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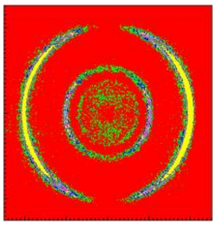
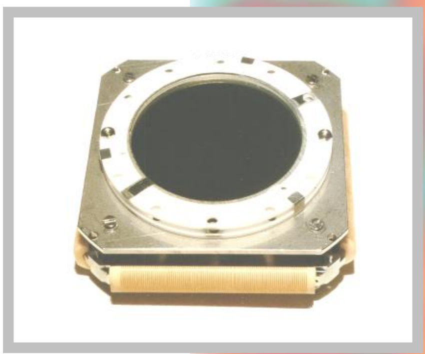
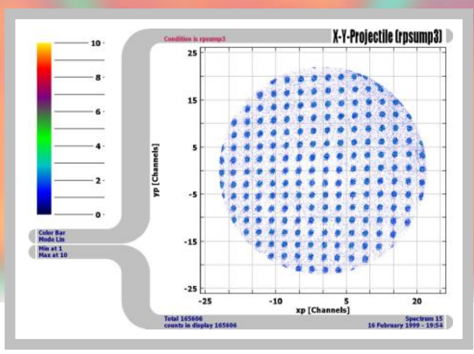
Supersonic Gas Jets
Detection Techniques
Data Acquisition Systems
Multifragment Imaging Systems



The HM1-B Module

(Version 9.5.907.1)





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1 Components

1.1 HM1 module

I/O connector is not SCSI- or Parallel-Port standard

Figure 1.1: HM1-B/T and HM1-B front panel

1.2 I/O interface card for PC (ISA or PCI)

This is not an SCSI interface card

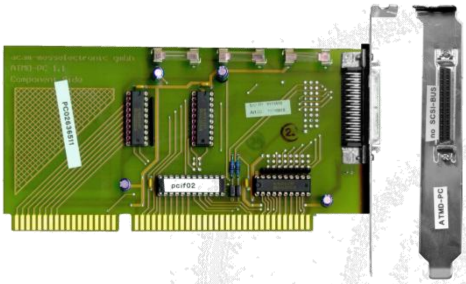


Figure 1.2: ISA interface card

Figure 1.3: PCI interface card

1.3 I/O interface card – HM1-B connection cable

This is a standard SCSI cable

Figure 1.4: HM1-B, I/O interface card connection cable

1.4 HM1 (all models) ECL cables or optionally NIM-ECL converter

Figure 1.5: HM1 ECL cable

Figure 1.6: NIM-ECL converter

2 Overview

The **HM1** is based on the GP1-chip of ACAM. It has a common-start input and 4 channels of stop inputs, all differential ECL. The resolution is 133ps or better (adjustable) the range is 14bit or up to 30bit in a special long-range mode (resolution and pulse-pair separation ability reduced). It can be operated in three modes:

a) In the standard mode, *"transparent mode"*, it can detect up to 3 or 4 hits per channel with a pulse pair resolution of about 15ns. The data acquisition (DAQ) in this operation mode is managed by the PC. The DAQ speed is limited to about 18kHz, divided by the number of hits to be detected per channel. The data are stored in list-mode on the PC- hard disc. Two **HM1** modules can be combined to a double module featuring effectively an 8-channel version (with half read-out speed), e.g. for coincident read-out two **DLD** detectors (ISA version only).

b) The *burst mode* is a pre-calculated transparent mode (only available in the **HM1-B** module). The values for x1,x2,y1 and y2 are calculated inside the **HM1-B** Module to x, y and z. x, y and z is then coded into a single 32bit value. The number of bit for x,y and z can be programmed. This 32bit value is store in a small FIFO. Only 1 hit can be detected in this mode. This mode is mostly controlled by the **HM1-B** itself, therefore the DAQ speed is about 150kHz.

c) In the so called *histogram mode* (optional, not for **HM1/T**) the DAQ speed is significantly enhanced (more than 1MHz). The data (only single hits per channel are registered) are stored on the TDC board in a 2D histogram (X and Y position, 11bit) or 3D histogram (X, Y and Z=TOF) memory. After a measuring cycle the content of the histogram can be transferred to the PC in a block for further data treatment. A dual memory bank on the board allows continuous data taking even during data transfer to the PC. The range of the TDC is limited by the histogram partitioning.

Figure 2.1: HM1-B/T and HM1-B front panel

Figure 2.2: PCI interface card

The **HM1-B** is fully compatible to the **HM1** as well as the **HM1/T** model. Additionally to the **HM1** this module has the *burst mode* ability.

2.1 Features of the HM1-B Module

- 4 Channel TDC, up to 4 times multihit detection
- Time range programmable from 50ns to 13.2µs
  in special long range mode up to 100ms
- I/O board for PC (PCI or ISA bus)
- Event Rate in ListMode operation up to 18kcnt/s
- Histogram mode event rate up to 1Mcts/s (optional)
- Burst event mode event rate about 150kcts/s

- Oscilloscope-Live Display during histogram/burst mode operation

- One 2D Histogram or two 1D Histograms (Mode 1) (optional)

- Different 3D histogram modes (optional)
  - Mode 2 = 512*512*16 channels
  - Mode 3 = 256*256*64 channels
  - Mode 4 = 128*128*256 channels

- * 16MByte (can be used alternately for continuous measurements)

The Histogram feature is optional

2.2 Applications

- fast 3D Imaging (2D position and time)

3 Operation modes of the HM1-B:

3.1 Transparent Mode (Used for List-Mode-Data-Acquisition) Standard TOF-Mode

# of channels	4 (common start)
# of hits per channel	3 or 4 (depends on GP1 operation mode)
input signal level	ECL
Resolution	133-808ps/Channel (adjustable)
Range	14 or 15bit -> up to about 2.1 - 13.2µs (depends on selected resolution) special long-range mode up to 100ms
multi hit dead time	20ns guaranteed, 15ns typical
DAQ Speed (400MHz/PII with CoboldPC)	typical 18kHz with 1 hit/channel on all 4 channels
PC-Bus System	ISA or PCI
Read-out software	CoboldPC

Table 3.1: Transparent Mode

3.2 Burst-Mode (Used for List-Mode-Data-Acquisition) pre-calculated Transparent Mode

# of channels	3 (x,y and z calculated from x1,x2,y1 and y2)
# of hits per channel	1
input signal level	ECL
Resolution	133-808ps/Channel (adjustable)
range	50 – 1350ns
DAQ Speed (400MHz/PII with CoboldPC)	typical 150kHz with 1 hit/channel on all 4 channels
PC-Bus System	ISA or PCI
Read-out software	CoboldPC

Table 3.2: Burst-Mode

3.3 Histogram-Mode Data format different from LMF-Mode (ASCII-Histogram)

# of channels	2 or 4 (fixed)
# of hits per channel	1
Resolution	133 – 808ps/Channel (adjustable)
Range	11bit out of 14 or 15bit → 262-1650ns out of 2.1 - 13.2µs
Histogram Speed	up to 1MHz (independent from CPU Speed)
Histogram Modes for - simultaneous position (2-dim) - simultaneous position and time (3-dim)	4 Mode 1 = 2048*2048 channels Mode 2 = 512*512*16 channels Mode 3 = 256*256*64 channels Mode 4 = 128*128*256 channels
Memory Banks	32 Mbyte 2 * 16 MByte (can be used alternately for continuous measurements)
Read-out Software	**HistoReadOut** (Windows XP or higher needed!)

Table 3.3: Histogram-Mode

4 Resolution modes of the HM1-B

We assume here a resolution setting to 133ps in resolution adjust mode.

Resolution mode	Setting (parameter 11)	Resolution (parameter 10)	Nominal Range	DNL (uncorrected)
low res mode	0	50 res (532ps)	14bit (8.7µs)	low
normal mode	1	50 res (266ps)	14bit (4.4µs)	low
high res mode	2	50 res (133ps)	14bit (2.2µs)	high

Table 4.1: Resolution settings and ranges

One “res” is a function of the parameters x, y (see above, default x-value or y-value respectively, i.e. about 133ps).
The method of time digitisation in the GP1 chip allows multi-stop acquisition on each channel with time resolution of about up to 133ps or even better in “high res mode” (default about 133ps). One consequence using this digitisation method for such low time resolution is the occurrence of the so-called differential non-linearity (DNL).

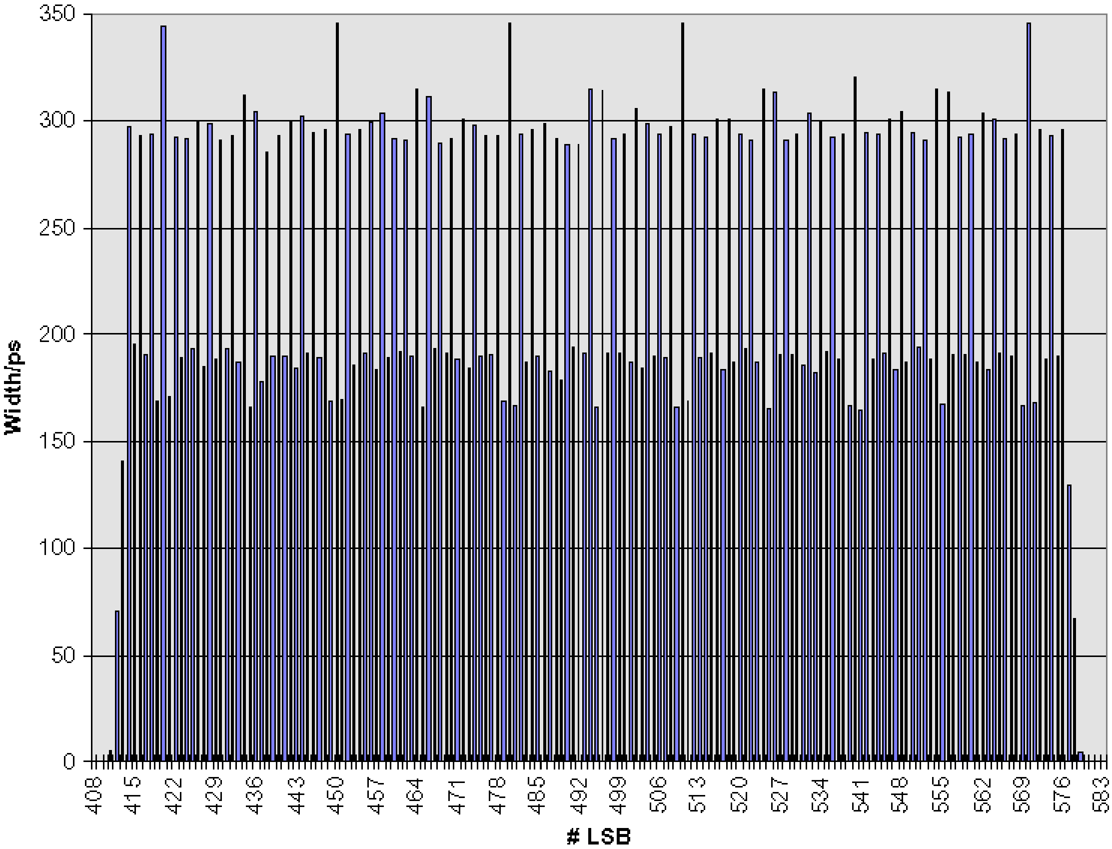


Figure 4.1: DNL in histogram, high res mode

Its main contribution produces an oscillation of the bin width every two channels which transforms a “flat” timing spectrum (channel bins having the same content) into an alternating spectrum where every second channel content is below/under average (see Figure 4.1).

To overcome this feature the number of relevant bits (the time resolution) can be reduced. This is done when operating the **HM1** in "normal" or "low" resolution mode as then the DNL is only a few percent (see Figure 4.2).

