 0 => sequence departing from the first column (normal) Val = 1 => sequence departing from the STOP (reduced readout depth) |

- **NB OF COLS TO READ** : this 8-bit register gives the number of columns that one wants to read in the matrix. The number of columns can be fixed between 0 et 128. The stored value is by default 128, which corresponds to the whole matrix.
- **CHANNEL MASKS** : each one of the 4 bits in this register individually validates a channel on the board. For this, they must be set at 1. At zero, the corresponding channel is masked and its data will not be recorded in the RAM. Caution : this modifies the format of the frame stored in the RAM (see IV.3).
- **POST STOP LATENCY** : this register permits the programming with steps of 2.5 μ s of the time during which the board waits for the validation signal in the mode where the latter is used to launch the readout of the MATAQ chips towards the RAM. The default value is of 10 μ s whereas the minimum one is of 2,5 μ s.
- **POST LATENCY PRETRIG** : this register fixes with steps of 2.5 μ s the time to wait before enabling the trigger again consequently to the absence of the validation signal during the window fixed by POST_STOP_LATENCY. The default value as well as the minimum one are of 2,5 μ s.
- **INTERRUPT** : this register memorizes the arrival of the interruption which signals the end of the acquisition phase. The INTERRUPT signal is forwarded towards the acquisition buses, but it can also be read here. It is also here that it must be released and reset at zero by a simple write access. It is anyhow reset by the START_ACQ command.
- **FP FREQUENCY**: this 2-bit register permits fixing of the Fp period. It is initialized at 1.

| Bits | Function |
|------|--|
| 0-1 | Val = 1 => Fsample = 2GHz. Val = 2 => Fsample = 1GHz. |

- **FPGA VERSION** : this 8-bit read-only register permits reading of the version number of the FPGA. The 3 MSbits give the type of board and the 5 LSbits the version number of the firmware stored in the PROM. The code corresponding to the MATAQ32 board is 3, which gives a root number of h60 for FPGA VERSION.
- **EN VME IRQ** : this 1-bit register permits authorization (1) or not (0) of the output of the interruption at the end of the acquisition towards the VME bus on VME_IRQ3.
- **NB OF BYTES TO READ IN BLOCK MODE** : for the readings in block mode by GPIB solely, this 16-bit register permits fixing the number of bytes contained in the block. In order to simplify the accesses by reading to the RAM, one will send as in the reading order 4 bytes of data : the 1st with hFF, the 2nd and the 3rd with respectively the LSBs then the MSBs of the number of bytes to read, and finally the 4th with the sub-address h0C for the RAM. The MSBs then the LSBs will then be sent successively. Do not forget to double the number of data to read in the RAM when passing from the number of words to the number of bytes.

IV.5. Synopsis of the board.

