MPA4T

8(4) Channel Multiparameter Data Acquisition System
5(6) Input 100ps Multi-stop TDC, Multiscaler, Time-Of-Flight
User Manual

Version 1.38, November 23, 2023

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The information in this manual describes the hardware and the software as accurately as possible, but is subject to change without notice.

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WARNINGS

**The metal case of the MPA4T might be hot.
Beware of burning yourself!**

The whole metal case works as a passive cooler for the device.
It can reach surface temperatures of well over 50°C.

The metal case of the MPA4T works as a passive cooler. Please provide ample airflow around the device. Do not cover the case. Do not place it inside a closed cabinet etc.

Static electricity discharges can severely damage the MPA4T. Use strict antistatic procedures when connecting cables and during handling of the device.

Take care not to exceed the maximum input voltages as described in the technical data.

The START and STOP inputs are ultra high speed, high sensitivity inputs and thus, susceptible to oscillation and noise pick-up. Take care to apply low impedance (≤ 50 Ω) source signals and well shielded, 50 Ω coaxial cables.

1. Introduction

The MPA4T Multiparameter System is an ultra fast listmode multichannel data acquisition system featuring performace and measurement capabilities previously not known in commercially available multiparameter systems.

A highspeed USB connection provides for easy connection to a computer and asure maximum data transfer rates into the PC.

With the MPA4T unit FAST ComTec combines the functions and performance of the MPA4 Multiparameter System and the MCS6A 5(6) input 100ps per time bin, multiple-event time digitizer (TDC).

The MPA4T Multiparameter System actually is a comprehensive set of 3 different data acquisition devices in one unified package.

First there is a 5(6) input channel 100ps per time bin, multiple event time digitizer (TDC) incorporating all the functions and performance already known from the MCS6A unit.

Then, there is an 8(4) input classical multiparameter system section providing very flexible acquisition combinations of upto 8 external NIM ADC port devices like ADC's, TDC's.

Third there are 8 independent 32bit 100MHz counters/scalers (option).

> **NOTE:**
>
> In the following text we may also refer to the MCS6A for the 100ps Time-of-Flight (TOF) functionality. When referring to the MPA4 model we address the classical multiparameter section available in that unit or the MCS6/MPA4 family in general.

An onboard DDR2 memory with a capacity of 1 or optionally 2 GB functions as large FIFO for buffering high event rates. The FIFO memory buffers enable to MPA4T to continuously transfer data rates of approximately 35 MByte/s to the connected computer.

Fig. 1.1: MPA4T unit

The MPA4T system allows to simultaneously acquire single and coincidence ADC data (e.q. energy spectra) from upto 8(4) input channels. Additionally time measurements with 100ps resolution can be accomplished in upto 5(6) channels.

First in time this high resolution time data can be related to the corresponding energy/ADC data. Thus, multiparameter spectra of time and ADC data can be accomplished in a single instrument.

A range of versatile additional features enables easily adapting the MPA4T system to a large variety of experimental requirements, complicated or almost impossible to fulfill with other systems.

Eight 32 bit counters with a maximum countrate of 100MHz each are provided (option). Each counter is presettable and can also be configured to free run at 100MHz. 2 of the counters provide a carry output for cascading and 2 can switch from UP to DOWN counting by external signal application. All of them can be gated as well.

An open-drain 'GO'-line (compatible to other products of FAST ComTec) enables overall experiment synchronization.

A versatile 8 bit digital I/O[1] port may further satisfy your experimental needs.

The MPA4T is designed with "state-of-the-art" components, which offer excellent performance and reliability. The high-performance hardware is matched by sophisticated WINDOWS™-based software (delivered with each MPA4T) providing a powerful graphical user interface for setup, data transfer and spectral data display.

Almost any thinkable combination of time, single and multiparameter spectra may be acquired and displayed while also writing the data in listmode to a harddisc for later analysis.

Some of MPANT´s features are high-resolution graphics displays with zoom, linear and logarithmic (auto) scaling, grids, ROIs[2], Gaussian fit, calibration using diverse formulas and FWHM[3] calculations. Macro generation using the powerful command language allows task oriented batch processing and self-running experiments.

A DLL (Dynamic Link Library) is available for operation in a Laboratory Automation environment. Drivers for LINUX are also available.

100ps TOF section:

The Model MPA4T is a 100ps per time bin, multiple-event time digitizer (TDC). It can be used in ultra-fast multi-scaler/TOF systems, in Time-of-Flight mass-spectrometry and time-resolved single ion- or photon counting.

A unique feature is the MPA4T's capability to detect the rising and the falling edges simultaneously. Thus, Time-over-Threshold (ToT) and Time-under-Threshold (TuT), i.e. pulse-width measurements are easily accomplished.

Pulse-width evaluation with 100ps resolution enables the user to calculate the area, the pulse-height of the detector pulse but also if multiple events have occurred – multiple events have a broader pulse width than single pulses.

A new genuine feature is the Constant-Fraction-Timing (CFT) mode. Some detectors will deliver different height signals depending on the number of particles detected. To derive most accurate timing information of the event a long known method is to use the constant fraction timing. This was previously only possible with analogue constant fraction timing discriminators. But these have a main downfall, namely the acceptable data rate. With the MCS6's capability of detecting rising and falling edges simultaneously it is now possible to do that on a digital and thus, not(!) bandwidth limited basis.

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[1] I/O: Input / Output

[2] ROI: Region Of Interest

[3] FWHM: Full Width at Half Maximum

Also a new capability is to evaluate coincidental events at a resolution of 100 ps. Thus multi-dimensional spectra with 100 ps time resolution can be generated.

In standard operation a sweep is started by a user supplied start (trigger) pulse. Then subsequent events detected at the STOP inputs are recorded, each in a specific time bin corresponding to the time of arrival relative to the start pulse. Compared to non-multi-hit devices the MPA4T can evaluate stop events at a rate of 10GHz state changes per second. In the pulse-width mode pulses as narrow as 100ps can be evaluated at a pulse repetition rate of up to 5GHz. The MPA4T is designed with fully digital circuitry capable of accepting at least 65,000 events at peak (burst) input rates of up to 10Gbit/s for each input.

The MPA4T has been optimized for the best pulse pair resolving while providing state-of-the-art time resolution available in digital designs. Six built-in discriminators can be adjusted for a wide range of input signal levels.

Sixteen TAG inputs allow for a wide range of spectra routing, multi detector experiments, sequential acquisition etc.

Two software configurable SYNC outputs provide synchronization and triggering of external devices or experiment monitoring.

The single sweep time range enables the user to take data of up to 20 days (54 bit setting) or 30 minutes (44 bit setting plus 16 TAG bits enabled) with a time resolution of 100 ps.

Via the 10 MHz reference I/O the already excellent stability of the internal oven controlled crystal oscillator can be further improved by connecting an optional available high stability external reference clock source such as a GPS or rubidium-disciplined oscillator.

For experiments requiring repetitive sweeps the spectral data obtained from each sweep can be summed in the PC enabling very high sweep repetition rates. In endless / wrap-around mode sweep repetitions with zero end-of-sweep dead time can be accommodated.

MPA4 external ADC input section

For dependent multiparameter data acquisition coincidence resolving times from low 20ns to 1.3ms can be selected in steps of 20ns. A programmable timeout counter (also 20ns to 1.3ms) for the maximum time to wait for a conversion being finished after a DEADTIME signal of the ADC was detected further helps to optimize the data throughput for a specific experiment.

With the MPA4 multiparameter system, FAST introduces a most flexible and versatile method to setup coincidence mode data acquisition. Coincident events may be defined as almost any combination of the 8(4) ADC ports and also the auxiliary connectors might be involved. Several different combinations may be defined as coincidence conditions at a time. Besides, it is possible to define the ADC ports that can actually start a coincidence independently. Thus, random coincidences and therefore the base level noise in the spectra is further reduced.

For special external data units the ADC ports can be configured to allow even 32, 48 or 64 bit wide interfaces.

An optional realtime clock with a 6.4ns resolution allows to time mark each ADC event.

Livetime correction on all ADC input ports is also provided.

The easy to use multiparameter operating software MPANT allows to fully control the complete system setup. A monitoring facility provides to on-line view single and dual parameter spectra.

Some of MPANT´s features are high-resolution graphics displays with zoom, linear and logarithmic (auto) scaling, grids, ROIs[4], Gaussian fit, calibration using diverse formulas and FWHM[5] calculations. Macro generation using the powerful command language allows task oriented batch processing and self-running experiments.

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[4] ROI: Region Of Interest

[5] FWHM: Full Width at Half Maximum

Almost any thinkable combination of time, single and multiparameter spectra may be acquired and displayed while also writing the data in listmode to a hard disk for later analysis.

List data can be stored on the local harddisk drive or any other directly accessible mass storage device.

Several single and multiparameter spectra may also be accumulated in the RAM of the PC. Multiple windows of dual and single parameter spectra can be simultaneously displayed. Any combination of ADCs can be selected thus, it is possible to define several single and dual parameter spectra which can be acquired and displayed.

A DLL (Dynamic Link Library) is available for operation in a Laboratory Automation environment. Drivers for LINUX are also available.

2. Installation Procedure

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2.1. Hard- and Software Requirements

For operating the MPA4T you need a standard PC with USB 2.0 port and Microsoft Windows XP or higher. USB 1.0 ports do not work. The MPA4T works well using only one USB 2.0 port. The maximum throughput then is 30 Mbyte/sec. This throughput can be somewhat increased by using two USB ports, but with the actual libusb(WINUSB) driver only the USB1 port can be used. The maximum throughput then is typically 35 Mbyte/sec but we have seen a record of about 40 Mbyte/sec on one computer.

The large 1 or 2 GB FIFO is able to buffer data recorded at 33 million events/sec. Of course it will take some time after stopping an acquisition to empty a full FIFO, 2 Gbyte / 30Mb/sec is about a minute. The filling status of the FIFO is shown in the software. There is also an indicator showing if any data is lost. The fast FIFOs on each 100ps TOF input channel can buffer data recorded with 10 GHz without loss up to 6.5 mikrosec. See chapter 4.3 in this manual.

We do not expect any problems with host compatibility as we do not use something else than any USB hard disk or memory stick. Of course, it is necessary that the PC has a true USB 2.0 port. Older PC's that do not have USB 2.0 on the motherboard can use a PCI card providing USB 2.0 ports. We have no good experience with such PCI cards, the throughput will be much lower, typically only 15..20 Mbyte/sec, and some cards may not work at all. So we recommend a PC with true USB 2.0 ports on the motherboard, as is now standard even for laptops.

First check you have all shipped equipment available:

- Transport case
- MPA4T module
- Power supply module 100…240 V_{AC} / 12 V_{DC}
- Power line cord
- (6x) SMA – BNC cable, RG316, 2 m
- USB 2.0 (A/B) cable, 3 m
- User manual
- USB stick with operating software

2.2. Driver Installation

To install the driver, please start the device manager. You can do it by right-clicking the computer shortcut on the desktop and selecting "Manage" from the drop-down-menu, then "Device Manager". Another way is to select in the Start Menu Settings..Control Panel, then System..Device Manager.
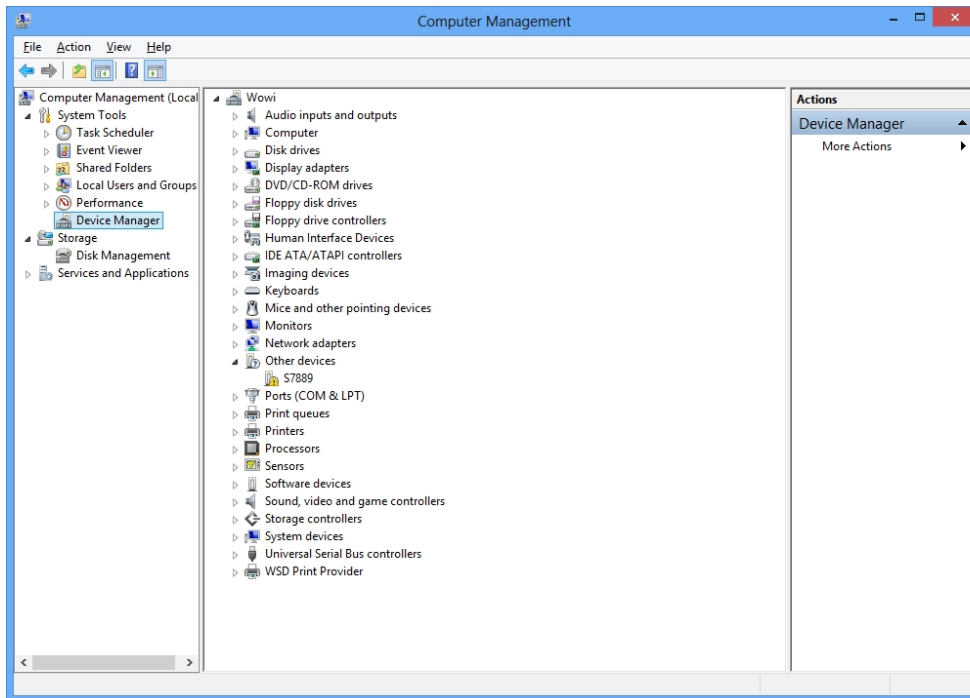
Fig. 2.1: Device manager

Connect the MPA4T and the power. The new device is displayed as "S7889" in a class "Other devices". Please right-click it and select "Update driver" from the drop-down menu.
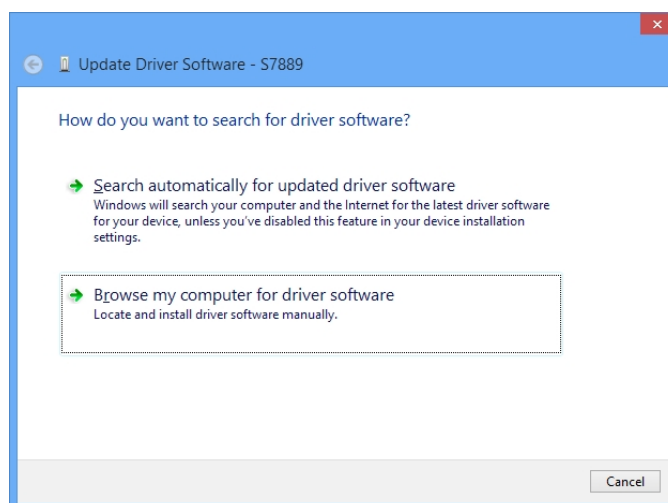
Fig. 2.2: Driver installation

Windows offers to search automatically for updated driver software or browse the computer for the driver software. Don't try the automatic installation, it will probably not work. Select to browse manually for the driver and select for example for Windows 10 the driver\fastusb2 folder on the CD or Software stick.
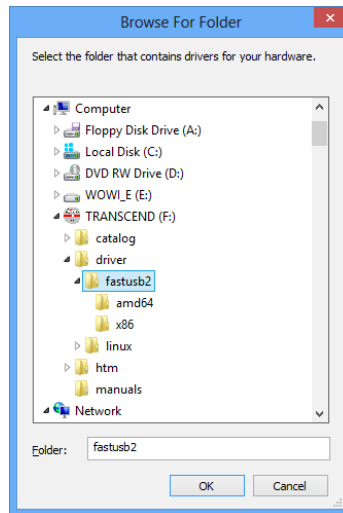
Fig. 2.3: Choosing the right folder

Please don't go deeper into the folder structure, the processor type (amd64, x86) is found automatically. After pressing "OK" the driver installation will proceed. The device manager will then show a "FAST ComTec USB2 device" in a class "libusb (WinUSB) devices" as shown in Fig. 2.4
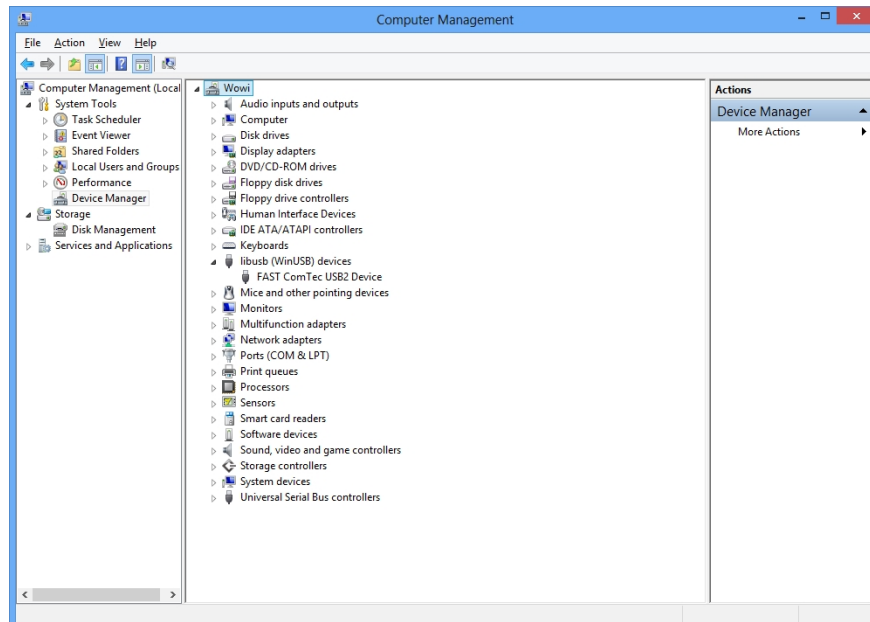
Fig. 2.4: Device Manager after successfull driver installation

Please check the Power Saving Options in the PC Settings. If the PC goes to sleep during a running acquisition and shuts the USB port down, the software will hang up. So it is recommended to disable automatic going to sleep in the energy options.

2.3.   Software Installation

Please check the Power Saving Options in the PC Settings. If the PC goes to sleep during a running acquisition and shuts the USB port down, the software will hang up. So it is recommended to disable automatic going to sleep in the energy options.

To install the MPA4T software on your hard disk insert the installation medium (CD or USB-Stick) and start the installation program **setupx86.exe** for the 32-bit software or **setupx64.exe** for the native 64-bit software.

A directory called C:\LMPA4Tx86 for the 32-bit software or C:\LMPA4T-x64 for the native 64-bit software is created on the hard disk and all MPA4T and MPANT files are transferred to this directory. Drive C: is taken as default drive. It is not mandatory that the MPA4T operating software is located in this directory. You may specify another directory during the installation or may copy the files later to any other directory.

The Setup program has installed a shortcut on the desktop. The icon starts directly the MPA4.EXE. The server program will automatically call the MPANT.EXE program when it is executed. The MPA4 Server program controls the MPA4T module but provides no graphics display capability by itself. By using the MPANT program, the user has complete control of the MCS6 along with the MPANT display capabilities.

To run the MPA4T software, simply double click on the "MPA4 Server Program" icon. To close it, close the MPA4 server in the Taskbar.

2.4.   Hardware Installation

Installation of the MPA4T is as easy as connecting a cable. Connect the power supply to the "POWER" connector and a USB 2.0 cable to the "USB 1" port. At the host computer plug in the USB cable into a high-speed capable USB 2.0 port. Since USB is a hot-pluggable interface the sequence of applying power and connecting the USB port is not important.

NOTE:

At the host computer a high-speed (480 Mbit/s[6]) capable USB 2.0 interface must be used.

When power is applied the "POWER ON" LED on the rear of the MPA4T should be lit and a second later "POWER GOOD" as well.

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[6] The USB 2.0 specification includes low-speed (1.5 Mbit/s), full-speed (12 Mbit/s) and high-speed (480 Mbit/s) signaling rates

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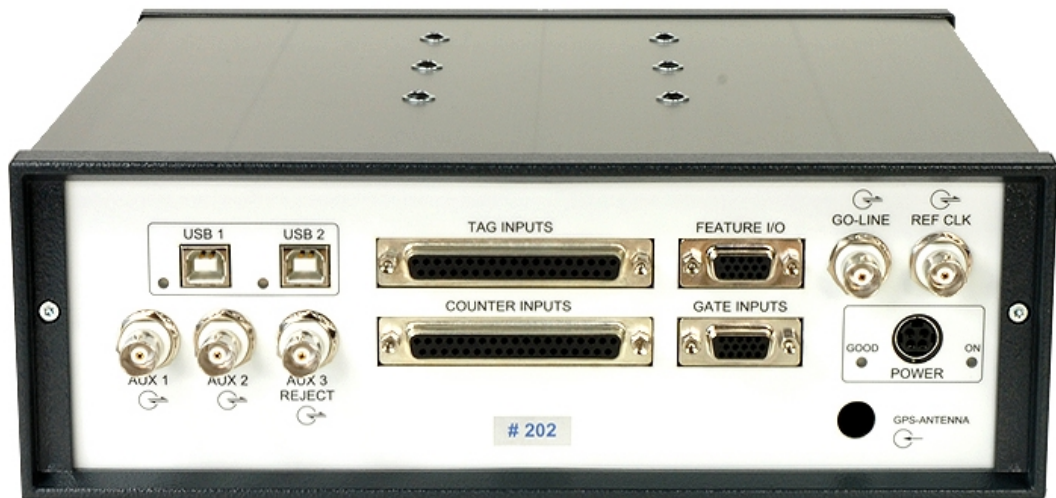
Fig. 2.5: MPA4T rear panel

With an older driver version it was also possible to get a slightly higher data rate by connecting "USB 2". With the libusb driver only the USB1 port must be connected.

IMPORTANT:

All setup and control data exchange is handled over "USB 1". Thus, "USB 1" must always be connected to the host computer.

When the software and driver are already installed the computer will detect the MPA4T automatically as soon as it is connected.

2.5. Getting Started

If you want to start with the TDC part using the internal pulser, you may now first read chapter 2.5.3.

2.5.1. Getting Started with a basic SINGLE ADC measurement

What we are going to setup now is a simple SINGLE measurement using one external ADC. The acquired spectrum will have a range of 1k channels corresponding to a 1k ADC conversion gain setting.

First step is to start the MPA4 software by double clicking the corresponding icon. This will automatically start the MPANT program. On startup the MPA4 Server is iconized and one does not have to worry about it since all hardware settings are also accessible from the MPANT program which actually is the graphical user interface and which will appear now on your screen (ref. Fig. 2.2).
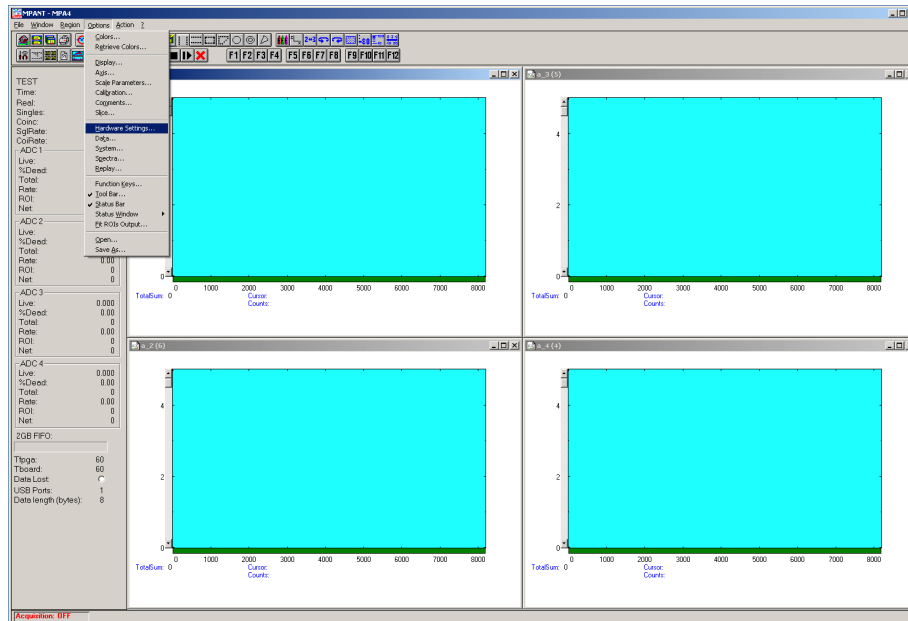
Fig. 2.6: MPA4 / MPANT startup screen

Now we have to change the system settings to one ADC (default is four or eight) only. Click on *Options – Hardware Settings…* or the icon to find the MPA4T Settings window pop up (see Fig. 2.2).
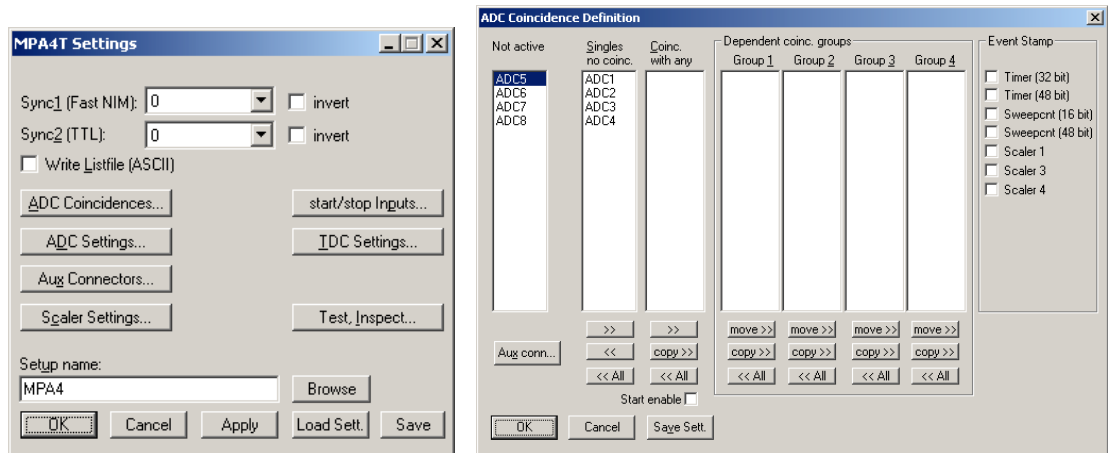
Fig. 2.7: MPA4T Settings and 'Coincidence Definition' dialogs

Click the *ADC Coincidences* button to open the *ADC Coincidence Definition* window. It should look like Fig. 2.7. Click the *<<All* button below the „Singles no coinc." box to remove all ADCs out of the list, then click the *>>* button to enter ADC1 again. Close the window with *OK*.

No we must set the range of the ADC to 1k. For this, click *ADC Settings...* Change the *ADC Settings – Range* to 1k = 1024 (ref. Fig. 2.8) and click *OK*. The spectrum display of ADC1 in the MPANT window changes to a full scale range of 1024 channels.
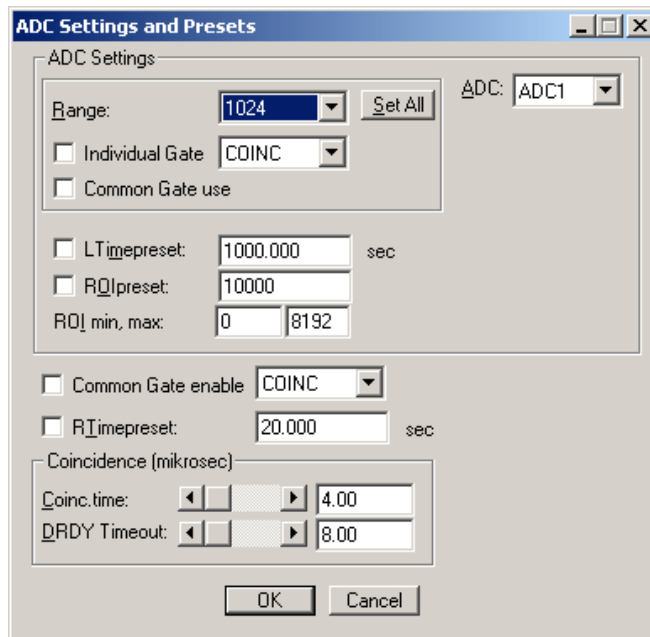
Fig. 2.8: Set ADC range to 1k range

Be sure you connected an external pulse height analyzing ADC (set to 1k conversion gain) to the ADC1 port. Input analog signals to that ADC, e.g. from a pulser.

Now start data acquisition by a click on the START button ▶ (ref. Fig. 2.9). Recognize that when you move the mouse pointer over a button a help message appears in the lower left corner of the MPANT window. In this case it is 'Erases and starts a measurement' meaning that the contents of the histograms is erased and then a new acquisition is started. Click **OK** in the message window that appears after clicking the START button.
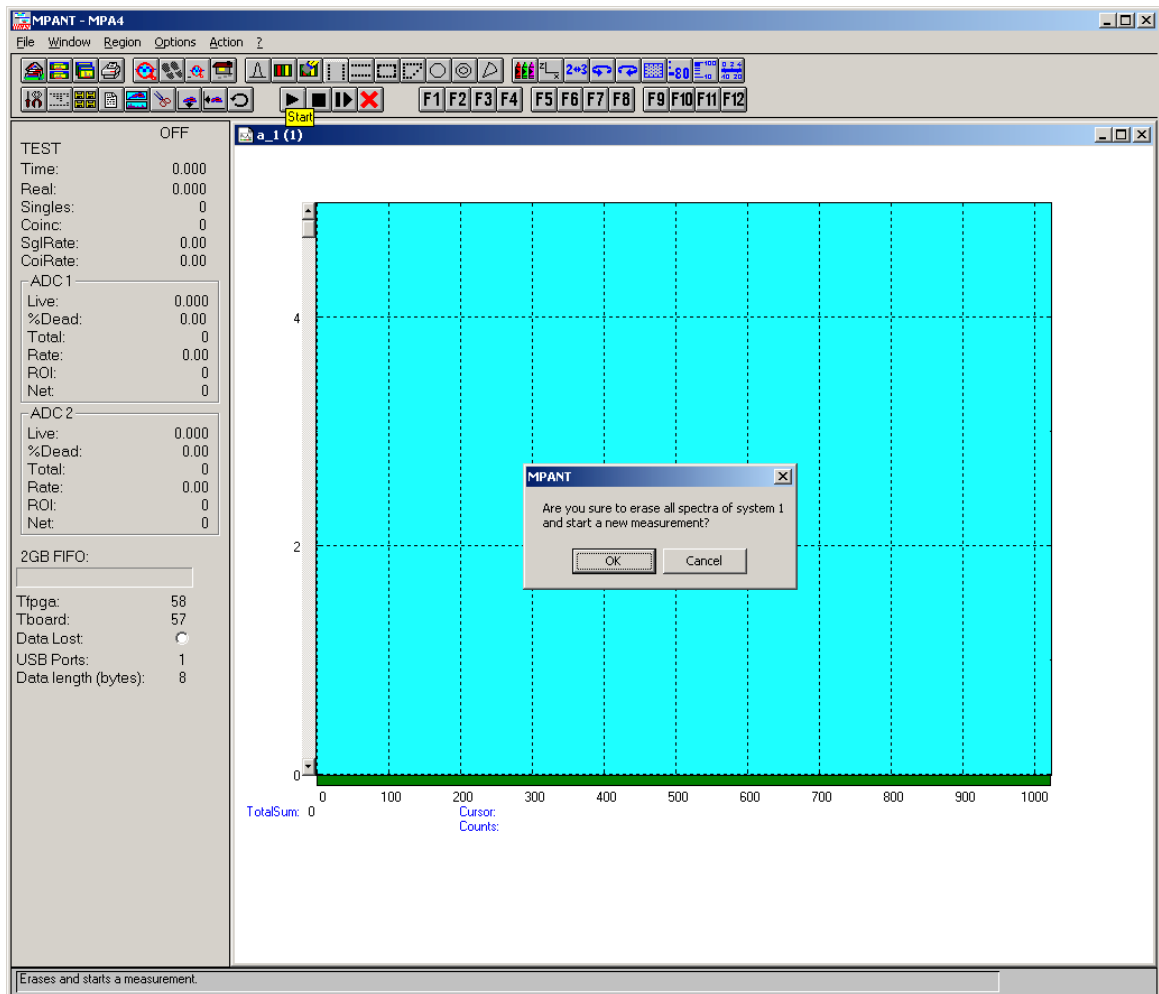
Fig. 2.9: START a SINGLE measurement with one ADC

See that the *Status* changes to *ON*. The *Real* time will begin to run also indicating that data acquisition is *ON*. Depending on your input signals a histogram should start to be accumulated (ref. Fig. 2.9). When you want to finish data acquisition click on the STOP button ■. The corresponding help message is 'Halts a measurement'.
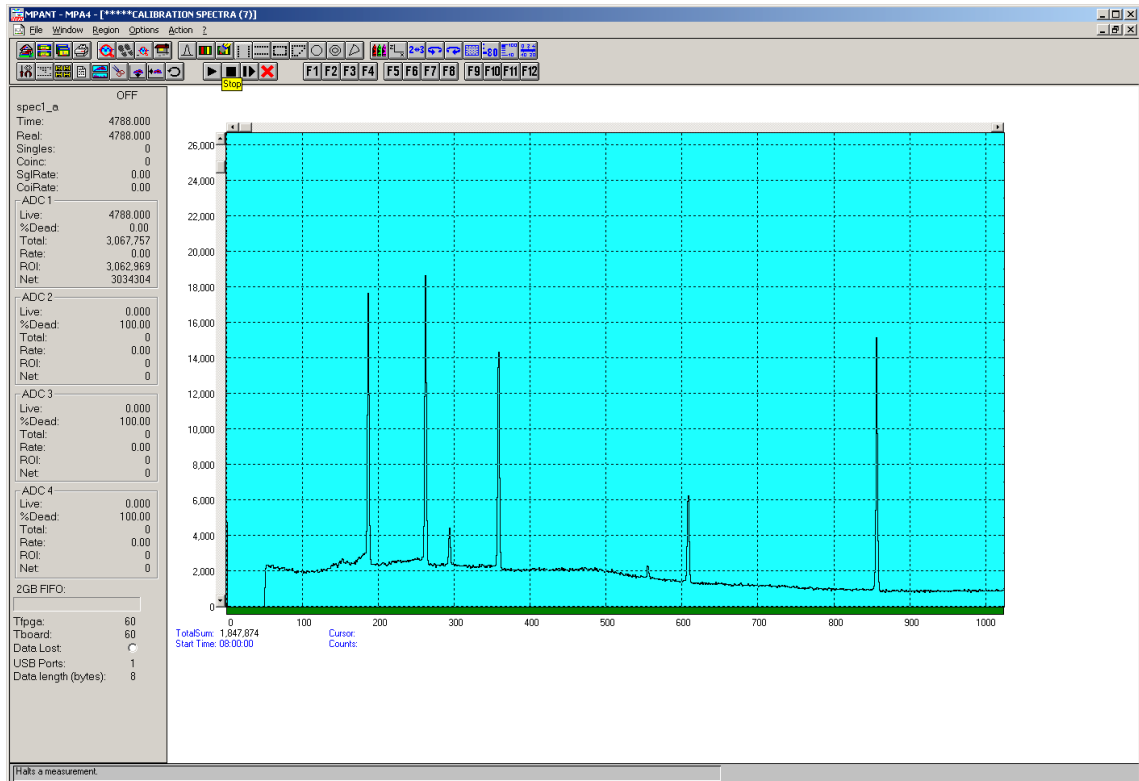
Fig. 2.10: Spectrum of a basic SINGLE measurement

2.5.2. Getting Started with a basic COINCIDENCE measurement

What we are going to do is to setup a basic COINCIDENCE measurement using two ADCs. The ADCs will be set to a conversion gain of 4k. The on-line displays are set to a single spectrum for each ADC and a two-dimensional spectrum of ADC1 x ADC2 with a resolution of 256 x 256 channels.

First open the *Coincidence Definition* window by a click on *ADC Coincidences* in the MPA4T Settings dialog. Use the **<< All** buttons to move all ADCs to the **Not active** box and then move ADC1 and ADC2 to the **Coinc. with any** box with the **>>** button below this field. By default they are displayed with a 'S' appended indicating that they are allowed to start a coincidence resolving time window. If the 'S' is not appended check the **Start enable** check box for each ADC. The *Coincidence Definition* window should look like Fig. 2.11 now.
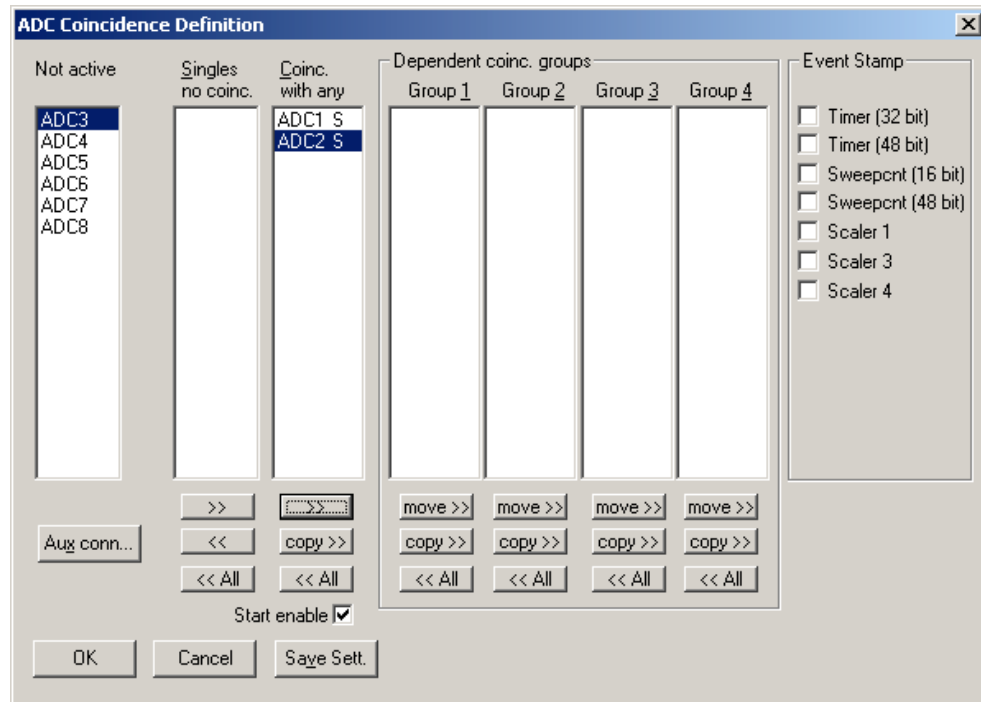
Fig. 2.11: Setup two ADCs for a COINCIDENCE measurement

Set the ADC ranges to 4096 using the *ADC Settings...* button *ADC Settings and Preset* window. Set the *Coinc time* to 10.00µs using the scrollbar. Then click into the data field of *DRDY Timeout* and type in 50.00 to set the DRDY timeout to 50.00µs. This is in accordance to a 100MHz Wilkinson type ADC (4k x 10ns ≈ 40µs + 10µs overhead for safety) like our model 7074 Quad ADC. The DRDY timeout is the maximum time the system waits for converted data (DRDY goes true) after the coincidence time window is closed. For a 7072 ADC a short DRDY timout of about 10 µs is reasonable. Click *OK* to accept the new settings and to close the *ADC Settings and Preset* window.
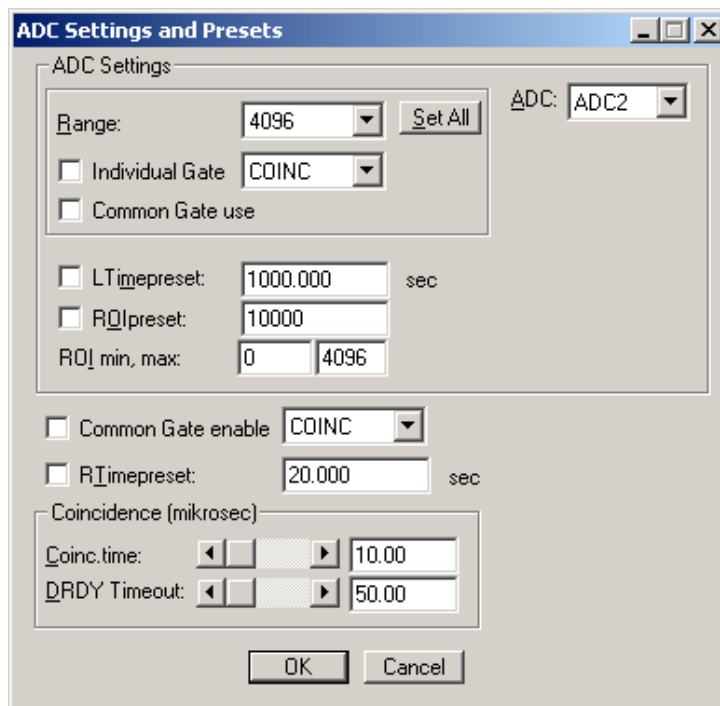
Fig. 2.12: Setup ADC range and coincidence resolving time

Now we will still have to define a two-dimensional spectrum of ADC1 x ADC2. Open the spectra definition window *Dualparameter and Calculated spectra* by a click on the *Spectra* button 🖼.