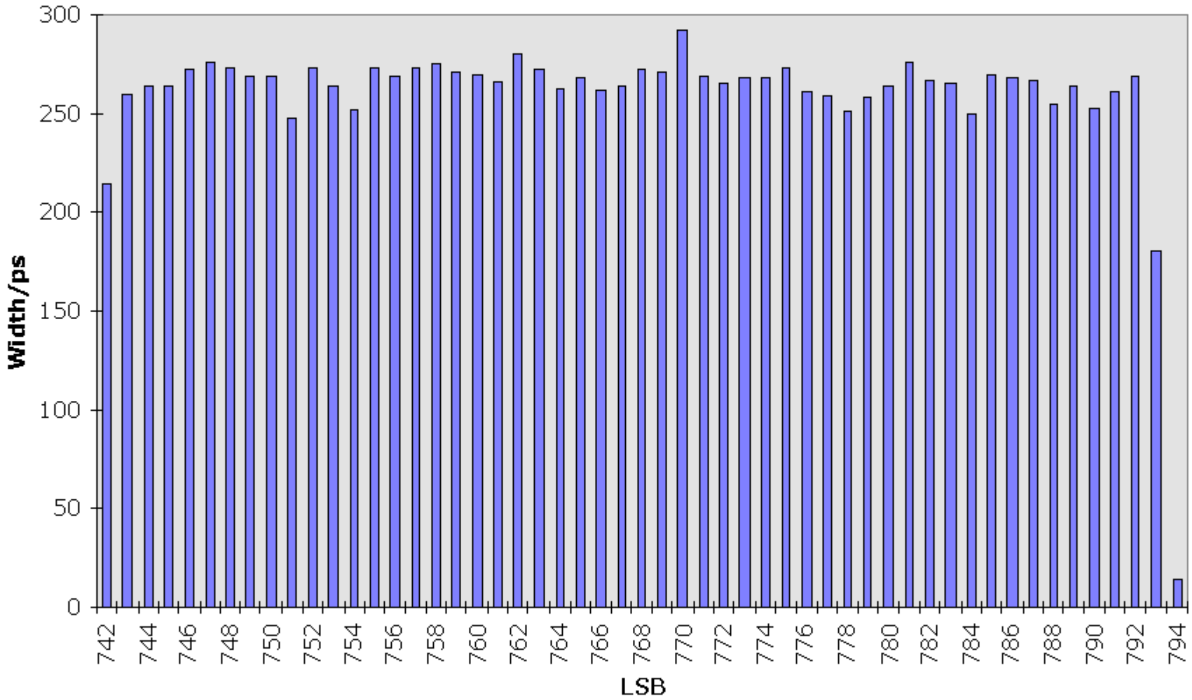


Figure 4.2: DNL in histogram, low res and normal res mode (normal res = high res + low res mode)

The DNL is more pronounced in "high" resolution mode. However, the **CoboldPC** software can correct the DNL mostly so that spectra acquired in "high" resolution will not be disturbed by this feature for usual precision demands. The **CoboldPC** command ***GP1Correct*** tries to determine the DNL from acquired (raw) data and corrects the displayed spectrum. However, this method leads only to reasonably results if the "test" spectrum is rather smooth. To achieve optimal results in DNL correction you may optimize the ***GP1Correct*** parameters by setting it to values close to the suggested by try-and-error method (see **CoboldPC** Help file for correct syntax). Note that "normal" and "low" resolution mode the results will be even better

A special feature of the GP1 chip is its ability to internally self-calibrate and to give digital outputs directly in time values instead of channel numbers (for resolution adjust this is done by transforming channel values into time using software). This output mode is unfavourable for operation with **CoboldPC** (channel orientated bins) as Moiré structures in the spectra may then occur, also the DNL can not be corrected by **CoboldPC** software.

However, in this mode up to 4 hits per channel can be collected and there is the possibility to increase the range significantly (long range mode)*. Please inquire at **RoentDek** if you want to use this mode.

* Note, that in the long range mode up to 4 hits per channels can be collected but the pulse-pair dead-time is at least 50ns

5 Installation of the HM1

- Shut down your computer.
- For your devices safety, turn off the power to your computer and all peripheral devices.
- Drain static electricity from your body by touching the metal chassis (the unpainted metal at the back of your computer).
- For your personal safety, remove the power cord from your computer.
- Remove the cover of the computer as described in your computer's manual.
- Check the I/O address setting on the I/O card to a free I/O address (ISA-I/O card version only). Do not forget to adjust *parameter 1* in your .ccf file to this I/O address or set the value of this parameter to 0 to automatically determine the I/O address.
- Locate a free ISA/PCI slot in your computer, and firmly insert the card into the selected slot. To avoid damaging our hardware, insert the card only into a slot with the same bus type as the card. Inserting the card into any other type of slot can damage your card, your computer, or both.
- Firmly secure the adapter with a screw (or clip), to ensure that the adapter is properly grounded to the computer's chassis.
- Replace the cover of the computer as described in your computer's manual.
- Connect the HM1 module with the I/O card using the connection cable. The three green LED on the HM1 module should be on now.

Note that the I/O card is not using SCSI signaling standard, although it has a SCSI socket and cable.
Major damage to your hardware will occur if you connect a SCSI device to the HM1 interface card or the HM1 to an SCSI controller.

5.1 The ISA-bus I/O Interface card

The ISA-bus card is mainly responsible for the decoding of the base I/O address.

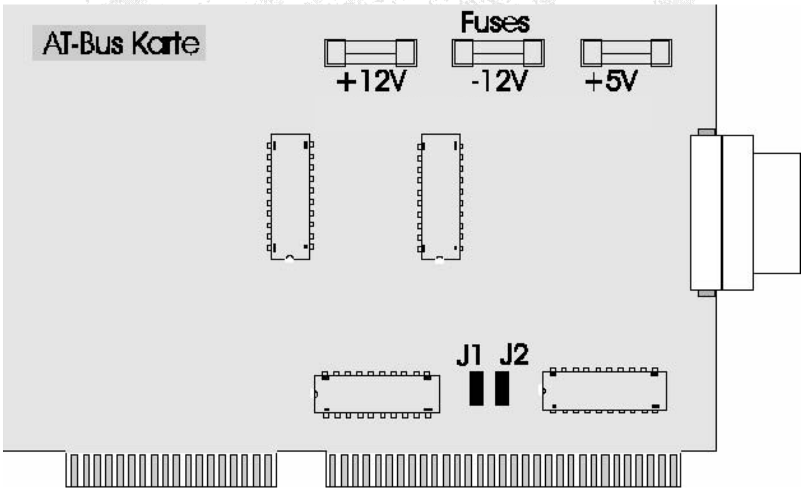


Figure 5.1: Schematic view of the ISA-bus I/O interface card

The interface card default settings are suitable for most computer systems. However, if the default settings conflict with another device in your system or if you need to install more than one interface card, you must reconfigure the interface card hardware.

The default setting for the I/O base address is 0x150 (hex 150, decimal 336)

With this setting, the interface card uses the I/O address space 0x150 through 0x15F (16 bytes). If this address range is already in use by another device or if you are installing more than one board, you have to change the jumper position to a new base I/O address. To locate the jumpers see Figure 5.1.

The following table lists the possible jumper settings:

JP1	JP2	I/O Address
X	X	0x150
X	O	0x200
O	X	0x300
O	O	No Address assigned

Table 5.1: ISA-bus interface card jumper settings

The interface board supplies the power to the external **HM1** module. The available voltages are:

+ 5V 1A
+ 12V 1A
- 12V 1A

The three supply voltages are protected by normal-lag fuses (for location see Figure 5.1). The correct function of the power supply is indicated by the three green LEDs on the back of the **HM1** system case.

5.2 The PCI bus I/O Interface card

The interface card allows accessing the **HM1** via the PCI bus.

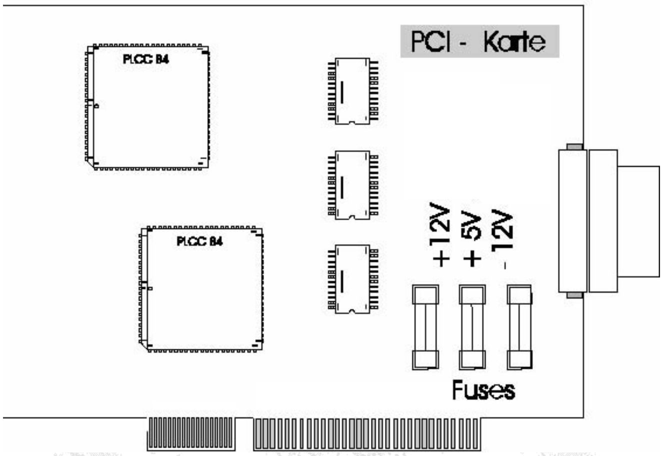


Figure 5.2: Schematic view of the PCI-bus I/O interface card

The **HM1** is designed to be accessed with 16bit I/O. For higher performance the **HM1**-PCI Interface can translate a 32bit access from the CPU into two 16bit accesses to the interface card. This is significantly faster than two 16bit accesses from the CPU.

There is no hardware configuration necessary for the PCI interface. The I/O base address of the board is set by the PCI BIOS. The **HM1**-PCI interface occupies 32 byte of I/O space. To determine the base I/O address you may download a small utility from our web-site (software section).

The interface board supplies the power to the external **HM1** module. The available voltages are:

+ 5V 1A
+ 12V 1A
- 12V 1A

The three supply voltages are protected by normal-lag fuses (for location see Figure 5.2: Schematic view of the PCI-bus I/O interface card). The correct function of the power supply is indicated by the three green LEDs on the back of the **HM1** system case.

5.3 LEDs at the HM1

The **HM1** is powered directly from the interface cards ISA-bus or PCI-bus. The correct function of the power supply is indicated by the three green LEDs shining on the backside of the **HM1** system case.

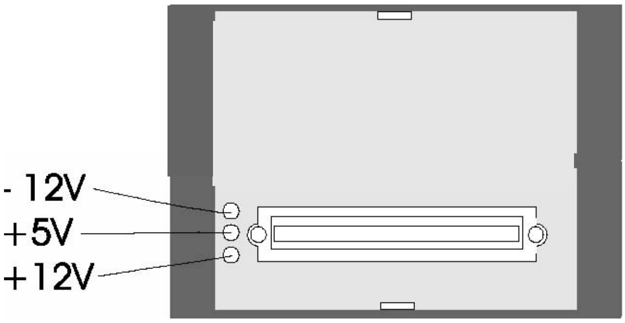


Figure 5.3: Power indicator LEDs

5.4 Jumper Settings at the HM1 Board

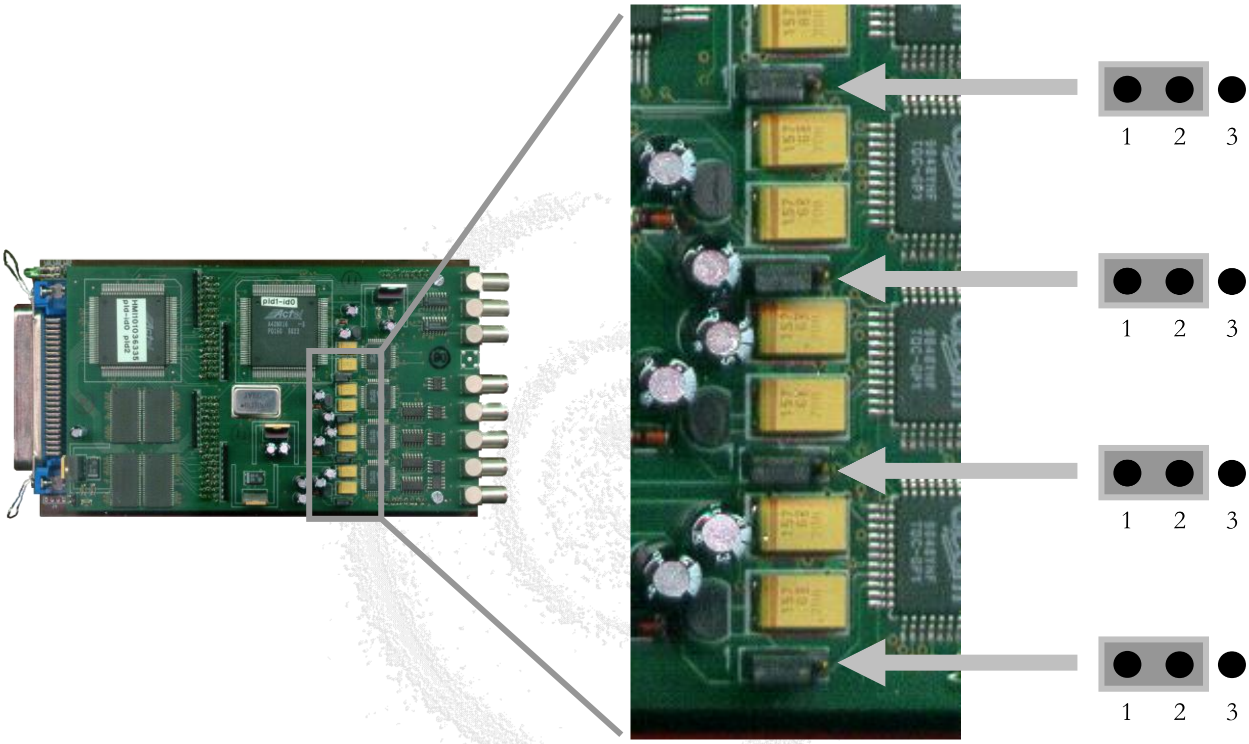
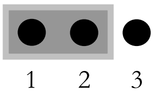


Figure 5.4: Jumper settings at the HM1 main board

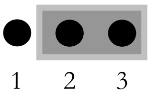
With the jumpers on the **HM1** board the operating voltage of PLL is controlled.

If the Jumper are in position needed for the *resolution adjust*



then the operation voltage is transferred to the PLL control. This is (default) setting.

In jumper position *resolution adjust*



a constant 5V operation voltage is applied to the TDC-GP1 chip. This means *non* setting.

The *resolution adjust* setting is only one possible operation mode of the GP1 chips on the **HM1** board (for details about the GP1 see www.acam.de or the GP1 manual). In the **HM1** *transparent mode* it is possible to address also the other read-out settings, for example *channel* and *long range mode* (but not the standard *burst* setting). For use with our detectors we can not recommend the *channel mode* because the bin width is not always stable. In this mode the **HM1** can be operated with 15bit range and 270ps (typical) resolution for up to 4 hits. In the *long range mode* the range is 30bit. These modes are only partially supported in **CoboldPC 2002** (please inquire).

If the **HM1** module is connected to the PC and the PC is switched on, the three green LED should be lit. If one or more of the LED are dark verify the connection to the I/O interface card, the proper mounting of the I/O interface card and the three fuses on the I/O interface card.