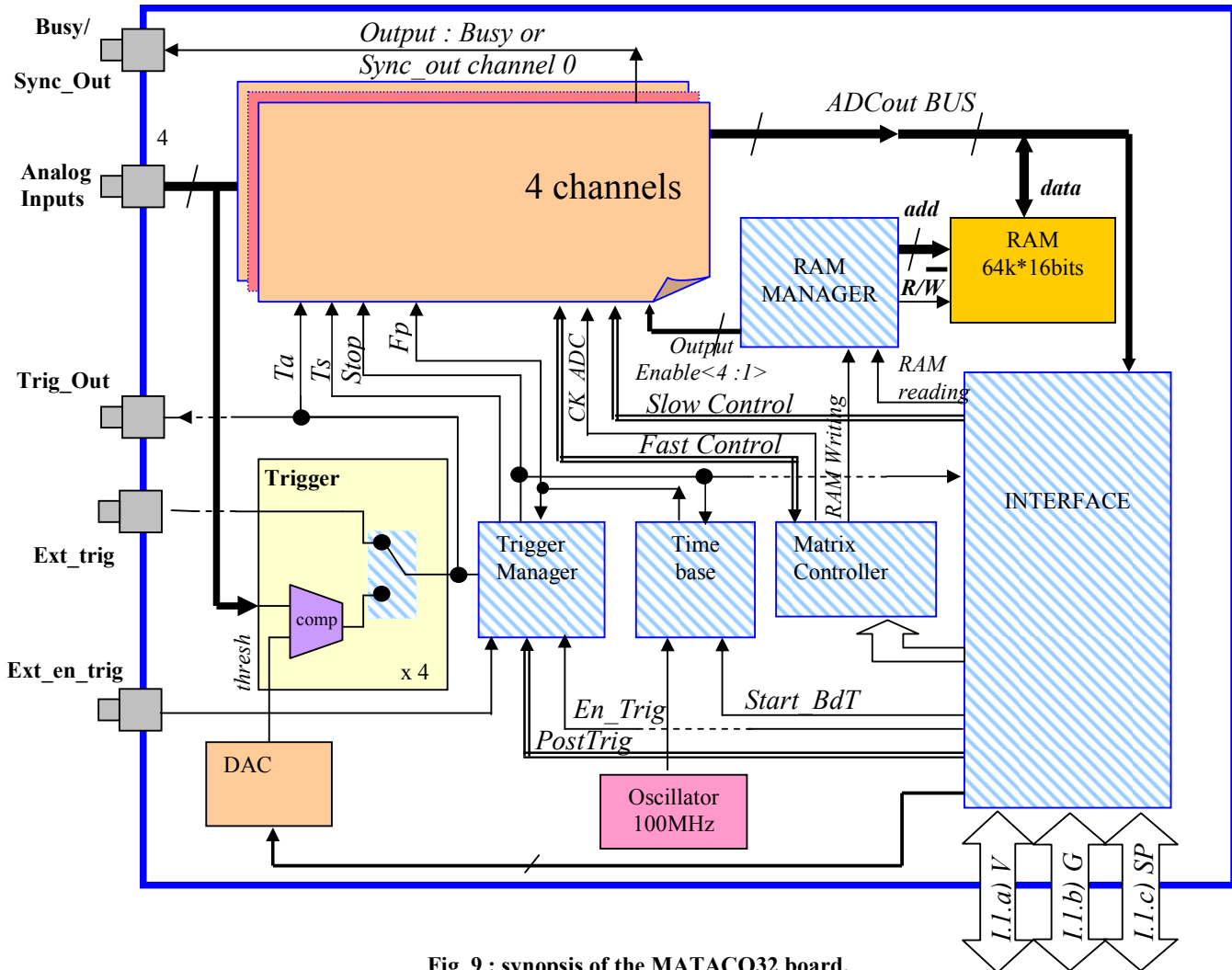


Fig 9 : synopsis of the MATAQ32 board.

The architecture of the MATAQ32 board (Fig 9) is modular. This architecture as well as the components used were selected so as to minimize the costs of conception and production of the board. The board is principally made up of six blocks :

- The 4 channels of acquisition and fast digitization (synopsis of a channel in Fig 10).
- The management of the trigger.
- The management of the clocks.
- The slower readout of the MATAQ chips.
- The management of writing and of re-reading the digital memory (RAM).
- The interfacing with the acquisition system.

The last four blocks (except the RAM itself) as well as the digital part of the trigger system are integrated in a single programmable component (FPGA). This considerably reduces the costs of production and will permit an easy upgrading of the system in the future.

The different logical level translations present on the board are not represented in the synopsis.