In the *Map and Calculated spectra* window click on *Add Multi…* button to add a new multiparameter spectrum. The *Multi Display Setting* window opens.
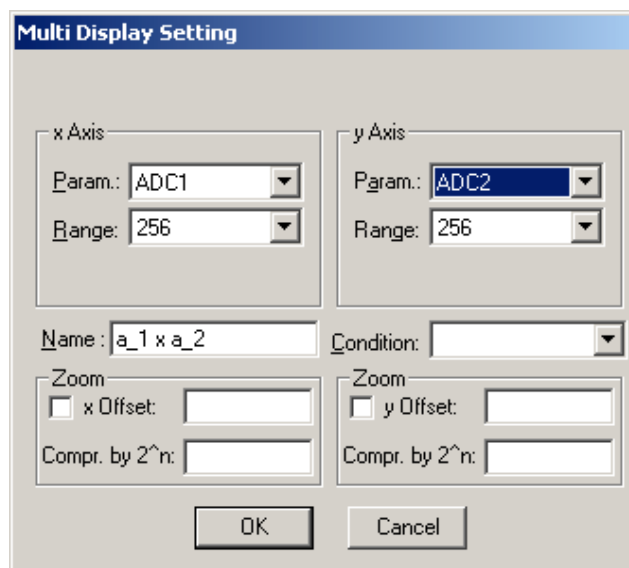
Fig. 2.13: Add a two-dimensional spectrum

Set the x-axis of the new spectrum to ADC1 with a range of 256 and the y-axis to ADC2 with also range 256. Type in a name for the spectrum, e.g. 'a_1 x a_2' like in Fig. 2.13 Click *OK*. In the *Dualparameter and Calculated spectra* window the new map appears (ref. Fig. 2.14).
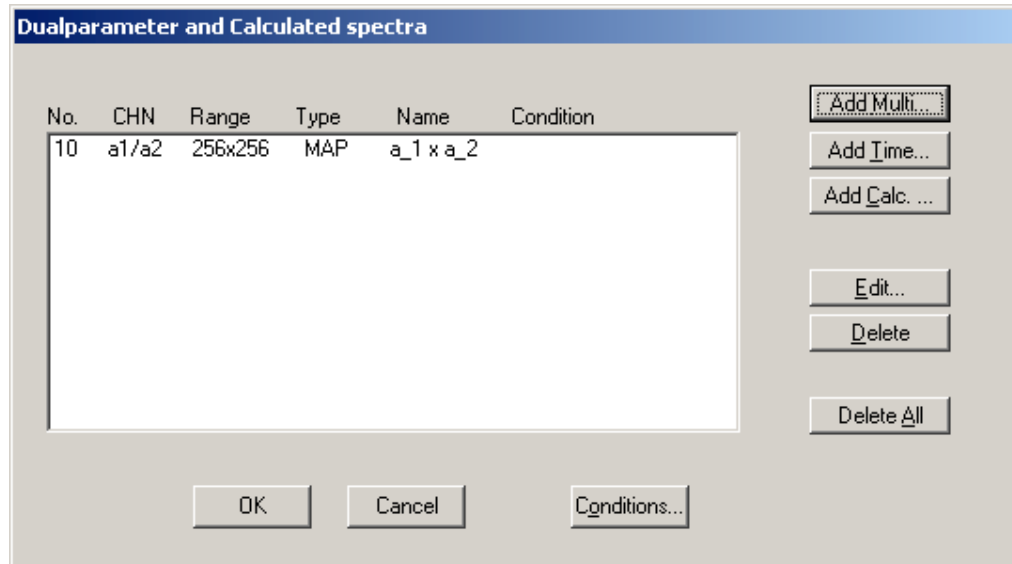
Fig. 2.14: New spectrum defined

Close *Dualparameter and Calculated spectra* and the MPANT display should show up with two single spectra (ADC1 and ADC2) and one multiparameter map (ref. Fig. 2.15).
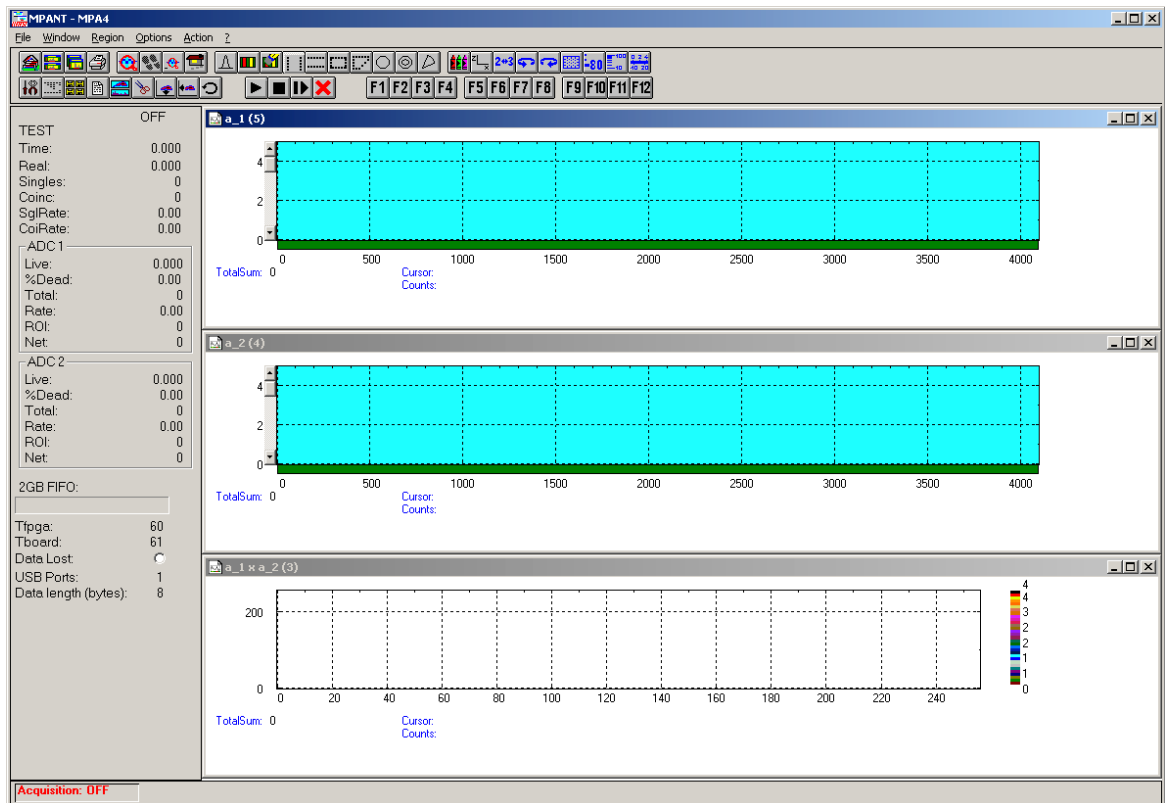
Fig. 2.15: Two single and one multiparameter spectra display

Connect input signals to the ADCs. In case of a pulser being the signal source split the pulser output to both ADCs since only pulses that reach ADC1 and ADC2 within a 10μs time window (the coincidence time) are counted. Actually in this case not coincident signals are also counted but in the map display they will show up on the base of x- and y-axis (zero) since the respective other ADC is read as a 'ZERO'.

Start data acquisition with the START button ▶. Depending on your signals spectra are shown. End data acquisition by a click on STOP ■.

2.5.3. 1st Basic TOF Measurements

The Model MPA4T has built-in signal generators for START/STOP TOF signals that enable you to get familiar with the device usage without any external signal sources.

There are 2 possible ways to get measurements running without external signals:
1) an internal pulse generator can be internally fed to all START / STOP inputs
2) the SYNC_1 output can be connected to inputs using cables and maybe a power splitter

To ease getting familiar with the use of the MPA4T we will now setup a first basic measurement. Thanks to the built-in signal generator and the "internal pulser" mode no external signals or additional connections are needed.

Start the MPA4 software by double clicking the corresponding icon. This will automatically start the MPANT program. On startup the MPA4 server is iconized and one does not have to worry about it since all hardware settings are as well accessible from the MPANT program which actually is the graphical user interface and which will now appear on the screen (ref. Fig. 2.16).
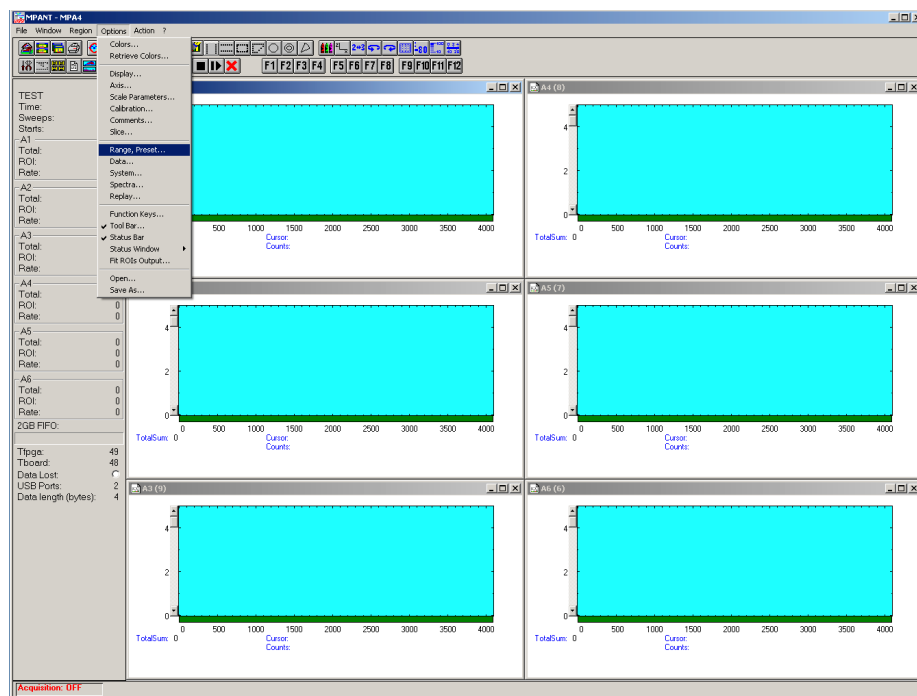
Fig. 2.16: MPA4 / MPANT startup screen

Now we first have to setup the MPA4T. What we will want to do is to setup the system such that we use the internal pulser and acquire a spectrum of 4096 time bins using input channel STOP 1.

Click on *Options – Hardware…* or 🔲 to find the MPA4 Settings window pop up. Click the *TDC Settings* button to open the respective dialog. Set the Range to 4096 time bins (Bin width = 1), which corresponds to a time range of 409.5 ns. Enable *Sweep preset* and set it to e.g. 20,000,000. Verify that *Timepreset* is not checked (ref. Fig. 2.17).
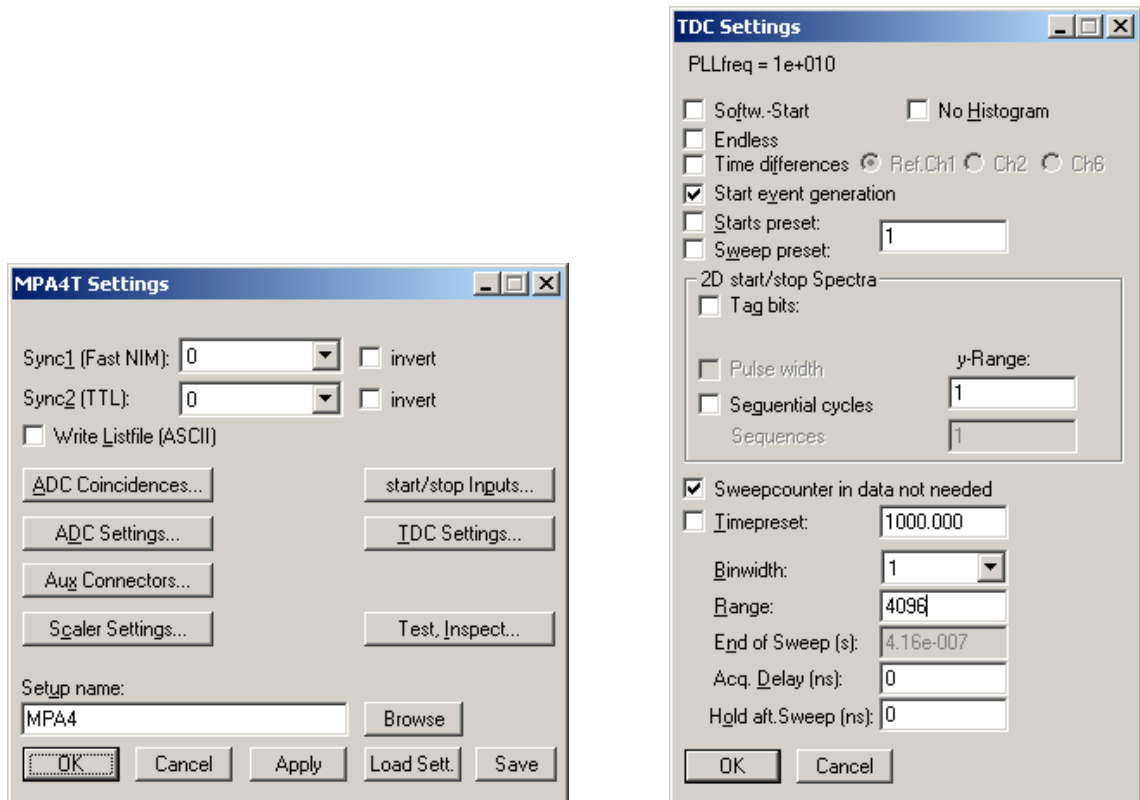
Fig. 2.17: "MPA4T Settings" and "TDC Settings" dialog

Now click on *Test, Inspect…* and you will see the Inspect MPA4 window pop up. Enable the internal pulser and select a signal of 10 MHz (ref. Fig. 2.18).
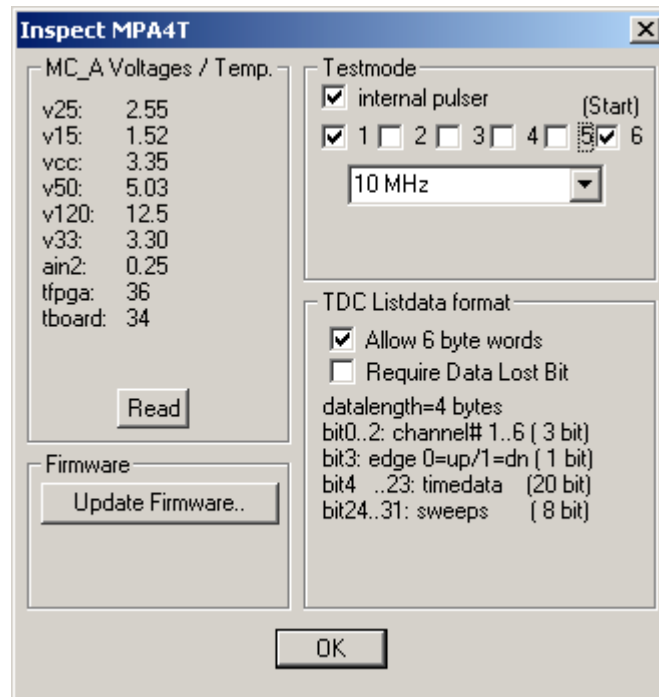
Fig. 2.18: "Inspect MPA4T" dialog

Now click on *start/stop Inputs…*. Select *CH 1* and deselect all other input channels. Check that *Falling Edge* is selected for both *CH 6 / Start* and *CH 1* (ref. Fig. 2.20). Do not worry about the threshold levels since we use the internal pulser, which does bypass the input discriminators. Click *OK*.

You are back in the Settings window. Also click *OK* here. Now we enable a grid selecting *Options – Axis…* or ▦ and ticking the grid enables (ref. Fig. 2.19).

Now start the acquisition by a mouse click on *Action – Start* or the start button ▶. You will see a spectrum growing that is comprised of needles separated by 1000 channels or 100ns, which corresponds to the selected 10 MHz pulser signal. After a while the sweep preset of 20,000,000 will be reached and acquisition is stopped (ref. Fig. 2.21).

You might want to zoom into a specific peak by holding the right mouse button and drawing up a window inside the spectrum. Then click on *Region – Zoom* or 🔍. With the left mouse button you can move a cursor round the spectrum giving information on its time position and counts in the corresponding bin. Play around with zooming in and out, toggling lin/log scale and Gaussian fit.
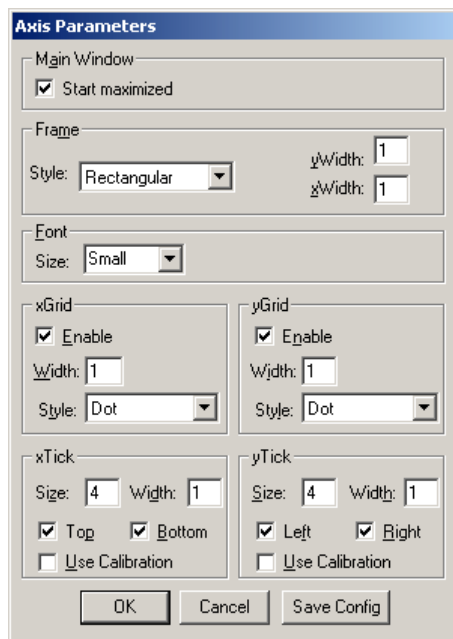
Fig. 2.19: Axis Parameters window
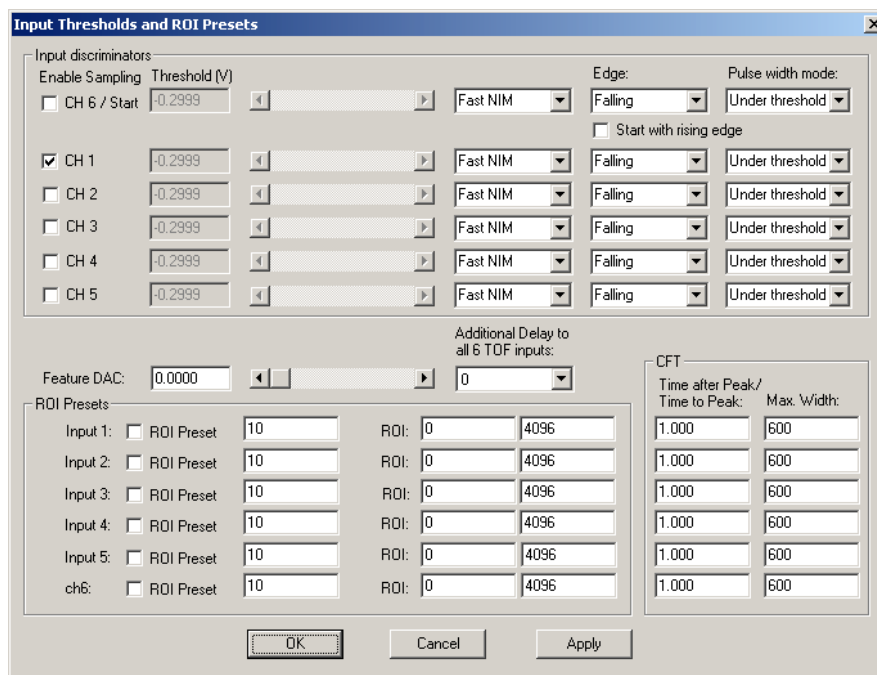
Fig. 2.20: Input Thresholds and ROI Presets window
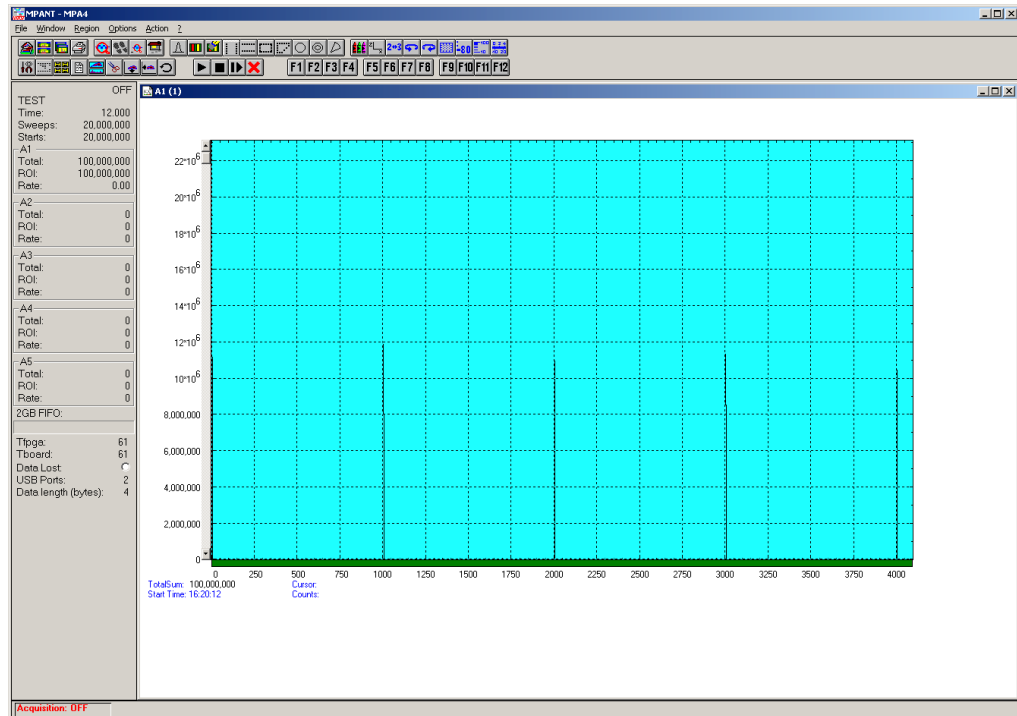
Fig. 2.21: Spectrum of a 10 MHz clock signal

2.5.4. 2nd Introductional Measurement

So far so good. Now lets plunge a little deeper into the capabilities of the MPA4T by using several channels measuring different edges of a more complex input waveform. We use a built-in pulse-train generator that delivers 10 ns wide, negative-going pulses that are separated by 30 ns and repeated N times (with N selectable from 1 to 255). The whole pulse-train is restarted every 10.24 µs.

Lets enable all 5 STOP channels and the sampling of the START input as well (ref. Fig. 2.22). Thus, after a sweep is triggered the subsequent events into the START channel are acquired as well. Using this feature the START input works like a 6th input channel. As can be seen in Fig. 2.22 we set the edge detection of CH 6 / START, CH 1 and CH 4 to 'Falling'. Channel 2 is set to 'Rising' and the channels 3 and 5 to 'Both Edges'. Triggering is done with the falling edge of the START input signal ('Start with rising edge' is not checked). The threshold voltages can still be ignored due to the use of the internal pulser.
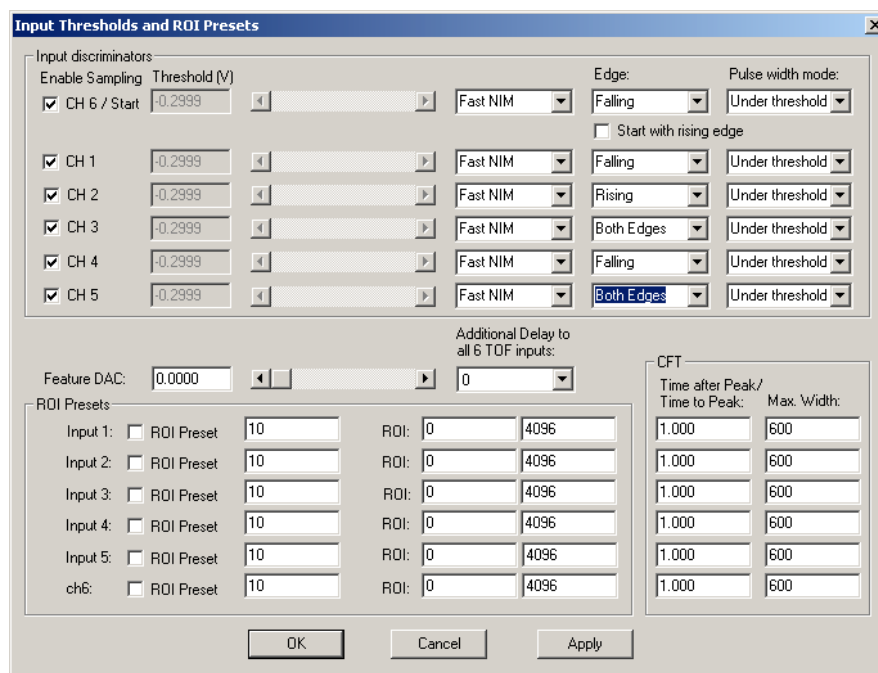
Fig. 2.22: Inputs set to 6 Input Channels and different Edges

Now let's set the internal pulser to pulse train mode and the number of subsequent pulses to seven (ref. Fig. 2.23).

Now that you have set the MPA4T to the use of 6 input channels the MPANT program will show 6 client windows, one for each input channel. The window 'A6' shows the START input, 'A1' to 'A5' the STOP inputs 1 to 5.
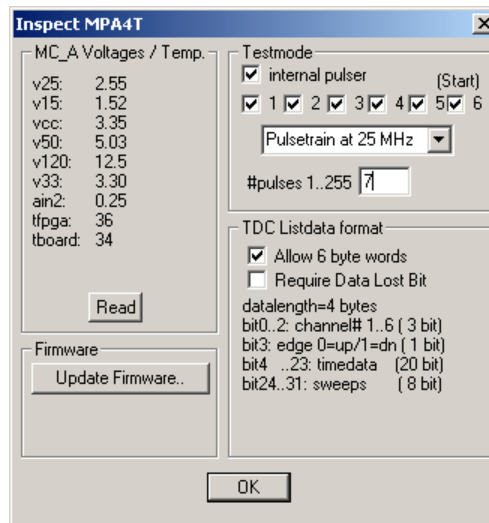
Fig. 2.23: Setup internal pulse train

When you start the acquisition now 6 spectra like in Fig. 2.24 will build up. To indicate the correlation of input signal edges to the peaks in the spectra the selected pulse train is drafted in the picture. You can easily see the signal period of 40 ns and that the sweeps were triggered on the falling edge etc. The pulse width of 10 ns can be very well seen in the spectra with both edges enabled.
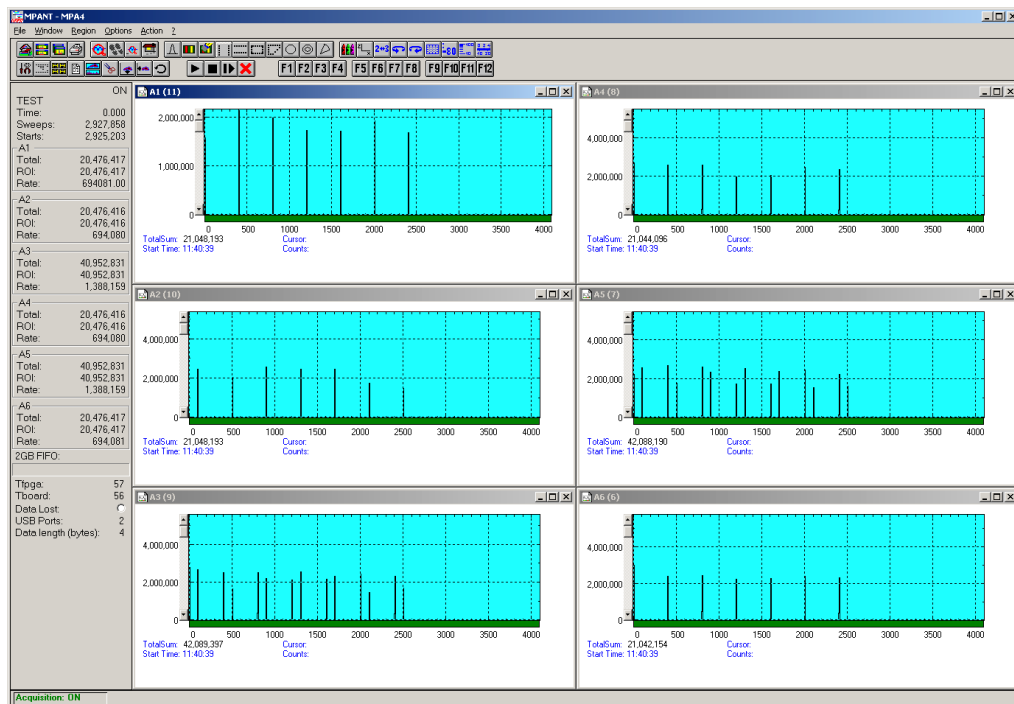
Fig. 2.24: Spectrum of a N=7 pulse train

Now we will introduce another feature of the MPA4T: the acquisition delay. This is very useful when we want to discard events in a specified time occurring directly after the trigger pulse. In some experiments this can dramatically reduce the measured event rate. In our example we will want to acquire data only beginning 96 ns (settable in steps of 6.4 ns only) after the START event. Go to the TDC Settings window again and insert '96' in the Acq. Delay field (ref. Fig. 2.25).

With all other settings left as before we will expect the first 960 time bins of the above spectra to "disappear" i.e. the spectra being shifted left by 960 bins or 96 ns.
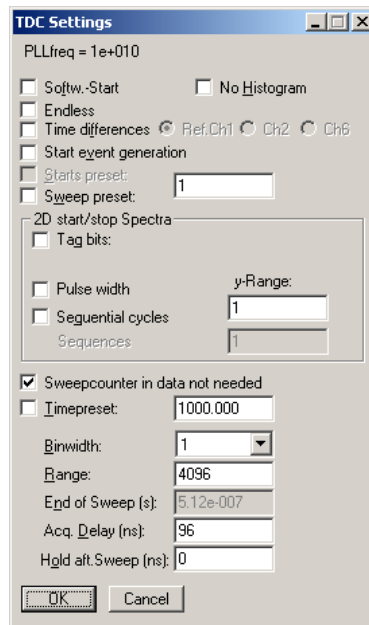
Fig. 2.25: TDC Settings – Acquisition Delay

Start acquisition and compare the delayed spectra data (ref. Fig. 2.26) with the above spectra that began instantly with the START pulse. Referring the input channel STOP 1 (A1) spectrum you see that the first 3 peaks at position 0, 400 and 800 have disappeared. The first peak in the new spectrum is at channel 240 corresponding to time bin 1200 in Fig. 2.24. And, as expected, only 4 peaks are left compared to the 7 peaks before.
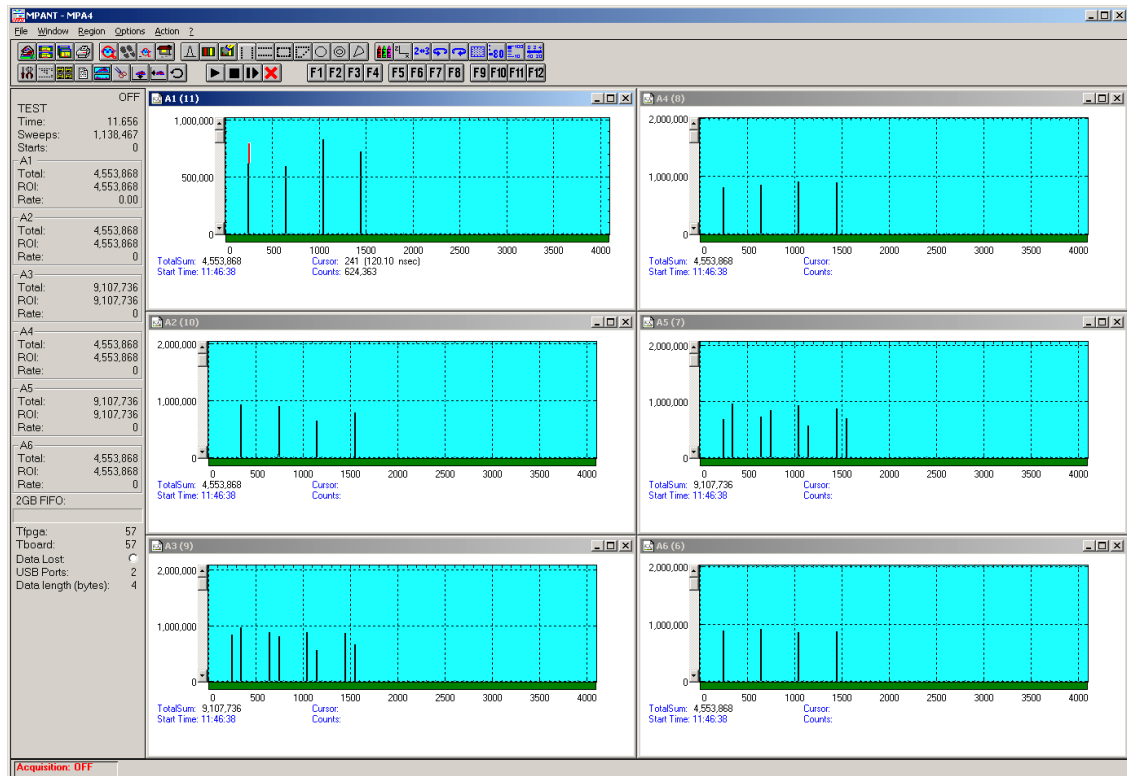
Fig. 2.26: Spectra with 96 ns acquisition delay

2.5.5. Pulse-Width Measurement

Now lets see how the pulse width measurement mode works and how the different graphical display modes can be used.

Go to the 'Inputs Thresholds and ROI Presets' window again and enable channel 1 with 'Both Edges' to be sampled (ref. Fig. 2.27). For 'Pulse width mode' select 'Under threshold'. This implies that a pulse is expected to start with a falling edge. Remember the internal pulser that we are using delivers negative going pulses of 10 ns every 40 ns. And, we start the sweeps with the first falling edge ('Start with rising edge' is not checked).
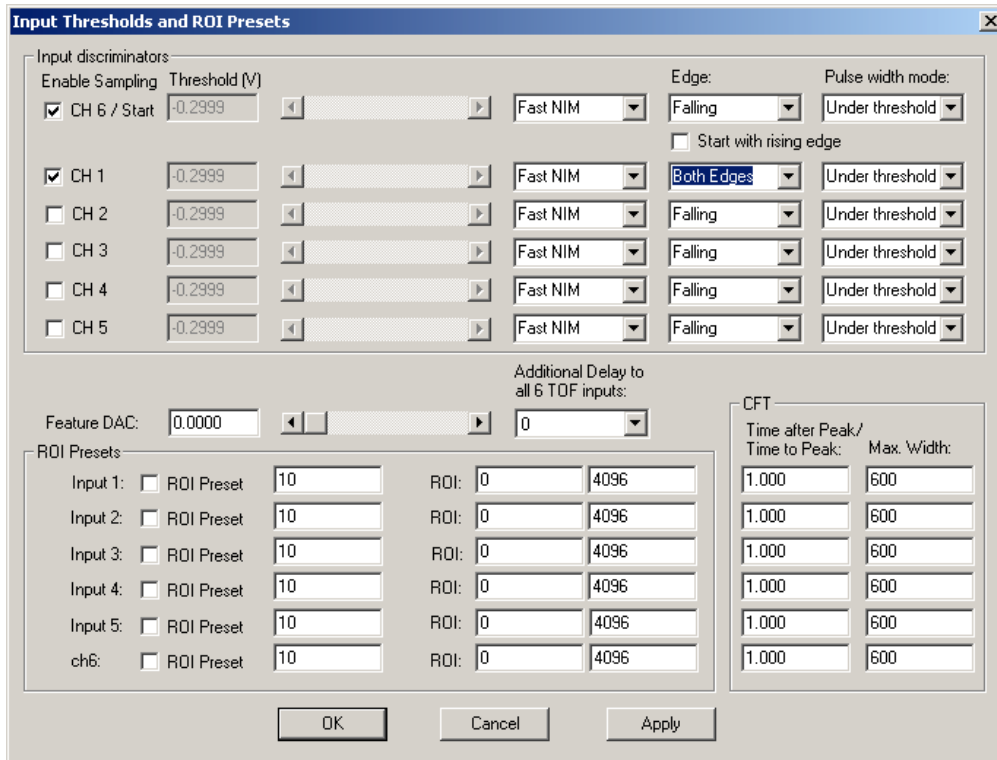
Fig. 2.27: Inputs setup for a pulse width measurement

Back in the 'TDC Settings' window make sure that 'Pulse width' is checked with an 'y-Range' of 2 for the falling and the rising edge (ref. Fig. 2.28). The acquisition delay should be '0'.
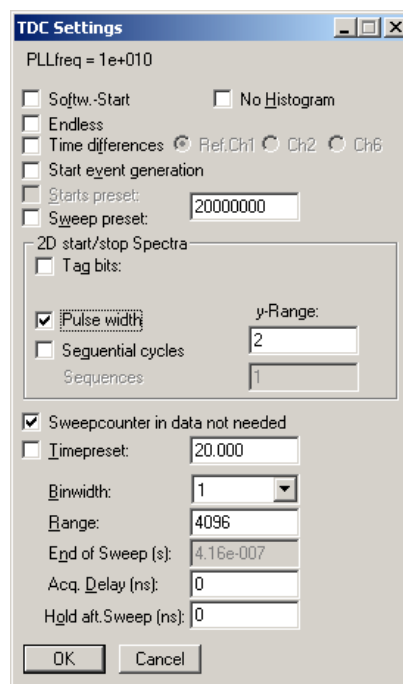
Fig. 2.28: TDC Settings for a pulse width measurement

The display will switch into a 'MAP View' mode, i.e. you are looking from a birds view onto two spectra – the lower for the falling edges and the upper spectrum for the rising edges.