5.5 Addition information

Additional information about the operation of the **HM1** is found in the software and data acquisition manuals. Refer to the main detector manual for using the **HM1** transparent mode. Additional information about the features of the GP1 chip and the I/O interface cards can be found in the GP1 manual from *acam GmbH* (http://www.acam.de).

6 Introduction to the HM1-B Module

The **HM1-B** module is a further development of the **HM1** TDC unit. It contains all functions of the **HM1** (*transparent* and *histogramming mode*) and has a new functionality, the so called *advanced burst mode**. The *advanced burst mode* uses part of the **HM1** histogramming functions, but instead of compressing the X, Y and Z (TOF) information into the histogram it transfers the data through an on-board FIFO in event bursts to the PC. So for every burst a "real time" can be deduced from the PC clock and stored for all events in this bursts. By this method a list-mode file is created, identical to the file format in the *transparent mode*. However, only single hits (first hit) are registered and the coordinate space is fixed to X, Y and Z (3D-mode, similar 1D and 2D modes are included).
The advantage over the *transparent mode* is the high data acquisition speed (comparable to the *histogramming mode*). The advantage over the *histogramming mode* is the larger range for X, Y and Z coordinates: In the *histogramming mode* the range for X and Y can not exceed 11bit or 2048 channels and the sum of bits for X, Y and Z is limited to 22bit due the limitation of the histogram memory size. This "sum limit" is now increased to 32bit for the *advanced burst mode*, e.g. X and Y can have 11bit resolution each, and 10bit resolution (1024 channels) of time information (Z) can be stored. The data is then transferred as 32bit word to the PC. Information about the actual resolution of X, Y and Z coordinate are stored in the list mode file. If the proper DAQ.Dll file is linked to the **CoboldPC 2002** program one can analyze such a "list-mode" file with the standard DAN.DLL and ccf-files. Of course, only PosX, PosY and SumX are valid coordinates.
There are two additional limitations in the burst mode due to its hybrid nature:

- only single hits can be registered
- x1 and x2, or y1 and y2 inputs must be present and x1+x2 or y1+y2 must be within the ZX-/ZY-range.

The "sum limit" of 32bit allows to operate the GP1, the TDC chip, at the maximum range of 14bit (in *resolution adjust* internal setting), resulting in maximum ranges of 15bit for X, Y and Z coordinates. For that reason, the **HM1-B** can always operate in 3D-mode without restricting the resolution for 2D or 1D demands (unlike in the *histogramming mode*).

The available settings are

Mode	# of Bits for X	# of Bits for Y	# of Bits for Z	# of channels for X	# of channels for Y	# of channels for Z
1	15	15	2	32768	32768	4
2	14	14	4	16384	16384	16
3	13	13	6	8192	8192	64
4	12	12	8	4096	4096	256
5	11	11	10	2048	2048	1024
6	10	10	12	1024	1024	4096
7	9	9	14	512	512	16384
8	8	8	16(15)	256	256	32768

Table 6.1: Bit - Channel raster of HM1 burst mode

Note that besides the general 15bit limitation for each coordinate, the maximum open time of the TDC is 1350ns (as in the histogram mode) further limits the range for the measurements, e.g. a maximum of about 20k channels for a resolution setting of 133ps (i.e. < 15bit) or 10k channels (<14bit) for 266ps.

The achievable read-out speed in the advanced burst mode is 150kEvents/s for the standard **HM1-B** with PCI-I/O board on an average PC.

* Note, that this mode is unlike the standard "burst mode" of the GP1 chip

7 Operating the HM1-B with CoboldPC in Transparent-Mode

For an introduction of **CoboldPC 2002** see the "**CoboldPC**" or the "**MCP DETECTOR WITH DELAY-LINE ANODE**" manual. An actual version of these manual can be found on our web-site.

The sample command files "HM1 Standard.ccf" provides already most of the desired data, i.e. 2d position spectra and time-of-flight spectra in various coordinate representations. This command file calls several sub-command files that define parameters and coordinates which are attributed to the data acquisition part and the data analysis part of the event handling. Finally it defines spectra (and conditions). Due to this modular construction it is possible to use almost the same data analysis sequences for different hardware (i.e. TDC types). Some users find this sequenced structure of the "HM1 Standard.ccf" file not adequate for their work. If so you may create your own "HM1 Standard_Personal.ccf" by replacing the "execute" commands by directly pasting the subprogram commands into the new "HM1 Standard_Personal.ccf". Please consider the order of commands.
The standard defined coordinates, spectra and condition gates in the "HM1 Standard.ccf" are (please refer also to the commented lines in the "HM1 Standard.ccf"):

Restart	(reset of earlier commands)
execute subDAQ\HM1\Standard-Parameters.ccf	(executes the commands in the specific file)
execute subDAN\Standard-Parameters.ccf	(executes the commands in the specific file)
execute subDAQ\HM1\Standard-Coordinates.ccf	(executes the commands in the specific file)
execute subDAN\Standard-Coordinates.ccf	(executes the commands in the specific file)
execute subDAN\Standard-Spectra.ccf	(executes the commands in the specific file)
; prepare measurement	(no command, only comment)
new	(defines the session type, calls selector box)
start ; start measurement	(see comment)
show status ; show the status screen	(see comment)

In the following we describe the structure and the meaning of commands in the ccf-files.

7.1 DAQ parameters

Parameter 1	Address of the I/0 card or 0 for PCI bus auto detection mode. PCI bus auto detection is only valid for the **HM1** Modules with PCI IO cards
Parameter 2	Time stamp for an event as obtained from the PC in µs. Setting this parameter to 1 or 2 will record the computer clock with the event as 32bit or 64bit value from the time data acquisition start. Please note that the accuracy of the recorded time is not guaranteed. The time information is also dependent on the mother board of your PC. 0 = no Timestamp, 1 = 32Bit Timestamp (Low.Low, Low.high) 2 = 64Bit Timestamp (Low.Low, Low.high, High.Low, High.high)
Parameter 3	System reset time (in seconds) in case of missing signals (do not change without consulting **RoentDek**)
Parameter 5	Time scaling (internal parameter) Used to calibrate the time stamp.
Parameter 6	DAQ-version number (internal parameter)
Parameter 7	Start time of list mode file (internally set)

Parameter 8 DAQ-ID (internal parameter)

DAQ_ID_RAW	0x000000	for RAW (no Data)
DAQ_ID_HM1	0x000001	for HM1 (single)
DAQ_ID_2HM1	0x000004	for 2 HM1
DAQ_ID_HM1_ABM	0x000006	for HM1 (Advanced Burst Mode)

Parameter 9 LMF-version number (internal parameter since V5)

Parameter 10 Resolution parameter ("FAK_DLL"). The **HM1** "normal" resolution is set according to the formula

$$resolution[ns] = \frac{40}{3*FAK\_DLL}$$

In low resolution mode this value has to be multiplied by 2
In high resolution mode this value has to be divided by 2

If the value of FAK_DLL is set too high the **HM1** will not be able to maintain this resolution. A warning message ("PLL not locked") will appear after start of the hardware acquisition. The ability of the **HM1** to operate at a certain resolution changes within certain manufacturing tolerances of the GP1 chips and is also affected by the temperature. If the selected FAK_DLL is close to the tolerance, it may happen that the resolution lock is lost during a data acquisition session. If this happens, all unlocked events can be recognized by the value 1 in the PLLstatus coordinate.
Typically, FAK_DLL values between 35 and 50 are "safe". This corresponds to a TDC "normal" resolution between 381 and 267ps or 190 and 133ps in fine (or "high") resolution mode, see parameter 11.

Parameter 11 Coarse resolution/range parameter
0 – coarse: (low res mode)
LSB (for FAK_DLL = 50) 533ps,
range 14 bit (8.74µs)
1 – normal: (high res mode + half res mode = normal mode)
LSB (for FAK_DLL = 50) 267ps,
range 14 bit (4.37µs)
2 – fine: (high res mode)
LSB (for FAK_DLL = 50) 133ps,
range 14 bit (2.18µs)
Setting parameter 11 to 1 or 0 reduces the differential non-linearity from the hardware (see parameter 101)

Parameter 12 trigger mode for Start
0 = trigger at rise
1 = trigger at fall

Parameter 13 trigger mode for Stop
0 = trigger at rise
1 = trigger at fall

Parameter 14 Resolution Adjust Flag
0 = off (not supported yet!)
1 = on (forced!!!)

Parameter 15 ABM (Advanced Burst Mode)
0 = off
1 = on

Parameter 20 TDC resolution in ns (internally set)

Parameter 21 TDC data type information (internally set)
0 = Not defined
1 = Channel information
2 = Time information (in ns)

Parameter 22 Test Overflow if available
0 = no Test

```
                    1 = do Test
Parameter 30      Event open time in µs.
                  Maximal time after the start that the TDC waits for stops.
Parameter 31      Auto trigger on or off. "on" disables Parameter 35 setting and
                  will always record the event if at least one stop after the
                  start in any channel was registered.
                        0 = off
                        1 = on
Parameter 32      number of channels to be read out (1..4)
Parameter 33      maximum number of hits to be read out
                        1..3 (first hit is the start) if HighRes is on)
                        1..4 (first hit is the start) if HighRes is off
Parameter 34      (only for HM1)
                  Hit mask that defines events to be recorded. Events are only
                  recorded, if at least the number of hits per channels according
                  to this mask have been detected. Note that internally the start
                  signal is counted as one hit on all channels. So a hit-mask
                  0x2222 will require 1(!) for each channel to validate the
                  event, while for example a hit mask of 0x4433 requires at least
                  3 hits in the first two channels (x1 and x2) and at least 2
                  hits in the last two channels (y1 and y2).
                        ( x x x x )
                          T T T T
                          D D D D
                          C C C C
                          3 2 1 0
                        TDC0 = x1, TDC1 = x2, TDC2 = y1 and TDC3 = y2

Parameter 40      DataFormat (Internally set)
```

7.2 DAQ coordinates

According to the settings of these parameters above the CoboldPC program will retrieve the following coordinates and (if selected) will store them event by event to the hard disc.
The format is defined in the CoboldPC manual, each event is a n-tupel {...,...,...,...,...}of the conducive coordinates as binary numbers depending on the settings of parameters 2, 32 and 33:

```
{
  TRaw1,TRaw2,TRaw3,TRaw4 - if selected   (TimeStamp raw information)
  S1,C1H1,...,C1Hn        - n = para 33   (H stands for hit number)
  ..., ..., ..., ..., ...,                (S stands for the status register)
  Sm,CmH1,...CmHn         - m = para 32   (C stands for TDC channel number)
}
```

Further coordinates are calculated by the DAN (data analysis part), however these will not be stored to disc but appended to the list, all coordinates (from DAQ and DAN) are internally numbered:

```
pEventData->GetAt(0)
pEventData->GetAt(1)
pEventData->GetAt(2)
. . .
```

For the "HM1 Standard.ccf" n is set to 1 (one hit read-out only) and m equals 4, the number of stored DAQ coordinates is 8 if the timestamp is disabled, otherwise 12. The Auto trigger is turned off and the "tested bit pattern" is set to 1111h which means all for channels must have at least one hit for a "true" event detection.

7.3 DAN parameters and coordinates:

While the parameters of the DAQ part have only the function to define and organize the hardware (and are mandatory), the DAN parameters are used in the data analysis part. The DAN.dll is a data analysis subprogram that complements the raw

DAQ coordinates by computed coordinates, such as the position or time sum (TOF) derived from the raw data. It also comprises some correction, shifting and rotation computations and coordinate system transformations, so that the basic computations for experiments with a position and time sensitive detector are already available without changing the DAN.dll supplied here.
The computations yield in an additional set of coordinates (DAN-coordinates) that are internally treated as independent coordinates and are internally listed by numbers, following the last hardware coordinate (although they are not stored to hard disc in the list-mode file). This DAN.dll may be altered using a MS-C++ or DEC-Fortran compilation (see **CoboldPC** manual) and the list of coordinates may be changed, creating additional coordinates (and parameters) for further computation, unused DAN coordinates may be removed. Any newly defined coordinate is available for further computations. Note that the program will only operate well, if all definitions in the filename.ccf (e.g. the "xxx Standard.ccf") are in accordance with the DAQ.dll and DAN.dll used. After the **new** or **start** command the program makes a consistency check and may give an error message if the number of coordinates and parameters defined are not sufficient, however, it will not detect all possible discrepancies.