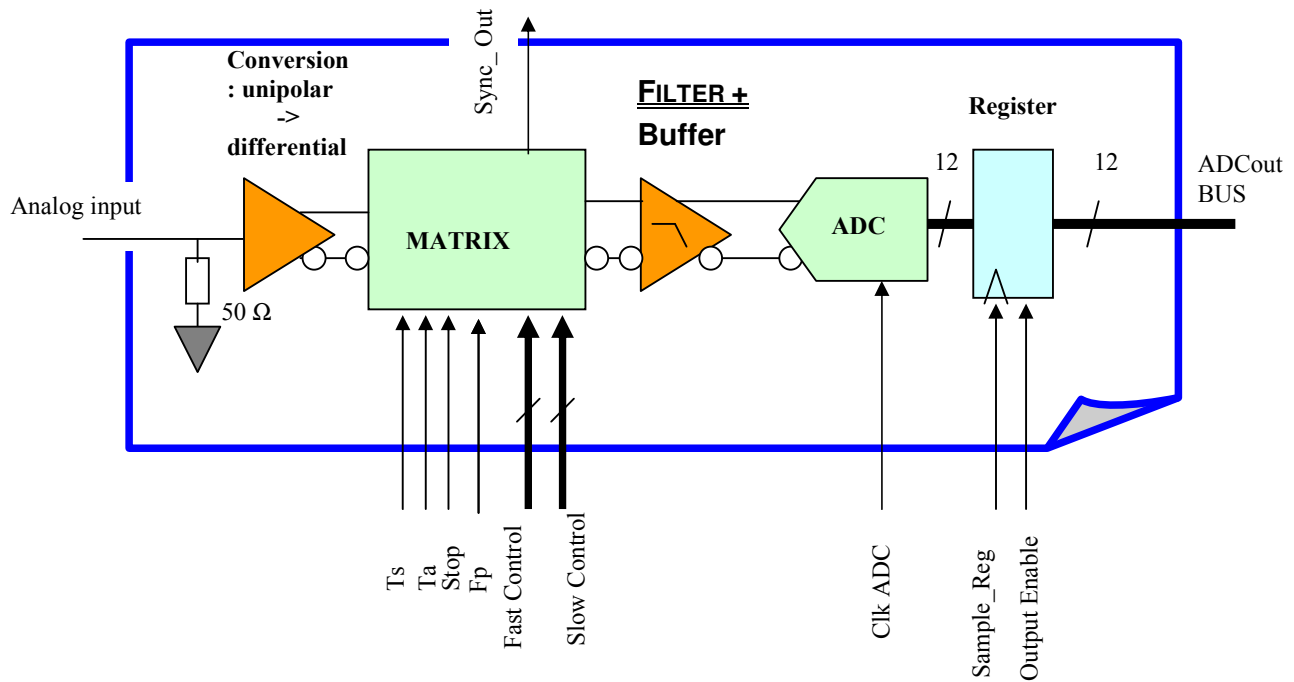


Fig 10 : Synopsis of an acquisition channel on the MATAcq board.

The elementary block of the analog acquisition is represented in Fig 10. It includes :

- The 50-Ohm adaptation of the input.
- A large bandwidth amplifier making it possible to feed the MATAcq chip in differential.
- The MATAcq chip.
- A bandwidth limiter filter.
- The 12bit-5MHz ADC, differential.
- A register allowing the multiplexing of the data coming from the different channels towards the RAM.

V. SPECIFICATIONS AND PERFORMANCES.

The following table summarizes the principal specifications and performances of the MATAcq32 board.

Input analog signals

| | |
|---------------------|---------------------------------------|
| Number of channels | 4 |
| Input impedance | 50 Ohms |
| Dynamic Range | +/- 0.5V |
| Bandwidth | 300MHz |
| Noise/signal ratio | > 12bit RMS (noise =180 μ V RMS) |
| Harmonic distorsion | < -60dB for sinusoidal input at 25MHz |

| | |
|--------------------------------|---------------|
| LSB (digitization step) | 0.25mV |
| Integral Non Linearity | < 1 per mil |
| Differential Non Linearity | < 0.5 per mil |
| Relative gain between channels | < +/-1%. |

Sampling

| | |
|-------------------------------------|--|
| Max Frequency | 2GS/s |
| Min Frequency | 1GS/s |
| Time precision in a single channel | 15ps RMS typical |
| Time precision between two channels | 20ps RMS typical |
| Depth per channel | 2560 points (of which 2520 are usable) |

Trigger

| | |
|---------------------------------|-------------------|
| Threshold setting dynamic range | +/- 0.5V |
| Threshold setting step | 0.25mV |
| Time precision | 50ps RMS typical* |

Analog to Digital Conversion

| | |
|---|---------|
| Conversion frequency | 5MHz |
| Resolution | 12 bits |
| Time to empty the matrices into the RAM | 650µs |

Acquisition

| | |
|--------------------------|---|
| Acquisitions rate (VME) | Up to 500 acquisitions/s over 4 full channels |
| Acquisitions rate (GPIB) | Up to 100 acquisitions/s over 4 full channels |

Front Panel Signals (TRIG_OUT, SYNC_OUT, TRIG_EXT)

NIM Standard (negative logics) :

| | |
|-----------------------------|---------|
| Input Impedance (TRIG_EXT) | 50 Ohms |
| Lower max level (logic 1) | -0.6V |
| Upper min level (logic 0) | -0.2V |

Power Supplies

| | |
|-------------------------|---------------------------------------|
| Min voltage on « +5V » | 4.5V |
| Min voltage on « +12V » | 6.5V |
| Min voltage on « -12V » | -6.5V |
| Consumption on +5V | 1.5A |
| Consumption on +12V | typ 1A (varies with acquisition rate) |
| Consumption on -12V | typ 1A (varies with acquisition rate) |

* includes both the sampling and trigger precision.

VI. BIBLIOGRAPHY.

[1] E. Delagnes, D. Breton , **Echantillonneur analogique rapide à grande profondeur mémoire.** French patent n°01 05607 from April 26th 2001. US Patent **6,859,375** from February 22nd 2005 : **Fast analog sampler with great memory depth.**