Start the acquisition and you will see peaks grow their height indicated by color-coding. With [2→3] you can toggle between the 2- and a 3-dimensional view.
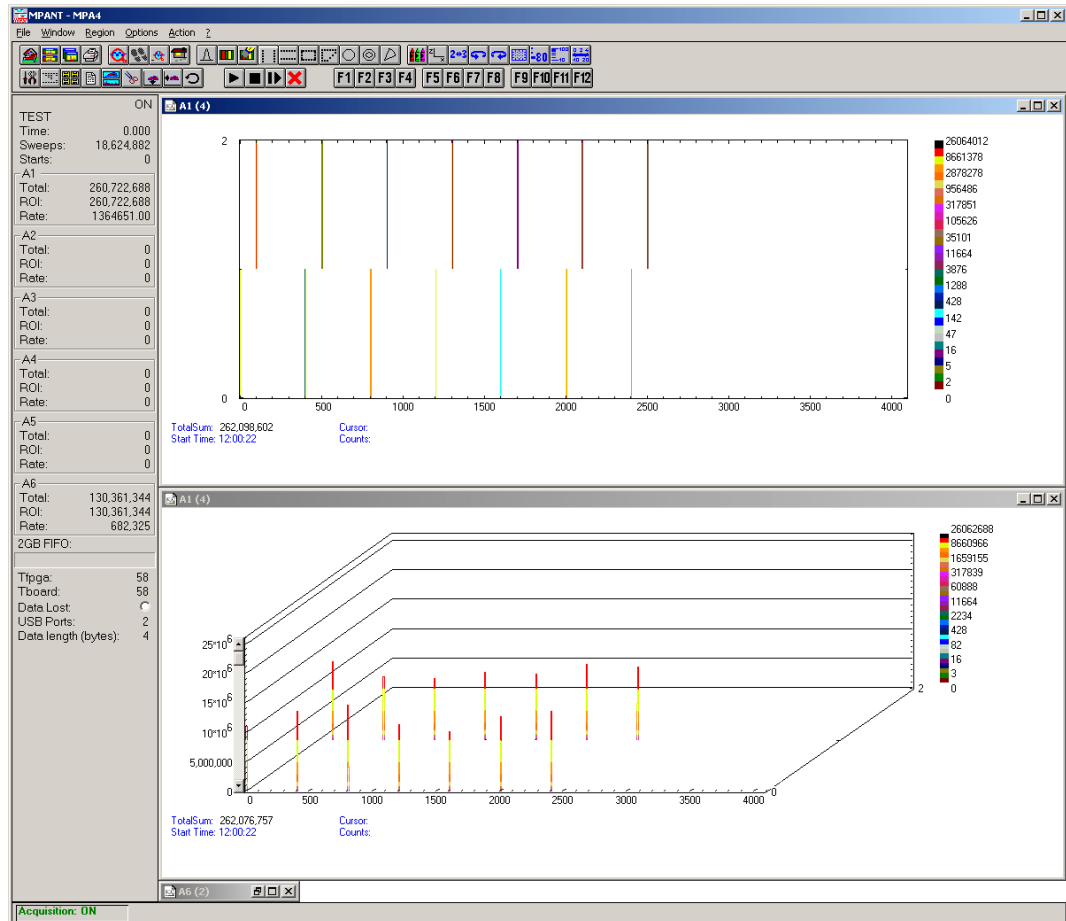
Fig. 2.29: MAP and Isometric View of a pulse width measurement

Go back to the 2-dimensional MAP view and then, click on *Options* – *Display…* and select '>> *Overlapped*' (Fig. 2.30).
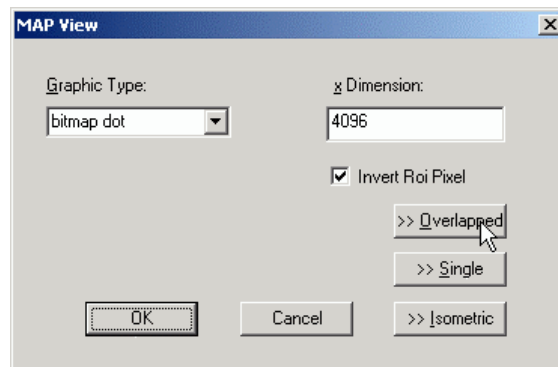
Fig. 2.30: MAP View display options

The spectrum display changes to a 2-dimensional spectrum with rising and falling edges that are drawn overlapped (ref. Fig. 2.32). With the Display Options window you can choose which edges

should be in the fore- and background (Fig. 2.31). Always the foreground spectrum can be measured using a mouse cursor. By pressing the left mouse button you can move the cursor and see the corresponding data of time bin and counts below the spectrum.
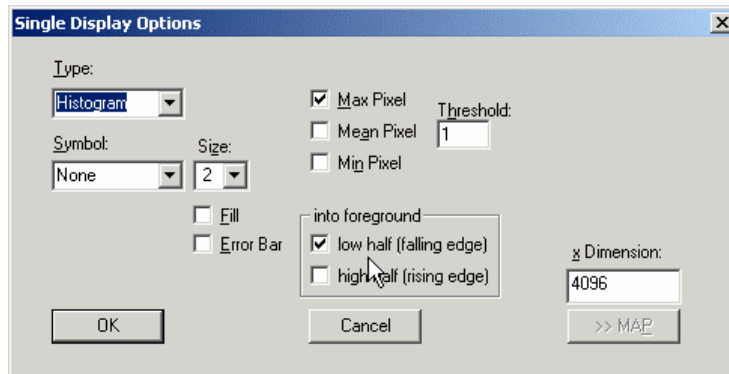
Fig. 2.31: Single Display Options
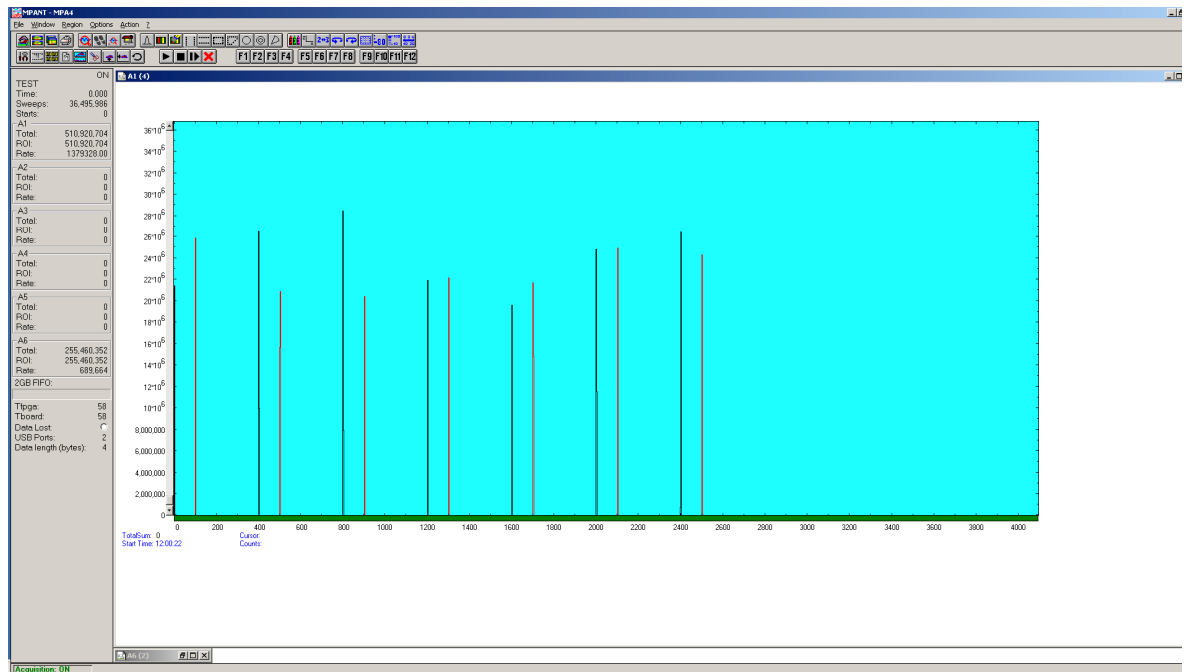
Fig. 2.32: Single View of a pulse width measurement

2.5.6. Basic Usage of the RealTimeClock Option

To familiarize with the usage of the 48 bit RealTimeClock / Timer option a simple experiment is setup. The intention is to measure the arrival time of single ADC events relatively to a start (trigger) signal like it might be done in Time-of-Flight or similar experiments. To do so a variable delay is used to shift analog output pulses relatively to the TTL trigger pulse that on the other hand resets (reloads) the 48 bit counter via the START input. Thus, in terms of TOF, the trigger signal acts as start and the ADC deadtime signal as stop input. The delay time is then measured with a resolution of 6.4 ns and a time spectrum of the very ADC is accumulated.
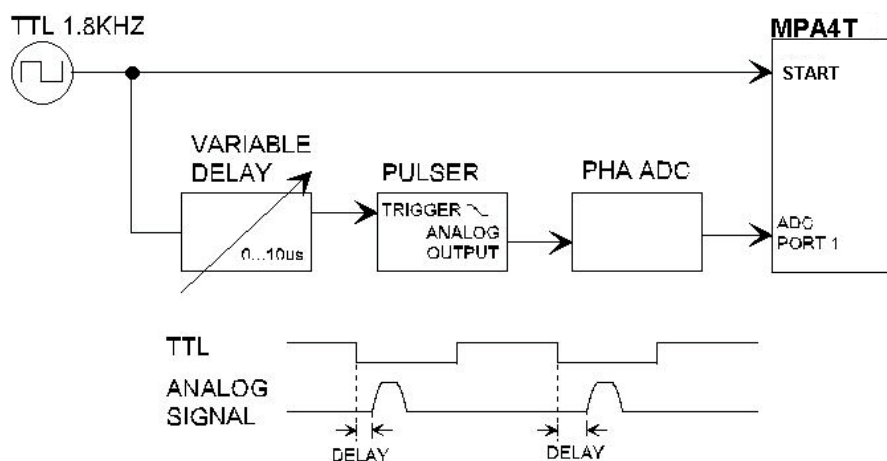
Fig. 2.33: Basic RTC Experiment

First, ADC 1 is defined as a SINGLE mode ADC (ref. Fig. 2.34). Now the RTC / Timer is set to reload (restart) with the TOF input START. The timer value capture command is derived from ADC 1 DEADTIME signal. And last but not least, time stamps must be inserted into the datastream to transfer the corresponding time and ADC data together. This is done automaitically if you have the RTC option.

Fig. 2.35 shows the TDC settings. Enable sampling for the CH6/Start input in the START / STOP Input settings dialog (ref. Fig. 2.36). The TOF and ADC parts will then run with synchronized timer, SINGLE events and a COINCIDENCE time window will be started only during an active sweep. Take care that the START trigger threshold is properly set in the START / STOP Input settings – to a positive voltage of about 0.5 V for a TTL signal. Since the here used analog pulser triggers on the falling edge the *Start with rising edge* checkbox is not crossed.

To visualize the timing relationship a spectrum is defined that shows the arrival time on the x-axis, the adc pulse height on the y-axis and the countrate in z-direction (ref. Fig. 2.37). Also a one dimensional spectrum is defined (set ADC range to 1) to show just a time spectrum (projection onto the x-axis).

In Fig. 2.38 the resulting spectra can be seen. Watching the map display (window (5)) amplitude variations show up as vertical lines whereas delay time variations result in horizontal lines. Window (6) is the pulse height analysis and (4) the time spectrum.
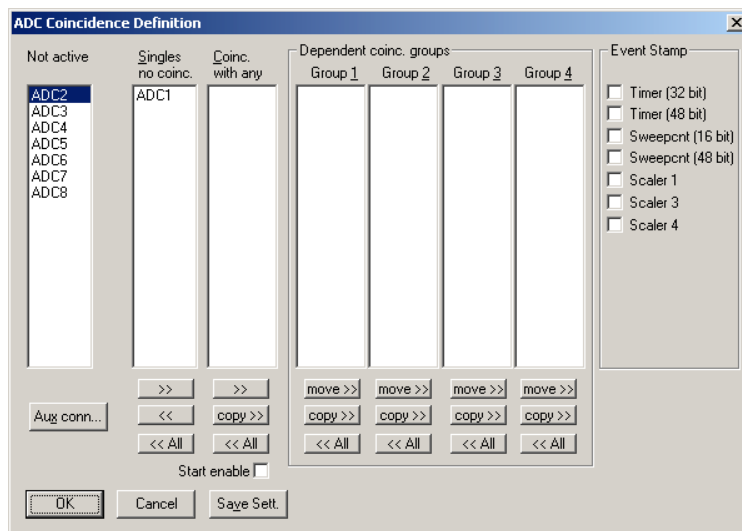
Fig. 2.34: ADC Coincidence Definition for RTC Experiment
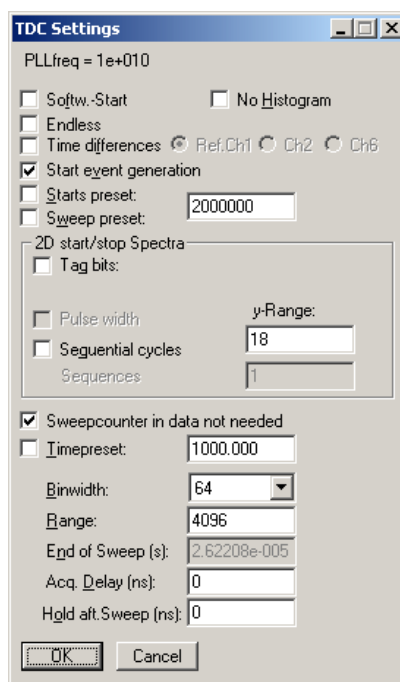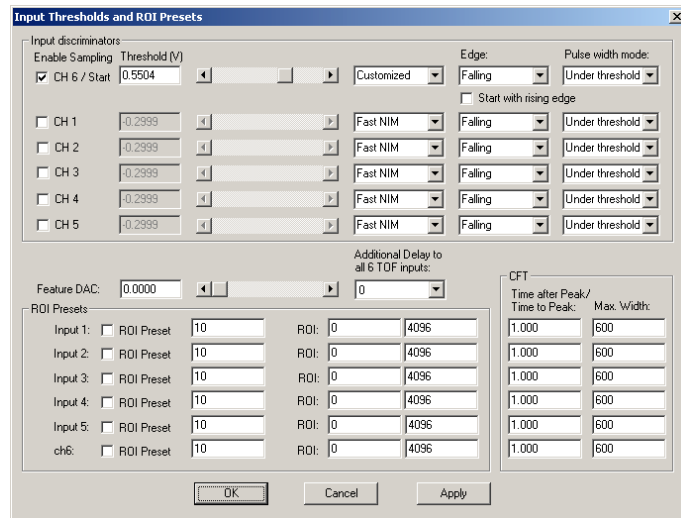
Fig. 2.35: TDC settings for RTC experiment

Fig. 2.36: Start / Stop Input settings for RTC experiment

Fig. 2.37: RTC Spectrum Definition
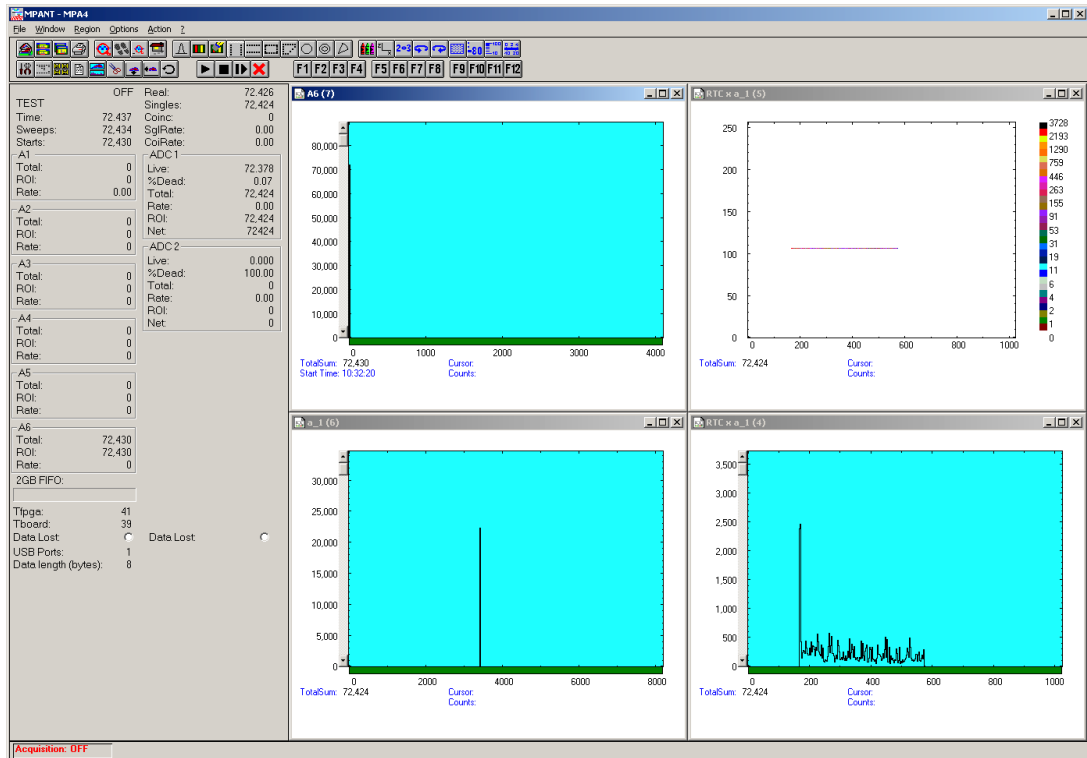
Fig. 2.38: Basic Time Spectra of a Single ADC

2.5.7. Usage of the RealTimeClock Option without TDC part

Instead of using the START input for the time trigger you can use also any one of the auxiliary connectors, for example AUX1. Disable Ch6/START in the Start / Stop Input settings. Take care that the AUX 1 interface is used as input (ouput disabled – ref. Fig. 2.39). Since the here used analog pulser triggers on the falling edge the AUX 1 input polarity is '*active Low*' to reload the timer when the TTL signal is high and let the timer free run when it is low. Select '*AUX1* ' in the 'RTC Reset' box to reset the RTC.
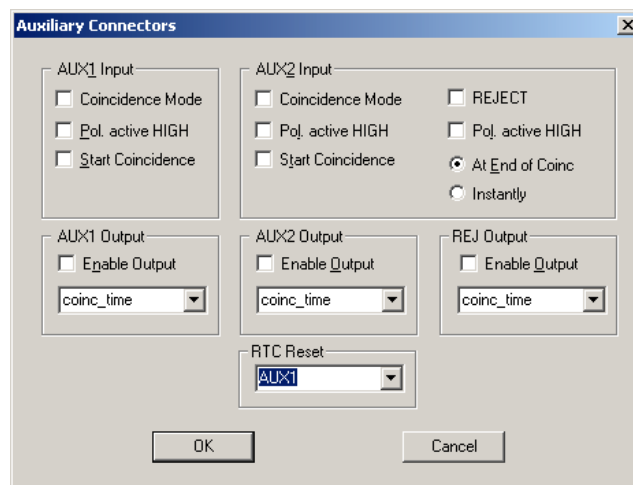
Fig. 2.39: Auxiliary Connectors for RTC experiment using AUX1 as time trigger

2.5.8. Using a two-dimensional position sensitive detector

Position-sensitive detectors often work by a delay-line readout. An example is shown in Fig. 2.40. To get a two-dimensional histogram usually at least two TDC's (time-to-digital converter) and a multiparameter data acquisition system is needed, for example the FAST ComTec 7072T and MPA-3 or MPA4. Now let's see how the MPA4T or MCS6A can be used to do the same without any external TDC or ADC.
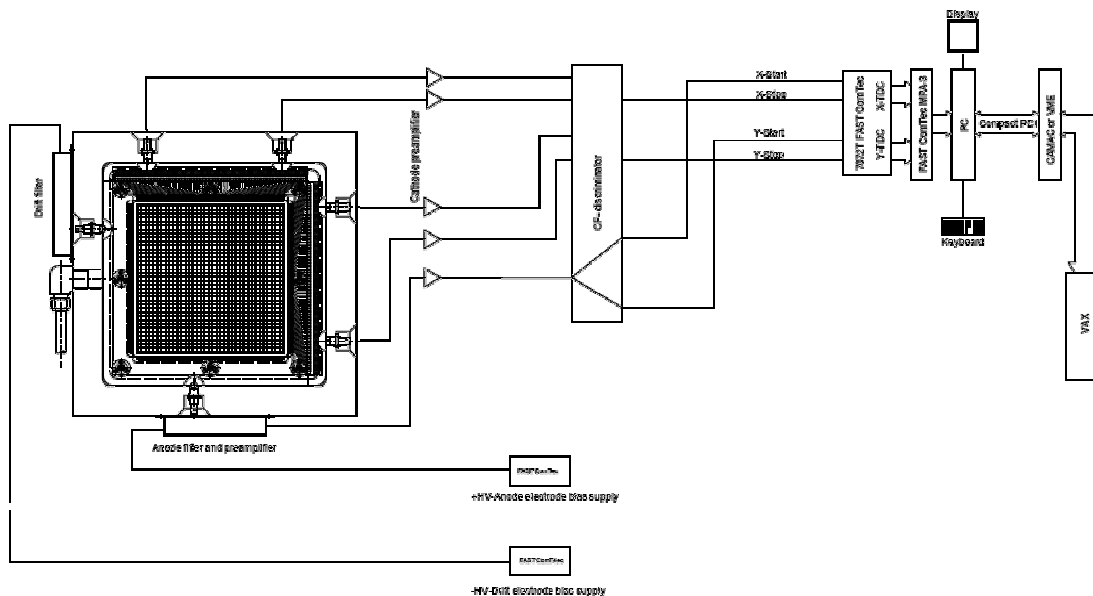
Fig. 2.40: Two-dimensional position-sensitive detector

Let's assume that the detector has in both x- and y- direction 150 wires and a delay-line of 2.7 ns between each wire, i.e. a total delay of 405 nsec. The MPA4T offers 100 psec time resolution, i.e. 4096 time bins would be the maximum possible range that could be used. For the 150 wires a resolution of 1k x 1k is certainly good enough, so a range of 1024 and a bin width of 4 is reasonable. A common trigger signal must be connected to the "START" input, the x-stop signal to the "STOP1" input, the y-stop signal to "STOP2".

Click the "Range, Preset" toolbar icon.

See Fig. 2.41 for possible settings. Set the bin width to 4. Make sure that the checkbox "Sweepcounter in data not needed" is not checked. The sweep counter actually is necessary to enable the unique assignment of events from separated input channels to the same trigger event.

Click the "Inputs" button to open the dialog for "Input Thresholds and ROI Presets"

The input channels CH1 and CH2 must be enabled, and suited thresholds for the signals must be set. In principle both edges of the signals could be evaluated and a "software constant fraction" method could be used to get an improved time resolution (see Fig. 5.9).
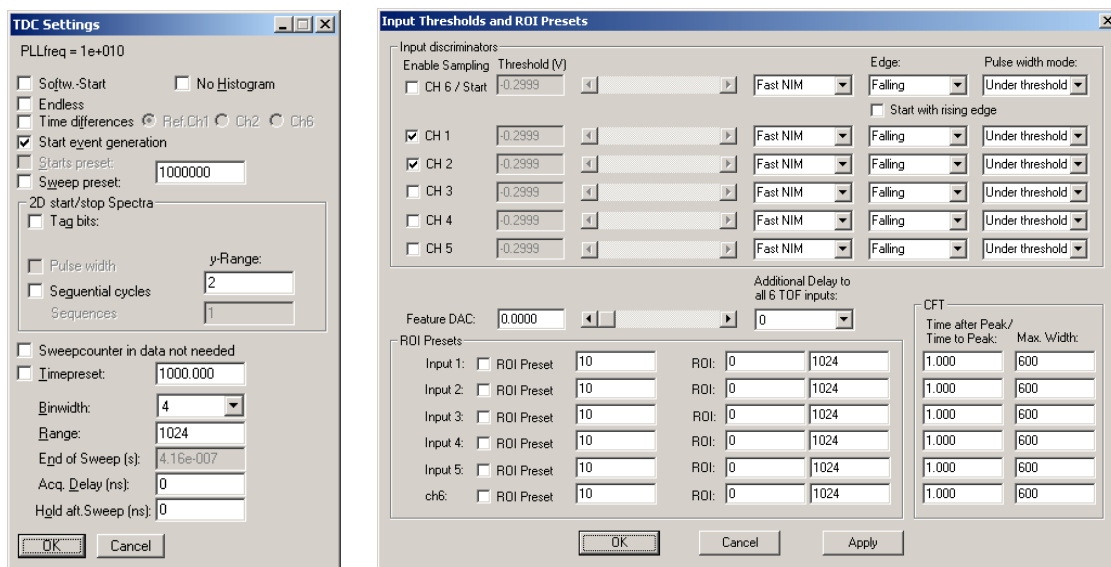
Fig. 2.41: Settings for acquisition with position-sensitive detector

Now a two-dimensional histogram for the two parameters must be defined. Open the "Spectra" dialog by clicking the corresponding toolbar icon.

Click "Add Multi" to define a dual-parameter spectra. In the "Multi Display Setting" dialog select CHN1 for the x-parameter and CHN2 for the y-parameter. Select 1024 for both Ranges.
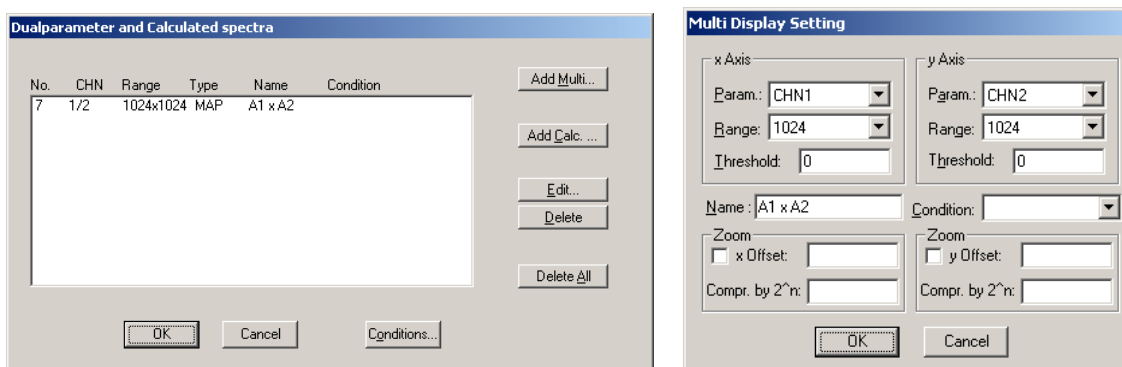
Fig. 2.42: Creating a dual-parameter spectra

Fig. 2.43 shows a view of such a dual-parameter spectra in the MPA4T software, Fig. 2.44 a photo of the corresponding experimental setup. An example spectra named "tongs.mpa" can be found in the sample data supplied with the software.

Instead of using only one signal for each position coordinate, one could read out the detector from both sides and get two signals for each direction, i.e. in total one trigger signal and four stop signals. The difference of the time from the left and right side gives an improved position parameter, and one could calculate in addition the sum of the signals from both ends and set a condition on events inside a ROI (Region of Interest) around the sum peak in the sum spectra. All this can be done with the MCS6, example settings are described in chapter 5-16.
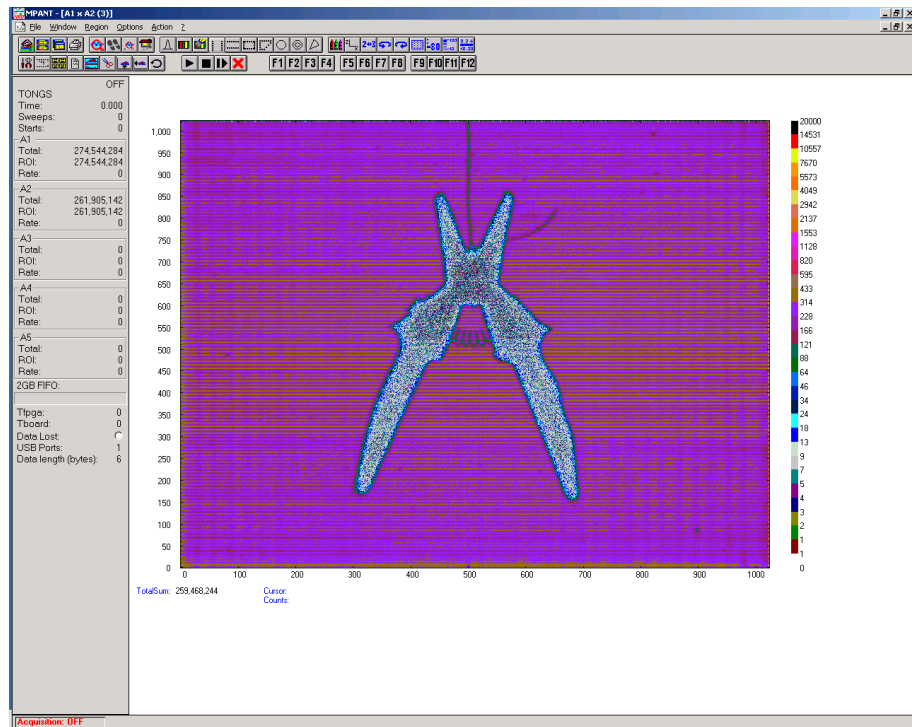
Fig. 2.43: View of dual-parameter spectra
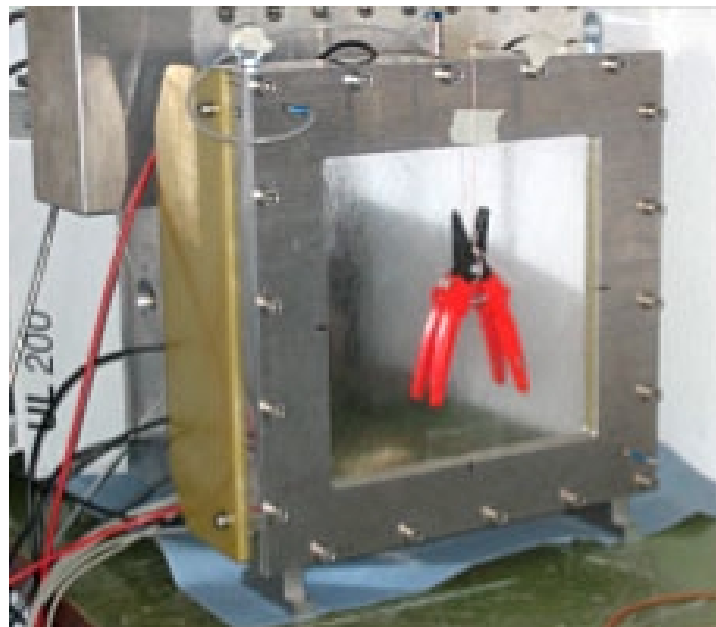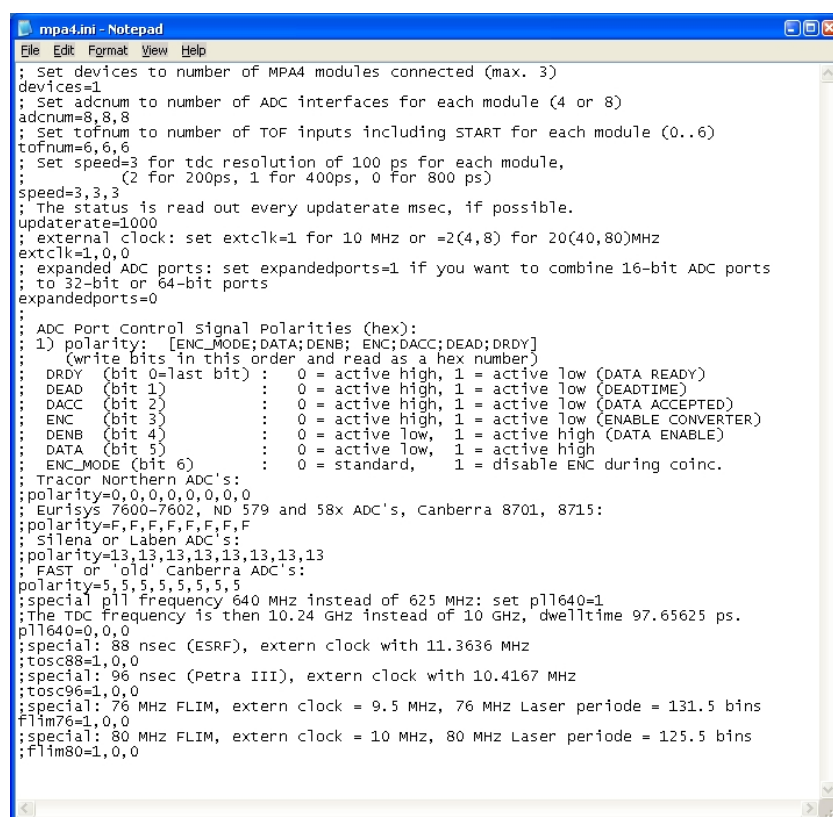
Fig. 2.44: Experimental setup

2.5.9. Fluorescence livetime imaging microscopy

Another special application should be mentioned here, fluorescence livetime imaging microscopy (FLIM). A laser fires short light pulses with a high frequency of, say, 76 MHz onto a target. The photons radiated from the target are detected and counted versus the time after the primary light pulse. The decay time gives information about the target material. The laser beam scans over the target and this way an image of the target can be created. To do this using a MPA4T, the PLL of the MPA4T must be reprogrammed and an external clock frequency of 9.5 MHz, i.e. 76 MHz / 8 must be connected to the external clock input. The PLL can be programmed to set the number of bins per period between 131 and 135 in steps of a half bin. For 131.5 bins per period edit the MPA4T.INI file and remove the semicolon at the beginning of the line ;flim76=1,0,0

Furthermore, set extclk=1 to indicate that an external clock is used, see Fig. 2.45.

Fig. 2.45: Editing MPA4.INI for the FLIM application

With this MPA4.INI file, the PLL will be reprogrammed and now 131.5 time bins of a width of 100 psec will exactly correspond to the periode of the 76 MHz laser frequency. It means that every two periods can be folded together and this way a time resolution of 50 psec can be obtained, as two neighbored periods are shifted by a half bin versus each other. The folding means just a resorting of the bins: bin 1, bin 133, bin 2, bin 134, ... , bin 131, bin 263, bin 132. The next 263 bins can be respectively added to the histogram and so on. A very long sweep can be done to avoid the end-of-sweep dead time, for example a sweep length of 65488 bins corresponding to 2 x 249 periods. This can be done with a data length of 4 bytes, so the maximum continuous count rate is limited by the USB bus to 30 Mbytes/sec / 4 bytes = 7.5 MHz. The maximum burst rate is 100 MHz. Sequential mode can be used to record the image synchronized to the target mover and the tag bits can be used to mark the data with the beam position. If you plan such a measurement and you have a somewhat different laser frequency, please contact FAST ComTec to modify the software for your special laser frequency. Folding is now supported in the software, see chapter 5.1.4.

2.5.10. Combined TOF/ADC acquisition

Let us create a dualparameter spectrum ADC versus TOF using the internal test pulser. The Sync2 TTL output can be used with the START-OF-SWEEP signal at pin 4 of the feature connector to create (after some pulse stretching as it is very short) a trigger signal for a pulser to get a suited signal for the ADC that is time correlated with the fast time signals. Fig. 2.45 shows all settings. In the TDC settings a large Hold off of 10^6 ns is set to reduce the count rate.
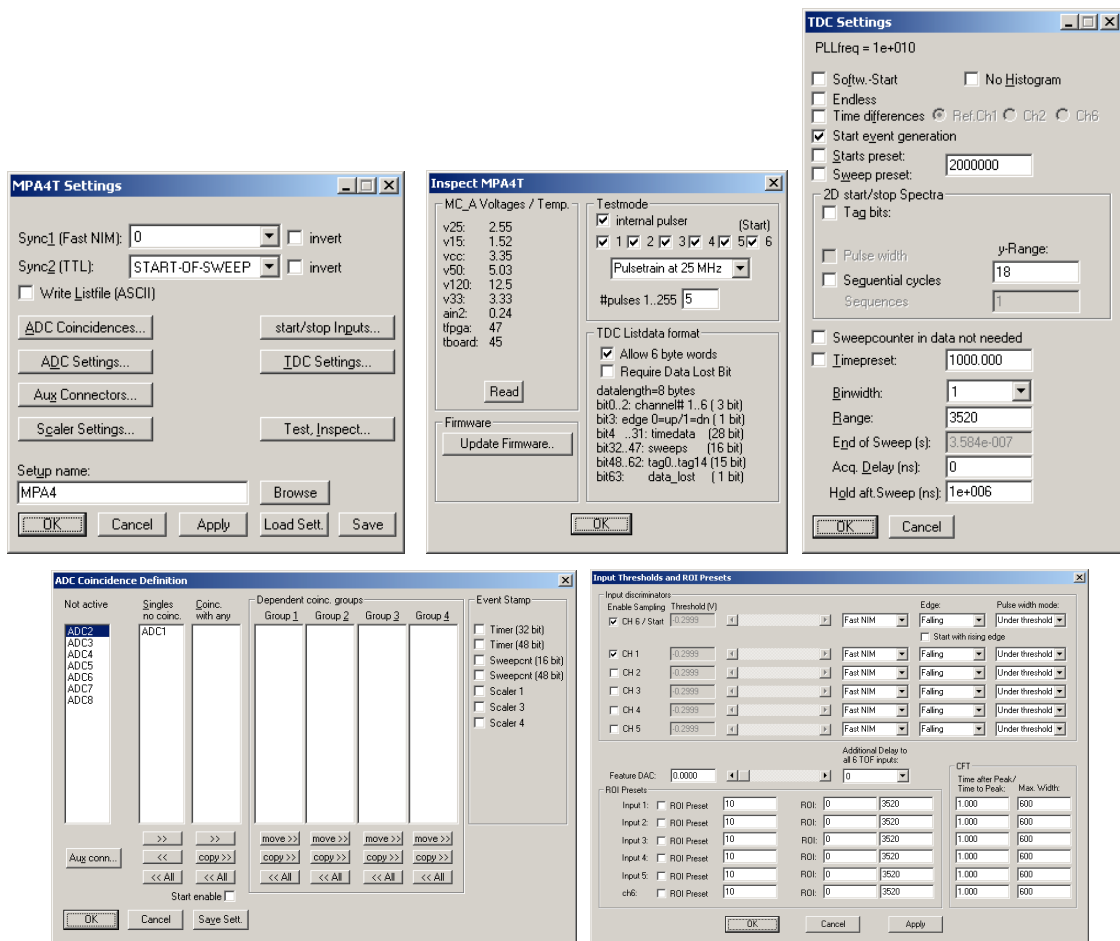
Fig. 2.46: Settings for testing combined TOF/ADC acquisition

Now create a „Mixed TDC/ADC" dualparameter spectrum as shown in Fig. 2.42.
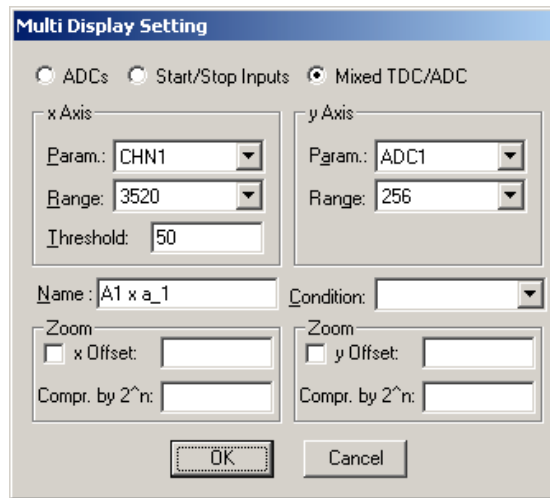
Fig. 2.47: Creating a mixed TDC/ADC dualparameter spectra

Fig 2.47 shows the resulting spectra.
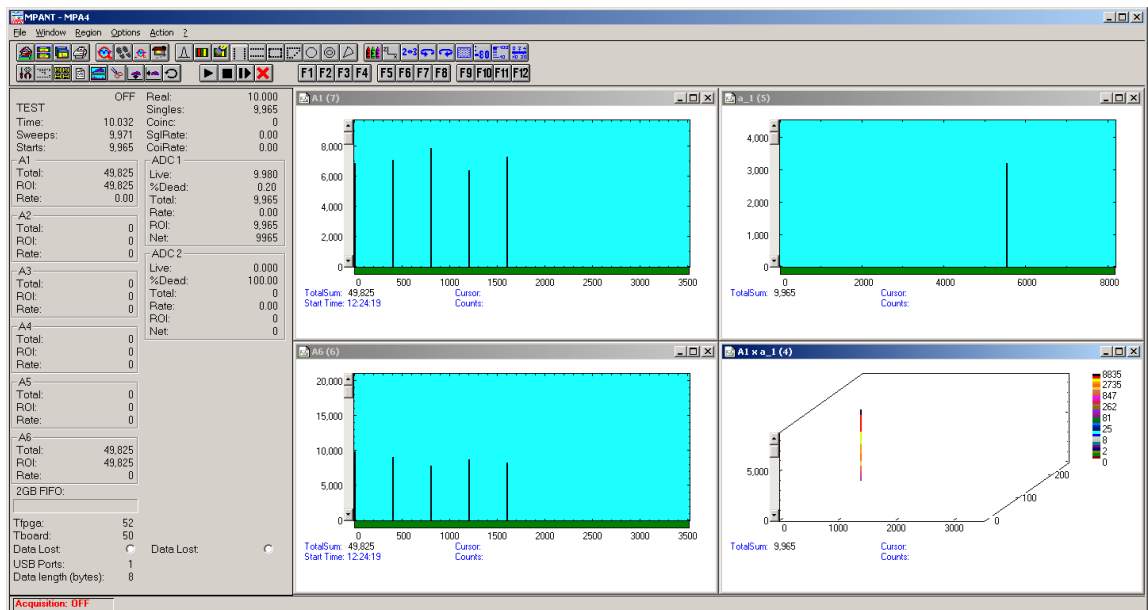
Fig. 2.48: TOF/ADC dualparameter spectra triggered with internal pulser

2.6. Installing more than one MPA4T module

The software is able to operate up to three MPA4T modules with a single computer (if you need more, contact us and we will expand the software). Each may be connected either by one or two USB cables. When using only one USB line per MPA4T module, it is simple: just connect them at USB1, switch on the power, and install the driver when you are prompted. When starting the software, you will be asked to edit the MPA4.INI file as more than one MPA4T modules are found, and the notepad editor will be automatically started with MPA4.INI loaded. Edit the line "devices=1" accordingly and save the file.
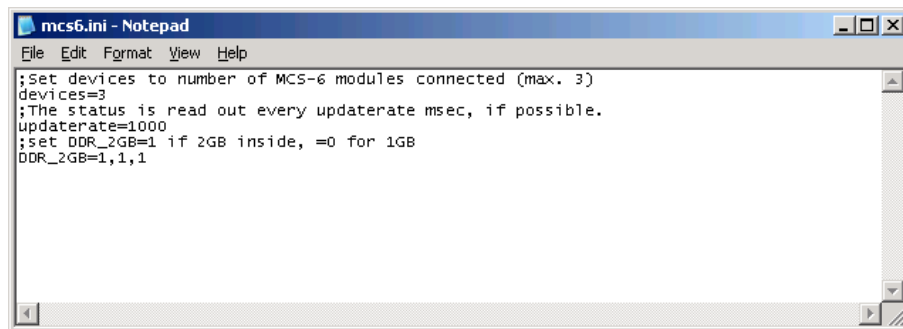
Fig. 2.49: Editing MPA4.INI

That is all you have to do, next time when you start the software all modules will be found and can be operated.
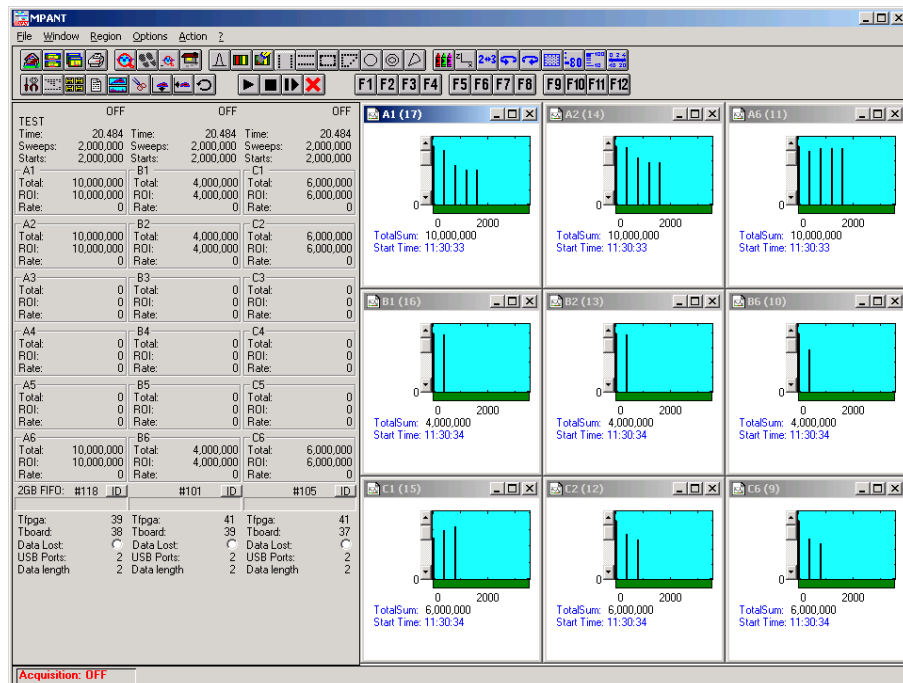
Fig. 2.50: Testing and identifying three MPA4T modules

When connecting 2 USB cables to one or more MPA4T modules, it is more complicated. The software cannot automatically identify which USB2 and USB1 ports belong together. So it is recommended to use the built-in test pulser and set different signals for each module, for example a pulse train with 5 pulses for module A, 2 pulses for module B and three pulses for module C. The data are transfered via the USB2 line, so the pattern may be exchanged between different modules to what you expect. In this case exchange the corresponding cables connected at USB2 and restart the software, until you get a picture as shown in Fig. 2.50.