7.3.1 DAN parameters

Even though the parameters from 1 to 99 are mainly used for the DAQ module some of this information is also useful for the data analyses. So some parameters are again listed here. During offline analysis these parameters are automatically set from the parameter information (settings during data acquisition) that is stored in the lmf-file. So these are DAN-parameters but they are reread from List-Mode file header.

```
Parameter  2      Save TimeStamp
                        0 = no Timestamp,
                        1 = 32Bit Timestamp     (Low.Low, Low.high)
                        2 = 64Bit Timestamp     (Low.Low, Low.high, High.Low,
                                                 High.high)
Parameter  5      TimeScaling (Internally set, tics per s)
Parameter  6      DAQ Version # (Internally set)
Parameter  7      Start time of list mode file (internally set)
Parameter  8      DAQ_ID
                        DAQ_ID_RAW        0x000000    for RAW (no Data)
                        DAQ_ID_HM1        0x000002    for HM1
                        DAQ_ID_2HM1       0x000004    for 2 HM1
                        DAQ_ID_HM1_ABM    0x000006    for HM1
                                                      (Advanced Burst Mode)
Parameter 20      Resolution of TDC in ns (internally set)
Parameter 21      TDC data type information (internally set)
                        0 = Not defined
                        1 = Channel information
                        2 = Time information (in ns)
Parameter 32      number of Channels (reread during offline)
Parameter 33      number of hits (reread during offline)
Parameter 40      DataFormat (Internally set)
```

The following DAN-parameters used in the DAN-part can have the function of variables for computations, of pointers or of flags. Some are mandatory, some are optional. Standard DAN will use the parameter range 100-299. The following parameters and coordinates are used in the "HM1 Standard.ccf":

Parameter 100 — Conversion Parameter for RAW data
Usually (parameter value 0), the data output from a **HM1** TDC channel is coded in *channel numbers**. The *channel number* is the number of resolution bins (i.e. LSB). If it is set to 1 the unit is transformed to ns, using the TDC resolution value (parameter 20). If the parameter is 2, a position in mm is calculated, using the values of parameters 110 and 111 (and 112). The time sum values are in ns unless the parameter is 0.

Parameter 102 — Hexanode calculations

* This expression is always written in *italic* font, not to be mistaken for the term "TDC channel", which denominates a TDC input slot.

0 = no Hexanode
1 = Hexanode
If a Hexanode is used additional calculations are required to retrieve the position information. For these parameters and coordinates please refer to the add-on manual.

Parameter 103 R-Phi conversion
0 = RAD [-π..π]
1 = RAD [0..2π]
2 = DEG [-180..180]
3 = DEG [0..360]
This parameter defines the angular range and unit for the Phi coordinate in the R-Phi representation of the 2d-image.

Parameter 105 Start of DAQ Data for DAN
This pointer value defines for the DAN program part the position in the coordinate list where the first of the TDC data appears (s1). Usually you can set this value also to 0 and the program will automatically enter the right number.

Parameter 106 Start of DAN Data
This pointer value defines the position in the coordinate list where the DAN coordinates begin, i.e. it should equal the number of hardware coordinates
(See chapter 7.2)
If you want to analyze the data from the first hit you can set this value also to 0 and the program will automatically enter the right number.

Parameter 107 Hit number to be analyzed. Usually the position is calculated from the first hit in the TDC channels (default value: 1). If you want to get position and time sum calculations with the standard "HM1 Standard.ccf" for a different hit number you have enter the hit value here. Note, that it can happen that the registered *channel numbers* do not necessarily correspond to the real particle hit if reflections on the raw amplifier signals produce "false" additional hits in a certain TDC channel number, or if hits are "lost" due to low signal height/high threshold settings.

Parameter 110 pTPCalX
Time to Position calibration factor for x ($v_\perp$ in mm/ns)
DLD40: 1.32, DLD80: 1.02, DLD120: 0.77
For Hexanode* (u): HEX80: 0.737, HEX120: 0.583

Parameter 111 pTPCalY
Time to Position calibration factor for y ($v_\perp$ in mm/ns)
DLD40: 1.43, DLD80: 1.13, DLD120: 0.82
For Hexanode* (v): HEX80: 0.706, HEX120: 0.567
These two parameters define the value of position to time calibration, the effective signal propagation speed across the delay-line. It depends on the size and geometry of the delay-line used. The suggested values are only accurate within few percent for a given delay-line. If a higher precision is needed one needs to make a position calibration with a test mask in front of the detector. If the detector shows an oval shape please exchange the values for X and Y (only for DLD) and try again to sort the data. Maybe the physical dimensions of the anode have been exchanged during mounting.

Parameter 112 pTPCalW
Time to Position calibration factor for Hexanode* (w):
HEX80: 0.684, HEX120: 0.540

* please note that it is required to calibrate these numbers for your anode more accurately. Please contact service@roentdek.com.

```
Parameter 120     pCOx   Rotation Offset Center for PosX
Parameter 121     pCOy   Rotation Offset Center for PosY
                  These parameters define the center point for an online detector
                  image rotation and also the center point in the X/Y plane for a
                  coordinate transformation into R/Phi representation. Note that
                  a R/Phi transformation will only give good results if the
                  position unit is mm (see parameter 100).
Parameter 122     pRotA   Rotation Angle mathematical direction
                  Rotation angle (counter clock wise) for an online detector
                  image rotation
                  (value to be supplied in RAD or DEG depending on parameter 103)
Parameter 135     pOPx   Offset for PosX
Parameter 136     pOPy   Offset for PosY
                  These two parameters are offset (additive) constants for
                  shifting the detector image in the X/Y plane. Note, that in
                  case of the Hexanode these values define the offsets for the
                  calculated x and y and not for the raw u and v values.
Parameter 137     pOPw
                  Offset for third anode layer (added to w, only for Hexanode)
Parameter 138     pOSum
                  Offset for Sum/Diff calculations
                  This offset value is an additive constant to all time sum/diff
                  coordinates
```

7.3.2 DAN coordinates, primary

The DAN coordinates are by definition only the additional coordinates that are computed from the (raw) DAQ coordinates retrieved from the hardware or from a previously accumulated event file. This "xxx Standard.ccf" picks only one set of delay-line coordinates for one of the hits (default: first hit, see parameter 105) and calculates position and time values for these coordinates. If you have changed parameter 2, 32 or 33 from their default value (first hit only) or if you sort a list-mode file acquired with a non-default parameter settings) you need to adjust the (pointer) parameters 105 and 106. It is such possible to apply the position and time calculations to the next hits if such are (or have been) acquired by adjusting these pointer parameters. The DAN.dll will read the values of the status registers and the *channel numbers* in the 4 (Hexanode: 6) coordinates defined by parameter 105 (default: first hits) and calculate the desired position and time informations. Note that even for the use of a DLD (4 delay-line signals only), the coordinates for two additional delay-line signals (as from the Hexanodes) are defined and set to 0. A first set of DAN coordinates is created by using the defined set of DAQ coordinates:

```
AbsoluteEventTime       absolute time of event from the start of data acquisition
                        in µs (only if enabled, see parameter 2)
DeltaEventTime          time between an event and the previous event in µs (only
                        if time stamp recording is enabled, see parameter 2).
                        This spectrum can be used to determine the average event
                        rate (use the "fit exp" CoboldPC command on the acquired
                        spectrum)
EventCounter            number of event from the start of data acquisition
True                    internal coordinate
ConsistenceIndicator    The value of this number for each event is:
                              ∑ u · 2^(i-1),
                        i is the TDC channel, u =1, if at least one hit in the
                        TDC channel i was  registered, otherwise 0. If each TDC-
                        channel for the selected hit number has received at least
                        one hit of the value is 15 for a DLD and 63 for a
                        Hexanode. This assumes that the first TDC channels are
                        used for the delay-line signals. Up to 16 TDC channels
                        are supported by this function.
PLLstatus               indicated PLL unit state
n1                      number of hits in TDC channel 1
n2                      number of hits in TDC channel 2
n3                      number of hits in TDC channel 3
```

```
n4                        number of hits in TDC channel 4
n5                        number of hits in TDC channel 5
n6                        number of hits in TDC channel 6
x1                        channel number of hit in channel 1 (default: hit 1)
x2                        channel number of hit in channel 2 (default: hit 1)
y1                        channel number of hit in channel 3 (default: hit 1)
y2                        channel number of hit in channel 4 (default: hit 1)
z1                        channel number of hit in channel 5 (default: hit 1)
                          only for Hexanode
z2                        channel number of hit in channel 6 (default: hit 1)
                          only for Hexanode

                          The values in these coordinates are calculated from the
                          retrieved  channel numbers of the selected DAQ-
                          coordinates, e.g.  (see above). Depending on parameters
                          100, 101, 104 these values have the specified units
                          (corrected or uncorrected) and are the basis for all
                          following computations. If a Hexanode is not used, z1 and
                          z2 are set to zero. Note that channel 5 and 6 (for TDC8)
                          can still be used for other timing signals. The
                          corresponding coordinates are the DAQ coordinates for
                          these TDC channels
```

These DAN coordinates are called primary because they retrieve the basic information in the DAQ coordinates for a first data review, assuming a delay-line detector is used. The following secondary DAN coordinates are computed from the primary coordinates and represent the first step of a (user defined) more elaborated data analysis. If you want to define additional coordinates you should append them to the secondary DAN coordinates. Here, basically the position in a given direction (e.g. x = x1 - x2) and the time sums (e.g. sumx = x1 + x2) are calculated from the primary DAN coordinates. Note that the "unit" of the secondary DAN coordinates is also defined by parameter 100. Additional shift parameters can be included and coordinate transformation or image rotation codes are provided. For the Hexanode please refer to the add-on manual.

7.3.3 DAN coordinates, secondary, for DLD detectors

```
x               x coordinate of the event      (x = x1 - x2)
y               y coordinate of the event      (y = y1 - y2)
w               set to zero
sumx            time sum of x                  (sumx = x1 +x2 + pOSum)
sumy            time sum of y                  (sumy = y1 +y2 + pOSum)
sumw            set to zero
sumxyw          sum of time sums               (sumxyw = sumx + sumy - pOSum)
diffxy          difference of sums             (diffxy = sumx - sumy + pOSum)
PosX            x-position                     (PosX = x + pOPx)
PosY            y-position                     (PosY = y + pOPy)
r               r coordinate after transformation in r/phi coordinates
                (from PosX/PosY)
phi             phi coordinate after transformation in r/phi coordinates
                (from PosX/PosY)
xRot            x-position after rotation
yRot            y-position after rotation

The following coordinates are only filled with valid information for the Hexanode
setup. Even though they have to be defined!

Xuv             x + pOPx
Yuv             1/sqrt(3) * (x-2y) + pOPy
Xuw             Xuv
Yuw             1/sqrt(3) * (2w-x) + pOPy
Xvw             (y+w) + pOPx
Yvw             1/sqrt(3) * (w-y) + pOPy
```

```
dX                Xuv - Xvw
dY                Yuv - Yvw
```

In order to take full advantage of the **Hexanode**'s ability to resolve multi-hits or to read-out detectors with a central hole you may need additional support and software from **RoentDek**. Please contact **RoentDek** as soon as you have the detector operable and have acquired first data with the ***TDC8PCI2-Hex Standard.ccf.*** Note, that in order to provide this support it is required for **RoentDek** to receive a data set acquired with your detector and to know details of the application. Please look for manual updates on our website http://roentdek.com.

8 Operating the HM1-B with CoboldPC in Burst-Mode

For an introduction of **CoboldPC 2002** see the "**CoboldPC**" or the "**MCP DETECTOR WITH DELAY-LINE ANODE**" manual. An actual version of these manual can be found on our web-site.

The data output of the *burst event mode* is very similar to the *transparent mode*. Thus it is straightforward to operate the **HM1-B** with the standard **CoboldPC 2002** program structure. A **HM1-B**-specific DAQ.dll in combination with appropriate ccf files account for the slightly different "nature" of the **HM1-B** data output compared to the standard list-mode format. The header contains all information about the actual settings during acquisition of a certain lmf-file. If no time stamp is recorded the file format is identical to the "typical" **CoboldPC 2002** lmf format. The **HM1-B** writes data as 32bit words, each word containing information about the three "raw" coordinates X, Y and Z. The DAN.dll will transform these values into PosX, PosY and SumX according to the parameter settings. Due to the "burst"-like read-out of the **HM1-B** into the PC RAM, a time stamp from the computer clock can only be attributed to the arrival time of the burst in the PC, i.e. all events in the burst have the same time stamp (32bit or 64bit word). If the time stamp shall be recorded in the usual **CoboldPC 2002** list-mode-file structure it will appear as part of each event. However, if a burst contains a large number of events the time stamp word (repeated in every single event) will occupy hard disc space unnecessarily and increase the file size (up to a factor of 2 or even 3). For that reason a new parameter has been introduced to store the data more space-saving: the *burst list mode format*.
Note that for lower data rates (only one to a few events in each burst) the file size of the *burst list mode format* is not at all or only sparsely reduced compared to the standard list-mode format.
Besides the *BURST lmf Fomat* parameter there are a few more additional parameters to set for the **HM1-B** operation:

```
Parameter  70     ZX-Range from (sum condition x) [0..65535]
Parameter  71     ZX-Range to (sum condition x) [0..65535]
Parameter  72     ZY-Range from (sum condition y) [0..65535]
Parameter  73     ZY-Range to (sum condition y) [0..65535]
Parameter  74     Select read out region x from [0..2047]
Parameter  75     Select read out region x to [0..2047]
Parameter  76     Select read out region y from [0..2047]
Parameter  77     Select read out region y to [0..2047]
Parameter  78     Offset X [-65535..65535]
Parameter  79     Offset Y [-65535..65535]
Parameter  80     Offset Z [-65535..65535]
Parameter  81     Histogram Mode [0..3]
Parameter  82     Oscilloscope dark invert flag (enabled = 1)
Parameter  83     2 Single Channel Mode (ErrorHist) (enabled = 1)
Parameter  84     Shift X result [0..7]
Parameter  85     Shift Y result [0..7]
Parameter  86     Shift Z result [0..15]
Parameter  87     Oscilloscope shift result [0..3]
Parameter  88     TDC Open Time in ns [50..1350 in steps of 50]
Parameter  89     future use, set to FFFFh
Parameter  90     future use, set to FFFFh
Parameter  91     ABM shift x result [0..8]
Parameter  92     ABM shift y result [0..8]
Parameter  93     ABM shift z result [0..16]
Parameter  94     ABM structure (see chapter 10)
Parameter  95     Correct Offset (X,Y,Z) values (enabled = 1)
```