To get a quick identification which physical MPA4T module belongs to a module shown in the software, you can use the "ID" button in the status window shown at the left beside the spectra in MPANT. The LED's at the front panel will blink and the internal serial number will be shown beside the ID button.

2.7.   Models and Upgrade Options

The MPA4T has eight ADC interfaces and 5 STOP inputs beside the START input, but not all may be useable. The size of the FIFO can be 1 GB or 2 GB. The number of useable ADC interfaces can be four or eight. The counters, up/down counters and Replay function may be active or not. See the following table showing available models and options that can be activated by a new licence key.

Model	Description
MPA4T-4	Multiparameter-4 system, 4 ADC interfaces, RTC, 5+1 Input 10 GHz TOF-Multiscaler, 100ps, 1GB Fifo, USB interface, MPA-NT Softw.
MPA4T-8	Multiparameter-4 system, 8 ADC interfaces, RTC, 5+1 Input 10 GHz TOF-Multiscaler, 100ps, 1GB Fifo, USB interface, MPA-NT Softw.
MPA4-+4ADC	Option: 4 additional ADC interfaces for "-4" systems: converts to a "-8" system
MPA4-FIFO2	Option 1 GB Fifo extra (2 GB total)
MPA4COUNT	Octal Counter / Scaler option for MPA4 / MPA4T, 32 bit, 8 channels, 100 MHz
MPA4UP-DN	Dual Up / DOWN option for MPA4 / MPA4T, requires MPA4COUNT
MPA4TAG	TAG bit option for MPA4T, 16 bits, 6.4 ns resolution
MPA4RPlay	MPA4 / MPA4T Replay progr. for off-line reconstr. of spectra from listmode, internal
MPA4TAT	Option atom controlled oscillator for MPA4T

It is very easy to upgrade an MPA4T for 8 ADC interfaces, extra FIFO, Counters, Up-down counters, Tag bits, Replay. Buy a new Licence key and select in the start menu under Programs.. FAST ComTec MPA4T.. the item "Upgrade MPA4T Licence". The software starts and you will be asked to enter the new licence key. Just enter the new key and after restarting the software the new option will be available. In the "About" box of the server program the installed options are visible.

The next table shows additional options that include hardware or software.

Model	Description
MPA4RplayEx	MPA4 / MPA4T Replay progr. for off-line reconstr. of spectra from listmode, Dongle
MPA4Rplay+Ex	MPA4 / MPA4T Replay progr. for off-line reconstruction, Dongle + int.
MPA4TDLL32	DLL for LabVIEW /"C"/ Visual Basic (32 and 64 bit) for the MPA4T
MPA4TLINUX	LINUX driver for MPA4T
MPA4-C1	TAG / Counter Cable, converts D-SUB to 18 separate BNC cables.
MPA4-C2	TAG / Counter Cable, converts D-SUB to 18 separate LEMO cables.

3. Hardware Description

3.1. Overview

The MPA4T is a USB 2.0 device with two high-speed USB 2.0 ports.

The MPA4T is able to measure multiple time events in up to 6 input channels at a time resolution of 100 ps. Simultanously the MPA4T allows to acquire data from upto 8 external devices[7] like ADC's, multiscalers, position analyzers etc that provide a standard NIM ADC interface. Furthermore a coincidence time window can reduce the acquired ADC data to specific coincident events only.

The acquired ADC data can be time stamped with a 6.4ns clock synchronous to the TOF section. Thus, the ADC data can be correlated to the 100ps TOF data and timely developments of experimental behaviour can be easily analyzed.

Additionally eight 32 bit 100 MHz counters are provided that can be used for scaling, normalization or other purposes.

And, the 8 bit versatile digital I/O port allows to control external equipment like sample changers etc. or to detect external status information.

The TOF logic is capable to accommodate an incredible burst edge rate of 10 GHz. Such a burst can last for up to 6.5 µs before any event might be lost. And, this is true for each input channel independently. No dead time between the time bins and secure prevention of double counting is established by the sophisticated input logic.

A unique feature is the MPA4T's capability to measure falling and rising edges simultaneously. Thus, Time-over-Threshold or pulse width measurements are easily accomplished.

Fig. 3.1: MPA4T front panel

Furthermore, a software CFT (Constant-Fraction-Timing) functionality can be established due to the fact that both edges of a pulse can be captured. By assuming that the shape of the signal

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[7] Referred to as ADC's or ADC data in the following

does not depend on its amplitude, one can get a very good estimation of the peak time by the assumption that it is always at the same fraction of time between both edges.

Each input channel has its own onboard discriminator with individually adjustable threshold levels. Adjustment is supported by a monitor capability of each discriminated signal.

Besides, two SYNC outputs with a large variety of output signal options (all software selectable) and the 'GO'-line (compatible with other FAST ComTec products) allow for easy synchronization or triggering of other measurement equipment.

Furthermore a very versatile 8 bit digital I/O port allows for a whole bunch of experimental control, monitoring or whatsoever tasks.

Moreover, the 16-bit TAG input allows more multi-detector configurations, sequential data acquisition etc.

Also improved are more built-in test capabilities than ever before. An internal pulse generator allows for hardware tests and also to get familiar with a lot of the operation modes without the need to setup external hardware.

And there is the optional 2 GB large FIFO that extends the onboard storage capabilities.

The MPA4T contains many very high-speed logic circuits, which usually need large supply currents and thus, produce high thermal power loss. To dissipate this thermal energy the complete metal case is used for passive cooling. This improves reliability since no mechanically moving devices like fans are involved. The downside is that the case can get quite warm or even hot. Refer Fig. 3.2, which is taken in a standard laboratory environment with a MCS6 placed on a table and no other devices nearby. The crosses indicate local temperatures. The upper left cross shows the ambient temperature of 22.9°C. The middle left cross indicates 45.3°C. With increasing ambient temperature the maximum case temperature will increase as well. And also reduced airflow will result in higher case temperature. In the software a temperature monitor feature is provided that shows the internal FPGA and PCB temperatures.
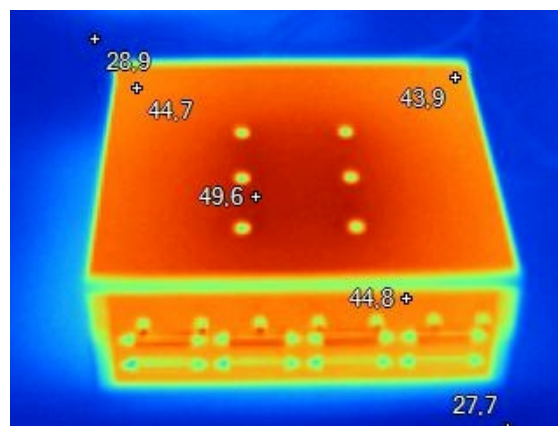
Fig. 3.2: Thermal picture of the metal case

WARNING:

The metal case can get very warm or even hot. Beware of burning yourself.

IMPORTANT NOTE:

Provide ample airflow around the device for proper cooling. Do not cover the case. Do not place it inside closed cabinets etc.

3.2.   General Functionality

3.2.1.   'GO'-Line

The 'GO' line is a system-wide open-drain wired-AND signal that can start and stop a measurement. This line is available on the FEATURE connector and on the specific BNC connector on the rear panel.

The 'GO' line may be enabled, disabled, set and reset by the software. The system-wide open-drain 'GO' line enables any connected device to enable and to stop all participating measurement equipment simultaneously. This allows for easy synchronization of electronic devices previously often not possible.

When watching of the 'GO' line is enabled for the MPA4T, a low line voltage will halt the measurement. When output to the 'GO' line is enabled, starting a measurement (i.e. the MPA4T is armed) will release the 'GO' line (high impedance output) whereas a halt of the measurement will pull-down the 'GO' line to a low state. Since it is an open-drain output wired-AND connection with other devices is possible. Also refer Fig. 3.3.

The 'GO' line is available on most of the other FAST ComTec products as well.

3.2.2.   FEATURE (Multi-) I/O Connector

A very versatile 8 bit digital I/O port is implemented on the 15-pin high-density female D-SUB connector. The pull-up and series resistors (ref. Fig. 3.3) of the digital I/O ports are socket mounted and thus, can be easily adapted to specific needs.

This I/O port is fully software controllable and each single (1-bit) port is individually configurable. Each individual port can be configured as input only (tri-stated output) or open-drain (pull-up) output with read back capability. Wired-OR/AND connections are also feasible.

It might be used for external alert signals, sample changer control, status inputs / outputs etc.

Fig. 3.3: Schematic of FEATURE I/O connector

NOTE:

Please contact factory if changes to the resistors are needed.

Also on the FEATURE connector there is the TTL level SYNC_2 output.

Furthermore an analog output is provided. The output voltage is software controllable in a range of 0…+2.5 V with a 14 bit or 0.15 mV resolution.

3.2.3. 100MHz Counters

The MPA4T includes eight 32bit synchronous 100 MHz up-counters (2 counters provide an UP/DOWN option).

All inputs are TTL like and are terminated with 50Ω to ground. For each counter input the polarity is software selectable.

Please refer Fig. 3.5 for details of the control logic of the counters. Also refer chapter 5.1.8 "Scaler Settings dialog".

Count action

The counters actually either count the software selected rising or falling COUNT input edges (counter mode) or work as 100MHz timers.

Carry Ouputs

Counters 1 and 2 provide a carry or terminal count output e.g. for cascading. The carry output signals are high as long as the counter value is 0xFFFFFFFF.

When using the carry outputs as count input to another counter you can cascade counters to build 64bit or 96bit deep counters.

The carry outputs are available in the ADC GATE connector (please refer Fig. 3.14 for details).

UP/DOWN counter option

Counters 3 and 4 provide an UP/DOWN input option (replacing the individual GATE) for change of counting direction. In this case the individual GATE inputs no longer work as GATE but as UP/DOWN inputs.
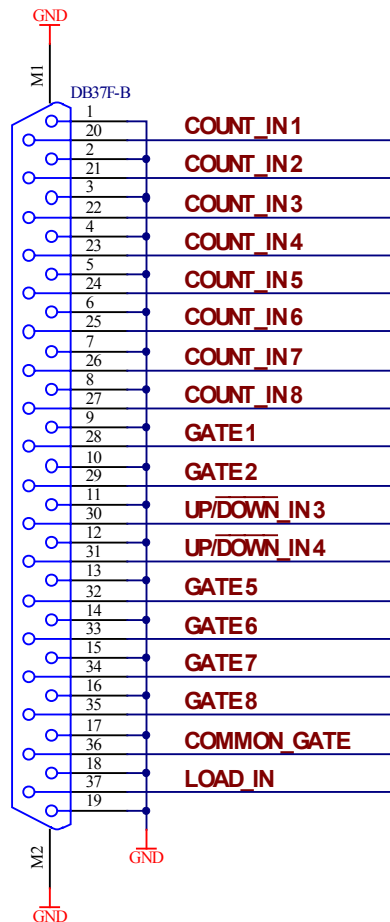
Fig. 3.4: Connector assignment for the 100MHz counters

Preset

Each counter is presettable allowing to halt the experiment when a preset value is reached by pulling the GO-Line low.

If PRESET is enabled for an individual counter it will halt the experiment when it actually reaches 0xFFFFFFFF. The software handles the calculation such that in fact 0xFFFFFFFF – PRESET_VALUE is loaded into the counter allowing to count PRESET_VALUE counts until 0xFFFFFFFF is reached.

COMMON and individual GATE

A COMMON GATE input is provided as well as individual GATEs.

Usage of the GATEs is individually settable for each counter in the software.

LOAD input

An external LOAD input allows to reset the counters to their individual start (load) value by an external signal. Usage of the LOAD input is individually selectable for each counter.

The start values are software settable and will typically be either 0x00000000 or "0xFFFFFFF – PRESET_VALUE".

GO line

The system wide GO-Line may also control the counting action. This can be set individually for each counter.
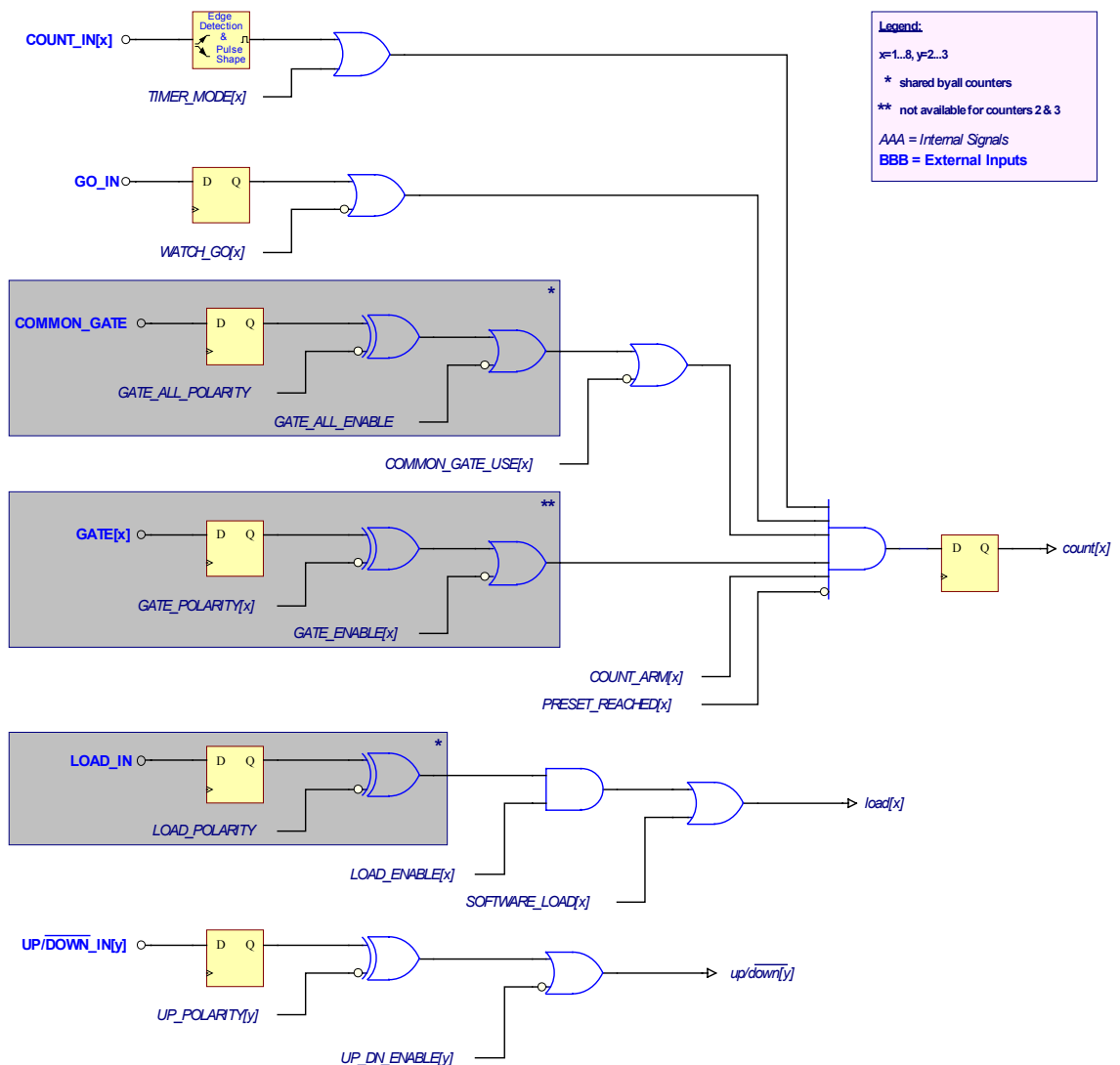
Fig. 3.5: 100MHz counters control logic

When the software reads the actual count value during a running measurement all values are simultanously transferred to readout registers. Thus, comparison of rates or values is easily feasible and accurate at any time.

3.2.4. Time Base / Reference Clock

To derive the outstanding temperature and long-term stability the MPA4T is equipped with an on-board ovenized crystal oscillator (OCXO). This OCXO stabilizes the 10 GHz PLL (phase locked loop) synthesizer that clocks the TOF sampling circuitry.

The reference is a 10 MHz clock. Either the internal (on-board) or an external reference is software selectable, see section 5.1.1. See in 8.2.3 for the signal impedance and amplitude. Optionally (software selectable) a 20, 40 or 80 MHz input clock maybe used as well.

For highest stability and accuracy Rubidium disciplined oscillators or GPS controlled clock generators are available.

3.3. 100ps Time-of-Flight Section

3.3.1. START / STOP Inputs

The START (trigger) and STOP 1…5 (event) inputs are SMA types located on the front panel. The input impedance is 50 Ω to ground. The inputs are edge sensitive with software selectable rising, falling or even both edges. The threshold is software tunable in a range of ±1.5 V. In most cases the threshold should be set right in the middle of the input pulse amplitude.

The sensitivity of these inputs is better than 10 mV. Please refer chapter 8.3.1 for example scope pictures and related spectra. .

$$V_{CL+}$$
$$V_{CL-}$$
$$V_{TH}$$
$$V_{CL} = V_{TH} +/- 1.5 V$$
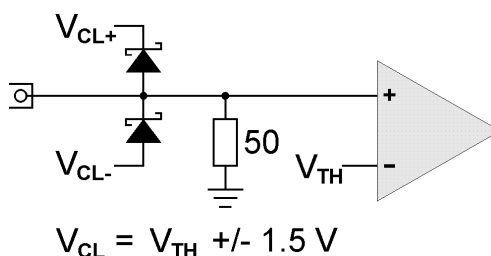
Fig. 3.6: START / STOP inputs

For input protection low capacity (approx. 1pF per diode) clamp diodes are provided. The clamp voltages follow the threshold level by ±1.5 V. Thus, the input voltage level should not exceed the threshold level by ±1.5 V or the diodes will become forward biased.

> **WARNING:**
>
> Take care not to exceed the maximum input voltages as described in the technical data.

Discriminator Propagation Delay Dispersion

The input discriminators propagation delay varies slightly with input overdrive voltage and slew rate. When overdrive varies from 10 mV to 500 mV and slew rate varies from 1 V/ns to 10 V/ns the delay can vary for up to 25 ps, which is ¼ of the bin width. This specification applies for both positive and negative going signals.

For overdrive voltages above 200 mV the delay variation due to overdrive dispersion is mostly negligible.

Monitoring the Inputs

To ease the adjustment of the threshold levels the discriminator outputs are sampled at a frequency of 312.5 MHz cor. 3.2 ns and can be output on the SYNC outputs. Preferable SYNC_1 should be used as it is a fast-NIM output and provides best speed and edge rates.

Due to the 3.2 ns sampling the delay of the monitor signal relative to the input pulse will vary by 3.2 ns as well. The minimum output pulse width will be 3.2 ns and thus, even for very narrow input pulses only 300…500 MHz scopes are necessary to see the monitor signals. Be aware that for pulses smaller than 3.2 ns the detection probability will be below '1' i.e. "pulse width [ns]/ 3.2". NOTE: this is only true for the monitor output and not for the spectrum acquisition. For spectrum acquisition the pulses can be as narrow as 100 ps and still are 100% detected.
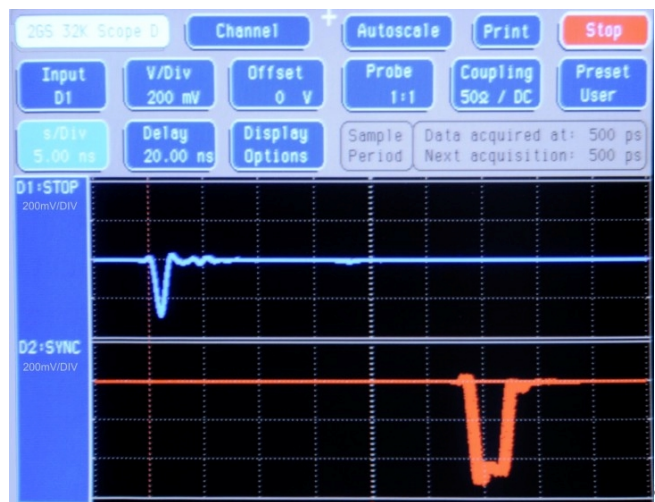
Fig. 3.7: MONITOR signal of a STOP input

Input Slew Rate Requirements

Due to the high bandwidth nature of the input discriminators, a minimum slew rate of the input signal should be met to ensure proper switching and that the input does not oscillate when the input signal crosses the threshold level. A minimum slew rate of 50 V/µs should ensure clean signal transition.

For other reasons the slew rate should be high as well. The extremely high bandwidth of the device means that broadband noise can have significant impact on the detection accuracy when the slew rate is low. The input termination resistors generate 120 µV of thermal noise over the discriminator's bandwidth at room temperature. With a slew rate of 50 V/µs, the inputs will be inside the noise band for over 2 ps. In reality the temperature will be higher and thus the thermal noise.

3.3.2. SYNC Outputs

The SYNC outputs provide a large variety of output signals for a lot of synchronizing, triggering, monitoring or whatever application. The 64 selectable output signals are as follows:

- 0   static "0"

- 10 MHz   10 MHz reference clock

- 78.125 MHz   10 GHz free running sampling clock / 128

---

[8] This scope picture is taken with a 2 GS/s, 500 MHz bandwidth digital scope

- 100.000 MHz   100 MHz free running clock
- 156.250 MHz   10 GHz free running sampling clock / 64
- 200.000 MHz   200 MHz free running clock
- 312.500 MHz   10 GHz free running sampling clock / 32
- START   monitor of the discriminated START input sampled at 312.5 MHz
- STOP 1   monitor of the discriminated STOP 1 input sampled at 312.5 MHz
- STOP 2   monitor of the discriminated STOP 2 input sampled at 312.5 MHz
- STOP 3   monitor of the discriminated STOP 3 input sampled at 312.5 MHz
- STOP 4   monitor of the discriminated STOP 4 input sampled at 312.5 MHz
- STOP 5   monitor of the discriminated STOP 5 input sampled at 312.5 MHz
- GO   GO-line state
- START-OF-SWEEP   6.4 ns pulse at the beginning of a new sweep
- ARMED   ready for START
- SYS_ON   acquisition ON
- WINDOW   measurement time window
- HOLD_OFF   active HOLD-OFF time
- EOS_DEADTIME   active from the end of a sweep till re-arm
- TIME[0]   6.4ns = 2^0 x 6.4 ns periodic timer signal active only when sampling
- TIME[1]   12.8ns = 2^1 x 6.4 ns periodic timer signal active only when sampling
  …   …
- TIME[31]   13.7s = 2^{31} x 6.4 ns periodic timer signal active only when sampling
- SWEEP[0]   bit 0 of the sweep counter
- SWEEP[1]   bit 1 of the sweep counter
  …   …
- SWEEP[10]   bit 10 of the sweep counter
- PRBS   Pseudo Random Bit Sequence with 5ns bit width (ref. also chapter 8.3.7)

All these signals may be output on the fast-NIM SYNC_1 output on the front panel and on the TTL SYNC_2 output on the FEATURE connector as well. They can also be inverted.

The sweep counter is incremented when a new sweep is started / triggered.
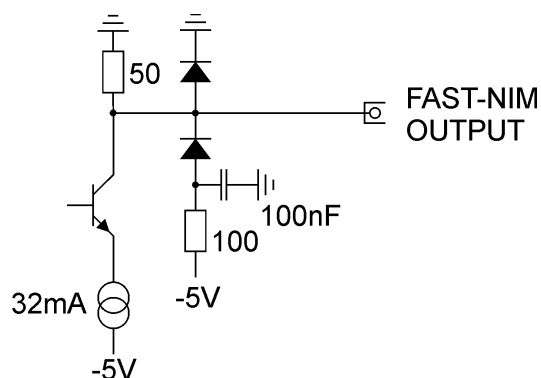
Fig. 3.8: Fast-NIM SYNC_1 output schematic

The fast-NIM SYNC_1 output is a current mode output and supplies standard fast-NIM (0...-0.8 V / 16 mA) signals into an external 50 Ω load. The output impedance is 50 Ω. For fast-NIM signals a logic 'TRUE' corresponds to a low voltage (-0.7 V), e.g. while a sweep is running 'ON' will result in –0.7 V (='TRUE') output. You can switch to negative logic by selecting 'inverted' in the corresponding settings.

3.3.3.   TAG Inputs

Another unique feature of the MPA4T is a 16-bit TTL/LVDS TAG input with a time resolution of 6.4 ns.

As can be seen from the simplified logic diagram in Fig. 3.10 the TTL ENABLE must be connected to +5 V when the TTL TAG inputs shall be used. A short between pin 37 and pin 19 on the 37-pin D-SUB connector will be sufficient.

For details on the pinning of the connector please refer Fig. 3.9 below.
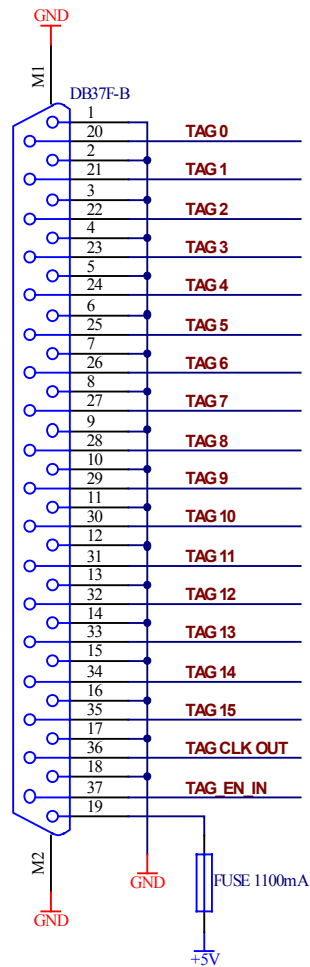
Fig. 3.9: TAG TTL input connector pin assignment

When in use the TAG inputs are stored with each detected event at a resolution of 6.4 ns.

Since it might mostly take some time to derive the proper TAG signals from the experimental setup (e.g. due to further external logic delays etc.) the MPA4T provides a software settable input delay to the START and STOP inputs. This can be set in 15 steps of 3.2 ns each in a range of 0…48 ns. Thus adjustment of the arrival times of TAG to STOP signals was never that easy.
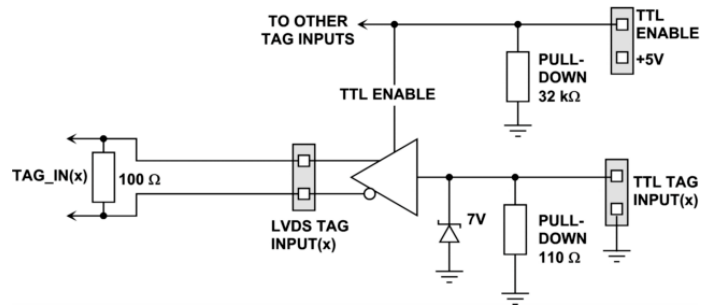
Fig. 3.10: TAG input logic

> **NOTE:**
>
> For usage of the LVDS TAG input mode please contact factory for details.

3.4. Classical Multiparameter Section

The classical multiparameter section provides the ability to connect upto 8 external ADC's, Multiscalers, Position Analyzers, Time-of-Flight units etc. with a DataReady / DataAccepted handshake.

3.4.1. ADC Port Connectors

All 8(4) ADC ports normally support upto 16 bit wide (64k channel) ADC's, TOF's etc.

But they provide the ability to be software configured for 32, 48 or 64 bit interfaces by using neighbouring ports. In that case the handshake (DRDY, DACC, DEADTIME etc.) is processed on the lowest ADC port connector only. The associated higher order ADC ports provide the higher order data bits only. E.g. if ADC port 1 is setup with 64 bit then data "bit 0" (LSB) corresponds to "ADC 1 / DATA[0]" and data "bit 63" corresponds to "ADC 4 / DATA[15].

All the corresponding signal polarities are software selectable.

DEADTIME = Time-to-peak + MAX(DecayTime; ConversionTime)
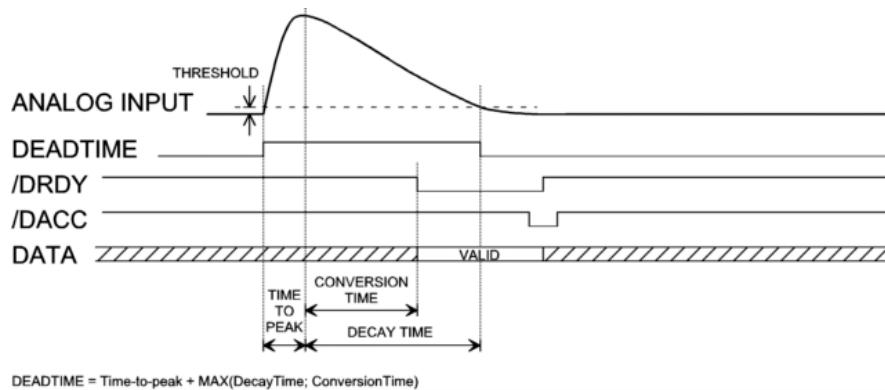
Fig. 3.11: Simplified ADC port timing
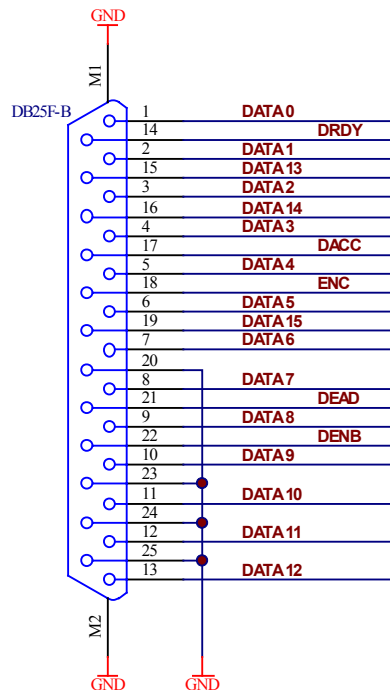
Fig. 3.12: ADC Port connectors' pin assignment

DATA 0…15 – Data inputs

DRDY – Data Ready input signal indicating that valid data is present

DACC – Data Accepted output signal indicating that the input data is registered

DEAD – Dead Time input signal

ENC – Enable Converter output signal to arm the connected device

DENB – Data Output Enable signal to enable tri-state output drivers

---

NOTE:

When using cables with all pins connected:
unused input signals should be tied to a valid level with low impedance since open wires tend to act as an antenna and might disturb proper data acquisition.

The handshake in fact is quite easy. When DRDY is asserted by the external device the MPA4T registers the valid data and then asserts DACC unitl DRDY is removed. Then DACC is also removed.

Always 4 ADC ports in a row (1…4 and 5…8) share a queue for the data transfer to the FIFO. Thus, the response time of each interface may vary by the number of simultaneously firing ADC's (ref. Chapter 8.3.8).

3.4.2. Auxiliary / Reject I/O Connectors

3 BNC type connectors provide additional flexibility particularly in COINCIDENCE mode.
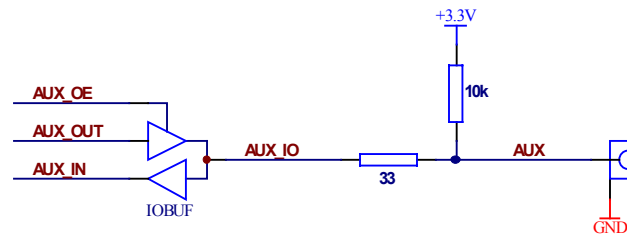
Fig. 3.13: AUX / REJECT I/O logic

The AUX/REJECT inputs can be used for additional coincidence conditions (also refer the corresponding software chapters).

The AUX I/O's also provide some software selectable output signals (ref. chapter 5.1.7).

3.4.3. ADC GATE Inputs

Each ADC port has an individual GATE input associated and a Common GATE as well.

These allow to selectively switch data acquisition on and off during a running measurement.
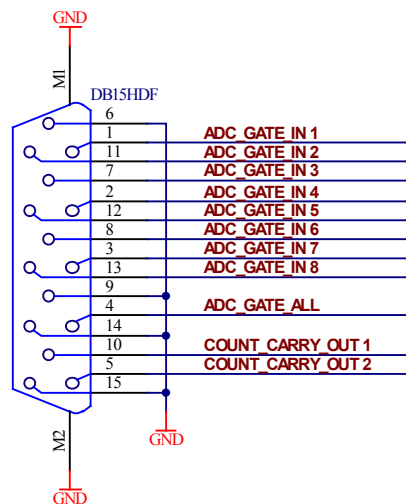
Fig. 3.14: ADC GATE input connector

3.4.4. 48Bit Realtime Clock

A 48 bit Real Time Clock with a resolution of 6.4ns synchronously to the TOF section allows to investigate correlations between TOF and ADC events.

It also provides the ability to tag any SINGLE or COINCIDENCE event with its corresponding arrival time.

The active going edge of DEAD is used for realtime capture.

4.   Functional Description

4.1.   Introduction

The MPA4T includes three major sections that will be described separately.

1)   100ps Time-of-Flight (TOF) section

2)   External ADC interfaces with MPA functionality

3)   Additional 100MHz counters / scalers (option) and Digital I/O's

In the 100ps TOF section the MPA4T measures the arrival time of STOP input events relative to a previous START signal. The resolution or time bin width is 100 ps. The full dynamic range is 54 bits which results in the incredible maximum sweep time of 20.84 days. 32 bits [6…37] of the timer are also accessible via the SYNC outputs (TIME[0…31], ref. Chapter 3.3.2). The measured data is transferred into the computer in list-mode, i.e. as they are acquired per each input channel.

A unique feature of the MPA4T is that the START channel can be sampled as well and thus can be used as a sixth input channel.

Since the time base for all 6 inputs is the very same and since each data transferred into the PC contains the channel number and a long time information relative to a common start (even software start) for the first time correlations between several input channels can be acquired with one single instrument. Time differences or correlations between specific events in up to 6 different channels can be measured. And this always at the full 100 ps resolution even for long time periods.

4.2.   TOF Modes of Operation

4.2.1.   Stop-After-Sweep Mode

This might be the mode many have used before with single channel instruments.

When the MPA4T is armed it waits for a START input signal. When one occurs the sweep is started / triggered, meaning the time starts to count. Now the arrival times of the STOP input signals relative to the start are acquired on all channels that are enabled. A STOP event can be either a falling or a rising edge or both. Even further signals into the START input can be acquired. Since the type of edge is detected and marked in the acquired data even Time-over-Threshold or pulse width measurements can be accomplished.

An acquisition delay time might be selected in steps of 6.4 ns to accept only STOP events that arrive after the selected delay.
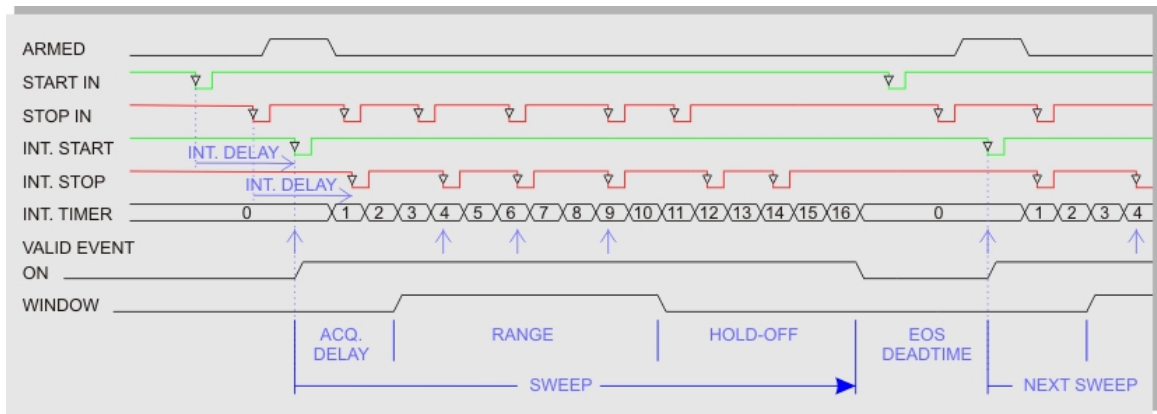
Fig. 4.1: Simplified timing diagram

When the selected measurement time range – selectable in steps of 6.4 ns - has elapsed the sweep and so the data acquisition ends. After a short (96 ns) end-of-sweep dead time the MPA4T is ready for a new start and will begin a new sweep as soon as the next START event occurs.

To reduce the overall average data rate a HOLD OFF time might be selected – as well in steps of 6.4 ns - that allows a new start only after this additional time has elapsed after the end of the sweep.

Acquisition delay, time range and hold-off are 48 bit values in 6.4 ns units each.

Acq.Delay + TimeRange + Hold-Off $\leq 2^{48}$ x 6.4 ns = 20 days max.

Since the time window in which events are actually acquired is programmable in such a wide range it is possible to count stop events at very high input rates even at late arrival times. This is due to the data reduction executed. The fact is that all events that occur outside the programmed time range window are discarded.

Example 1:

Average STOP data rate of 100 MHz. Interesting time window is 1 µs at 1 ms after the START / TRIGGER signal:
In a time range of 1 ms the 100 MHz input rate would result in 100,000 STOP events which would cause data loss due to filled FIFO's. When programming an acquisition offset of 1 ms and a 1 µs measurement time window the resulting number of events per sweep is only 100. Thus, no data loss at all will occur. And even with highest speed sweep repetition rates an average data rate of only some 1000 sweeps/sec x 100 events/sweep = 100,000 events/sec has to be stored.

Additionally a trigger hold-off time, also programmable in increments of 6.4 ns, can be selected to further reduce the average data rate by accepting only a new start / trigger after this additional time has elapsed.

Example 2:

Average number of STOP events per sweep is 1,000. Say your computer allows an average transfer rate over the USB of 10 Mevents/s a maximum of 10MHz / 1000 = 10kHz sweep repetition rate can be accepted. With a sweep length of e.g. <5 µs and start signals every 5 µs the average data rate would be 200 MHz. A trigger hold off after every sweep of 95 µs will reduce the start rate to 10 kHz and thus the average count rate to 10kHz x 1,000 = 10MHz.

Sweep counter

A presettable 48-bit sweep counter is incremented at every start of a sweep. In fact the sweep counter counts the real start of a new sweep rather than the completion of the sweeps. When a preset is enabled and the preselected number of sweeps has occurred any further start of a sweep is prohibited.

The lowest 12 bits of the sweep counter may be output and watched on the SYNC outputs. They are particularly useful when some experiment should be periodically changed after a fixed number of sweeps.

4.2.2. Endless Mode

In the endless mode data acquisition is started only once, e.g. by a software start i.e. asynchronously to the rest of the experiment. Then all arriving events are recorded and stored with an absolute time relative only to the initial start. Since the dynamic range is up to 54 bit or 20 days the available absolute time range will be sufficient for every imaginable experiment.

4.2.3. Tagged Spectra Acquisition

16 TAG inputs allow for sequenced spectra acquisition, multi detector configurations etc. The 16 Tag's are sampled synchronously to the START / STOP inputs. The time resolution is 6.4 ns.

E.g. in a multi detector experiment it is feasible to measure which detector (even if more than 5) has fired and still maintain the incredible 100 ps bin width. This allows also for ultra fast coincidence measurements with very little external logic required.

In most cases the arrival time of the TAG signals relative to the corresponding STOP signals will be late. To ease the adjustment of the arrival time between TAG and STOP signals a digital selectable additional delay to the START /STOP signals is provided. This can delay those signals in steps of 3.2 ns in a range of 0 to 48 ns. Thus, normally no external delay lines will be needed.

In case of using the TAG bits part of the upper 32 bits of the 64 bit data word are replaced by the Tag's.

4.3. MPA Modes of Operation

There are two basic modes available with the external ADC interfaces: SINGLE and COINCIDENCE mode and any combination of them. Each interface may be simultaneously used in both modes.

For Livetime correction every 1ms the DEADTIME signals of each port are sampled and transferred to the PC.

4.3.1. SINGLE Mode

In SINGLE mode of operation each ADC data is simply transferred to the PC as it arrives.

The data maybe tagged with 32 bit of the Real Time Clock. Thus, the timely development of the events maybe analyzed.

And 9 least significant bits of the TOF sweep counter value maybe included which is important in the combined TOF and MPA mode of operation.

4.3.2. COINCIDENCE Mode

The basic purpose of introducing COINCIDENCE mode is to acquire only data that meets some predefined timing relationship.

Events that will be accumulated must occur inside the coincidence resolving time window. Thus, events that do not fall in this coincidence time window will be discarded and do not show up in the acquired histograms.

The versatility of the coincidence definitions in the MPA4 system allows to select various combinations of ADC events that either have to occur within the coincidence time window or where just some have to occur to accumulate them.

In COINCIDENCE mode of operation the active going edge (programmable rising or falling edge) of the ADC's DEADTIME signal is used as time-of-arrival of an ADC event. This is done because the DEADTIME signal usually is the most accurate time information obtainable from an ADC.

On detecting an active going edge of a DEADTIME signal a coincidence resolving time window is opened. While a coincidence window is open all arriving DEADTIME edges are stored. After the coincidence time has elapsed the system waits for all DRDY signals of the corresponding ADC ports (meaning that the port contains valid data) to become true. The maximum time to wait for this is software selectable (ref. DRDY timeout chapter 5.1.5). When all expected DRDYs have arrived - or at the latest when the DRDY timeout elapsed – the corresponding data is transfered to the PC in listmode. If a port has no new data (DRDY did not go active until the timeout occurred) a zero is transfered for this port.

The ADC ports that are allowed to open a coincidence time window are software selectable as well (ref. chapter 5.1.6). This enables for further data reduction.

In COINCIDENCE mode of operation the corresponding ADC ports accept new data only when a coincidence time window is open. This is usefull to reduce the system deadtime caused by not coincident or unwanted ADC events.
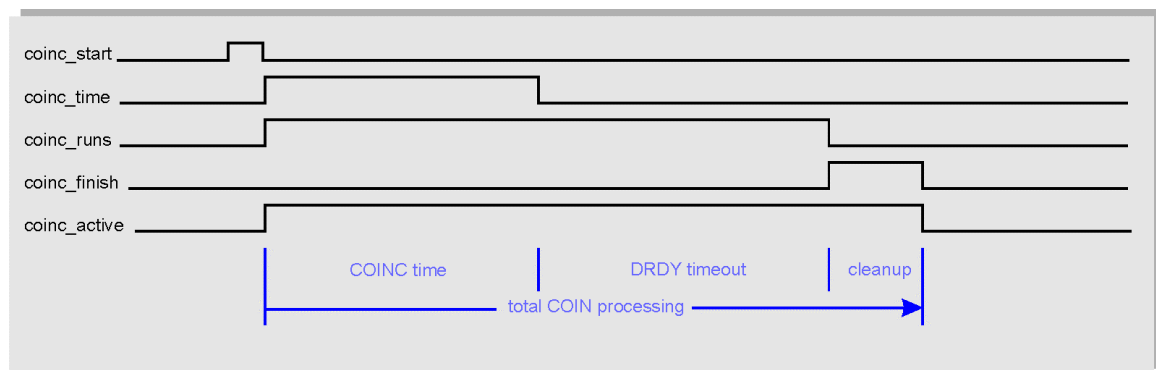
Fig. 4.2: Coincidence processing and timing

The corresponding timing signals as in Fig. 4.2 are available on the auxiliary IOs (ref. chapter 5.1.7).

The transferred concidence data block may also include the real time of the coincidence window being opened. And, the values of the 100MHz counter 1, 3 and 4 at that time may be included. And also the TOF sweep counter value which is important in the combined TOF and MPA mode.

4.3.3.   Combined TOF and MPA Mode

When you want to simultaneously acquire or even correlate TOF and ADC data you might probably use the Stop-after-Sweep mode as shown in Fig. 4.3.

In this mode ADC data is only acquired while sys_on=1 i.e. – during an active sweep. It is important to realize that the ADC data might be delayed in respect to the corresponding TOF STOP event. Thus, after an active TOF sweep time range has elapsed there must be a long enough Hold-Off period to allow even the latest ADC data to arrive while sys_on=1.
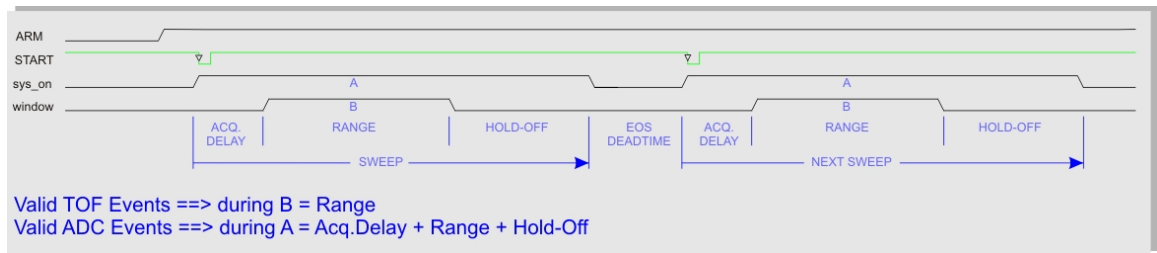
Fig. 4.3: Combined TOF and MPA Timing

The corresponding timing signals as in Fig. 4.2 are available on the auxiliary IOs (ref. chapter 5.1.7).

Referring Fig. 4.3 and Fig. 3.11 the Hold-Off time must be at least the analog time to peak plus the ADC conversion time. ADC data is acquired during period "A" while TOF STOP events are aquired during "B".

4.4. FIFO Concept

A multi-stage FIFO concept is used to optimize for the two main difficulties of those data acquisition systems. On the one hand ultra high burst count rates (here 10 Gevents/s) should be acceptable for a period of time as long as possible.
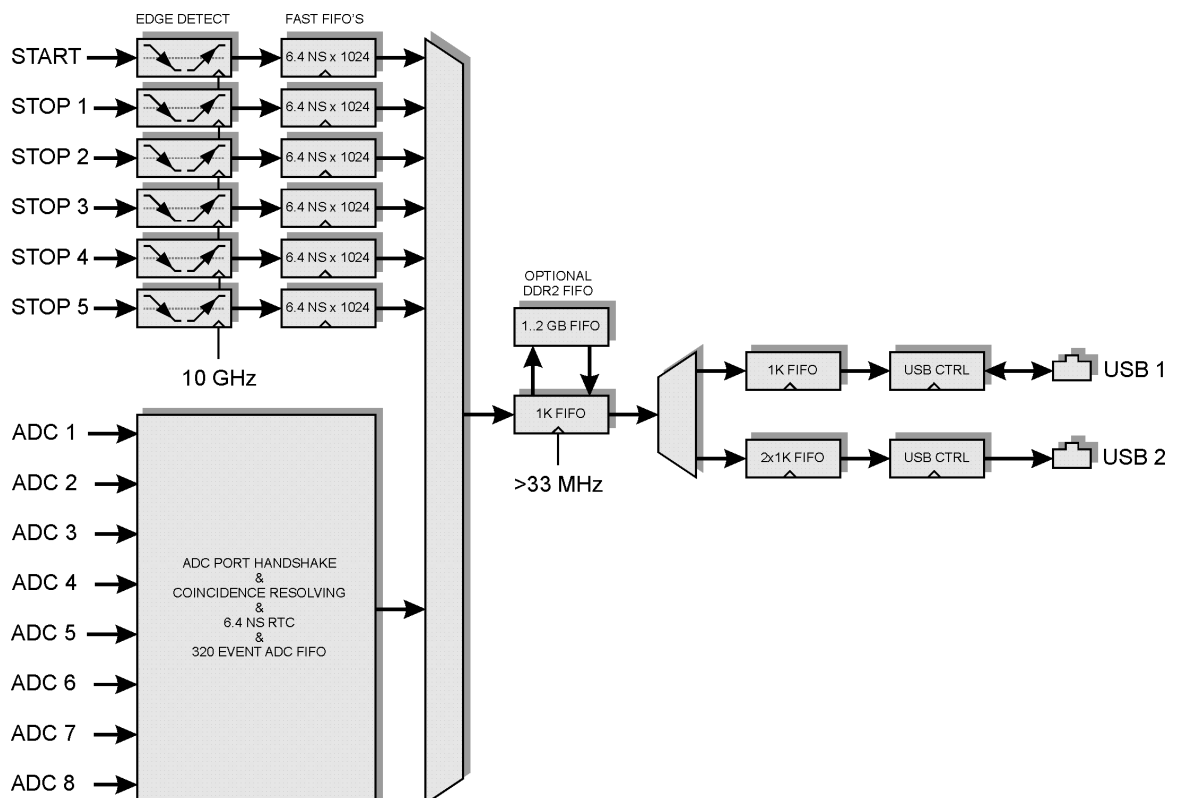
Fig. 4.4: FIFO concept

In the case of the MPA4T each individual START / STOP input has its own 6.4 ns x 1024 FIFO. These are able to store burst rates of as high as 10 G edge events per second for up to 6.5 µs before any event might be lost. Each FIFO word is comprised of the complete event structure in a

6.4 ns period. It is worth noting that these ultra fast FIFO's are really independent for each channel.

Since the maximum ADC data rate is comparably slow a smaller ADC event FIFO of 320 events is sufficient.

On the other hand a high average count rate must be stored without loss of events. The decoding and binary time coding of the raw data as buffered in the first FIFO stage is accomplished at a rate of over 33 MHz. Since the bandwidth of the USB 2.0 transmission is limited to something like 35 MB/s a large second FIFO is provided that is able to store a high number of data.

NOTE:

Since September 2015 a new Firmware v 14 can be downloaded from www.fastcomtec.com that uses 3 decoding machines parallel and increases the rate to fill the large FIFO from 33 MHz to **100 MHz** !

The optional up to 2 GB large DDR2 FIFO is designed to be used in an optimized way depending on the number of bytes that is transferred for each single event. I.e. for 64 bit = 8 byte data words up to 2 GB / 8 = 256 Mevents can be buffered. The same is true for 48 bit = 6 byte words. For 32 bit = 4 byte data up to 512 Mevents, for 16 bit = 2 byte data up to 1 Gevents can be stored in a 2 GB DDR2 module.

5.   Software Description

The window of the MPA4 server program is shown here. It enables the full control of the MPA4T to perform measurements and save data. This program has no own spectra display, but it provides - via a DLL ("dynamic link library") - access to all functions, parameters and data. The server can be completely controlled from the MPANT software that provides all necessary graphic displays. The view of the server window depends on the number of active input channels, here all 6 TDC and 8 ADC channels are active.
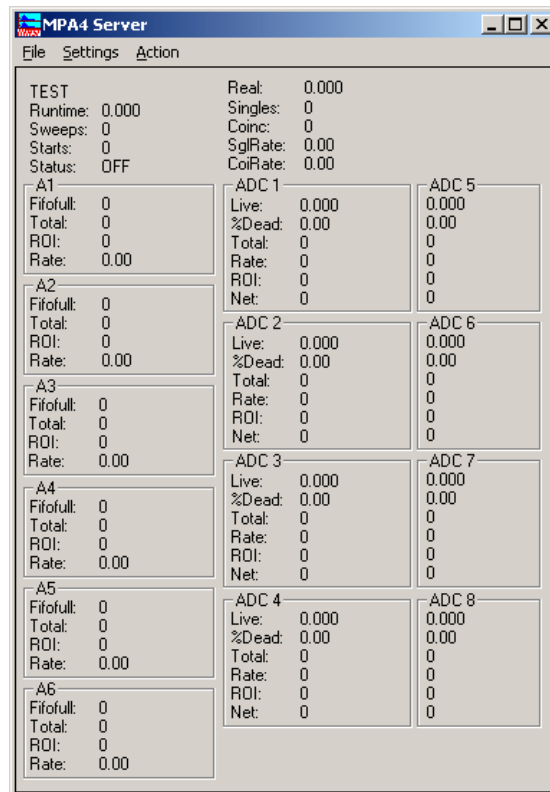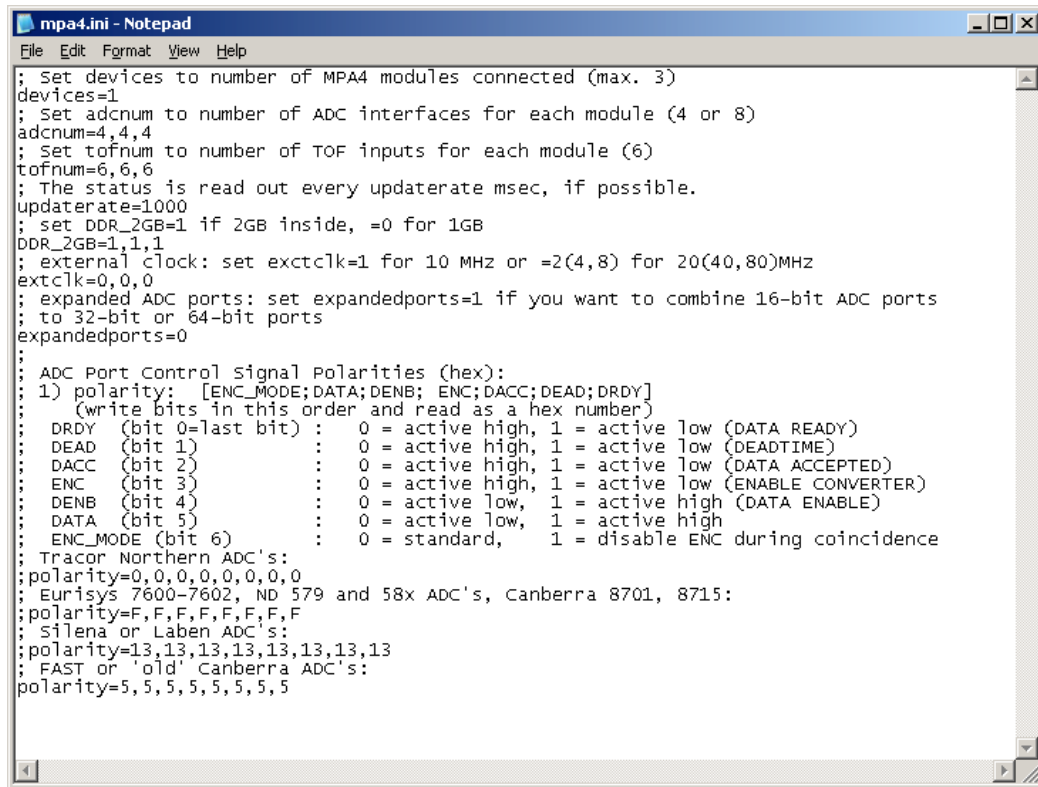
Fig. 5.1: MPA4 Server Window

5.1.   Server functions

To start the software, just double click a shortcut icon linking to the server program. The server program performs a test whether the hardware works well on this computer, then starts MPANT and gets iconized. Usually you will control everything from MPANT, but it is possible to work with the server alone and independently from MPANT.

5.1.1.   Initialization files

At program start the configuration files MPA4.INI and MPA4A.SET are loaded.

Fig. 5.2: MPA4.ini File

Parameters that can be set by editing the MPA4.INI file are the update rate in msec for the refresh of the status, and it can be specified whether 2GB or 1GB RAM is built in. Set DDR_2GB=0 for 1GB.

Expanded ADC ports: set expandedports=1 if you have a device with more than 16 bits that you want to connect to combined ADC ports.

External clock: If you have a good external 10 MHz reference signal, for example a Rubidium or GPS clock, you can use it the following way:

Change the MPA4.INI file and insert a line

extclk=1

After power up always the internal clock is used, so you should not yet connect the external clock signal. Start the software. You will be prompted by a Messagebox to connect the external 10 MHz signal to the BNC connector labeled "10 MHz" at the back side. If you later exit and restart the software, let it connected. But after power down please disconnect it. When using the internal clock the same connector outputs the internal 10 MHz signal.

The ADC port handshake signal polarities are defined also in this file. Several standard ADC's are already predefined and can be enabled simply by removing the semicolon at the beginning of the respective line. Lines starting with such a semicolon are just used as comments.

The file MPA4A.SET contains the default settings. It is not necessary to edit this file since it is saved automatically. Instead of this .SET file any other setup file can be used if its name without the appendix 'A.SET' is used as command line parameter (e.g. MPA4 *TEST* to load TESTA.SET).

5.1.2. Action menu

The server program normally is shown as an icon in the taskbar. After clicking the icon it is opened to show the status window. Using the „**Start**" menu item from the action menu a measurement can be started. In the status window every second the acquired events, the counting rate and the time are shown. Clicking the „**Halt**" menu item the measurement is stopped and via „**Continue**" proceeded.
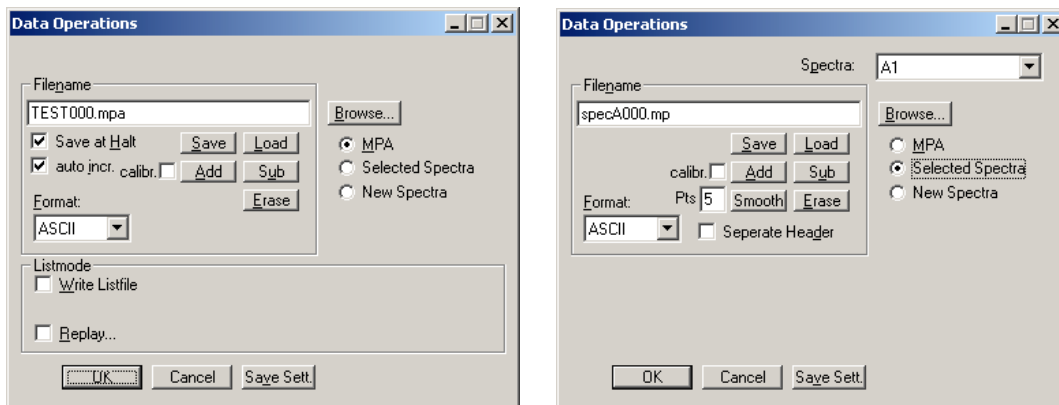
Fig. 5.3: Data Operations dialog for MPA data (left) and selected spectra (right)

5.1.3. File menu

Clicking in the File menu on the Data... item opens the Data Operations dialog box.

This dialog allows to edit the data format settings and perform operations like Save, Load, Add, Subtract, Smooth and Erase. The Radio Buttons **MPA**, **Selected Spectra** and **New Spectra** provide a choice between handling of the complete data set (MPA) or selected spectra, or to load new selected spectra for compare. Mark the checkbox **Save at Halt** to write a MPA file containing the configuration and all spectra at the stop of a measurement. The filename can be entered. If the checkbox **auto incr.** is crossed, a 3-digit number is appended to the filename that is automatically incremented with each saving. The format of the data can be ASCII (extension for separated spectra .ASC), binary (.DAT), CSV (.CSV). If **Separate Header** is not checked, the Header and data is saved together in a file with extension .MP, otherwise the file with extension .MP contains only the header and the data is written separately into a file with appropriate extension. The buttons **Save**, **Load**, and **Erase** perform the respective operation. With **Add** and **Sub** spectra can be added or subtracted from the present data. The checkbox **calibr.** can be checked to use a calibration and to shift the data then according to the calibration. The **Smooth** button performs an n-point smoothing of selected single spectra. The number of points to average can be set with the **Pts** edit field between 2 and 21. Check the **Write Listfile** checkbox to write a listfile during a run. **No Histogramming** prevents calculating any spectra to save computing time and concentrate the system on writing the listfile.

The menu item File – Replay... opens the Replay dialog. The Replay software for ADC data is an option, the licence is either programmed into the MPA4 module or you need an USB dongle. Replay of pure TDC data works without licence.
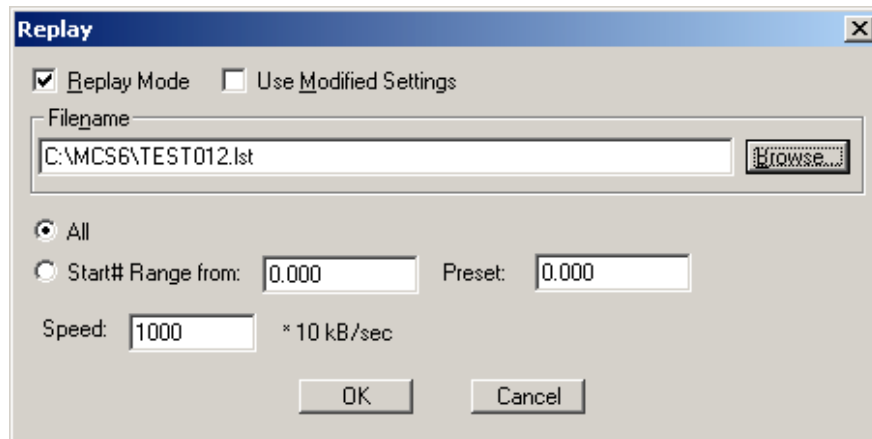
Fig. 5.4: Replay Settings dialog

Enable **Replay Mode** using the checkbox and specify a **Filename** of a list file (extension .LST) or search one by pressing **Browse...** With the radio buttons it is possible either to choose the complete list file by selecting **All** or a selected **Start# Range**. Specify the sweep range by editing the respective edit fields **from:** and **Preset:** . The Replay **Speed** can be specified in units of 100 kB per sec. To **Use Modified Settings** enable the corresponding checkbox; otherwise the original settings are used. To start Replay press then Start in the Action menu or the corresponding MPANT toolbar icon.

The menu item File – About... opens the About MPA4 window where some information of the System can be found. Particularly the serial number is important for support purposes. This serial number is unique for each MPA4T system.
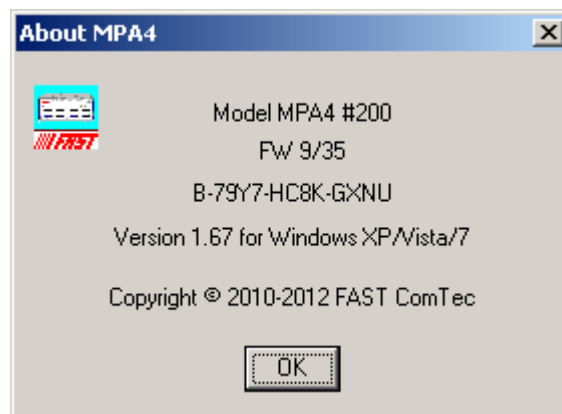
Fig. 5.5: About MPA4 dialog box

The MPANT menu item in the file menu starts the MPANT program if it is not running.
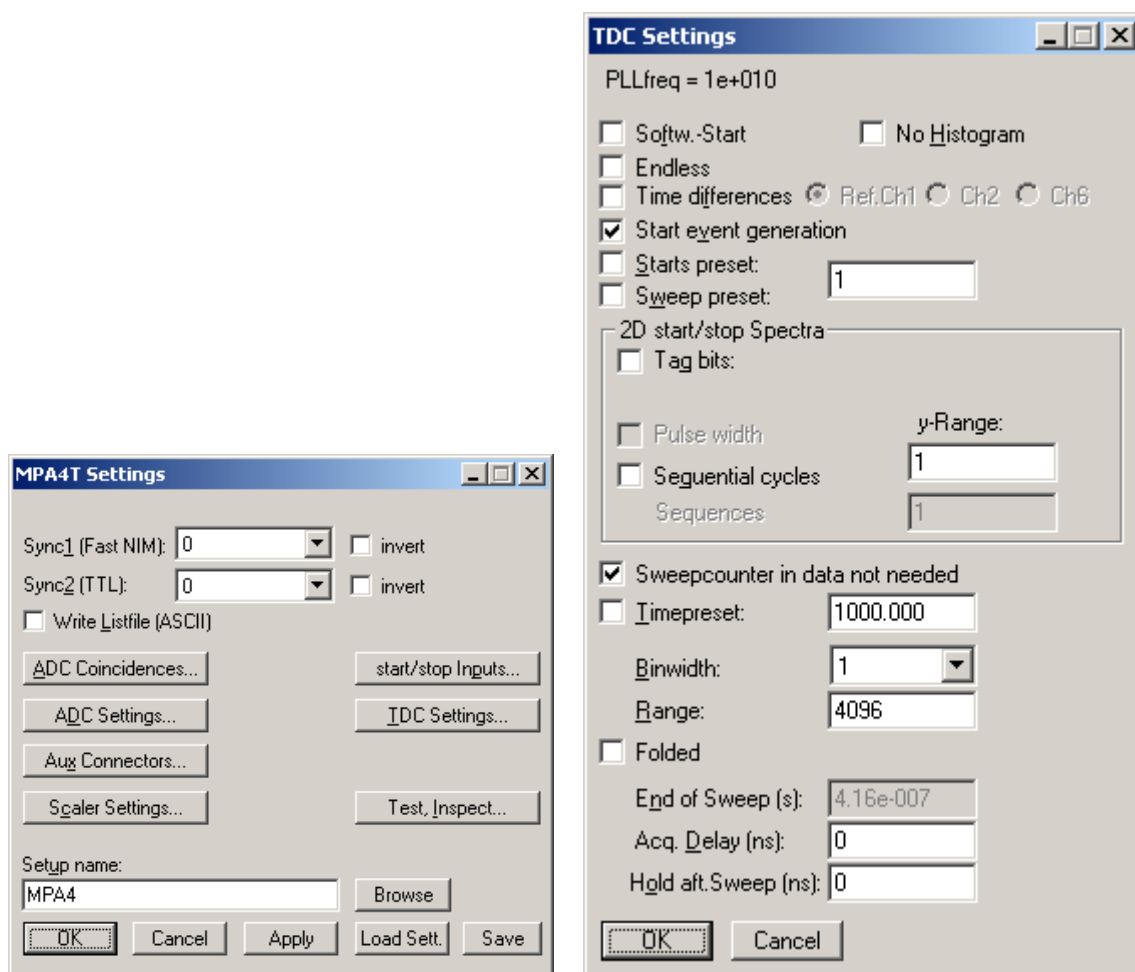
Fig. 5.6: Settings overview and TDC settings dialog

5.1.4. TDC Setting dialogs

The Hardware... item in the Settings menu opens the MPA4T Settings dialog box. It contains several buttons that open special setting dialogs.

Via the **Sync out** - combo boxes you can specify the signal you want to observe. See chapter 3.3.2. You can observe the **START** and **STOP1…STOP5** signals. Use it as a monitor and vary the input thresholds to find the best threshold settings. The Sync Outs can deliver **10 MHz, 78.125 MHz, 100 MHz, 156.25 MHz, 200 MHz** and **312.5 MHz.** The three frequencies above 100 MHz are only available at the Sync1 Fast NIM output. **SYS_ON** indicates a running sweep, **WINDOW** indicates the active measurement time window, **HOLD_OFF** is the Trigger hold off time window, **EOS_DEADTIME** is the dead time at the end of a sweep. **TIME[0]**..**TIME[31]** are the Bits 0..31 of the time counter. Furthermore, the bits of the sweep counter can be monitored at the Sync outputs by specifying **SWEEP[0]**..**SWEEP[11]**. The time counter is incremented after 64 basic dwell times i.e. after about 6.4 nsec. The signal for the synchronization of the experiment can be obtained from one of the two Sync Out outputs. The level can be logical inverted by checking the **invert** checkbox. A List file can be written by checking the corresponding checkbox **Write Listfile**. The data format can be ASCII or binary depending on the format settings in the data operations dialog.

Click on **TDC Settings...** to topen the respective dialog.

The mode of the measurement can be **Endless** if the corresponding checkbox is crossed, or Sweep mode. In Sweep mode usually via an external start signal a sweep is started, after completion the next sweep starts with the next start pulse. Endless mode means that the sweep is started once and runs forever until the acquisition is stopped by software. The time counter will count for ever (when using 54 bits for the time information up to 20.8 days) and in a list file the full time information for every stop event is written, but the channel pointer for the histogram wraps around and keeps counting along from zero. This mode can be used together with the sync out to synchronize the experiment. If **Softw. Start** is marked no start signal is necessary. The time-counter for the spectra is masked corresponding to the chosen range. The signal for the synchronization of the experiment can be obtained from one of the two Sync Out outputs.

An acquisition mode "**Time differences**" is implemented for analyzing pulse trails. In this mode the first stop event is used as a reference point and for following stop events the time difference to the reference is calculated. The displayed spectrum is then a relative time distribution of stop events related to the reference point. Even wrap around mode works in this differential mode. The first stop event that falls out of the chosen time range after a reference event is taken as a new reference point.

If **No Histogram** is checked, no histogramming and on-line evaluation is done, this could make sense if a list file is written. If **Start event generation** is checked, a start event is inserted as a zero into the data stream and counted by the software. The measurement can be stopped automatically after a specified number of sweeps by checking **Starts preset** or **Sweep preset**. In the former case the start events are used, in the latter case the hardware sweep counter.

A series of measurements can be acquired into separate memory parts by checking **Sequential cycles** and specifying the number of cycles. Each single measurement should be terminated by any of the preset conditions, the complete run stops after performing the specified number of cycles or is repeated accordingly if the specified number of **Sequences** is greater than 1.

Tagged spectra allows to sort the spectra into up to 65536 separated parts, depending on tag bits. MPANT will show the spectra in a 2 dimensional view. You can either select **one hot** mode or **binary** for the tagging scheme. In "one hot" mode you get n+2 rows for n tag bits: the first row contains the data for no tag bit set, the next row is data with tag bit 0 set, the next with tag bit 1 set, and so on. The last row is the data with more than one tag bit set.

In "binary" tagging scheme, y is the pattern of tag bits seen as a binary number.

The data acquisition can be ended after a given time via the **Time preset**. In the edit field **Range** the length of the spectrum can be entered. A **Bin width** of 1 means the highest time resolution. The Bin width can be chosen in powers of 2 up to 1677216 times the elementary dwell time. If an **Acq. Delay** is specified, data are acquired in a sweep not before the specified time. **Hold after sweep** allows to wait a specified time after a sweep before the next sweep can be started.

If the MPA4T clock is synchronized with the measured data, for example by using an external clock or controlling the apparatus by a sync-out signal, it is useful to enable the **"Folded"** checkbox. If it is crossed, an edit field **"Periods"** and a checkbox **"Interlaved"** appear. For example for the FLIM application with a 76 MHz Laser synchronized with the MPA4T and a periode of 131.5 time bins mentioned in chapter 2.5.9 the recommended settings are 263 for the Range and "interleaved". The number of periods defines then the sweep length as Range * Periods, for example 1000000 periods are possible with a data length of only 4 bytes, if "Sweepcounter in data not needed" is crossed. The sweep length is then 26.3 msec and the spectrum length only 263. For a 80 MHz laser and a periode length of 125.5 bins the suited range setting is 251 (interleaved).

The data word length of MPA4T data can be 2, 4, 6 or 8 bytes and is chosen automatically depending mainly on two parameters, the selected sweep range length and whether you have checked "**Sweep counter in data not needed**". See the table in chapter 0. If you need any correlations between events from different input channels, it is important that sweep counter data is inserted into the data. The sweep counter in the event data word is the only way to uniquely identify events from different channels belonging to the same sweep, as they are inserted independently into the data stream as fast as possible from each input line.

By pressing the "**Test, Inspect...**" button a special dialog is opened that allows to inspect the data format in detail. Here are two more checkboxes to influence the data word length: By unchecking "**Allow 6 byte data words**" you can require that only the binary values 2, 4 or 8 bytes are allowed as a valid data word length. You can check "**Require Data Lost Bit**" to select a data format with a bit set if the fast FIFO was full. You can then inspect the number of events with data lost bit set from each channel in the server window. In the "Test mode" box you can check "**internal pulser**" and can then select one of the offered frequencies from the drop-down list for testing the MPA4T hardware without any external signal, as described in chapter 2.5. The pulser signal can be selected for each input individually. The LED's beside the corresponding input connectors will blink if the input is enabled and switched to the internal pulser.

You see in addition information about the voltages and temperatures of the FPGA and the MPA4T board. Pressing the Read button can refresh that information.
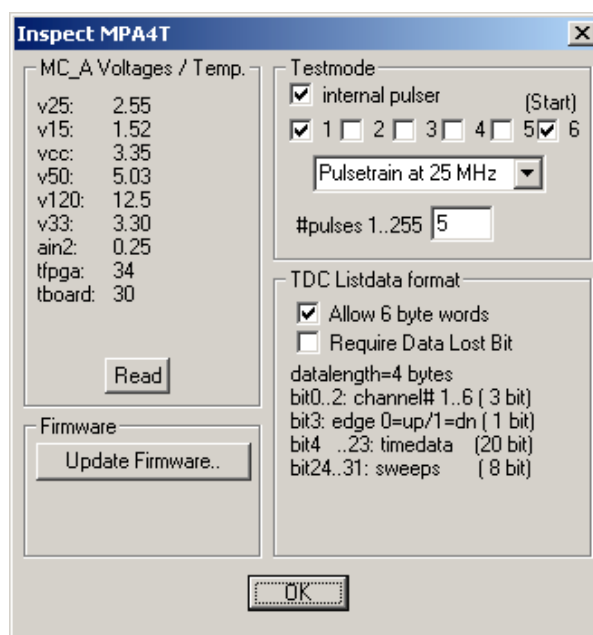
Fig. 5.7: Inspect MPA4T dialog
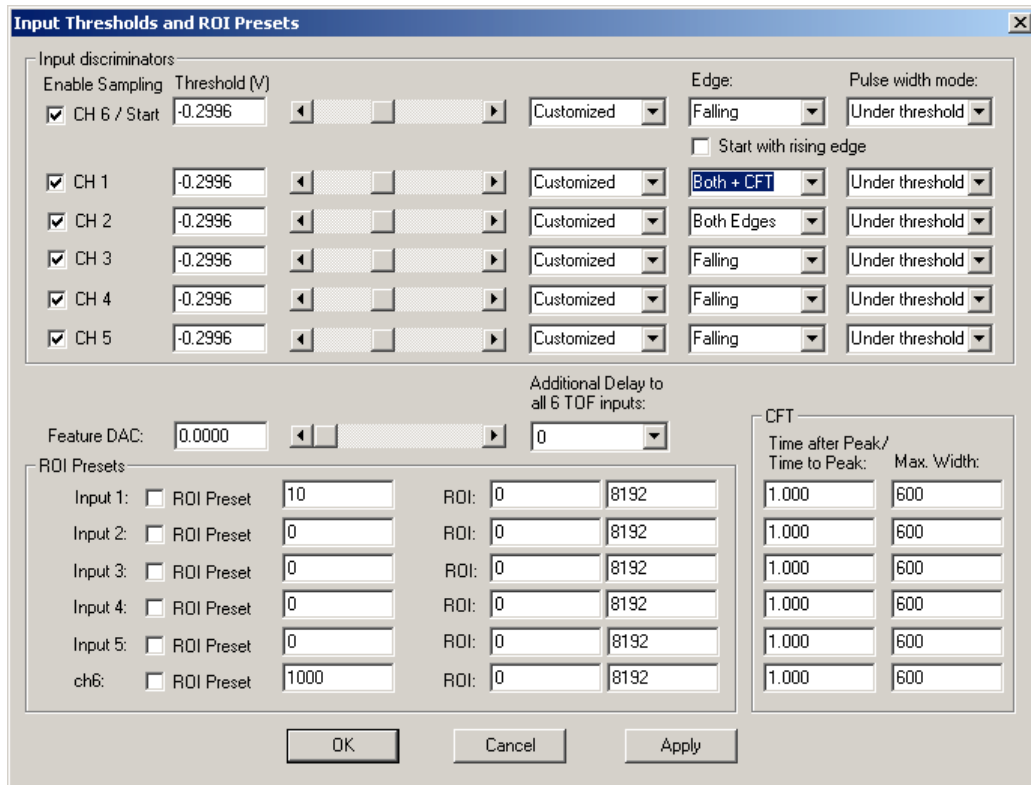
Fig. 5.8: Input Thresholds dialog

The **start / stop Inputs...** button opens the Input Thresholds and DAC's dialog box. For all 6 inputs you can **Enable Sampling** and you can specify for the START and STOP1..STOP5 inputs the **threshold** level of the input signal and select **Falling** or **Rising Edge**. The combo box provides a choice between standard Fast NIM (-0.3 V) and customized, i.e. Voltage level set by hand between -1.5 .. +1.5 V (scroll bar or edit field). It is also possible to choose both edges. Also the voltages for the free usable **Feature DAC** output can be set in this dialog. If one of the **ROI Preset** checkboxes is marked, the measurement will be stopped after acquiring more events than specified in the corresponding edit field. The events are counted only if they are within the **ROI** limits, i.e. >= the lower limit and < the upper limit. It is not necessary that this ROI is within the spectra range.

A common **additional input delay** to all 6 TOF inputs in steps of 3.2 ns until 48 nsec can be set in the input settings dialog. It may be useful for adapting the timing of tag bits to the inputs.

As the edge information is contained in bit 3 of the data (a 1 in that bit means falling edge) it is possible to distinguish stop events from rising and falling signals and it is possible to analyze the pulse width of the signals, if **Both Edges** are chosen. There is a choice between "**Over threshold**" or "**Under threshold**" for the Pulse width analyzing, depending on the corresponding setting in the "inputs" dialog. To see the events from rising and falling signals separated, just enable **Pulse width** in the settings dialog and set **y-Range** to **2** inside the box labeled "2D spectra". You will get a two dimensional spectra with a y-dimension of 2, for y=0 it contains the stop events from rising edges and for y=1 from falling edges. You can see here the separation time between both edges. If you set then the y-Range to a value larger than the maximum pulse width in channels, you will get a 2-dimensional spectra with the time of the first edge as x coordinate and the pulse width as y coordinate (see chapter 2.5.5).