9 Operating the HM1-B in Histogram Mode using HistoReadOut

The histogram mode is used for demands with very high data acquisition speed, i.e. at particle rates on the detector up to 1MHz . The acquisition will only operate in a single hit mode (first hit is considered). The position X and Y is calculated by the formula X = x1 – x2 and Y = y1 – y2 on the board (without communication to the PC). The time sums ZX = x1 + x2 and ZY = y1 + y2 are also calculated on-board. The partitioning of the histogram can be adjusted.
In mode 0 (see below) the X and Y coordinate span a 2D histogram of 11bit by 11bit. For each particle hit the values X and Y are determined and the corresponding slot value in the histogram is incremented by a unit. The range is 32bit. As many particles are collected this histogram builds up to form a 2D image. It is also possible to acquire up to two independent 1D delay-line detector positions (ErrorHistogram mode, see below).
When a measurement cycle is over the data (the histogram content) can be transferred to a PC RAM (ASCII format) for visualization and further data treatment. The region for read-out in the histogram can be selected to reduce the amount of data to be transferred. It is also possible to set on-line "gates" on ZX and ZY regions to collect only desired time slots in the histogram. Particle hits that are not within these time sum gates are rejected and not stored into the histogram
Furthermore it is possible to address read-out modes where the time-sum in X-coordinate (ZX) is also stored to allow position and time sensitive measurements (3D mode). ZX is then the origin of the "time-value" Z (plus an adjustable offset). The ZX and ZY gates are also valid in this case, the histogram base of 11bit by 11bit is partitioned into smaller units with reduced bit range for X and Y, but the thus "spare" bits are used to allow acquiring several X/Y images as a function of the Z coordinate which equals ZX. Three 3D modes are available with different histogram partitionings X/Y/Z: mode 1 (9/9/4), mode 2 (8/8/6) and mode 3 (7/7/8). Additionally it is possible to increase the effective range of the coordinates by shifting the bits of the raw X, Y (and Z) coordinate values before these are numbers are used to address the histogram values. Effectively, this bin shift reduces the bin size in ns (the resolution) by multiples of 2, increasing the range (in ns) by the same factor.
There are two 16MB memory banks available so that data can be acquired in one bank while the other is read out.
The dead-time for detecting and storing an event in the histogram is about 650ns plus the "open time" of the TDC. This "open time" defines the time span after the start when stops are accepted the open time can be selected and has a range from 50..1350ns.
The X and Y numbers can be visualized on an oscilloscope (operated in X-Y mode) using the analog outputs. A "OZ"-trigger output can used to "blank" or "light" the oscilloscope (see your oscilloscope manual, for high rates this is not necessary)

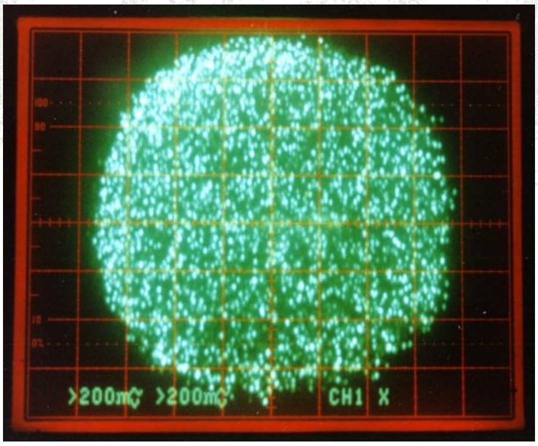


Figure 9.1: Sample oscilloscope output of the HM1 module

To operate the **HM1** in the histogram mode there are two options.
The program **HistoReadOut.exe** is a simple program that allows to control the parameter and to perform individual measurement or to operate the **HM1** analog outputs.

9.1 The HM1 histogram mode

In the histogram mode the position (and arrival time) of a particle can be recorded at a very high data acquisition speed of about 1,000,000cts/s. To achieve this high data throughput the digital numbers in the TDC channels (coding of position and time of a particle) are ***not*** read out event-by-event under control of the **CoboldPC** program ("transparent" or "list-mode"). In the histogram mode they are computed on-board and also stored on the HM1 board in a large memory buffer (16+16MB histogram). In this mode the TDC will not handle multi-hit events, i.e. after a start only the first hits on the channels are registered and considered to be the raw coordinates x1, x2, y1, y2 originating from the same particle. Due to a limited

histogram size is not the full 14bit range of the internal TDC chips for each coordinate value can be stored. "Regions of interest" must be defined to account for the limited storing capacity of the histogram. First, values for the particle's x and y position from the 14bit raw coordinates are computed according the formulas ***x = x1 – x2, y = y1 – y2*** (plus offsets, details see below).
A "***time-sum*** check" is used to assure that all four raw coordinate values are present and indeed belong to the same particle. If the TDC is started by the MCP signal, the values of ***ZX = x1 + x2*** and ***ZY = y1 + y2*** are constant within a few bin widths if start and stop signals belong to the same particle. The raw coordinates are only used to determine a particle position if ***ZX*** and ***ZY*** have values in a predefined range.
In an advanced mode (3D mode, see below) it is also possible to record the flight time of each particle with its position. As time-of-flight (TOF) marker the value ***z = ZX +offset*** is used. The value ***z*** marks the arrival time of the particle (plus a constant) if the **HM1** is started with the MCP. The constant is a function of the delay-line size and cable lengths. Therefore, if the **HM1** is started by a signal marking the "zero" of the TOF, different particle TOFs correspond to varying values of ***z*** accordingly.
Parameters are used to control further computation of the ***x, y*** position and ***z*** (TOF) values into ***X, Y*** and ***Z*** coordinates that are "tailored" to fit into the limited histogram memory. There are three options to operate the **HM1** histogram mode:

a) within **CoboldPC 2002** the start of a histogram acquisition can be initiated with the *shell* command.
b) With a DOS command *histo.exe* or any other program that can incorporate DOS commands
c) With the HistoReadOut program (manual)

In the following, the main functions of the **HM1** histogram mode are described. For general info please refer to the HM1 short manual first.

9.2 Operating the HM1-B in histogram mode

In the histogram mode a data acquisition session is initialized by a command sent from the PC. After the initialization the board is operating independently from the PC, handling the data acquisition, i.e. determining the ***X,Y*** and optionally the time-value (***Z***, see "3D mode" in the next section) of a detected particle, until this session is stopped either by another command sent from the PC, or when pre-set time has passed. During the data acquisition session the data are stored in a histogram with a pre-defined structure (***X,Y*** and ***Z*** range and bin size). After the data acquisition has been stopped, the histogram content (ASCII-format) can be transferred to the PC RAM for further handling (storing, display, and further computation), before the next data acquisition session can be initialized.
As the **HM1** board has two independent memory banks, data acquisition can take place almost continuously by switching between the two memory banks: While the first is read out by the PC (read-out can take several seconds) the other one can acquire the next data simultaneously.
The advantage of the histogram mode is the high data acquisition speed of over 1Mcts/s for single hits. The maximum time range of the **HM1** in this mode is 1.2µs, however, it is advisable to reduce this "open time" if the expected start-stop time differences are much smaller. The sum of the internal dead time for each read-out cycle (about 650ns) and the "open time" define the data acquisition speed limit. The setup of these parameters and the addressing of the histogram mode are described in the next chapter.

9.2.1 2D histogram mode

Mostly, the histogram mode is used to acquire a 2D image with high data throughput, comparable to a phosphor/CCD-camera read-out, but having superior imaging characteristics. The 2D histogram can be seen as a checkerboard with 2048 * 2048 fields, forming the ***X-Y*** plane. An arriving particle with a position ***X*** and ***Y*** is allocated to the nearest field (cell) on the histogram and the value in this field is incremented by one unit ("a stone is added to the checkerboard field"). Thus "columns" on this checkerboard build up as more particles are collected at various positions (***X-Y*** combinations). This is the usual definition of a 2D histogram format as used by many standard programs (i.e. MS-Excel or Origin). It is also equivalent to the structure of a **CoboldPC** 2D spectrum (see main **CoboldPC** manual) as used in the transparent (list) mode. However, the "spectrum range" (see spectrum definition commands in the main **CoboldPC** help file) is fixed to 2048 * 2048 channels and the "bin size" is fixed to 1. Unlike in the transparent mode, the maximum "height" of the "columns" (referred to as ***Z***-max in the **CoboldPC** program) is restricted to 32bit (per column) by the limited memory size on the board. This corresponds to a range of about 4.3 billion particles arriving with the same ***X-Y*** position before an overflow in the histogram cell occurs.

If the "`SCM`" flag (Single Channel Mode (1D imaging), see parameter list below) is set then the DAQ sequence on the **HM1** is not automatically checking for the presence of both X and Y signals. If either a valid pair of ***x1, x2*** *or* ***y1 y2*** is present (verified by the ***ZX*** or ***ZY*** gates). The ***X*** and/or the ***Y*** position are stored. If only one coordinate has been present the other is set to 0 and the particle hit is sorted to the ***X***/0 or the 0/***Y*** cell. Thus it is possible to operate in a *1D mode*, i.e. a one-dimensional delay-line detector can be operated or even two of them simultaneously.

Note that although CoboldPC can be used to control the histogram mode's DAQ and spectrum display it is not required.

A limited set of commands is used to address the histogram handling and the start/stop of acquisition. The data output format of the histogram is standard ASCII and is stored in the PC RAM or on the hard drive, for further data treatment and/or display with any suitable program.
During acquisition in histogram mode there is no online control via the PC. However the **HM1** TDC has an analog output for the ***X*** and ***Y*** position (via DACs) for online control on an oscilloscope (***X-Y*** mode), but only operating during data acquisition in histogram mode. The ***Dark-Out***-output on the **HM1** TDC delivers the "***Dark-Out***"-trigger output for a standard (analog) oscilloscope in ***X-Y*** mode. Note that this ***Dark-Out***-trigger has no correspondence to the ***Z***-coordinate that will be referred to in the next paragraph.

9.2.2 3D histogram mode

The histogram mode can serve for more than just acquiring a detector image with or without timing trigger.
If the time shall be recorded to give information about the particles' flight times with respect to an outer trigger (trigger signal to be connected to the "start") there are three different histogram portionings to select. The information on the time is deducted from the time sum value ***ZX*** of the ***X***-delay-line layer for a detected particle (see above). This number is referred to as the value of the ***Z***-coordinate (see above).
The base size of the **HM1**'s histogram is 22bit (e.g. 11bit * 11bit or 2048 * 2048 cells in the 2D mode). To allow a 3D mode the histogram memory has to be portioned differently. If the histogram is seen as checkerboard with 2048 * 2048 fields in the 2D mode, then there exist several checkerboards parallel for the 3D mode(s), as many as there are time sum (***Z***) bins. This number is selectable to be 16, 64 or 256 (4, 6 or 8bit).
As the total number of fields on all the checkerboards (total number of cells in the histogram) is limited to 22bit, the number of bits for the ***X*** and ***Y*** coordinates must be reduced from 11 each in the 2D mode to 9bit, 8bit or 7bit each. The three different histogram modes are referred to as 9bit * 9bit * 4bit (512 by 512 by 16 channels), 8 * 8 * 6 and 7 * 7 * 8, the last number defining the available channel depth for the time sum. The 2D mode, 11bit * 11bit, can also be used as a crude 3D mode although **no** time information is stored. By setting the ***ZX*** values (high and low) to a narrow gate at the desired TOF position and starting the TDC by the TOF trigger, one can effectively set a "region of interest" on the ***Z*** (time) coordinate, i.e. store only those particles that arrived in that specific time window. Varying the gate allows a series of time-gated image acquisition (but not simultaneously as in the "true" 3D modes).