A well known method named "Constant Fraction Timing" (**CFT**) is used in electronic discriminators to get an enhanced time resolution for a trigger signal made from a detector signal. Due to the capability of detecting both edges of a peak a similar method can be used in the MPA4 software too. By assuming that the shape of the signal does not depend on the amplitude, one

can get a good estimation for the time of the peak by assuming that it is always at the same fraction of the time between both detected edges. Select **Both + CFT** in the drop-down listbox for the edge detection, and enter a suited value for the fraction "**Time after Peak / Time to Peak**" i.e. time-after-peak divided by time-to-peak. For example enter 2 for a peak shaped like shown in Fig. 5.9, when the time after peak is twice the time to peak. A suited **Max. Width** for the pulse width in units of time bins must be entered, to reject spurious signals with too large width. Note that for using CFT again the "Pulse width mode" must be chosen accordingly as "Under threshold" for low going (negative) pulses or "Over threshold" for rising pulses. It is important that no data are lost, as both edges of a signal pulse must be detected. Make sure that the count rate remains below a value that the "Data Lost" indicator in the MPANT status window will not get on.
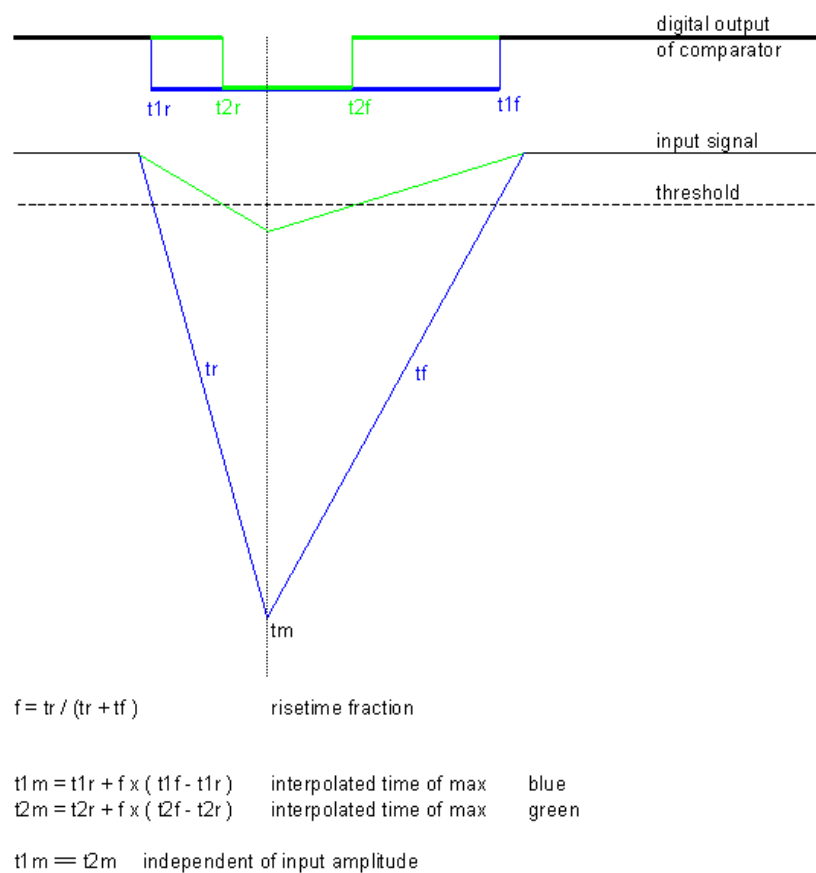
Fig. 5.9: Principle of "Software CFT"

5.1.5. ADC Settings dialog

Clicking in the Settings overview the **ADC Settings...** button opens the ADC Settings and Presets dialog box. Here parameters like presets, range parameters, coincidence time, etc. can be set.
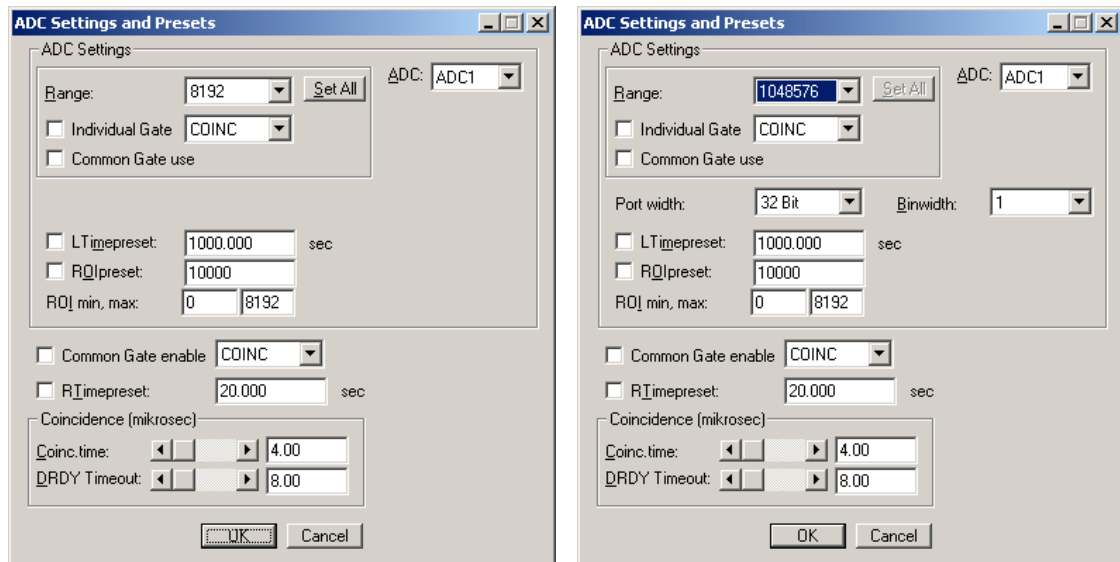
Fig. 5.10: ADC Settings and Presets dialog box, right: with expanded ports enabled

If expanded ADC ports are enabled in the MPA4.INI file, additional controls for **Port width** and **Binwidth** appear as shown right in Fig. 5.8.

In the edit field **Range** the length of the spectrum can be chosen in binary steps. **Set All** sets the range for all ADCs, otherwise each ADC can be selected from the drop down list and changed seperately. If the checkbox **ROIpreset** is marked, the measurement will be stopped after acquiring more events than specified in the corresponding edit field. The events are counted only if they are within the **ROI**[9] limits, i.e. >= the lower limit and < the upper limit. Another possibility is to acquire data for a given run time via the **RTimepreset** or a given live time via the **LTimepreset**. A measurement will be stopped if the corresponding checkbox is marked. The width of the coincidence window can be set between 0.15 and 3276 µsec in steps of 50 nsec by entering the number or using the scroll bar. The **Data Ready Timeout** can be set within the same limits. It must be large enough to cover the ADC conversion time. **OK** takes all settings. **Cancel** cancels all changes. Pressing **Save Settings** writes all settings into the file **MPA4A.SET** resp. the entered setup name.

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[9] ROI: Region Of Interest

5.1.6. Coincidence Definition dialog
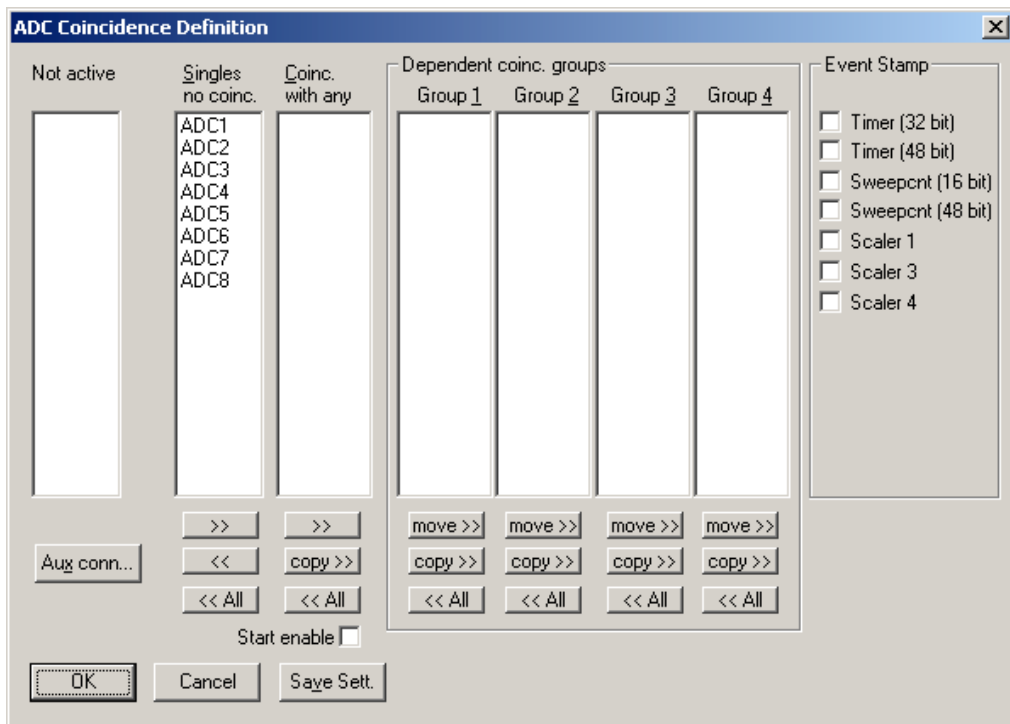
Fig. 5.11: Coincidence Definition dialog box

Clicking in the MPA4T Settings dialog on ADC Coincidences... opens the Coincidence Definition dialog box. Here the several ADCs can be combined to be used either in single mode, i.e. without regarding any coincidence, to be not activated, or to use it in coincidence mode. The Button **<<All** removes all ADCs from the respective list above it. To insert an ADC into a list, first select it in the list where it is and then press the **>>** button below the list where you want to insert it. To change an ADC from single mode into coincidence mode, first deactivate it and then insert it into the list **Coinc. with any**. Any ADC inserted into that list by default has the ability to start a coincidence time window. If you want to disable it, uncheck the checkbox **Start enable**. An 'S' after an ADC name in the list indicates whether the Start of coincidence window is enabled or not. You can then define **Dependent coincidence groups** by inserting selected ADCs from the 'Coinc. with any' list into one of the four available groups. ADCs in one of the groups must all have data within the same coincidence window, otherwise the event is dropped. The same ADC may be in several groups, therefore it is possible either to **move >>** or **copy >>** it into a Dependent coincidence group. It is possible to use an ADC as well in Single as in Coincidence mode. In this case the histogram length will be twice the ADC range, in the lower half the single data is shown and in the upper half the coincidence data. In the **Event Stamp** box there are checkboxes to insert 32 or 48 timer bits, the sweepcounter (16 or 48 bit) and scalers 1, 3 and 4 into coincidence event data. (Scalers 3 and 4 can be optionally up/down counters that could for example directly indicate the x, y position controlled by two stepping motors.)

Click **OK to** accept all settings. **Cancel** cancels all changes. Clicking „**Save Settings**" stores all settings in the file **MPA4A.SET**.

5.1.7. Auxiliary Connectors dialog
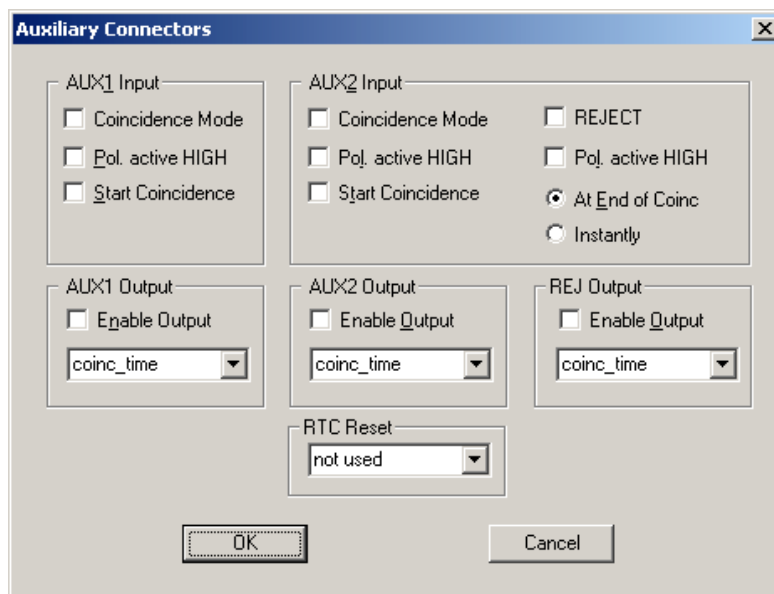
Fig. 5.12: Auxiliary Connectors dialog box

The **Aux conn...** button opens the **Auxiliary Connectors** dialog to define the use of the auxiliary connectors. The AUX1 and AUX2 and also the REJ connector can be used either as an input or an output. In input mode AUX1 and either AUX2 or REJ can be used. **Coincidence Mode** must be checked to get it into the 'coinc. with any' list. **Start Coincidence** can be checked to allow starting a coincidence resolving time window from the input connector. The Polarity of the TTL signal can be set by checking or unchecking **Pol. active HIGH (**means rising edge). For use as an output, check **Enable Output** and choose any of the signals from the drop down list.

Available output signals are:

coinc_time	active while a coincidence resolving time window is open
coinc_runs	active while a coincidence resolving time window is open plus the Data Ready Timeout
coinc_finish	active during cleanup after handling coincidence
coinc_active	total coincidence processing time
sweep_on	sweep is active
sweep_start	sweep start
dead_1	ADC 1 is busy
dead_2	ADC 2 is busy
...	...
dead_8	ADC 8 is busy
0	LOW level
1	HIGH level

Refer "Fig. 4.2: Coincidence processing and timing" for details on the coincidence timing signals.

The **REJECT Input** connector can be used similar to the AUX inputs. Check **Coincidence Mode** to have /REJ in the 'Coinc. with any' list. A signal to the Reject input then drops any coincidence event in the corresponding coincidence group, either **Instantly** or **At End of Coinc**idence window. One of the three auxiliary connectors can be used as a trigger to reset the RTC, this is selected in the **RTC Reset** box.

Note: AUX1 can be used independently of the other auxiliary connectors in coincidence mode. AUX2 and REJ share the same coincidence entry, so only one of them can be used in coincidence mode.

5.1.8. Scaler Settings dialog
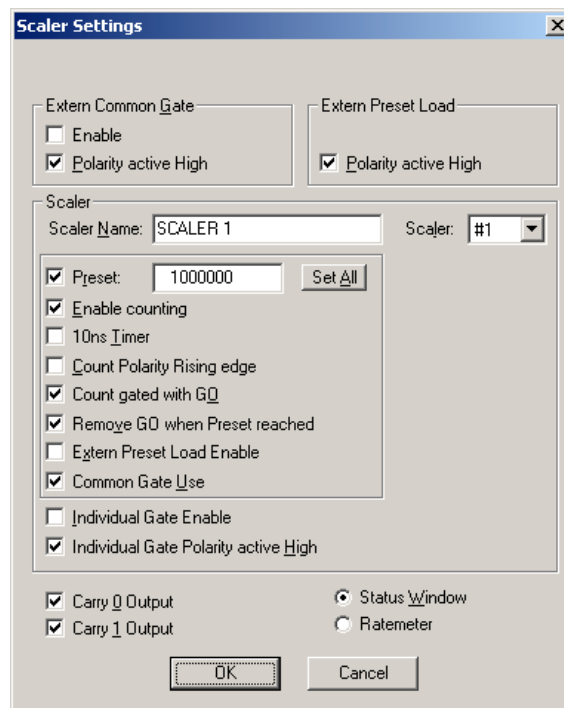
Fig. 5.13: Scaler Settings dialog box

The **Scaler Settings...** button opens the respective dialog to define the use of the 8 100 MHz Scaler/Counters. This is an option, see chapter 3.2.3. A utility program mpa4scal.exe is started automatically and shows the scaler values, optionally as a ratemeter. The scalers can be individually named, the values are saved into the data file. For an exact synchronizing of start and stop of the scalers with the acquisition it is recommended to enable **Count gated with GO** and **Remove GO when Preset reached**. Furthermore, the three checkboxes concerning the GO-line in the system definition dialog should be crossed, see chapter 5.1.9.
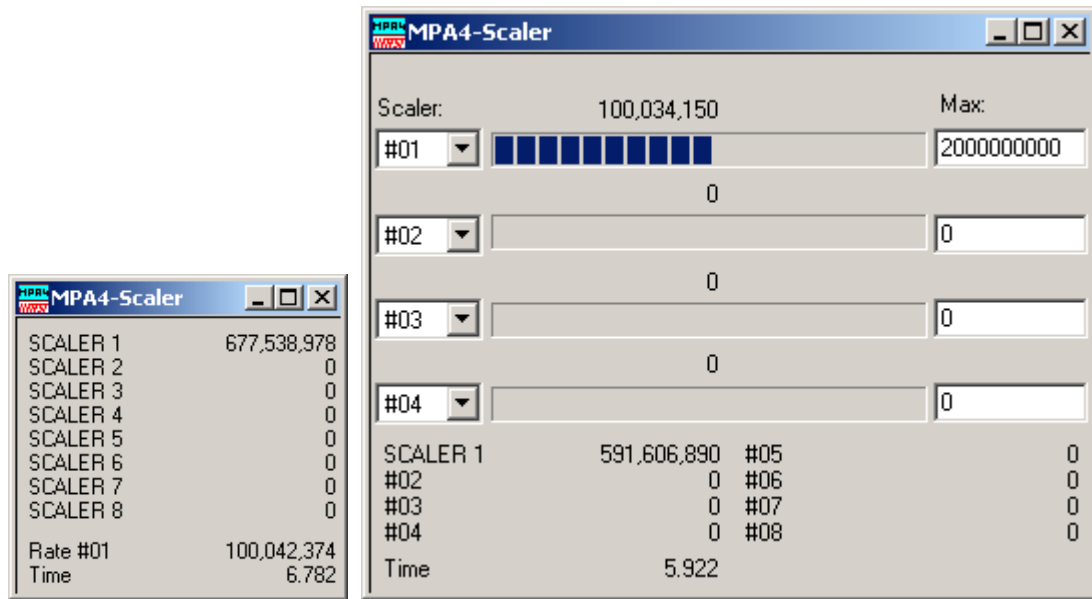
Fig. 5.14: Left: MPA4-Scaler Status utility, right: as ratemeter

5.1.9. System definition dialog

The „System..." item in the settings menu opens the System Definition dialog box. The use of the Digital Input / Output and the GO-Line can be defined: It can be used either to show the status of the MCA if the checkbox **Status Dig 0** (0..3 for more modules) is marked. At the respective pins +5 Volt are output if an acquisition is running and 0 V if not. The polarity can be inverted by checking **Invert**. Alternatively, it can be used for example with a sample changer by checking **"Value inc. at Stop"**. Here, the 8-bit value entered in the edit field (a number between 0 and 255) is output at the Dig I/O port. This value will always be incremented by 1 if the MCS6 is stopped. The **Invert** checkbox allows inverting the logical level. See also the commands **pulse** and **waitpin** how to handshake a sample changer. The output mode of the Dig I/O ports is Open Drain.

It is also possible to use the digital input 4 as an external trigger for starting the system (**DESY control line**). If the corresponding checkbox is marked, a start command for the respective system will not immediately start the system. After the start command, the digital input will be permanently checked for its logical level. If the level changes from high to low, the data for the system is cleared and it will then be started. It will stop if the level returns to high (or vice versa if **Invert** is marked) and can again be restarted with the next level change. A stop command for the system will finish the digital input checking. By checking **Clear before Start** the spectra is cleared before the start. As an alternative to controlling Start/stop via digital input 4 also the GO-line can be used by checking **GO High** in the "Start with" box.

The Use of the GO-Line is controlled via the 3 checkboxes **Watch**, **High when ON**, and **Low at Stop**. The GO line gates directly the hardware. "Low at Stop" means that the GO line is immediately pulled down by the hardware when a sweep preset is reached, or as fast as possible by the software at any other stop.
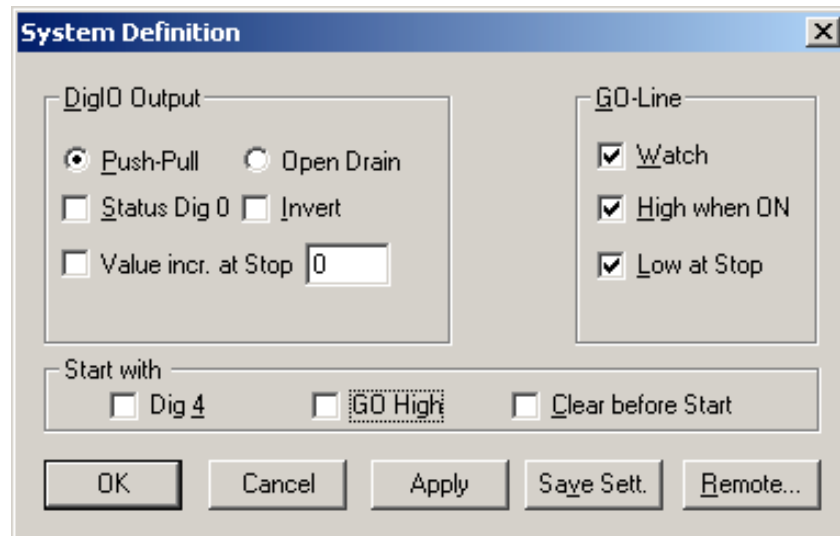
Fig. 5.15: System Definition dialog box

If more than one MPA4T modules are used, the system definition dialog box comes up as shown in Fig. 5.16. Here the several units can be combined into a single system or different systems that can be started, stopped and erased by one command. A checkbox "**Any Preset stops all**" allows to automatically stop all modules combined in a system when in any individual MPA4T a preset is reached.
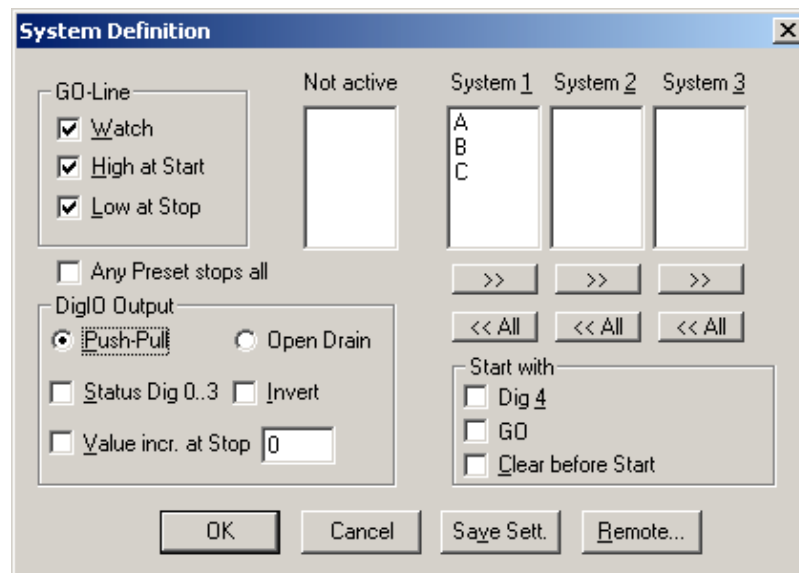
Fig. 5.16: System Definition dialog box, three MPA4T modules

In the shown setting a single system is formed. The modules A, B and C are combined. System 1 can be started, stopped, erased, and continued with the respective commands in the Action 1 menu. It is also possible for example to form two independent systems 1 and 2: Click on the button labeled **<<All** below the list box „System1" to remove all units from system 1. They are then shown in the „Not active" list box. Then select unit A and click on the button labeled **>>**

below the „System 1" list box to include it into system 1 and perform the respective action for unit B and System 2.

OK accepts all settings. **Cancel** rejects all changes. Pressing „**Save Settings**" stores all settings in the file **MPA4A.SET** using the control language (see the following section). This file is loaded at program start automatically and the parameters set.
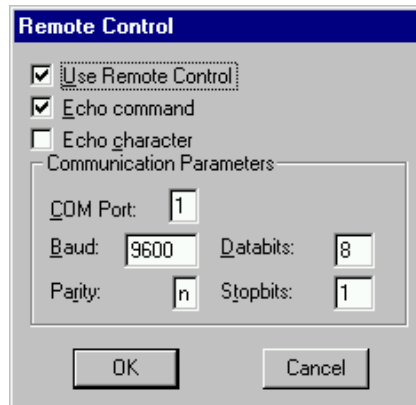
Fig. 5.17: Remote control dialog

The **Remote...** button opens the Remote control dialog box. Here all settings can be made for the control of the MCS6 server program via a serial port. If the Checkbox **Use Remote Control** is marked and the MPA3COM.DLL is available (i.e. you have bought the optional **MPANT external Control software**), the specified COM port will be used for accepting commands (see Control language). If **Echo command** is marked, the input line will be echoed after the newline character was sent. **Echo character**, on the other hand, immediately echoes each character.

5.1.10. Dual-parameter and Calculated spectra dialog

The data from the 6 input channels are buffered individually with own FIFO's and fed independently into the data stream (see chapter 4.3), so it is necessary to have the sweep counter in the data when considering concidences between events recorded from separate start/stop input channels. The MPA4T software allows to create dual-parameter and calculated spectra from coincident events arising from different channels. When using such coincident spectra, automatically the checkbox "Sweepcounter in data not needed" in the settings is cleared and a 16 bit wide sweep counter is then available in the data. This way it is possible to use the TDC input channels like TAC's (Time to Amplitude Converters) with a multiparameter system and create coincident spectra belonging to events triggered together. The range of the time spectra is limited to 65536 time bins for this application. Only one stop event per channel is evaluated, it is the first stop event after a time threshold that can be set in the software.

By clicking "Map Spectra..." in the Settings menu or the corresponding MPANT toolbar icon the Dualparameter and Calculated Spectra dialog box of the MPA4T server is called. Here additional dual parameter and calculated spectra can be added, modified and deleted from the list.
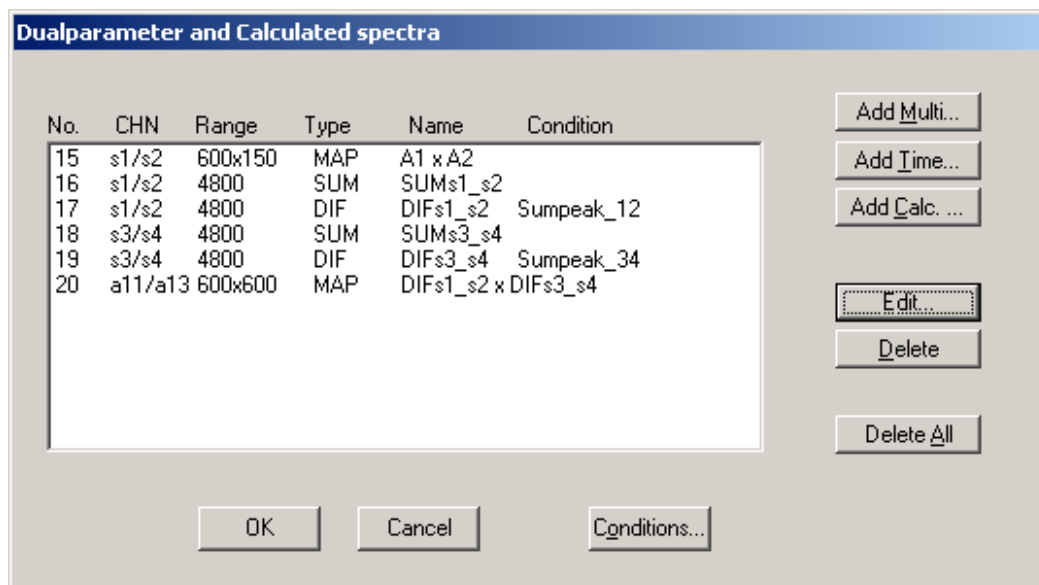
Fig. 5.18: Dualparameter and Calculated spectra dialog box

Press **Add Multi** to define a new multi parameter spectra in the **Multi Display Settings** dialog. In this dialog there is a choice between **ADCs** or **Start/Stop Inputs** or **Mixed TDC/ADC** as coincident parameters. ADC's must be used in coincidence mode when using dualparameter spectra between two ADCs. For Start/Stop signals only the first event in a sweep after a specified time offset (threshold) can be used for correlation with the respective signal from another start/stop input channel like a TAC (time-to-amplitude converter). Mixed TDC / ADC spectra can be defined with a Start/Stop input as parameter for the x-axis and an ADC as a parameter for the y-axis. The ADC can be used in single or coincidence mode. If it is defined as single as well as coincidence, the single ADC data are used. For the correlation of mixed TDC/ADC data the first respective event with the same sweep number is used.
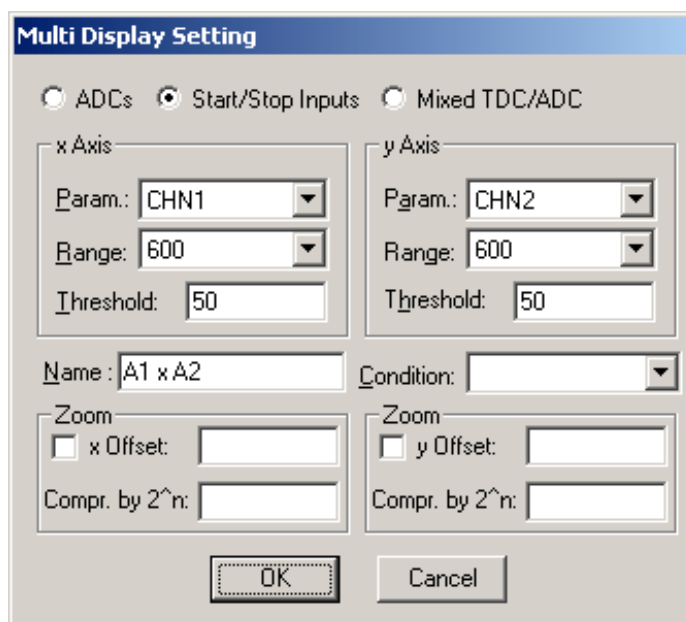
Fig. 5.19: Multi Display Setting

For the x Axis and y Axis a **Parameter** and **Range** must be chosen from the respective drop down list. A time **Threshold** in units of time bins can be entered for start/stop input channels. You can edit a **Name** of the new multi spectra, or you can left the 'Name' edit field untouched to choose an automatically generated name like A1 x A2. If Conditions are defined, one can be selected as a necessary **Condition** for incrementing a channel in this dual-parameter spectra. For **zoomed Maps** check the **x Offset** and **y Offset** checkbox and enter a value for the respective Offsets and Compression. The Offset point marks the lower left corner of the zoomed map, and the **Compr. by 2^n** means the power of two by which the spectra are compressed. A value of zero means full resolution.

Press **Add Time** to define a new Time spectra in the **Multi Time Display Settings** dialog.

Fig. 5.20: Multi Time Display Setting

For the x Axis and y Axis a parameter and range must be chosen from the respective drop down list. The time axis can be either the x Axis or the y Axis, select the respective radio button. The time parameter can be either the 1 msec Real time from the standard real / live timer or the 6.4 nsec RTC clock when the respective option is available. Define the **Time Offset** and **Time Bin size** in the corresponding edit fields and **Unit** selection boxes. A **Name** can be entered for the new time spectra, or you can left the 'Name' edit field untouched to choose an automatically generated name like RTC x a_1. The checkbox **Time Differences** enables using an absolute time for each event while recording time spectra relative to an event in any selected ADC. If Conditions are defined, one can be selected as a necessary **Condition** for incrementing a channel in this spectra. For **zoomed Maps** check the **x Offset** or **y Offset** checkbox and enter a value for the respective Offsets and Compression. The Offset point marks the lower left corner of the zoomed map, and the **Compr. by 2^n** means the power of two by which the spectra are compressed. A value of zero means full resolution. For a one-dimensional time spectrum just use 1 for the ADC range.

Press **Add Calc** from the Map and Calculated Spectra dialog to define a new calculated single spectrum in the **Calculated Spectrum Setting** dialog.

Fig. 5.21: Calculated Spectrum Setting, left: for TDC inputs, right: ADCs

You have a choice between several formulas to combine two parameters: **Sum** = left + right makes a sum spectrum, and **Diff** = Range + left - right can be used to subtract two spectra. The **Range** and **Name** can be defined in the edit fields or default values will be taken. Any such calculated spectrum can be used as a parameter for a new dual parameter spectrum. If Conditions are defined, one can be selected as a necessary **Condition** for incrementing a channel in this spectra. The **COPY** type of spectra allows to set conditions for copies of primary spectra. Of course this "copy" can be quite different from the primary spectra, as only the first stop event after the time threshold is selected. For ADC inputs in addition the **Pos** = Range * right / (left + right) formula is available, that is often used for position dependent detectors read out from both sides, and the Division formula **Div** = Range * left / right can be used to divide two spectra. The **Range** and **Name** can be defined in the edit fields or default values will be taken. Any such calculated spectrum can be used as a parameter for a multi parameter spectrum. If Conditions are defined, one can be selected as a necessary **Condition** for incrementing a channel in this spectra. The **COPY** type of spectra allows to set conditions for copies of primary ADC spectra. **HISTORY** allows to display a history plot of an ADC as a new spectra, i.e. you can see the data of the ADC as they come in versus the event number. The length of the history plot can be defined free, just edit the Range number.

Spectra containing the sum of counts from several ADC's can be used to create a "superdetector" from multiple smaller detectors. It doesn't matter if the ADC's are used in single or coincidence mode, the sum spectra is calculated from the complete single spectra. Select the "**Or = Sum of counts**" radio button.
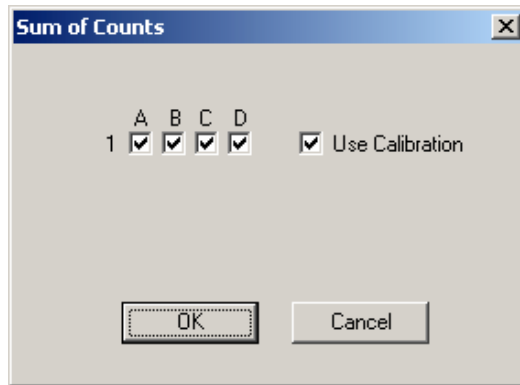
Fig. 5.22: Sum of Counts Dialog

In the "Sum of counts" dialog you can select which ADCs will contribute to the superdetector. It is recommended to enable "Use Calibration" and to perform a careful calibration of all selected ADC's:

Make a short acquisition using a pulser or a calibration source so you get a peak in each used ADC. In each ADC zoom into the spectra, then by keeping the right mouse button pressed drag from left to right over the peak to mark a fit region and click on the "Fit" toolbar icon to make a Gaussian peak fit. Note the position value of the peak in the first ADC. For the first ADC you can just enable "Use Calibration" in the calibration dialog and use the standard parameters p0=0, p1=1. In the next ADC enter two calibration points: for the first point enter 0 for the Channel and 0 for the value and click "Add>>". For the second calibration point use the result of the fit: Click "Fit" to enter the Channel value of the fitted peak position. For the "Value" enter the fit result of the peak position in the first ADC. Click "Calibrate" and enable "Use Calibration", then click "OK". Proceed this way until all used ADCs are calibrated. You will immediately get the effect: Instead of a peak multiplet you will see a single sharp peak in the sum spectra.
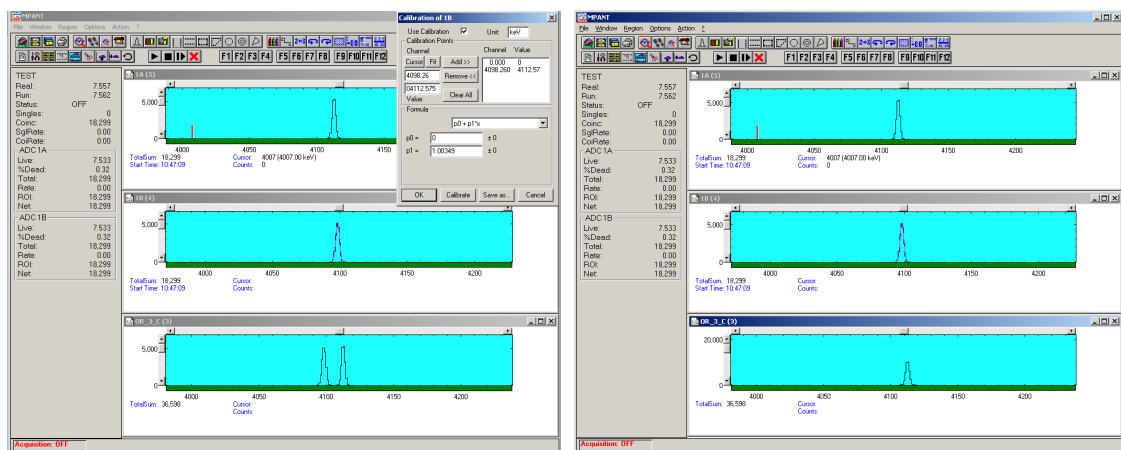
Fig. 5.23: Sum of counts spectra before and after calibration

The automatic generated spectra name is for example "OR_3_C". The 3 is here an hexadecimal bit pattern indicating that ADC1 (bit 0) and ADC2 (bit 1) contribute to the OR sum. The C at the end of the name means that "Use Calibration" is enabled.

Press **Conditions...** from the "Dualparameter and Calculated Spectra" dialog to define or edit ROI Conditions in the **Conditions** dialog.
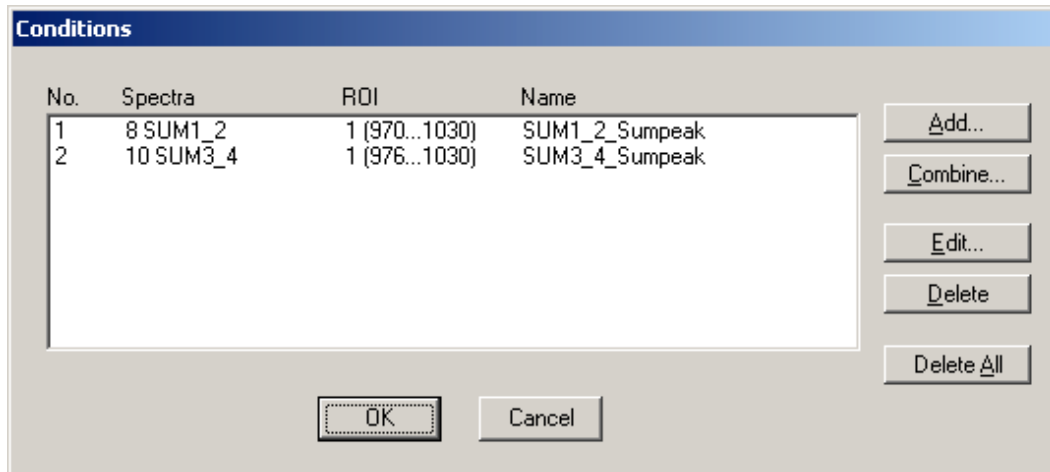
Fig. 5.24: Conditions

To define a new condition, press **Add...** to open the **ROI Condition** dialog.
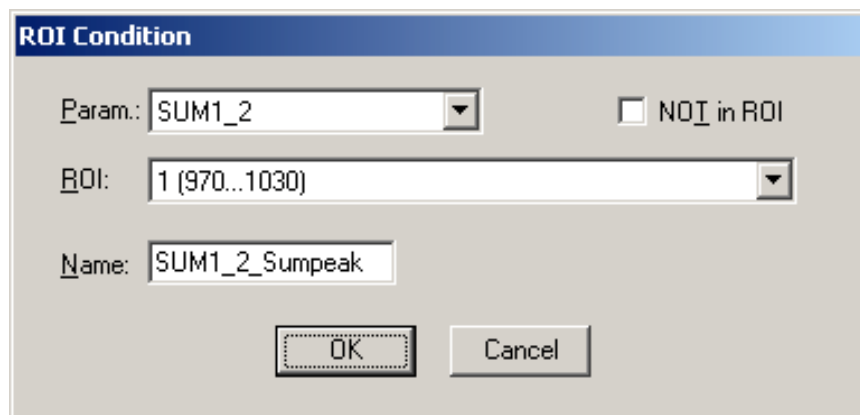
Fig. 5.25: ROI Conditions dialog

Here it is possible to define a Condition as an event inside or outside of an ROI in any parameter spectra i.e. a calculated parameter or a "copy" of a primary spectra. There are two drop-down list boxes for the **Parameter** and **ROI**. Of course the ROI must be defined before by using the MPANT program, it is not possible here to add any new ROI. A checkbox labeled **NOT in ROI** allows to define a condition as an event outside the ROI. Using the edit field **Name** it is possible to define a name for the Condition. A default name built by the parameter name and ROI number will be set automatically.