9.3 Adjusting the raw position and time coordinates to the histogram memory

The bin size for the coordinates ***X, Y*** and ***Z*** of the histogram memory corresponds to the least significant bit (LSB) that the TDC can operate with, e.g. 133ps or binary multiples of it. The number of bits for ***X, Y*** and ***Z*** defines the range in time that is covered for a certain coordinate in the histogram (i.e. 11bit corresponds to 2048 times 133ps or about 272ns). By multiplying the bin size by multiples of two the effective precision of the measurement is getting worse but the *range* (in time units) of the histogram for a certain coordinate is increased by the same multiples of 2. This is referred to as "bit shift".
The "raw" values ***x = x1 - x2, y = y1 - y2*** (or ***z = x1 + x2***) cover internally a range between -2^{14} and 2^{14} (or 0 and 2^{15}). As this is too large for the histogram storage, a read-out range must be selected before storage, according to the available (mode selected) bit range, starting from 0 (only positive numbers can be addressed). The start bit can be shifted by units of one so that effectively the time range is doubled (quadrupled,…) while on the same time the effectively stored LSB is also doubled (quadrupled…, thus reducing the precision).
It is also possible (and often even required) to add certain offset values to the raw ***x, y*** and ***z*** values before the bit shift (and reduction to the histogram size) for a coordinate value takes place. These offset values are especially necessary for ***X*** and ***Y*** coordinates as the "raw" ***x*** and ***y*** value regions of interest usually extent to negative numbers.
Example: A **DLD40** needs about 60ns time range in ***x*** and ***y*** to display the complete active area. If the LSB of the **HM1** is set to 133ps, 512 * 512 cells or 9bit * 9bit are sufficient to cover the whole active area for storage. In the 2D mode even 11bit * 11bit are available. As the raw ***x*** and ***y*** numbers can be both negative and positive it is required to add offsets to the raw numbers in ***x*** and ***y***, e.g. an offset of 1024. Then the detector "image" will be centered on the 2048 * 2048 fields "checkerboard".
If the 3D mode 7 * 7 * 8 shall be used, an offset value of 64 (2^6) and a bit shift of 2 (factor 4) have to be used to accommodate the full detector image in the ***X-Y*** histogram(s), the position resolution however is also worse by a factor of 4. In this case, if a bit shift of less than 2 is chosen, not the whole detector can be displayed in this 3D mode (but the local position resolution can then be better). By changing the offset, certain areas of interest on the detector can be selected, with better position resolution.
The same concept allows for the ***Z***-coordinate to *zoom* into selective TOF regions and to acquire images as function of the different time bins in this region.

9.4 Starting the histogram read-out

The main advantage of the histogram mode is the achievable data acquisition speed. But this advantage is also combined with simplicity of read-out method: in order to acquire images only few command sequences are necessary and the rather complex CoboldPC program package can be bypassed.
For many applications, the limitation in the number of coordinates that can be acquired simultaneously is not of importance (e.g. for "pure" imaging applications), and also the available bit range (up to 2048 * 2048 at 32bit depth for imaging) is sufficient. The histogram mode is then the method of choice. If all combinations of range partitioning in the 3D mode are not sufficient it is possible to use the event *burst mode* (only available with the **HM1-B**). Please refer to the separate manual

A user may decide to include the histogram control command sequences in a program of his own make (contact RoentDek for support). The **HM1** is standardly delivered with the CoboldPC program package and an independent elementary read-out program called **HistoReadOut.exe** (executable file from MS-Windows-OS). It can be used for initial verification of the histogram mode operation, or even as a standard tool to operate the **HM1**. Another program, the **HistoReadOut.exe**, can be executed as a DOS command. As such it can be used as part of another program that can address DOS commands as a subsequence (such as CoboldPC, see command "shell" in the main CoboldPC help file). In case of the **HistoReadOut.exe** the **HM1** read-out parameters are directly added as command parameters. This command line version of the program can also be used/executed by script files written in perl, wscript, vbs etc.

Generally, both programs control the parameters of the **HM1** histogram mode start/stop the data acquisition and retrieve the histogram for storage to the hard drive and/or further data treatment.

These programs will only work if you have purchased the histogram option for the **HM1** and if you have installed CoboldPC 2002!

9.5 The HistoReadOut program

The **HistoReadOut.exe** is a simple control and read-out program for the **HM1** histogram mode. It operates completely independent of the CoboldPC program (although CoboldPC 2002 must be installed). The program is considered to be "self explaining".
This program can be operated in GUI mode (GUI = Graphical User Interface) or in CMD (CMD = CommandMoDe). If you call **HistoReadOut.exe** without any parameters from the command line (cmd.exe) or directly by double-clicking it'll start in GUI mode. As soon as a parameter is transferred the program starts in CMD mode.
This program needs Windows XP or higher!

Please contact RoentDek if further instructions are needed.

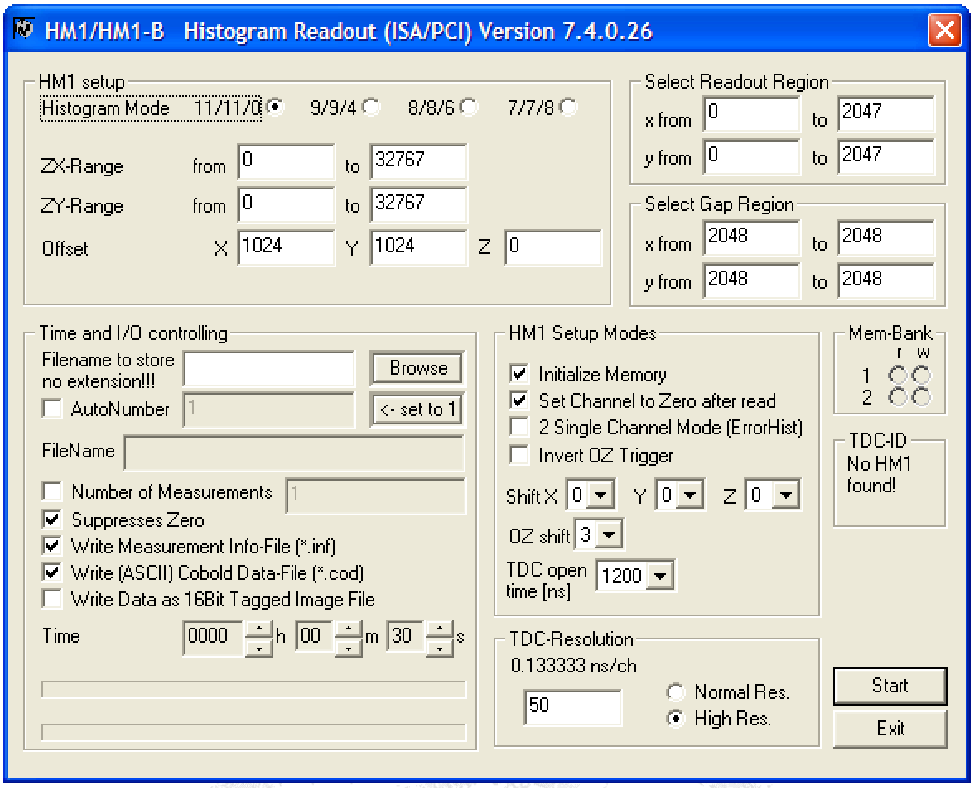


Figure 9.2: Display of the dialog based HistoReadOut program

9.5.1 TDC-ID

The information given in this field is the internal serial number of the **HM1** and the base I/O address to access the **HM1** module.

9.5.2 HM1 setup

9.5.2.1 Histogram Mode

Here it is specified which histogram type is selected. There are 4 different modes giving you 4 different memory configurations.

- **11/11/0** (bits for each Axis as **X,Y** and **Z**)
  This is the standard 2D Mode with a histogram size of 2048 * 2048 channels
- **9/9/4** (bits for each Axis as **X,Y** and **Z**)
  16 histogram of the size of 512 * 512 channels are handled
- **8/8/6** (bits for each Axis as **X,Y** and **Z**)
  64 histogram of the size of 256 * 256 channels are handled
- **7/7/8** (bits for each Axis as **X,Y** and **Z**)
  256 histogram of the size of 64 * 64 channels are handled

9.5.2.2 ZX/ZY Range

With these parameters you can set a condition for valid events to **x1+x2** and **y1+y2**. Only if this condition is true the event will be transferred to the histogram.

9.5.2.3 Offset

The Offset applies always to the **HM1** raw data. **X = x1 – x2 + OffsetX, Y = y1 – y2 + OffsetY** and **Z = x1 + x2 + OffsetZ.**

9.5.3 Select Readout Region

This area will specify the readout region of the 2D histogram. The option is only valid in 2D (11/11/0) mode. When you are operating the 1D histogram mode (2D mode with selected *2 Single Channel Mode* flag) then you can set the x region from 0 to

2047 and y from 0 to 0 when only looking for the x 1D histogram (or vice versa for y 1D histogram). If you are taking 2 independent 1D histograms for x and y the full range from 0 to 2047 should be selected for both, x and y.

9.5.4 Select Gap Region

For special reasons it is sometimes important to insert a "dead region" to the taken data. This can be done with the Gap Region. For x and y axis the following calculation is performed:

Delta = Max – Min + 1
If Channel < Min then $Channel_{Final} = Channel_{Initial}$
If Channel ≥ Min then $Channel_{Final} = Channel_{Initial} + Delta$

Please note that it is now possible to get a maximum channel greater than 2047.
Note: to avoid GAP calculation the value for Min and Max must be 2048!

9.5.5 Mem-Bank

The "LED" will indicate which bank is operated in what mode. Two memory banks are available 1 and 2. A memory bank can either be read or written. Only during memory initialization all 4 "LED" will be lit. During the first and the last access only one of the "LED's" will be on.

9.5.6 HM1 Setup Modes

General **HM1** settings are selected here.

9.5.6.1 Initialize Memory

Select this flag to make sure that the memory is cleared. The memory clear operation will be operated when a measurement is started by pressing the start button. The process last 5s. The progress is indicated by setting all 4 LED's on in the *Mem Bank* area and the upper progress bar (lower left area).

9.5.6.2 Set Channel to Zero after read

When this option is set every memory cell read will be set to zero after the read process. Typically this flag is on. If you want accumulative readout then deselect this flag.

9.5.6.3 2 Single Channel Mode (ErrorHist)

If one or two 1D histogram should be taken then this flag must be on. It disables the need of the presence of all 4 inputs. Only x1 and x2 or y1 and y2 must have valid hits to become a true event.

9.5.6.4 Invert OZ Trigger

During the **HM1** histogram operation all data that are stored in the histogram will also be passed to two 8bit DAC's. The output of the DAC's is X-OUT and Y-OUT. These signals can be applied to the oscilloscope's x and y channels. Then select the oscilloscope's X-Y display. Some oscilloscopes do need a special trigger. The trigger is normally operating in positive or negative TTL logic. The trigger signal can be taken from the **HM1**'s ***Dark Out*** output. The OZ trigger flag switches from positive to negative TTL logic for this trigger signal.

9.5.6.5 Shift X, Y and Z

To make sure all your data can be stored correctly in an histogram the 14bit range of the TDC has to be reduced to the 11bit of the histogram memory (further reductions due to the histogram mode selection is done internally). With this option you can specify the number of shifts to perform this task. So for this operation the shift for x and y should be set to 3 (this will also reduce your resolution by 2^3). If the measure range of your detector is only less than 270ns then there is no need for this reduction and the shift setup for x and y can be set to 0.
The same applies to the z coordinate (x1+x2) in the 3D modes. Here the 14bit TDC range has to be reduced to 4, 6 or 8bit.

9.5.6.6 OZ Shift

Because the built in DAC's are only 8bit wide there is an additional reduction necessary for the 11bit histogram → oscilloscope output. Therefore you can apply shifts from 0 to 3 for the oscilloscope output (see Figure 9.1).

9.5.6.7 TDC open time [ns]

The maximum measure time for one event is selected here. The TDC will accept stop signals applied to x1,x2,y1 and y2 from the time t_0 = Start trigger up to $t_{max} = t_0 + t_{TDC\ open\ time}$.

9.5.7 TDC-Resolution

The TDC resolution can be adjusted in a limited range. This setup parameter allows you to adjust the TDC resolution. Typically this value should be in the range of 35..50. The resolution is calculated by this formula and displayed.

$$T = \frac{1600}{120 * SetupValue * HigresFlag}[ns]$$

HighresFlag is 1 if "Normal Res." radio-button is selected and 2 if "High Res." radio-button is selected.

9.5.8 Time and I/O controlling

9.5.8.1 Filename to store

Here the base output filename is specified. Do not specify a file extension. The file extension COD is appended automatically. The name may also specify a valid folder or network path (UNC).
If no filename is given no the file output and the readout of the **HM1** will be skipped.

9.5.8.2 AutoNumber

It is possible to append an automatically increased number to the base filename. Every measurement cycle this number will be increased by one.

9.5.8.3 FileName

Here the complete filename will be displayed. If the filename is too long then the middle parts of the name will be replaced by three dots (i.e. C:\test1\...\test.0000000001.cod).

9.5.8.4 Number of Measurements

This flag allows the user to perform continuous measurements. This option enables automatically the AutoNumber option. Every measurement cycle the specified number will be decreased by one. The last measurement is performed when this number reaches one. After stopping the measurement the number is restored to the original input value. After each measure cycle the memory banks are swapped (Mem-Bank "LED's"). The swapping of the memory banks lasts only a fraction of a second compared to the **HM1** readout time of up to several ten seconds. Therefore it is possible in this mode to perform continuous measurements over a long time period.

9.5.8.5 Suppresses Zero

If this flag is set then channels with no count will not be written to a file. This can reduce the file size extremely.

9.5.8.6 Write Measurement Info-File

Selecting this option will produce for every measurement cycle an information file that contains ASCII information about the setup of the **HM1** for this measurement. The file has the same file name as the **HM1** output file except that the file extension is INF instead of COD (INF = Information, COD = Cobold Data File).

9.5.8.7 Write (ASCII) Cobold Data-File

Selecting this option will produce for every measurement cycle a CoboldData File file that contains the content of all histograms in ASCII for this measurement. The file has the same file name as the **HM1** output file with the extension of COD (COD = Cobold Data File).

9.5.8.8 Write Measurement Tagged Image File (*.tif)

A TIF is also created when selecting this option. The file has the same file name as the **HM1** output file except that the file extension is TIF instead of COD (TIF = Tagged Image File). If a 3D mode is selected then a series of TIFs will be written. In this case a number in the form ***.xxx*** is added prior to the file extension.

9.5.8.9 Time

The time for a measurement cycle can be adjusted here. If the *Number of Measurements* option is selected the minimal time allowed is 30s. In that mode it is necessary that the measure time last longer than the readout time of the **HM1**. If the readout takes longer than the "measure time" the complete measurement is aborted.

- ***Progress bars***
  - The upper progress bar indicates at start time the memory initialization progress. After that it switches to show the progress of a measure cycle.
  - The lower progress bar is showing the progress of the **HM1** readout (if selected). In 2D mode the w is indicating the number of lines written to the file. Y is showing the actual line the **HM1** is reading out. In 3D mode w is also counting the written line number and z is showing the histogram that is momentarily operated during readout.

9.5.9 Start

After pressing the ***Start*** button the **HM1** starts to perform the tasks selected in the programs dialog box. The start button is then renamed to ***Stop.*** With this button it is possible to interrupt the measurement.
Two new buttons will be displayed during a measurement. ***Pause*** and ***Stop + Read***. These buttons are only selectable when the **HM1** is not in "data read out" mode (lower progress bar showing no information). Then with ***Pause*** it is possible to hold a measurement for an infinite time. After being pressed the button changes to ***Continue***. Pressing ***Continue*** will resume the measurement. The ***Stop + Read*** button allows the user to stop a complete measurement but read out the last data taken by the **HM1**.

9.5.10 HistoReadOut command line

```
HistoReadOut [/Mode HM1Mode] [/ZXFrom zxfrom] [/ZXTo zxto] [/ZYFrom zyfrom]
     [/ZYTo zyto] [/OffX offx] [/OffY offy] [/OffZ offz]
     [/ReadXMin readxmin] [/ReadXMax readxmax] [/ReadYMin readymin]
     [/ReadYMax readymax] [/GapXMin gapxmin] [/GapXMax gapxmax]
     [/GapYMin gapymin] [/GapYMax gapymax] [/FN filename]
     [/AutoNum autonum] [/Loops loops] [/SZ b] [/WI b] [/WD b] [/WT b]
     [/ST b] [/Time hhh:mm:ss] [/IM b] [/SCZ b] [/SCM b] [/IOT b] [/ShX shiftx]
     [/ShY shifty] [/ShZ shiftz] [/OS os] [/TOT opentime] [/TR timeres] [/TM b]

  /Mode         Set the HM1 mode
  HM1Mode       11 for 11*11*0 Mode
                 9 for 9*9*4 Mode
                 8 for 8*8*6 Mode
                 7 for 7*7*8 Mode
  /ZXFrom       Set the from value for Sum-X condition
  zxfrom        [0..65535]
  /ZXTo         Set the to value for Sum-X condition
  zxto          [0..65535]
  /ZYFrom       Set the from value for Sum-Y condition
  zyfrom        [0..65535]
  /ZYTo         Set the to value for Sum-Y condition
  zyto          [0..65535]
  /OffX         Set the offset for the x coordinate
  offx          [-65535..65535]
  /OffY         Set the offset for the y coordinate
  offy          [-65535..65535]
  /OffZ         Set the offset for the z coordinate
  offz          [-65535..65535]
  /ReadXMin     Set the readout region xMin value
  readxmin      [0..2047]
  /ReadXMax     Set the readout region xMax value
  readxmax      [0..2047]
  /ReadYMin     Set the readout region yMin value
  readymin      [0..2047]
  /ReadYMax     Set the readout region yMax value
```

```
readymax      [0..2047]
/GapXMin      Set the gap region xMin value
gapxmin       [0..2048]
/GapXMax      Set the gap region xMax value
gapxmax       [0..2048]
/GapYMin      Set the gap region yMin value
gapymin       [0..2048]
/GapYMax      Set the gap region yMax value
gapymax       [0..2048]
/FN           Set the base filename for the outputs
filename      filename including drive and path, no extension!!
/AutoNum      Enable Auto numbering
autonum       [0..2147483647], start number of the auto numbering
/Loops        Enable Loop mode
loops         [1..2147483647], take up to # measurements
/SZ           Suppress zeros during readout
b             [0..1], 0 = no or off, 1 = yes or on
/WI           Write information file (*.inf)
b             [0..1], 0 = no or off, 1 = yes or on
/WD           Write data file (*.cod)
b             [0..1], 0 = no or off, 1 = yes or on
/WT           Write TIFF image file (*.tif)
b             [0..1], 0 = no or off, 1 = yes or on
/ST           Scale TIFF image color by maximum count in
              histogram readout area
b             [0..1], 0 = no or off, 1 = yes or on
/Time         Measure time per cylce
hhh:mm:ss     hhh [0..9999], mm and ss[0..59]
/IM           Initialize Memory
b             [0..1], 0 = no or off, 1 = yes or on
/SCZ          Set channel to zero after read
b             [0..1], 0 = no or off, 1 = yes or on
/SCM          Single channel mode
b             [0..1], 0 = no or off, 1 = yes or on
/IOT          Invert oszi trigger
b             [0..1], 0 = no or off, 1 = yes or on
/ShX          Shift X result
shiftx        [0..7]
/ShY          Shift X result
shifty        [0..7]
/ShZ          Shift X result
shiftz        [0..15]
/OS           Oszi shift result
os            [0..3]
/TOT          TDC open time
opentime      50, 100, 150, 200, 250, 300, 350, 400, 450, 500, 550, 600,
              650, 700, 750, 800, 850, 900, 950, 1000, 1050, 1100, 1150,
              1200, 1250, 1300, 1350
/TR           Time resolution of TDC
timeres       [0..255]
/TM           Time resolution mode
b             [0..1], 0 = normal mode, 1 = highres mode
```

9.6 Data file format

All data is stored in ASCII format.
In 2D mode the data file output line is

XChannel,YChannel,Counts

In 3D mode the data file output line is

XChannel,YChannel,ZChannel,Counts

This is a typical data information file:

```
Histogram Mode                     11/11/0
ZX-Range                           000000 - 032767
ZY-Range                           000000 - 032767
Offset (x - y - z)                 001024 - 001024 - 000000
Readout region x                   000000 - 002047
Readout region y                   000000 – 002047
Gap region x                       002048 - 002048
Gap region y                       002048 - 002048
Initialize Memory                  selected
Set Channel to zero after read     not selected
2 Single Channel Mode              selected
Invert OZ Trigger                  not selected
Shift (x - y - z)                  0 - 0 - 00
Shift Oszi                         3
TDC open time [ns]                 1200
TDC Resolution                     050 -> 0.133333
Write to Bank                      0
Read from Bank                     1

Total Measure Time is              days: 0, hours: 00, mins: 00, secs: 30
Data set                           1 out of 1
```

9.7 Histogram mode in CoboldPC

In the Tools section of the feature selection during **CoboldPC** setup procedure there is a feature "**CoboldPC** - ***HM1".*** This will install a separate **CoboldPC 2002** version in the Tools folder with two command line programs that handles the 1D, 2D readout of the **HM1-B** module. Also two CCFs are placed in that subdirectory.
The CCFs performs the following operation:

- Restart **CoboldPC** to get a clean document
- Define the 1 or 2 dimensional spectrum
- Call the Histo1D.exe or Histo2D.exe program with the ***Shell*** command with appropriate parameters
- View the spectrum 1 for one and two dimensional
- Import data taken from **HM1-B** to the displayed spectrum (here spectrum 1)
- View spectrum 1 again (update)

Now the acquired histogram or part of the information has been converted to a spectrum on the screen for 1D and 2D operation. The information content in this spectrum is the same as in the histogram.

The data taken by the Histo*X*D.exe program is stored in the Histo*X*D-Temp.dat in the same folder and will be overwritten when calling the CCF the next time. (*X* = 1 or 2 for 1D or 2D histogramming).

You can now use all **CoboldPC** spectrum treatment commands to analyse the data and export them finally.

9.7.1 Hirsto1D.exe command line

```
HM1 1dim Readout (V2)
---------------------
Readout of the HM1 Module in 1Dimensional Histogram mode

Histo1D [/cl[MarginValue]] [/ch[MarginValue]] [/co[OffsetValue]]
   [/rcl[ReadMarginValue]] [/rch[ReadMarginValue]]
   [/im] [/io] [/sz] [/w[OpenTime]]
   [/res[RValue]] [/dx[CValue]] [/do[COValue]]
   [/b[Number]] [/t[Time]] [/fn[PathFileName]] [/ff[Format]] [/fa]
   [/ss[Separator]] /as[Axis]]
```

```
 [Axis]               ASCII [x or y]
 [COValue]            number [0..3]
 [Format]             ASCII [v or h] for vertical or horizontal
 [MarginValue]        number [0..65535]
 [MaxChannel]         number [0,,2047]
 [Number]             number [0..1]
 [OffsetValue]        number [0..2047]
 [OpenTime]           Time in ns
 [PathFileName]       FileName including Path
 [ReadMarginValue]    number [0..2047]
 [RValue]             number [1..255]
 [Separator]          ASCII [any character, \t for tab]
 [Time]               time in ddd:hh:mm:ss format

 /as        Axsis readout selection
 /b         Use Memory Bank 1 or 2
 /cl        Set sum check low channel for x channel
 /ch        Set sum check high channel for x channel
 /co        Set the offset for x channel in channels
 /do        Divide Oszi output by 2^COValue before analog conversion
 /dx        divide x channel by 2^CValue before store to matix-memory
 /fn        Filename for Outut file. Output to console if not specified
 /ff        Format of output file
 /fa        Append data to file
 /im        Initialize HM1 Memory (set to zero)
 /io        Invert Oszi Trigger outout
 /rcl       Set the readout low channel for x channel
 /rch       Set the readout high channel for x channel
 /res       TDC resolution
 /sz        Set channel to zero after read
 /w         TDC open time in ns
 /t         Time to acquire data before readout
 /ss        Select separator

Default for MarginValue is low = 0; high = 65535
Default for ReadMaringValue is low = 0; high = 2047
OffsetValue = 1027
OpenTime = 250ns
CValue = 3
COValue = 3
RValue = 51 -> 800/120/RValue = 0.130719ns/channel
Number = 1
Separator = ,
no initialization of the memory
no invertation of the oszi trigger
no "set to zero after read"
```

9.7.2 Histo2D.exe command line

```
HM1 2dim Readout (V3)
---------------------
Readout of the HM1 Module in 2Dimensional Histogram mode

Histo2D [/cxl[MarginValue]] [/cxh[MarginValue]] [/cxo[OffsetValue]]
   [/cyl[MarginValue]] [/cyh[MarginValue]] [/cyo[OffsetValue]]
   [/rxcl[ReadMarginValue]] [/rxch[ReadMarginValue]]
   [/rycl[ReadMarginValue]] [/rych[ReadMarginValue]]
   [/im] [/io] [/sz] [/w[OpenTime]]
```

```
   [/res[RValue]] [/dx[CValue]] [/dy[CValue]] [/dz[CZValue]] [/do[COValue]]
   [/b[Number]] [/t[Time]] [/fn[PathFileName]] [/ff[Format]] [/fa]
   [/ss[Separator]] [/se[EFlag]]
   [/gxmin[GAP]] [/gxmax[GAP]] [/gymin[GAP]] [/gymax[GAP]]

 [CValue]             number [0..7]
 [CZValue]            number [0..15]
 [COValue]            number [0..3]
 [EFlag]              number [0..1]
 [Format]             ASCII [v or h] for vertical or horizontal
 [GAP]                Gap channel [0..2048]
 [MarginValue]        number [0..65535]
 [Number]             number [0..1]
 [OffsetValue]        number [0..65535]
 [OpenTime]           Time in ns
 [PathFileName]       FileName including Path
 [ReadMarginValue]    number [0..2047]
 [RValue]             number [1..255]
 [Separator]          ASCII [any character, \t for tab]
 [Time]               time in ddd:hh:mm:ss format

 /b         Use Memory Bank 1 or 2
 /cxl       Set sum check low channel for x channel
 /cxh       Set sum check high channel for x channel
 /cxo       Set the offset for x channel in channels
 /cyl       Set sum check low channel for y channel
 /cyh       Set sum check high channel for y channel
 /cyo       Set the offset for y channel in channels
 /do        Divide Oszi output by 2^COValue before analog conversion
 /dx        divide x channel by 2^CValue before store to matix-memory
 /dy        divide x channel by 2^CValue before store to matix-memory
 /dz        divide x channel by 2^CZValue before store to matix-memory
 /fa        Append data to file
 /ff        Format of output file
 /fn        Filename for Outut file. Output to console if not specified
 /gxmin     Gap from xmin
 /gxmax     Gap to xmax
 /gymin     Gap from ymin
 /gymax     Gap to ymax
 /im        Initialize HM1 Memory (set to zero)
 /io        Invert Oszi Trigger outout
 /reso      TDC resolution
 /rxcl      Set the readout low channel for x channel
 /rxch      Set the readout high channel for x channel
 /rycl      Set the readout low channel for y channel
 /rych      Set the readout high channel for y channel
 /se        Set error histo flag (2 1D histograms)
 /ss        Select separator
 /sz        Set channel to zero after read
 /t         Time to acquire data before readout
 /w         TDC open time in ns

EFlag = 0
Default for MarginValue is low = 0; high = 65535
Default for ReadMaringValue is low = 0; high = 2047
OffsetValue = 1027
OpenTime = 250ns
CValue = 0
CZValue = 3
```

```
COValue = 3
RValue = 49 -> 800/120/RValue = 0.136054ns/channel
Number = 1
Separator = ,
GAP = 2048
no initialization of the memory
no invertation of the oszi trigger
no "set to zero after read"
```