Press **Combine...** to open the **Combine Conditions** dialog.
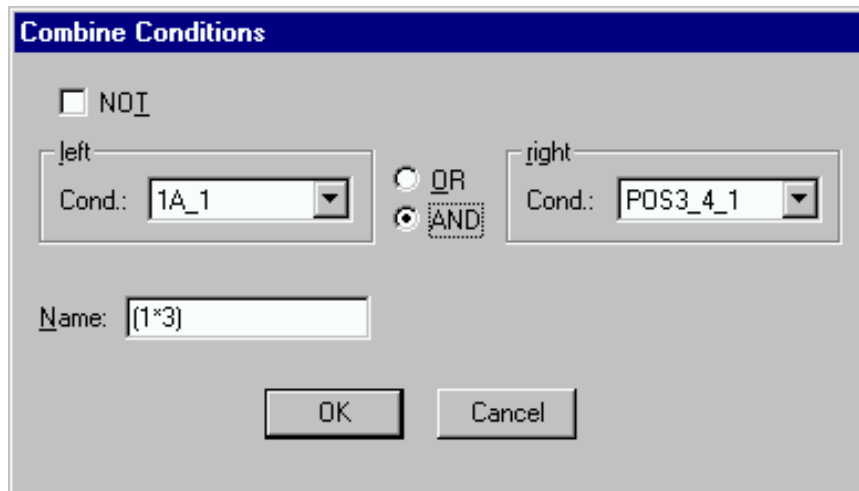
Fig. 5.26: Combine Conditions dialog

Here it is possible to define a Condition as a combination using the Boolean operators **NOT**, **OR** or **AND** of already defined conditions. The OR will be symbolized in the automatically generated name by a plus sign "+", the AND by an asterisk "*".
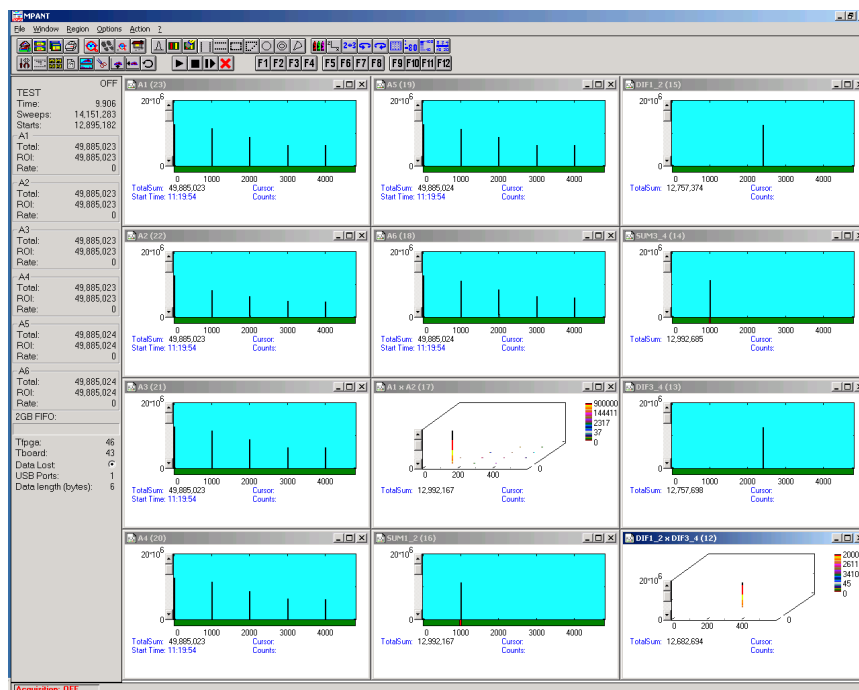
Fig. 5.27: Test acquisition with calculated spectra

Fig. 5.27 shows an acquisition with calculated spectra using the built-in test pulser. The settings could be used as an example for a two-dimensional position dependent detector.

5.1.11. Dual-parameter spectra with a scaler parameter

If the scaler option is installed, it is possible to have scaler data of scalers 1, 3 and 4 in the event stamp, see chapter 5.1.6. If such scaler data and ADCs in coincidence mode are are enabled, it is also possible to create dualparameter spectra of an ADC versus a scaler parameter. The dialog for creating dualparameter spectra contains then a button labeled "**Add Scaler...**", see Fig. 5.28.
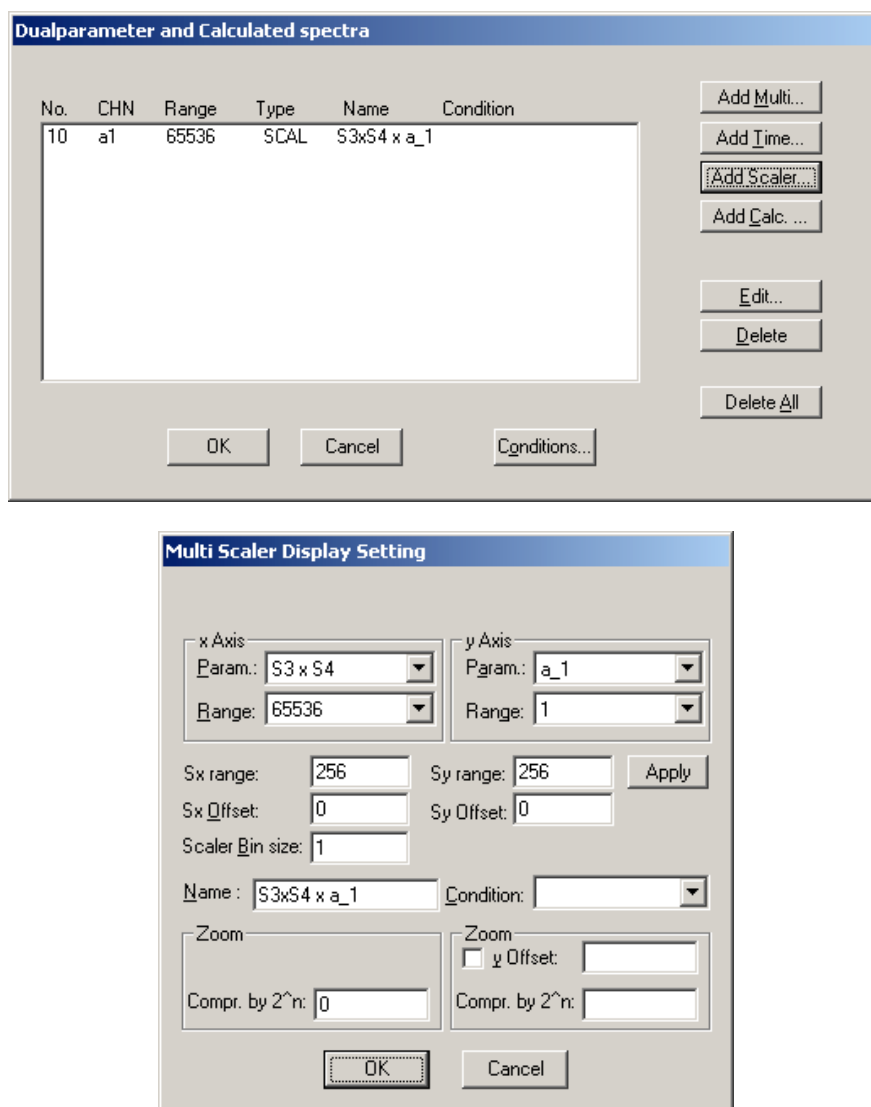
Fig. 5.28: Creating a dualparameter Scaler spectrum

There is a choice of Scalers S1, S3, S4, and S3xS4 as scaler parameters. Especially interesting is selecting S3xS4, if for these scalers the Up/Down counting option is enabled. "S3xS4" means actually that the x-parameter is calculated as S3 + S4 * Sx-range. S3 and S4 could be connected to counters that are incremented or decremented if the x- or y-coordinate of a beam position on a target is moved. So it is then possible together with setting conditions on peaks in the ADC spectrum to create images of element distributions on a target, using **PIXE** or similar methods. In the dialog the image dimensions can be chosen as **Sx range** and **Sy range**. Press **Apply** to make changes actual. The default beam position can be defined with **Sx Offset** and **Sy Offset**.

5.1.12. Getting 50 psec resolution

A resolution of 50 psec by interleaved using two input channels each for start and stop is implemented in the software. Set **endless**, **time differences with ref Ch6** in the settings. In the spectra dialog   you will find a new button "**Interleaved**". Here you can define two calculated spectra. Use Ch6 (START) and CH1 for the start using the same signal using a power splitter. Suited power splitters can be ordered as an option, see in the appendix 8.6. The signal of CH1 should be delayed by 50 ps (or 150 ps, 250 ps..) versus CH6. It can be tuned by small changes of the CH1 threshold voltage. The same way use CH2 and CH3 for the stop signal using another power splitter, and a second spectra can be defined for CH4 and CH5 with a second stop signal. The calculated spectra is the sum of the respective time channels belonging to the same event, resulting in a 50 psec resolution. The Odd and Even Sums in the shown spectra view are displayed to help minimizing the odd/even effect arising if the delay between the signals is not exactly 50 ps, by tuning one of the threshold voltages. The maximum allowed time distance between edges of the input signals for recognizing signals belonging to the same event can be set in the dialog seperately for CH6-CH1 (Start), CH2-CH3 and CH4-CH5.
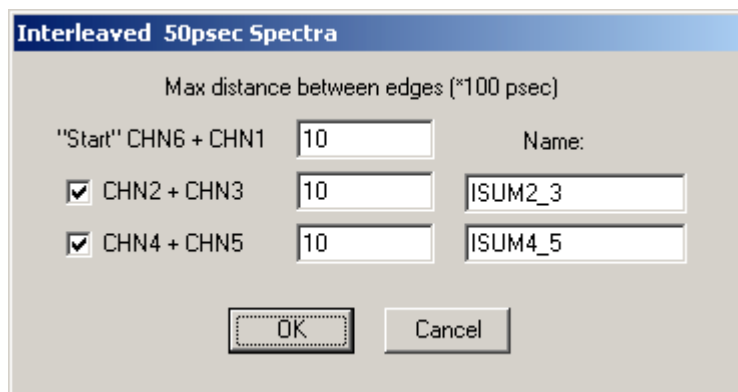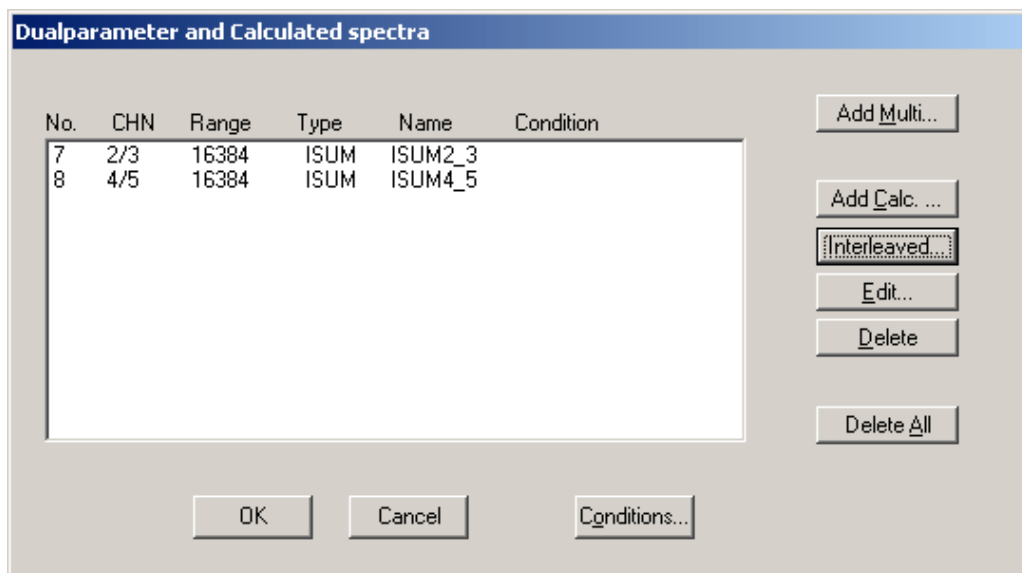
Fig. 5.29: Defining two Spectra with Interleaved 50 psec time resolution

Fig. 5.30 shows how to adjust the thresholds using a 100 kHz pulser. Define ROIs around the peak in each channel, then adjust first the Ch1 threshold so that the centroid is 0.50 time bins away from the centroid in Ch6, then adjust the Ch3 threshold so that the centroid is 0.50 bins later than the centroid in Ch2, and then the same for Ch5 versus Ch4. Note that the splitter reduces the voltage to the half value.

Fig. 5.30: How to adjust thresholds for Interleaved 50 psec time resolution

5.1.13. File formats

The **.mpa** format is used to save all spectra in a single file. It starts with an ASCII header containing the settings and then the spectra follow one after the other, each proceeded with a header line like

[TDAT0,4096]

(This means the first single spectra with a length of 4096 channels.)

[TDAT1,4096]

(This means the second single spectra...)

[CDAT0,16384]

(This is the first dual parameter or calculated spectra with a length of 16384 channels. The enumeration starts again at zero after all "physical" spectra.)

The format of the data itself can be ASCII, binary, or CSV (see below). Individual spectra can also be saved into single files. If "separate header" is checked in the data operations dialog, such spectra data is written into two separate files, one with extension **.mp** containing configuration data and one containing pure spectra data with an extension indicating the chosen format. The **.mp** file contains the settings in ASCII format using the control language described in section 5.2.

Spectra data files with extension **.asc** contain in each line one decimal number in ASCII containing the corresponding count value in the histogram.

Binary data files with extension **.dat** are written with 4 bytes per data value, as usual in the Intel world in reverse order i.e. the least significant byte comes first.

Another ASCII file format is the x y format with extension **.csv**. It can be read for example with Excel and contains the channel number and content as two decimal numbers in ASCII per line separated by a TAB character.

List files have the extension **.lst** and start with a header containing the usual report and configuration data in ASCII as in the .mpa or .mp files. The header ends with a line containing [DATA]. Immediately before the [DATA] label there is a line time_patch= and some comment lines that describe the data length and the meaning of the data bits. An example is:

```
time_patch=5
;datalength=4 bytes
;bit0..2: channel# (1..6)
;bit3:    up/dn
;bit24..31: sweeps (8 bit)
[DATA]
0100000e
0100044a
01003e8e
01003dd9
..
```

Then follows the data, depending on the format chosen for the data file either in ASCII or binary. In ASCII format one data word is written in hex format per line. In binary format each stop event is written with 2, 4, 6 or 8 bytes as specified in the comment lines. As usual in the Intel world in the reverse order, i.e. the least significant byte comes first.

The following table shows the possible data formats for TDC list data characterized by the time_patch parameter, together with the maximum possible sweep length. Bit 0..3 contain for all data formats the channel number 1..6, where 6 means the start channel. Bit 3 is the edge information, 1 means falling edge. In some combinations a "Data lost" bit provides information if the fast FIFO was full.

Time_patch value (hex)	Data length	Data lost bit	Tag bits	Sweep counter	Time bits	Max. sweep length
0	2 bytes	-	-	-	12	0.4096 µs
5	4 bytes	-	-	8 (Bit[24:31] = Sweeps[0:7])	20	0.105 ms
1	4 bytes	-	-	-	28	0.027 s
1a	6 bytes	-	-	16 (Bit[32:47] = Sweeps[0:15])	28	0.027 s
2a	6 bytes	-	8 (Bit[40:47] = Tag[0:7]	8 (Bit[32:39] = Sweeps[0:7])	28	0.027 s
22	6 bytes	-	8 (Bit[40:47] = Tag[0:7]	-	36	6.872 s
32	6 bytes	1 (Bit[47])	-	7 (Bit[40:46] = Sweeps[0:6])	36	6.872 s
2	6 bytes	-	-	-	44	1759.2 s = 0.49 h
5b	8 byte	1 (Bit[63])	15 (Bit[48:62] = Tag[0:14])	16 (Bit[32:47] = Sweeps[0:15])	28	0.027 s
Db	8 byte	-	16 (Bit[48:63] = Tag[0:15])	16 (Bit[32:47] = Sweeps[0:15])	28	0.027 s
f3	8 byte	1 (Bit[47])	16 (Bit[48:63] = Tag[0:15])	7 (Bit[40:46] = Sweeps[0:6])	36	6.872 s
43	8 byte	1 (Bit[63])	15 (Bit[48:62] = Tag[0:14])	-	44	1759.2 s = 0.49 h
c3	8 byte	-	16 (Bit[48:63] = Tag[0:15])	-	44	1759.2 s = 0.49 h
3	8 byte	1 (Bit[63])	5 (Bit[58:62] = Tag[0:4])	-	54	500.4h = 20.85 d

5.1.14. Optimizing the data throughput

The USB 2.0 interface limits the data throughput to about 30 Mbyte / sec when using one USB port and 35 Mb/sec for two ports. On a 64 bit Windows 7 or 8 these limits are enhanced to about 35 Mb/sec or 40 Mb/sec, respectively. The somewhat disappointing enhancement when using two ports can be understood as the USB ports are connected inside the PC to the same USB hub. These are optimal values for on-board USB ports and are limited by the PC architecture. External USB ports on plug-in cards are usually much worse.

The table above shows how to get a higher data throughput by choosing a smaller data size. The data size is shown in the left status window of the MPANT program and in the "Test, Inspect" dialog. It is mainly influenced by the sweep length and by options in the Settings dialog like "Sweepcounter in data not needed" and "Require Data Lost Bit". For example the smallest possible data size of 2 byte can be get on a MPA4T with 100 ps resolution with a sweep length of 4032 time bins $(2^{12} - 64)$. The maximum possible total countrate for an acquisition that is longer than what can be buffered in the large FIFO (i.e. longer than about a minute) is then 20 MHz (64 bit Win7, 2 USB ports). For bursts longer than 6.5 µsec the rate is limited by the decoding machine to 100 MHz, see section 4.4. Shorter bursts with up to 10 GHz edge events are recorded without loss.

When list file writing is enabled, the throughput is also limited by the speed of the harddisk. In this case it is recommended to write the list file on an extra harddisk that is not used by the operating system, of course a SSD disk is then very usefull.

If ADCs are enabled, only 8 byte data length or multiples of 8 byte for coincidence data are possible. In the table for TDC list data only the last 6 rows can then occur. Bit 0..2 of an 8 byte data word signals if it is TDC data, then it is the channel number 1..6, if it is a timer event, then it is zero, or ADC data, then it is seven.

A **timer event** is inserted every millisecond, if ADCs are enabled. Bit 0..3 is 1000 for a timer event. Bit 4 signals a counter preset reached, bit 5 signals armed TOF logic, bit 6 signals an active TOF sweep, bit 7 signals real time preset reached. Bits 8..15 signal if ADC1..8 are busy (corresponding bit is zero) or not. So the number of timer events with corresponding ADC busy bits of 0 gives the live time of the ADC. By comparing it with the real time, that is the number of timer events, the dead time is calculated and displayed in the software. Bits 16..31 are the lowest 16 bits of the sweep counter, bits 32..63 is the counter 1.

A 64-bit **single ADC** data word has the bit pattern 111 in the three lowest bits, the ADC number 0..7 in bits 3..5, and a zero in bit 6. Bits 6..15 are the lowest 9 bits of the sweep counter. Bits 16..31 is the 16 bit ADC data. Bits 32..63 is the time of the ADC single event in units of 6.4 ns.

Coincidence ADC data start with a 16 bit word defining the structure and length of the data belonging to a coincidence event. It has again the bit pattern 111 in bits 0..2. In bit 3 and bit 4 is marked if AUX1 and AUX2 had a signal, bit 5 is zero, bit 6 is 1 (this is the unique difference to a single ADC event), bit 7 is 0. Bits 8..15 indicate if the corresponding ADC1..8 had valid data within the coincidence time window. Then follow for each respective ADC 16 bit data words, then eventually a 32 or 48 bit time stamp for the coincidence event, 16 or 48 bit sweep counter, and scaler data of counters 1,3,4, as defined in the coincidence settings dialog. The event data is filled with dummy words to hold the boundary of multiples of 8 bytes.

The data structure is documented as a comment in each list file, an example for single ADC data in a listfile is shown here:

```
time_patch=5b
;datalength=8 bytes
; bit0..2:   0 == 1ms timer event, 7 == ADC event
; 1ms timer:  bit0..3 == 0x8
;          bit4 = count preset reached
;          bit5 = ARMED
;          bit6 = SYSON
;          bit7 = timer preset reached
;          bit8..15: 0 == ADC busy
;          bit16..31 == sweep(16 bit)
;          bit32..63 == counter_1(32 bit)
; single ADC: bit6 = 0
;          bit3..5 == ADC#
;          bit7..15 sweep(9 bits)
;          bit16..31: data
;          bit32..63: time
; coinc  ADC: bit6 = 1
;          bit3..4 == (AUX2,AUX1)
;          bit8..15: ADC#
;          following 16bit ADC data
;          then up to 3 16bit dummy words to fill up 8 bytes
[DATA]
000000000000fc28
00000e4815b90007
00000e4715a7000f
00004b5715b40007
00004b5515a5000f
0000886015b60007
0000885f15a8000f
0000c56d15b80007
0000c56c15a6000f
```

```
0001027935be0007
0001027715a9000f
00013f8415b80007
00013f8315a5000f
00017c8f15b90007
00017c8e15a6000f
0001b99d15ba0007
0001b99c15a8000f
0001f6a615b80007
0001f6a415a6000f
000233b115b90007
000233b015a6000f
000000000000fc28
```

5.2.   Control Language

A sequence of commands that are stored in a file with extension .CTL can be executed by the MPA4 server program or MPANT with the „Load " command. Also the configuration files MPA4A.SET or the header files with extension .MP contain such commands to set the parameters. Each command starts at the beginning of a new line with a typical keyword, the case is ignored. Any other characters in a line may contain a value or a comment.

Following methods are available to execute commands:

* Load the command file using the Load command in the file menu.

* Enable remote mode in the server and send commands via the serial connection. A special DLL is necessary which is part of the optional available MPANT EXTERNAL CONTROL software.

* Open a DDE connection and send the commands via DDE as described in section 5.3. The application name for opening the DDE connection with the standard MPA4T server program MPA4.EXE is **MPA4**, the topic is **MPA4-**. Implemented are the DDE Execute to perform any command, and the DDE Request with items RANGE and DATA.

* Send the commands over a TCP/IP net using a remote shell and the optional available MPANT EXTERNAL CONTROL software. It is necessary to have a TCP/IP Winsock installed and that the remote shell daemon program MPA4NET is running. See the readme file on the installation disk.

* Send the commands via the DLL interface from LabVIEW, a Visual Basic program or any other application (software including the complete source code of the DLL and examples optional available).

* From your own Windows application, register a Windows message and then send the command as can be seen in the DLL source code.

The file MPA4A.SET contains a complete list of commands for setting parameters. An example is:

range=8192	; Spectrum length
fstchan=0	; sets acquisition delay = number of first bin / 64
holdafter=0	; sets hold after sweep in units of 64 basic dwelltimes
sweepmode=ffdeb080	; (hex) sweepmode & 0xF: 0 = normal, 4=sequential
	; 1=differential (relative to first stop in sweep)
	; 5=seq.+diff (Ch1), bit0 = differential mode
	; 9=differential to stop in Ch2, bit3 = Ch2 ref (diff.mode)
	; 0xD = seq.+diff (Ch2)
	; bit 4: Softw. Start
	; bit 6: Endless
	; bit 7: Start event generation
	; bit 8: Enable Tag bits
	; bit 9: start with rising edge
	; bit 11: pulse width mode for any spectra with
	; both edges enabled
	; bit 12: abandon Sweepcounter in Data
	; bit 13: "one-hot" mode with tagbits
	; bit 14: ch6 ref (diff.mode)
	; bit 15: enable ch6 input
	; bit 16..bit 20 ~(input channel enable)
swpreset=1000	; Sweep-Preset value

pr_ena=0	; Presets enabled (hex)
	; bit 0: realtime preset enabled
	; bit 2: sweep preset enabled
	; bit 3: ROI1 preset enabled
	; bit 4: Starts preset enabled
	; bit 5: ROI2 preset enabled
	; bit 6: ROI3 preset enabled
	; bit 7: ROI4 preset enabled
	; bit 8: ROI5 preset enabled
	; bit 9: ROI6 preset enabled
syncout=0	; sync out (hex): bit 0..5 NIM sync out, bit 8..13 TTL sync out
	; bit7: NIM syncout_invert, bit15: TTL syncout_invert
fdac=0	; (hex) feature dac 0..16383 --> 0..2.5V
rxdelay=0	; (hex) additional delay to all 6 TOF inputs in steps of 3.2 ns, 0..15
cycles=1	; cycles for sequential mode
sequences=1	; for sequential mode (default 1)
	; specifies how often to repeat
	; after performing cycles acquisitions
tagbits=8	; number of tagbits
dac0=2664	; (hex) dac0 value (START)
	; bit 16: Start with rising edge
	; (bit 14,15) : 0=falling, 1=rising, 2=both, 3=both+CFT
dac1=2664	; (hex) dac1 value (STOP1)
	; (bit 14,15) : 0=falling, 1=rising, 2=both, 3=both+CFT
dac2=2664	; (hex) dac2 value (STOP2)
dac3=2664	; ..
dac4=2664	
dac5=2664	;..(STOP5)
bitshift=0	, Binwidth (0: 1, 1:2, 2:4, 3:8,...)
timepreset=50	; Timepreset (seconds)
digio=0	; Use of Digital I/O (hex):
	; bit 0: DIG I/O bit 7 output status
	; bit 1: Output digval and increment digval after stop
	; bit 2: Invert Polarity
	; bit 4: Input pin 4 Trigger System 1
	; bit 8: GOWATCH
	; bit 9: GO High at Start
	; bit 10: GO Low at Stop
	; bit 11: Clear before external triggered start
	; bit 12: Only triggered start
digval=0	; 0..255 DIG I/O Output value
sen=0	; Start coincidence window enable word (hex).
	; Bit 0 means Start enable for ADC1, Bit 1 for ADC2...
coi=0	; Coincidence enable word (hex).
	; Bit 0 means Coinc. Enable for ADC1...
sct=3	; Single Control regster.
	; 1 in Bit 0 Enable 32 bit TOF time storage with each single event
	; 1 in Bit 1 Enable 9 bit Sweep counter storage with each single event

ctm2=200	; Coincidence time in units of 20 nsec. ; A value of 200 means 4 mikrosec
dtm2=400	; Data Ready timeout in units of 20 nsec.
aux1=0	; Aux1 Control ; Bit 0: AUX1 polarity, 1=active high ; Bit 1: AUX1 enable to start a coincidence window ; Bit 2: AUX1 coinc. mode like a Dead time signal ; Bit 3: AUX1 output enable ; Bit 4..7: AUX1 output: ; 0 = coinc_start ; 1 = coinc_runs ; 2 = coinc_ok ; 3 = coinc_not_ok ; 4 = system_on ; 5 = sweep_start ; 6 = dead_1 ; 7 = dead_2 ; 8 = dead_3 ; 9 = dead_4 ; A = dead_5 ; B = dead_6 ; C = dead_7 ; D = dead_8
aux2=0	; Aux2 Control, see AUX1..
rej=0	; REJ control ; Bit 0: REJ polarity, 1=active high ; Bit 1: REJ enable like a Dead time signal ; (ORed with AUX2 coinc mode) ; Bit 2: REJ mode 0=instant, 1=at end of coinc.time
stamp=0	; timer / sweepcnt / scaler stamp in coincidence data set ; bit 0: TIM_0 lowest 16 bit of timer ; bit 1: TIM_1 bits 16-31, high word of timer ; bit 2: TIM_2 bits 32-47 ; bit 3: SWP_0 16 bit sweep counter in data stream ; bit 4: SWP_1 32 bit ; bit 5: CNT_1 32 bit scalers in data stream ; bit 6: CNT_2 32 bit ; bit 7: CNT_3 32 bit
gate=0	; bit0..7: individual gate enable, bit 8..15 polarity, 1 = ANTICOINC
commongate=0	; bit0..7: common gate enable, bit 8 polarity, 1 = ANTICOINC
aux1sys=0	; System definition words for AUX1 ; active & 0xFF ==0 not used ; ==2 coinc with any ; bit 4..7 in group 1..4
aux2sys=0	; System definition words for AUX2
rtpreset=20.000	; realtime preset in seconds, using 1 ms timer
autoinc=0	; 1=Enable Auto increment of filename
savedata=0	; 1=Save at Halt
mpafmt=dat	; data format used in MPA files ; (dat=binary, asc=ASCII, csv=CSV, spe=GANAAS, emsa=EMSA)

sephead=0	; 1=Seperated Header file (extension MP) and ; Data file (extension dat, asc or spe) for separated spectra
fmt=dat	; data format used in separated spectra (extension MP) ; (dat=binary, asc=ASCII, csv=CSV, spe=GANAAS, emsa=EMSA)
mpacaluse=0	; 1 if calibration should be used for shifted summing data from a file
smoothpts=5	; Number of points to average for a smooth operation
wndwidth=237	; Sets width of server window
wndheight=263	; Sets height of server window
sysdef=0	; Defines which module belongs to a system, relevant only for more ; modules
[CHN1]	; The following section concerns parameters of CHN1 (= STOP1)
range=8192	; Spectrum length
active=1	; System definition word for ADCs and spectra (hex): ; active & 0xFF ==0 not used ; ==1 single, System 1
cftfak=12c0100	; CFT parameter in hex: ; Low Word: 256 * time_after_peak / time_to_peak ; High Word: Max. Width
evpreset=10000	; ROI preset value
roimin=1	; Lower ROI limit
roimax=8192	; Higher ROI limit
caluse=0	; bit 0=1: Use calibration, higher bits: calibration formula
calch0=0.00	; First calibration point channel
calvl0=0.000000	; First calibration point value
calch1=100.00	; Second calibration point channel
calvl1=100.000000	; Second calibration point value
caloff=0.000000	; Calibration parameter: Offset
calfact=1.000000	; Calibration parameter: Factor
calunit=keV	; Calibration unit
[CHN2]	; The following section concerns parameters of CHN2 (= STOP2)
...	
[ADC1]	; The following section concerns parameters of ADC1
range=8192	; Spectrum length
active=1	; Definition word for ADCs ; active & 0xFF ==0 not used ; ==1 single ; ==2 coinc with any ; bit 4..7 in group 1..4 ; Definition words for calculated spectra: ; active & 0xF ==3 MAP, ((x-xoffs)>>xsh) x ((y-yoffs)>>ysh) ; ==0xB TIM, MAP with RTC or RT as x or y ; ((x-xoffs)>>xsh) x ((y-timeoffs)>>timesh) ; or((x-timeoffs)>>timesh x ((y-yoffs)>>ysh) ; bit4==1: x zoomed MAP

; bit5==1; y zoomed MAP
; ==4 POS, (y<<xsh) /(x + y)
; ==5 SUM, (x + y)
; ==6 DIV, (x<<xsh) / y
; ==7 ANY, (for compare)
; ==8 COPY, x
; ==9 DLL, fDLL(x,y,z)
; ==0xA HISTORY, x
; ==0xC DIFF, (x+range-1-y)>>xsh
;   bit 8..11 xsh, bit 12..15 ysh or bit 8..15 xsh
; ==0xF OR, Sum of counts;
;   LOWORD(param) is the mask for spectra to sum up,
;   param & 0x80000 use calibration
; HIWORD(active) = 1+condition no. (0=no condition)

prena=0	; bit0=1: Livetime preset enabled
	; bit1=1: ROI preset enabled
ltpreset=1000.000	; Livetime preset value
roipreset=10000	; ROI preset value
roimin=0	; Lower ROI limit
roimax=8192	; Higher ROI limit
[ADC2]	; The following section concerns parameters of ADC2

The following commands perform actions and therefore usually are not included in the MPA4A.SET file:

start	; Clears the data and starts a new acquisition of system 1.
	; Further execution of the .CTL file is suspended until any
	; acquisition stops due to a preset.
halt	; Stops acquisition of system 1 if one is running.
cont	; Continues acquisition of system 1. If a time preset
	; is already reached, the time preset is prolongated
	; by the value which was valid when the „start„ command
	; was executed. Further execution of the .CTL file
	; is suspended (see start).
erase	; Clears all spectra of system 1.
savecnf	; Writes the settings into MCS6A.SET
savempa	; Saves all configuration and spectra data.
	; An existing file is overwritten.
pushname	; pushes the actual mpa filename on an internal stack that can
	; hold 4 names.
popname	; pops the last mpa filename from the internal stack.
loadmpa	; Loads mpa data; the filename
	; must be specified before with a command mpaname=...
addmpa	; Adds mpa data to actual spectra; the filename
	; must be specified before with a command mpaname=...
submpa	; Subtracts mpa data from actual spectra; the filename
	; must be specified before with a command mpaname=...
MC_A	; Sets actual input channel to MC_A (STOP1) for the rest of
	; the control file.

MC_B ... **MC_F**	; Sets actual multichannel analyzer to MC_B (STOP2) ; ... MC_F (ch6) for the rest of the control file.
savedat	; Saves data of actual channel as separated ; spectrum (extension .MP) An existing file ; is overwritten.
loaddat	; Loads data of actual channel, the filename ; must be specified before with a command datname=...
adddat	; Adds data into actual spectra; the filename ; must be specified before with a command datname=...
subdat	; Subtracts data from actual spectra channel; the filename ; must be specified before with a command datname=...
smooth	; Smoothes the data in actual spectra
erasedat	; Clears the data of actual spectra.
exit	; Exits the server (and MPANT) programs
alert Message	; Displays a Messagebox containing Message and an OK ; button that must be pressed before execution can continue.
waitinfo 5000 Message	; Displays a Messagebox containing Message, an OK ; and an END button. After the specified time (5000 msec) ; the Messagebox vanishes and execution continues. OK ; continues immediately, END escapes execution.
beep *	; Makes a beep. The character '*' may be replaced with '?', '!' or ; left empty. The corresponding sound is defined in the WIN.INI ; file in the [sounds] section.
delay 4000	; Waits specified time (4000 msec = 4 sec).
pulse 100	; Outputs a pulse of 100 ms duration at dig 3.
waitpin 4000	; Waits 4000 ms for going the level at dig 5 going low. ; After a timeout a Messagebox warns and waits for pressing OK ; Can be used for connecting a sample changer.
loadcnf configfile	; Loads a configuration stored in a configfile like mcs6a.set.
run controlfile	; Runs a sequence of commands stored in controlfile. This ; command cannot be nested, i.e. it is not possible to execute ; a run command from the controlfile called with a run command, ; only if it was called with a load command.
onstart command	; The command is executed always after a start action when the ; acquisition is already running. The command can be any valid ; command, also 'run controlfile' is possible.
onstart off	; Switches off the 'onstart' feature. Also a manual Stop command ; switches it off.
onstop command	; The command is executed always after a stop caused by a ; preset reached or trigger. This can be used to program measure ; cycles. For example the command 'onstop start' makes a ; loop of this kind.
onstop off	; Switches off the 'onstop' feature. Also a manual Stop command ; switches it off.
lastrun=5	; Defines the file count for the last run in a measure cycle. After a ; file with this count or greater was saved with autoinc on, instead ; of the 'onstop command' the 'onlast command' is executed.

numruns=5	; Defines the file count for the last run in a measure cycle. The ; last count is the present one plus the numruns number. After a ; file with this count was saved with autoinc on, instead of the ; 'onstop command' the 'onlast command' is executed.
onlast command	; The command is executed after a stop caused by a preset ; reached or trigger instead of the 'onstop command', when the ; last file count is reached with autoinc on. This can be used to ; finish programmed measure cycles.
onlast off	; Switches off the 'onlast' feature. Also a manual Stop command ; switches it off.
exec program	; Executes a Windows program or .PIF file. ; Example: exec notepad test.ctl ; opens the notepad editor and loads test.ctl.
fitrois	; Makes a single peak Gaussian fit for all ROIs in the active ; Display of MPANT and dumps the result into a logfile. This is ; performed by the MPANT program and therefore can be ; made only if this application is running.
fitrois MC_1	; Similar to the fitroi command, but using the argument allows to ; specify which spectrum should be evaluated independently of ; which child window is activated in MPANT. MC_1 means CHN1 ; (=STOP1)
autocal	; Makes a single peak Gaussian fit for all ROIs in the active ; Display of MPANT for which a peak value was entered in the ; MPANT Region Edit dialog and uses the results for a ; calibration. This is performed by the MPANT program and ; therefore can be made only if this application is running.
autocal MC_1	; Similar to the autocal command, but using the argument allows ; to specify which spectrum should be evaluated independently of ; which child window is activated in MPANT
deleteallrois	; deletes all ROIs in the active MPANT window.
deleteallrois MC_#	; allows to delete all ROIs of a specified spectra (1 for # means ; A1..).

The following commands make sense only when using the serial line or TCP/IP control or DLL control interface:

MC_A?	; Sends the status of A1 (STOP1) via the serial port and make ; CHN1 actual.
...	
MC_F?	; Sends the status of ch6 via the serial port and ; make it actual.
?	; Send the status of the actual ADC
sendfile filename	; Sends the ASCII file with name 'filename' via the serial line.

The execution of a control file can be finished from the Server or MPANT with any Halt command.

5.3. Controlling the MPA4 Windows Server via DDE

The MPA4 program can be a server for DDE (Dynamic Data Exchange). Many Windows software packages can use the DDE standard protocols to communicate with other Windows programs, for example GRAMS, FAMOS or LabVIEW. In the following the DDE capabilities of the P7889 program are described together with a demo VI („Virtual Instrument") for LabVIEW. It is not recommended to use the DDE protocol for LabVIEW, as also a DLL interface is available that is much faster. The following should be seen as a general description of the DDE conversation capabilities of the MPA4 program.

5.3.1. Open Conversation

application: MPA4
topic: MPA4-

Any application that wants to be a client of a DDE server, must open the conversation first by specifying an application and a topic name. The application name is MPA4 and the topic is MPA4-.
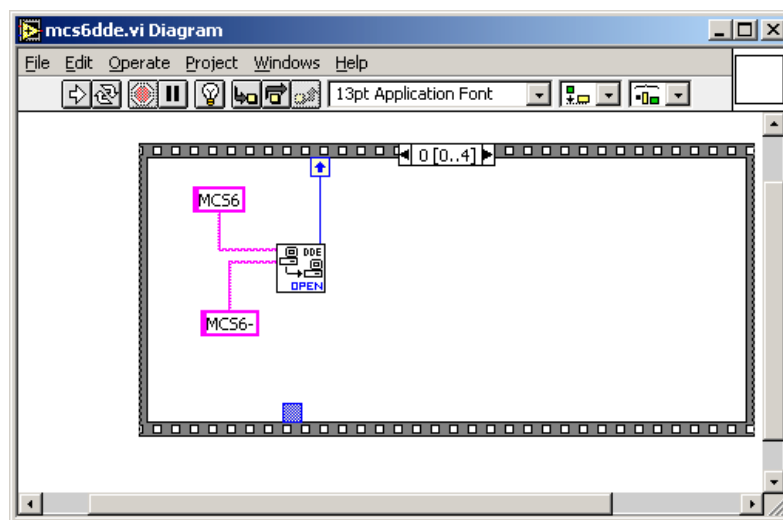
Fig. 5.31: Opening the DDE conversation with the MPA4 in LabVIEW

5.3.2. DDE Execute

The DDE Execute command can be used to perform any action of the MPA4 program. Any of the Control command lines described in section 5.2 can be used. For example a sequence of control commands saved in a file TEST.CTL can be executed by specifying the command

RUN TEST.CTL

The MPA4 program then executes the command and, after finishing, it sends an Acknowledge message to the DDE client. This can be used to synchronize the actions in both applications.
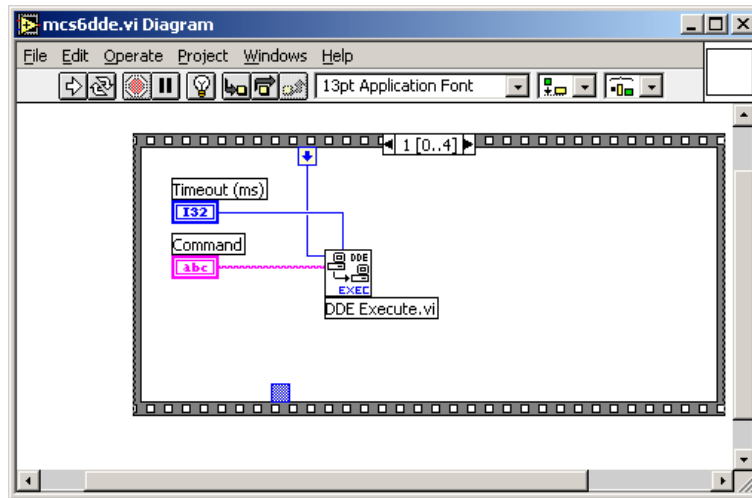
Fig. 5.32: Executing a MPA4 command from a LabVIEW application

5.3.3.   DDE Request

The DDE Request is a message exchange to obtain the value of a specified item. Only two items are defined for DDE request up to now: RANGE and DATA. The value is obtained as an ASCII string, i.e. it must be converted by the client to get the numbers. All other parameters concerning the setup can be obtained by the client application by reading and evaluating the configuration file.