10 HM1 Registers

ATMD-MB (MB = Motherboard)

Control Register ATMD (module independent)

Bit No.	Bit Assignment	Bit No	Bit Assignment
0	MODULE0 Reset	8	MODULE1 Reset
1	MODULE0 Burst mode On	9	MODULE1 Burst mode On
2	MODULE0 Port1	10	MODULE1 Port1
3	MODULE0 Port2	11	MODULE1 Port2
4	MODULE0 Port3	12	MODULE1 Port3
5	MODULE0 Port4	13	MODULE1 Port4
6	MODULE0 Port5	14	MODULE1 Port5
7	MODULE0 Port6	15	MODULE1 Port6

Address and Register structures of the HM1

Physical Address = Address * 2 + BaseAddress
BaseAddress : 150h, 200h or 300h (h = hex number) or above 300h for PCI versions

Address	Read	Write
0	Sys-ID	ContReg FPGA1
1	***	ContReg FPGA2
2	TDCs	TDCs
3	***	Addressee ind. 1
4	STATUS ATMD	Address ind. 2
5	Low word FIFO	Addressee ind. 2
6	High word FIFO	Control Register ATMD

ATMD Motherboard Status Register (Control Register ATMD)			
Bit 0	Low word fifo empty flag	Bit 8	High word fifo empty flag
Bit 1	Low word fifo full flag	Bit 9	High word fifo full flag
Bit 2	Module0 Burst-Mode on	Bit 10	Module1 Burst-Mode on
Bit 3	Interrupt (Y1)	Bit 11	Not used
Bit 4	Interrupt (Y2)	Bit 12	Not used
Bit 5	Interrupt (X1)	Bit 13	Not used
Bit 6	Interrupt (X2)	Bit 14	Not used
Bit 7	Not used	Bit 15	Not used

	Add on Control Register FPGA1	Add on Control Register FPGA2
0	Clear Stopenable	Initialization of Histogram Memory
1	Set Stopenable	Histogram on
2	Histo-Modus 0	Bank select of Histogram
3	Histo-Modus 1	Histogram data read on
4	Set-Start-Enable	Bank select of Data read of Histogram
5	Dark Invert (Analog x,y Oscilloscope)	Write Zero after read on
6	Errorhisto-Mode	
7	Advanced Burst Mode (a version)	0 = ABM off, 1 = ABM on

How to use indirect addressing:
Using the indirect addressing there are 8 additional register in the FPGA1 available for writing. For the indirect address use the lower 4 bit in Control Register FPGA1 (Address 0). Write the data then to Address 3 (Addressee ind. 1).

Indirect Address	Addressee 1 (writing !)	Addressee 2 (writing!)
0	ZX upper limit low Byte	X Min
1	ZX upper limit high Byte	X Max
2	ZX lower limit low Byte	Y Min
3	ZX lower limit high Byte	Y Max
4	ZY upper limit low Byte	
5	ZY upper limit high Byte	
6	ZY lower limit low Byte	
7	ZY lower limit high Byte	
8	X Offset low Byte	
9	X Offset high Byte	
10	Y Offset low Byte	
11	Y Offset high Byte	
12	Z Offset low Byte	
13	Z Offset high Byte	
14	Add on Control Register	
15	Shift Register	
16	Watchdog-Register	
17	Histogram Level 7..0 (for sorting)	
18	Histogram Level 15..8 (for sorting)	
19	ABM-XShift (3..0), YShift (7..4)	
20	ABM-ZShift (3..0), Structure (7..4)	

	Structure Control Register 1	Structure Control Register 2
0	Indirect Address 0	
1	Indirect Address 1	
2	Indirect Address 2	
3	Indirect Address 3	
4	Indirect Address 4	
5	TDC Address 0	
6	TDC Address 1	
7	TDC Address 2	
8	TDC Address 3	
9	Common Address Flag for all TDCs	
10	TDC-SEL 0	
11	TDC-SEL 1	

Note:
The initialization of the histogram memory, (by setting the Bit0 of the Control Register FPGA2 enabled is started by setting the burst mode bits in the Control Register ATMD. The initialization is observable at bit 4 of the ATMD motherboard Status Register. The initialization clears both memory banks and lasts about 5s.

ABM (Advanced Burst Mode) Structure for 32Bit value		
#	*X / Y*	*Z*
0	16/16	00
1	15/15	02
2	14/14	04
3	13/13	06
4	12/12	08
5	11/11	10
6	10/10	12
7	09/09	14
8	08/08	16

Address Partitioning of the Histogram-Modes		
Histogram-Modus-Bits	*X / Y*	*Z*
00	11 / 11	0
01	9 / 9	4
10	8 / 8	6
11	7 / 7	8

Register 0 **Address: 0**

Bit Nr.	Name	Function	Default
7	CAL	Enables a separate CAL run	0
6	CALIBRATE	If 1 then a calibration is started after the measurement	0
5	MULTIPLICATE	If 1 then multiplication after calibration	0
4	MESSB2	Enables measureing range 2 with prescaler, 1= with prescaler	0
3	EN_CAL_AUTO	Enables automatic calibration after measurement	0
2	EDGE_STP2	Select rising/falling edge at Stop2-Input 0=rise	0
1	EDGE_STP1	Select rising/falling edge at Stop 1-Input 0=rise	0
0	EDGE_STA	Select rising/falling edge at Start-Input 0=rise	0

Register 1 **Address: 1**

Bit Nr.	Name	Function	Default
7	RESO_ADJ	Enables resolution adjust mode	0
6	HIGH_RES	Enables high resolution mode	0
5	ADJ<5>	Adjust bit 5 of HIGH RES mode	0
4	ADJ<4>	Adjust bit 4 of HIGH RES mode	0
3	ADJ<3>	Adjust bit 3 of HIGH RES mode	0
2	ADJ<2>	Adjust bit 2 of HIGH RES mode	0
1	ADJ<1>	Adjust bit 1 of HIGH RES mode	0
0	ADJ<0>	Adjust bit 0 of HIGH RES mode	0

Register 2 **Address: 2**

Bit Nr.	Name	Function	Default
7	HIT2_IN<3>	HIT2 with fine count calculation	0
6	HIT2_IN<2>	"	1
5	HIT2_IN<1>	"	0
4	HIT2_IN<0>	"	1
3	HIT1_IN<3>	HIT1 with fine count calculation	0
2	HIT1_IN<2>	"	1
1	HIT1_IN<1>	"	0
0	HIT1_IN<0>	"	1

Register 3 **Address: 3**

Bit Nr.	Name	Function	Default
7	FAK_DLL<7>	Adjustment factor of the DLL	1
6	...		0
5	...		0
4	...		0
3	...		0
2	...		0
1	...		0
0	FAK_DLL<0>		0

Register 4 **Address: 4**

Bit Nr.	Name	Function	Default
7	SEL_CLK_TDC<2>	Ratio for calibration clock TDC	0
6	SEL_CLK_TDC<1>	...	0
5	SEL_CLK_TDC<0>	...	0
4	NEG_PH_PLL	Invert the phase outputs of the DLL	0
3	SET_PAR_PLL	Track Mode of the DLL	0
2	SEL_CLK_DLL<2>	Ratio of the reference clock DLL	0
1	SEL_CLK_DLL<1>	...	0
0	SEL_CLK_DLL<0>	...	0

Register 5 **Address: 5**

Bit Nr.	Name	Function	Default
7	RLC_NR<2>	Select how many and which RLC ports will be measured	1
6	RLC_NR<1>	"	0
5	RLC_NR<0>	"	0
4	SINGLE_EN	Measure selected port = 1, 0= all ports von 1 to RLC_NR	0
3	C_SEL	Measure capacity ratios = 1	0
2	SEL_CLK_RLC<2>	Ratio for clock of the RLC unit	0
1	SEL_CLK_RLC<1>	"	0
0	SEL_CLK_RLC<0>	"	0

Register 6 **Address:6**

Bit Nr.	Name	Function	Default
7	INT_SEL	Interrupt Select	0
6	QUEUING	Enable Queuing in measure range 1	0
5	RETRIG_EN	Enable Retrigger Modus	0
4	NOISE_EN	Noise Enable	0
3	RLC_EN	Start of a RLC measurement	0
2	USE_TRANS	1= using an external transistors at the RLC Unit	0
1	SPEED<1>	Frequency setting BIGALU clock	1
0	SPEED<0>	"	0

Register 7		Address 7	
Bit Nr.	Name	Function	Default
7	HALF_RES	Enable half resolution mode	0
6	EN_SUI	Enable spike reduction at RDN	0
5	EN_HIT2<2>	Number of allowed hits at channel 2	1
4	EN_HIT2<1>	"	0
3	EN_HIT2<0>	"	0
2	EN_HIT1<2>	Number of allowed hits at channel 1	1
1	EN_HIT1<1>	"	0
0	EN_HIT1<0>	"	0

Register 8-10
Adresse:8-10

		Default
Register 8	Multiplication factor <7..0>	0
Register 9	Multiplication factor <15..8>	0
Register 10	Multiplication factor <23..16>	128

Status register 1

Address: 8
Content

Bit Nr.	Name	Function
7	PLL_LOCK	Lock of the PLL
6	OFL	Overflow of measurement unit
5	HIT2_TDC<2>	Available hits at channel 2
4	HIT2_TDC<1>	Available hits at channel 2
3	HIT2_TDC<0>	Available hits at channel 2
2	HIT1_TDC<2>	Available hits at channel 1
1	HIT1_TDC<1>	Available hits at channel 1
0	HIT1_TDC<0>	Available hits at channel 1

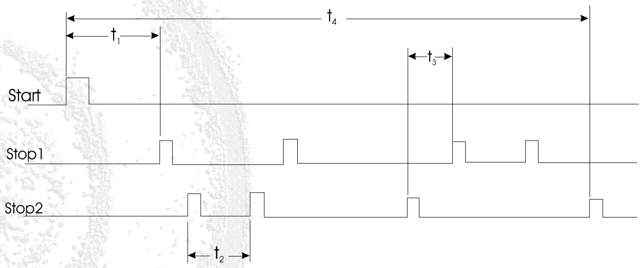
Status register 2
Address: 9
Content

Bit Nr.	Name	Function
7	N.C.	Not used
6	N.C.	Not used
5	RLC_END	End of an RLC measurement
4	Multiplicate	Indicates multiplication
3	Calibrate	Indicates calibration calculation
2	LD_REGS<2>	Load state of the output register
1	LD_REGS<1>	Load state of the output register
0	LD_REGS<0>	Load state of the output register

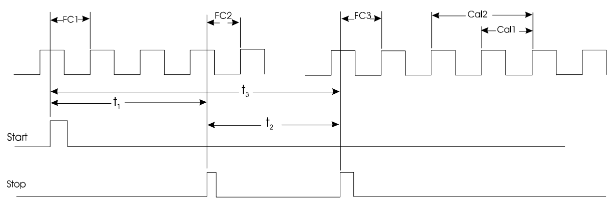
Address 11: **Special address für initialization**

Bit Nr.	Name	Function
7	POR.	Power On Reset (1)
6	POR.	Power On Reset (0)
5	POR.	Power On Reset (1)
4	POR.	Power On Reset (0)
3	Not connected	
2	CLK_NOISE	Clock for PRBS Counter in Auto Noise Unit
1	INIT_BIGALU	Init for BIGALU Unit
0	INIT_TDC	Init for TDC Unit

Possible measurement sequence and measurement times.



- After a Start there must be no signal at the stop lines before 3ns. Stops arriving earlier will be ignored
  → $\mathbf{t_{1\,min} = 3\ ns}$
- Between two events on the same channel there must be a pause of at least 14ns (pulse pair resolution). If the second event arrives earlier then it'll be ignored.
  → $\mathbf{t_{2\,min} = 14\ ns}$
- Between to events on different channels there is no restriction about a time difference.
  → $\mathbf{t_{3\,min} = 0\ ns}$
- All events must arrive prior to 30.720 LSBs (2^{15}-2^{11}) after the start
  → $\mathbf{t_{4\,max} \approx}$ **6,7 µs (typ.)**



$$time = period*(CC + \frac{FC1-FC2}{Cal2-Cal1})$$

CC = value of the precounter

- After a start no stops should arrive prior to two calibration clock cycles. Stops prior to that will be ignored.
  → $\mathbf{t_{1min}}$ **= 2 * CAL_CLK**
- There is a minimum time between two stop events of two calibration clock cycles. If the 2nd stop arrives earlier then it'll be ignored.
  → $\mathbf{t_{2min}}$ **= 2 * CAL_CLK**
- All stops must arrive prior to 2^{16} calibration clock cycles.
  → $\mathbf{t_{3max} = 2^{16}}$ *** CAL_CLK**

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