RANGE

The RANGE item can be used to obtain the total number of data.
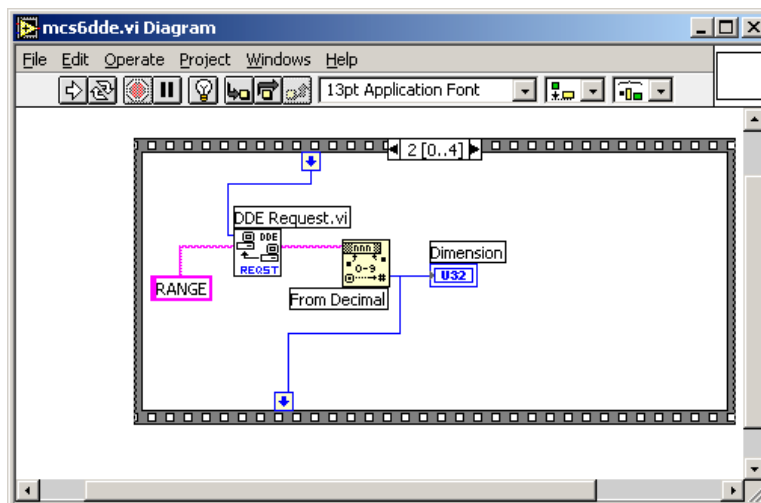
Fig. 5.33: Getting the total number of data with LabVIEW

DATA

With the DATA item the data is obtained. The value of this item is a multiline string that contains in each line a decimal number as an ASCII string.
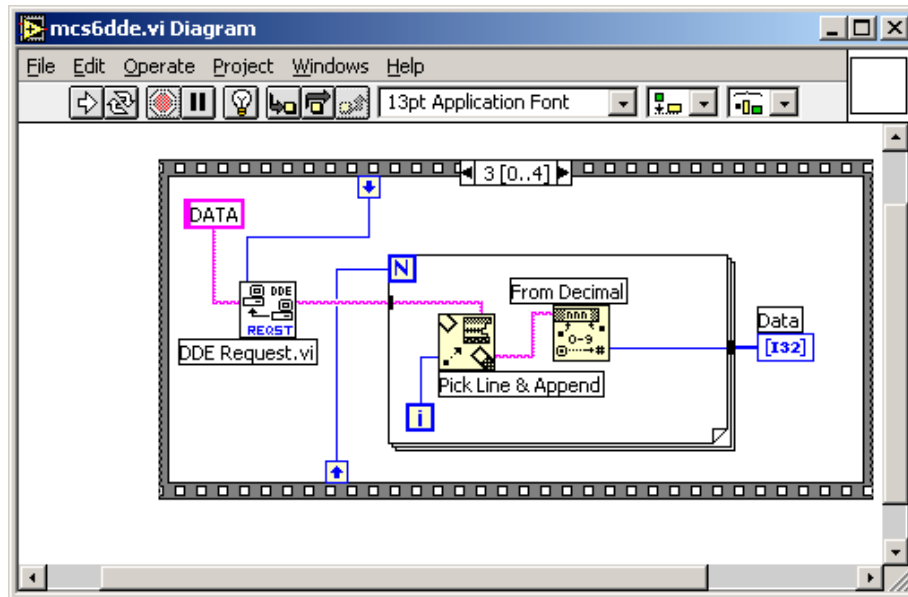
Fig. 5.34: Getting the data with LabVIEW

5.3.4. Close Conversation

After finishing the DDE communication with the server program, it must be closed.
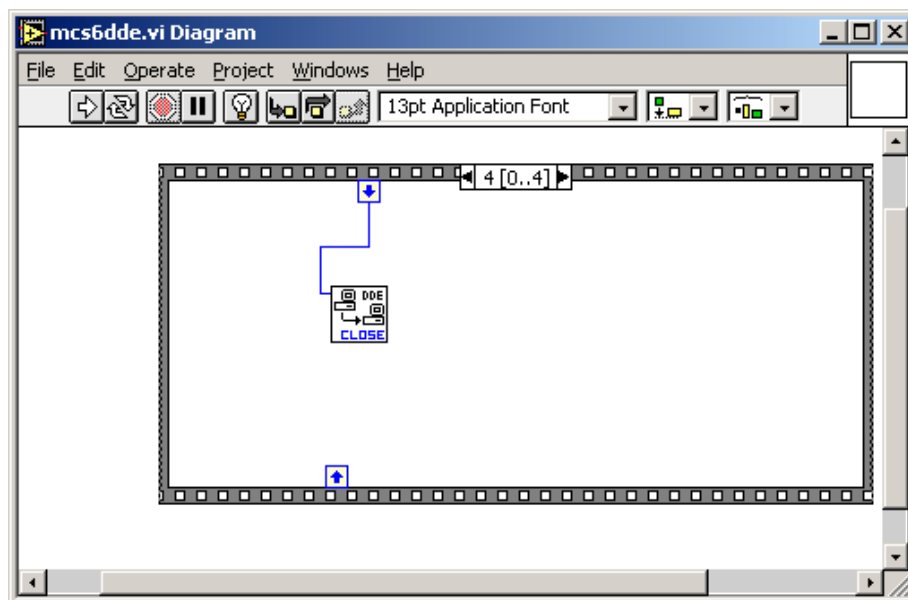
Fig. 5.35: Closing the DDE communication in LabVIEW

The following figure shows the „Panel" of the described VI for LabVIEW.
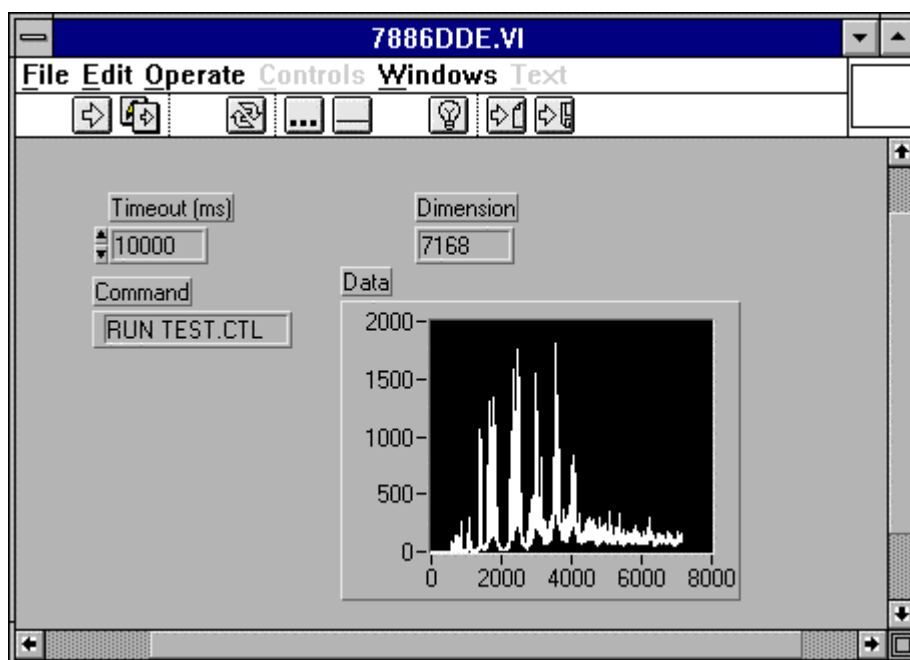
Fig. 5.36: Control Panel of the demo VI for LabVIEW

5.3.5. DDE Conversation with GRAMS/386

The following file GRAMS889.CIF can be used to get the MCS6 data into GRAMS/386 via DDE
using the „Collect" menu:

```
MPA4 DDE Test
Query
MPA4
MPA4-
DATA


save

end
spc
1 second
```

5.4. Controlling the MPA4 Windows Server via DLL

The MPA4 server program provides access to all functions, parameters and data via a DLL („dynamic link library"). So the server can be completely controlled by the MCDWIN software that provides all necessary graphic displays.

In the following some parts of the header and definition files of the DMPA4.DLL are listed, that may help an experienced programmer to use the DLL for own applications. The arguments „item, nDevice, nDisplay, nSystem" are only for compatibility with other devices controlled by the MPANT software and must be zero.

> **NOTE:**
>
> The complete documented **sourcecode of the DLL** including fundamental VI's and an example VI for **LabVIEW** and an example **Visual Basic** and **C** program is available as an **option**.

```
#define ST_RUNTIME    0
#define ST_OFLS          1
#define ST_TOTALSUM   2
#define ST_ROISUM     3
#define ST_ROIRATE    4
#define ST_SWEEPS     5
#define ST_STARTS     6

typedef struct{
  unsigned long started; // aquisition status
  unsigned long maxval;  // maxval
  double cnt[7];         // status: runtime in msec, ofls,
                                  // total sum, roi sum, roi rate,
sweeps, starts
} ACQSTATUS;


typedef struct {
  long savedata;              // bit 0: auto save after stop
                              // bit 1: write listfile
                              // bit 2: listfile only, no evaluation
  long autoinc;               // 1 if auto increment filename
  long fmt;                   // format type (seperate spectra):
                              // 0 == ASCII, 1 == binary,
                              // 2 == CSV
  long mpafmt;                // format used in mpa datafiles
  long sephead;               // seperate Header
  long smpts;
  long caluse;
  char filename[256];
  char specfile[256];
  char command[256];
} DATSETTING;


typedef struct {
  long use;                   // 1 if Replay Mode ON
  long modified;              // Bit 0: 1 if different settings are used
  long limit;                 // 0: all,
                              // 1: limited sweep range
  long speed;                 // replay speed in units of 100 kB / sec
  double startsfrom;          // first start#
  double startsto;            // last start#
  double startspreset;        // last start - first start
  char filename[256];
} REPLAYSETTING;
```

```
typedef struct{
  long range;            // spectrum length
  long cftfak;           // LOWORD: cft factor (256 * t_after_peak /
                         //   t_to_peak)
                         // HIWORD: Max. Width
  long roimin;           // lower ROI limit
  long roimax;           // upper limit: roimin <= channel < roimax
  long nregions;         // number of regions
  long caluse;           // bit0: 1 if calibration used,
                         // higher bits: formula
  long calpoints;        // number of calibration points
  long param;            // for MAP and SUM/DIF:
                         //   LOWORD=x, HIGHWORD=y
  long offset;           //  zoomed MAPS:
                         //    LOWORD: xoffset, HIGHWORD, yoffset
  long xdim;             //  x resolution of maps
  long bitshift;         // LOWORD: Binwidth = 2 ^ (bitshift)
                         // HIWORD: Time threshold for Coinc.
  long active;        // Spectrum definition words for CHN1..6:
                         // active & 0xF  ==0 not used
                         //               ==1 enable
                         // bit 8: enable Tag bits
                         // bit 9: start with rising edge
                         // bit 10: time under threshold for pulse width
                         // bit 11: pulse width mode for any spectra with
                         //             both edges enabled
                    // Spectrum definition words for calc. spectra:
                         // active & 0xF  ==3 Dualparameter MAP,
                         //      ((x-xoffs)>>xsh) x ((y-yoffs)>>ysh)
                         //          bit4=1: x zoomed MAP
                         //          bit5=1: y zoomed MAP
                         //             ==5 SUM, (x + y)>>xsh
                         //             ==6 DIFF,(x - y + range)>>xsh
                         //             ==7 ANY, (for compare)
                         //             ==8 COPY, x
                  // HIWORD(active) = condition no. (0=no condition)
  double eventpreset;  // ROI preset value
  double dummy1;       // (for future use..)
  double dummy2;       //
  double dummy3;       //
} ACQSETTING;


typedef struct {
  long sweepmode;        // sweepmode & 0xF: 0 = normal,
                         // 1=differential
                         //   (relative to first stop in sweep)
                         // 4=sequential
                         // 5=seq.+diff (Ch1), bit0 = differential mode
                         // 9=differential to stop in Ch2,
                         //   bit3 = Ch2 ref (diff.mode)
                         // 0xD = seq.+diff (Ch2)
                         // bit 4: Softw. Start
                         // bit 6: Endless
                         // bit 7: Start event generation
                         // bit 8: Enable Tag bits
                         // bit 9: start with rising edge
                         // bit 10: time over threshold for pulse width
                         // bit 11: pulse width mode for any
                         //   spectra with both edges enabled
                         // bit 12: abandon Sweepcounter in Data
                         // bit 13: "one-hot" mode with tagbits
                         // bit 14: ch6 ref (diff.mode)
                         // bit 15: enable ch6 input
                         // bit 16..
                         //   bit 20 ~(input channel enable)
                         // bit 24: require data lost bit in data
```

```
                            // bit 25: don't allow 6 byte datalength
    long prena;             // bit 0: realtime preset enabled
                            // bit 2: sweep preset enabled
                            // bit 3: ROI preset enabled
                            // bit 4: Starts preset enabled
                            // bit 5: ROI2 preset enabled
                            // bit 6: ROI3 preset enabled
                            // bit 7: ROI4 preset enabled
                            // bit 8: ROI5 preset enabled
                            // bit 9: ROI6 preset enabled
    long cycles;            // for sequential mode
    long sequences;         //
    long syncout;           // LOWORD: sync out;
                            // bit 0..5 NIM syncout, bit 8..13 TTL syncout
                            // bit7: NIM syncout_invert,
                            // bit15: TTL syncout_invert
                            //   0="0", 1=10 MHz, 2=78.125 MHz, 3=100 MHz,
                            //   4=156.25 MHz, 5=200 MHz, 6=312.5 MHz,
                            //   7=Ch0, 8=Ch1, 9=Ch2, 10=Ch3,
                            //   11=Ch4, 12=Ch5, 13=GO,
                            //   14=Start_of_sweep, 15=Armed,
                            //   16=SYS_ON, 17=WINDOW, 18=HOLD_OFF,
                            //   19=EOS_DEADTIME
                            //   20=TIME[0],...,51=TIME[31],
                            //   52...63=SWEEP[0]..SWEEP[11]
    long digio;             // LOWORD: Use of Dig I/O, GO Line:
                            // bit 0: status dig 0..3
                            // bit 1: Output digval and
                            //    increment digval after stop
                            // bit 2: Invert polarity
                            // bit 4: Input pins 4 Trigger System
                            // bit 8: GOWATCH
                            // bit 9: GO High at Start
                            // bit 10: GO Low at Stop
                            // bit 11: Clear at triggered start
                            // bit 12: Only triggered start
    long digval;            // digval=0..255 value for samplechanger
    long dac0;              //  DAC0 value (START)
    long dac1;              //  DAC1 value (STOP 1)
    long dac2;              //  DAC2 value (STOP 2)
    long dac3;              //  DAC3 value (STOP 3)
    long dac4;              //  DAC4 value (STOP 4)
    long dac5;              //  DAC5 value (STOP 5)
                            // bit (14,15) of each word:
                            // 0=falling, 1=rising, 2=both, 3=both+CFT
    int fdac;               // Feature DAC 0..16383 --> 0..2.5V
    int tagbits;            // number of tagbits
    int extclk;             // use external clock
    long maxchan;           // number of input channels (=6)
    long serno;             // serial number
    long ddruse;            // bit0: DDR_USE, bit1: DDR_2GB
    long active;            // module in system
    double holdafter;       // Hold off
    double swpreset;        // sweep preset value
    double fstchan;         // acquisition delay
    double timepreset;      // time preset
} BOARDSETTING;


typedef struct{
  unsigned long HUGE *s0;          // pointer to spectrum
  unsigned long far *region;       // pointer to regions
  unsigned char far *comment0;     // pointer to strings
  double far *cnt;                 // pointer to counters
  HANDLE hs0;
  HANDLE hrg;
  HANDLE hcm;
```

```
      HANDLE hct;
} ACQDATA;


typedef struct {
  int nDevices;          // Number of channels = number of modules * 6
  int nDisplays;         // Number of histograms = nDevices
                         //     + Positions + Maps
  int nSystems;          // Number of independent systems = 1
  int bRemote;           // 1 if server controlled by MPANT
  unsigned int sys;      // System definition word:
                         // bit0=0, bit1=0: dev#0 in system 1
                         // bit0=1, bit1=0: dev#0 in system 2
                         // bit0=0, bit1=1: dev#0 in system 3
                         // bit0=1, bit1=1: dev#0 in system 4
                         // bit2..bit6:
                         // bit6=1, bit7=1: dev#3 in system 4
  int sys0[16];          // System definition words for CHN1..16:
                         // bit 0 CHN active
                         // bit 1 =1 CHN coinc, =0 single
                         // bit 2..4 CHN in system1..7
  int sys1[16];          // (reserved:) CHN in System
} ACQDEF;


/*** FUNCTION PROTOTYPES (do not change) ***/
BOOL APIENTRY DllMain(HANDLE hInst, DWORD ul_reason_being_called,
     LPVOID lpReserved);
VOID APIENTRY StoreSettingData(ACQSETTING FAR *Setting, int nDisplay);
                       // Stores Settings into the DLL
int APIENTRY GetSettingData(ACQSETTING FAR *Setting, int nDisplay);
                       // Get Settings stored in the DLL
VOID APIENTRY StoreExtSettingData(EXTACQSETTING FAR *Setting,
     int nDisplay);
                       // Stores extended Settings into the DLL
int APIENTRY GetExtSettingData(EXTACQSETTING FAR *Setting,
     int nDisplay);
                       // Get extended Settings stored in the DLL
VOID APIENTRY StoreStatusData(ACQSTATUS FAR *Status, int nDisplay);
                       // Store the Status into the DLL
int APIENTRY GetStatusData(ACQSTATUS FAR *Status, int nDisplay);
                       // Get the Status
VOID APIENTRY Start(int nSystem);          // Start
VOID APIENTRY Halt(int nSystem);           // Halt
VOID APIENTRY Continue(int nSystem);       // Continue
VOID APIENTRY NewSetting(int nDevice);
                       // Indicate new Settings to Server
UINT APIENTRY ServExec(HWND ClientWnd);
                       // Execute the Server MCS6.EXE
VOID APIENTRY StoreData(ACQDATA FAR *Data, int nDisplay);
                       // Stores Data pointers into the DLL
int APIENTRY GetData(ACQDATA FAR *Data, int nDisplay);
                       // Get Data pointers
long APIENTRY GetSpec(long i, int nDisplay);
                       // Get a spectrum value
VOID APIENTRY SaveSetting(void);           // Save Settings
int APIENTRY GetStatus(int nDevice);
                       // Request actual Status from Server
VOID APIENTRY Erase(int nSystem);          // Erase spectrum
VOID APIENTRY SaveData(int nDisplay, int all);     // Saves data
VOID APIENTRY GetBlock(long FAR *hist, int start, int end, int step,
   int nDisplay);
                       // Get a block of spectrum data
VOID APIENTRY StoreDefData(ACQDEF FAR *Def);
                       // Store System Definition into DLL
int APIENTRY GetDefData(ACQDEF FAR *Def);
                       // Get System Definition
```

```
VOID APIENTRY LoadData(int nDisplay, int all);      // Loads data
VOID APIENTRY AddData(int nDisplay, int all);       // Adds data
VOID APIENTRY SubData(int nDisplay, int all);       // Subtracts data
VOID APIENTRY Smooth(int nDisplay);        // Smooth data
VOID APIENTRY NewData(void);
                         // Indicate new ROI or string Data
VOID APIENTRY HardwareDlg(int item);
                         // Calls the Settings dialog box
VOID APIENTRY UnregisterClient(void);
                         // Clears remote mode from MPANT
VOID APIENTRY DestroyClient(void);         // Close MPANT
UINT APIENTRY ClientExec(HWND ServerWnd);
                         // Execute the Client MPANT.EXE
int APIENTRY LVGetDat(unsigned long HUGE *datp, int nDisplay);
                         // Copies the spectrum to an array
VOID APIENTRY RunCmd(int nDisplay, LPSTR Cmd);
                         // Executes command
int APIENTRY LVGetRoi(unsigned long FAR *roip, int nDisplay);
                         // Copies the ROI boundaries to an array
int APIENTRY LVGetOneRoi(int nDisplay, int roinum, long *x1, long *x2);
                         // Get one ROI boundary
int APIENTRY LVGetCnt(double far *cntp, int nDisplay);
                         // Copies Cnt numbers to an array
int APIENTRY LVGetStr(char far *strp, int nDisplay);
                         // Copies strings to an array
VOID APIENTRY StoreMCSSetting(BOARDSETTING *Defmc, int ndev);
                         // Store BOARDSETTING Definition into DLL
int APIENTRY GetMCSSetting(BOARDSETTING *Defmc, int ndev);
                         // Get BOARDSETTING Definition from DLL
VOID APIENTRY StoreDatSetting(DATSETTING *Defdat);
                         // Store Data Format Definition into DLL
int APIENTRY GetDatSetting(DATSETTING *Defdat);
                         // Get Data Format Definition from DLL
VOID APIENTRY StoreReplaySetting(REPLAYSETTING *Repldat);
                         // Store Replay Settings into DLL
int APIENTRY GetReplaySetting(REPLAYSETTING *Repldat);
                         // Get Replay Settings from DLL
int APIENTRY GetDatPtr(int nDisplay, long *xmax, long *ymax, LPSTR *pt);
                         // Get a temporary pointer to spectra data
int APIENTRY ReleaseDatPtr(void);
                         // Release temporary data pointer
long APIENTRY GetSVal(int DspID, long xval);
                         // Get special display data like
                         // projections or slices from MPANT


EXPORTS
;       Functions in lmcs6.dll
        StoreSettingData         @2
        GetSettingData           @3
        StoreStatusData          @4
        GetStatusData            @5
        Start                    @6
        Halt                     @7
        Continue                 @8
        NewSetting               @9
        ServExec                 @10
        StoreData                @11
        GetData                  @12
        GetSpec                  @13
        SaveSetting              @14
        GetStatus                @15
        Erase                    @16
        SaveData                 @17
        GetBlock                 @18
        StoreDefData             @19
        GetDefData               @20
        LoadData                 @21
```

```
NewData                      @22
HardwareDlg                  @23
UnregisterClient             @24
DestroyClient                @25
ClientExec                   @26
LVGetDat                     @27
RunCmd                       @28
AddData                      @29
LVGetRoi                     @30
LVGetCnt                     @31
LVGetOneCnt                  @32
LVGetStr                     @33
SubData                      @34
Smooth                       @35
StoreExtSettingData          @36
GetExtSettingData            @37
StoreMCSSetting              @38
GetMCSSetting                @39
StoreDatSetting              @40
GetDatSetting                @41
StoreReplaySetting           @42
GetReplaySetting             @43
GetDatPtr                    @44
ReleaseDatPtr                @45
LVGetOneRoi                  @46
GetSVal                      @47
```

6. MPANT Software

The window of the MPANT program is shown here. It enables the full control of the MPA4T via the server program to perform measurements and save data, and shows the data on-line in several windows.

The server program MPA4.EXE automatically starts MPANT. If you try to start MPANT before the server is started, a message box warns that you should start the server first.
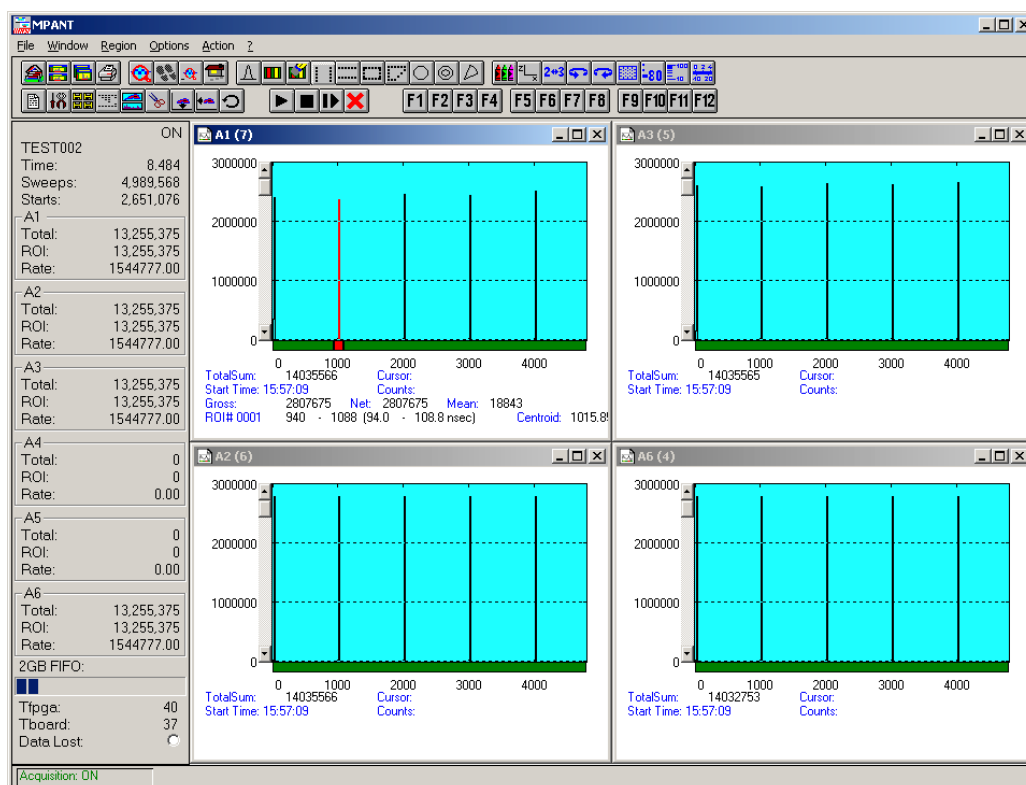
Fig. 6.1: MPANT main window

MPANT has viewing capabilities for single- and two-dimensional spectra. For ROI's the ROISum, Net sum and now also the mean counts per channel (i.e. ROISum divided by number of channels) and the centroid is displayed (<x> for single spectra, <x> and <y> for two dimensional). A single spectrum can be converted into a two-dimensional one by specifying the x dimension in the display option dialog. It is possible to drag a rectangle and zoom into this rectangle. Rectangular ROI's can be set and the ROISum and Net ROISum is displayed. The Net Sum is calculated the same way like in the single view, by subtracting a linear interpolated background from the both outmost channels in x-direction. This Net sums are then summed up in y-direction. The ROI editing dialog is changed into a Rectangular Editing dialog for MAP and ISO displays. The Cursor can be moved in x and y direction using the mouse and the arrow keys, in ISO display only using the arrow keys.

A status window at the left side gives all information about the status of the MCS6. Below the different counting rates you can see the present temperature of the board and main FPGA. It is refreshed every minute. A "Data Lost" indicator shows if the FIFO was full at any time during an acquisition, a progress bar shows how full the large FIFO presently is.
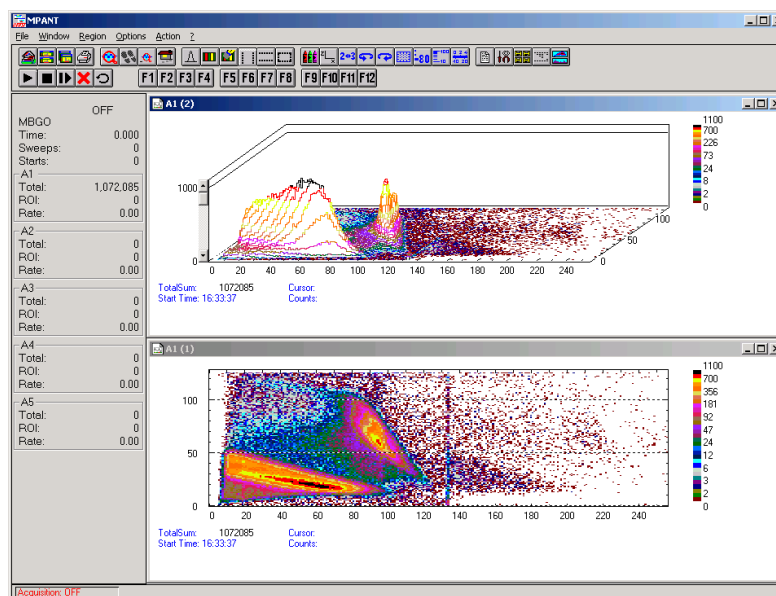
Fig. 6.2: MPANT Map and Isometric display

A toolbar provides fast access to many used functions in the menu. A status bar at the bottom gives help about the meaning of the toolbar icons. A cursor appears when clicking the left mouse button inside the graphics area. The cursor can be moved using the arrow keys. To get rid of the cursor, make a double click with the right mouse button outside the graphics area. To define a region, press the right mouse button, and while keeping the button pressed, drag a rectangle. In zoomed state a scrollbar appears that allows scrolling through the spectrum.

In the following the several menu functions are described together with the corresponding toolbar icons.

6.1. File Menu

Load..., Add..., Save Display As..., Save MPA As...

These menu items provide the usual functions for loading and saving data, either a complete data set when loading or saving a .MPA data file, or separated spectra when loading or adding a .MP data file. The 'Load' function creates then a new spectrum for compare, whereas the 'Add' functions adds the data to the spectrum selected by the active window. For saving a selected spectrum into a seperate file, click on the respective display window and select "Save Display As..." from the MPANT File menu. If you want to have the data file seperated from the header containing the configuration, first open the data operations dialog using the toolbar icon showing the 4 yellow diskettes, select ""Selected Spectra" and check "Seperate Header" as shown in chapter 5.1.3. When saving data, you have the choice between binary (.DAT), ASCII (.ASC), and CSV (.CSV) format by selecting it from "Save type As...". To read a CSV file with Excel, load it as a text file and configure TAB characters as seperators.

When you load data, select a header file (extension .MP). This file contains the information about the size and format of the data file, which is then automatically read. With „**Add**" the data is added to the present data. The data read from a file is shifted according to the calibration, if it is available and 'Use Calib' is checked in the MCS6A Data Operations dialog.

New Display...

With the Open New menu item or the corresponding icon a new Display window can be created and shown as the active window. In the „**Open New Display**" dialog box the spectra for the new display can be selected.
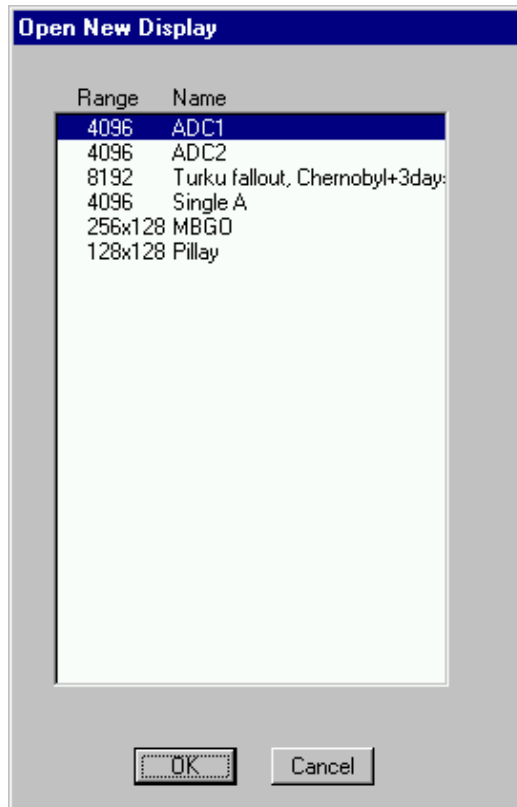
Fig. 6.3: File New Display dialog box

Open All

By selecting the Open All menu item, all available Displays are shown. The windows of the last opened Display become active.

Print...

The Print menu item opens the print dialog. It allows to arrange several pictures on a page into zones. The number of zones in vertical and horizontal direction can be specified. The Color can be black/white, RGB (colored) or Gray scale. RGB is recommended also for black laser printers. Some info lines containing date, filename and title can be added. For each page a temporary file PRINT1.WMF, PRINT2.WMF... will be created. This file is in Windows Metafile format and can be exported into some other Windows applications.
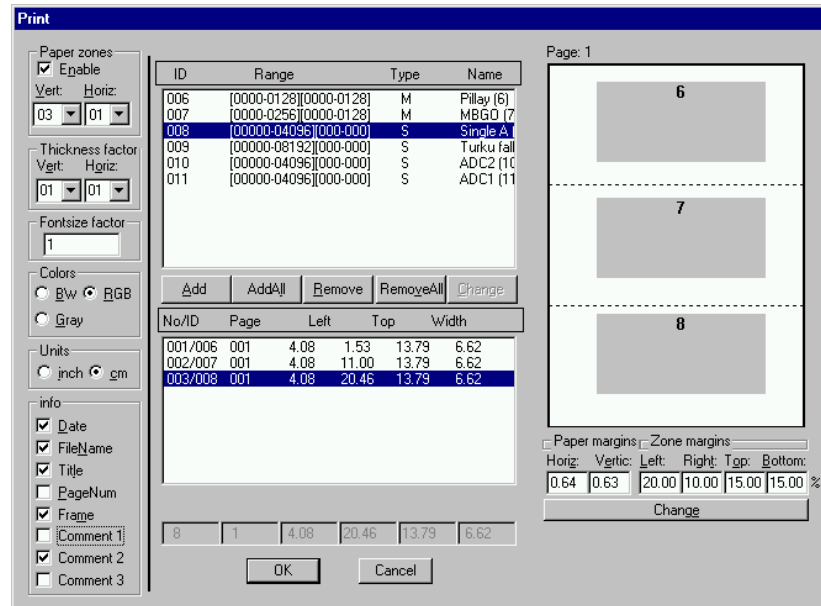
Fig. 6.4: Print dialog box

Setup Printer...

The Setup Printer menu item allows to configure the printer.

Exit

The Exit menu item exits the MPANT.

6.2. Window Menu

The Window menu allows to arrange the Display windows.

Tile

With the Tile menu item or clicking the corresponding icon, all opened and displayed MPANT Display windows are arranged over the full MPANT client area trying to allocate the same size for each window.

Cascade

The Cascade menu item or respective icon arranges all windows in a cascade display.

Arrange Icons

By the Arrange Icons menu item, the minimized MPANT Display windows are arranged in a series at the bottom of the MPANT client area.

Close All

By selecting the Close All menu item, all Display windows are closed.

Window list

At the end of the Window menu, all created Display windows are listed with their names, the current active window is checked. By selecting any of the names, this window becomes the active window and is displayed in front of all the others.

6.3. Region Menu

The Region menu contains commands for Regions and ROI's (Regions of Interest). A Region can be defined by marking it in a display, with the mouse using the right mouse button and dragging a rectangle over the area one is interested in. A ROI, i.e. an already defined region in a single spectrum can be shown zoomed by double-clicking with the left mouse button on the corresponding colored area in the bar at the bottom of the spectra display. A single mouse click with the left button on the corresponding colored area makes this to the selected ROI and lets the counts contained in this ROI be displayed in the information lines of the respective window. Advance the selected ROI to the next or previous one using the "+" or "-" key from the numeric keypad.

Polygonal and curved ROI's in MAP displays are now implemented in addition to the rectangular ROI's. The boundaries can be polygonal, circular, annular or pie. Make a choice of the shape using the Menu Region...Shape or the corresponding toolbar icon. Define the ROI using the right mouse button, the TAB and the END key (please read the help in the status bar) and save the ROI using the toolbar icon "Create new ROI". Advance the selected ROI to the next or previous one using the "+" or "-" key from the numeric keypad. The ROI boundary is displayed by lines or circles and the ROI area can in addition be displayed in inverted color by enabling the checkbox "Invert ROI Pixel" in the MAP Display options dialog. The sum and net sum of counts within the selected ROI is displayed. The net sum is calculated by subtracting a background integral by summing line integrals S(y) for each y coordinate using the mean value of the counts at the lowest and highest x coordinate of the ROI.

Zoom

The Zoom item or respective icon enlarges a Region to the maximum Spectrum Display size.

Back

The Back menu item or clicking the corresponding icon restores the last zoom view. Each time a Back command is clicked the view is stepped back one step.

Zoom Out

The Zoom Out menu item or clicking the corresponding icon enlarges the actual zoom view by a factor 2, if possible.

Home

Clicking the Home menu item or the corresponding icon restores a Display to the basic configuration.

Shape

Selecting the Shape menu item opens a submenu with the items Rectangle, X-Slice Y-Slice and Rectangle, Polygon, Circle, Annular and Pie to choose the ROI shape.

Rectangle

Sets the region shape to a rectangle with arbitrary dimensions. To enter the rectangular region, press the right mouse button, drag a rectangle, and release the button to define the region.

X-Slice

Sets the Region shape to the rectangle with maximal height.

Y-Slice

Sets the Region shape to the rectangle with maximal width.

Polygon

Sets the Region shape to polygonal. To enter a polygonal Region using the mouse, press the right button for each point, the TAB key for a next polygon and the END key to close it.

Circle

Sets the Region shape to circular. To enter a circular Region using the mouse, click the right button at the center, move the mouse and press the END key to finish.

Annular

Sets the Region shape to annular. To enter an annular Region using the mouse, click the right button at the center and first circle and press the END key at the second circle.

Pie

Sets the Region shape to pie. To enter a pie Region using the mouse, click the right button at the center and first radial end-point, press the END key at the second radial line end-point.

Create

The Create menu item creates a new ROI from the current marked Region.

Delete

By selecting the Delete menu item or the respective icon, the current active ROI is deleted and the previously defined ROI is activated.

Edit...

With the Edit item, a dialog box is opened which allows to edit the ROI list, i.e. create a new or delete, change and activate an existing ROI. Also the peak values for an automatic calibration

can be entered here. A ROI can be edited and added to the list. It can also be made to the „Active ROI", that is the special ROI that is used by the server program to calculate the events within this ROI and look for an event preset. The ROI list can be cleared and it can be written into a file with extension .CTL, which can be directly loaded into the server to restore the ROI list.
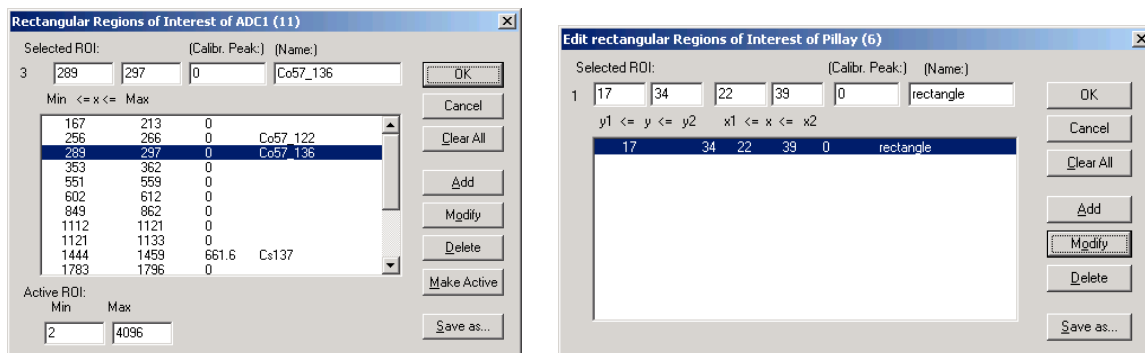
Fig. 6.5: Slice and rectangular ROI Editing dialog box

Clicking on it in the ROI list can change the selected ROI. In the MPANT spectrum display the total and net sum of the selected ROI is displayed.

ROI names are now implemented. The name can be entered in the ROI editing dialog. Press "Modify" to insert a new name from the edit field of the selected ROI into the list.
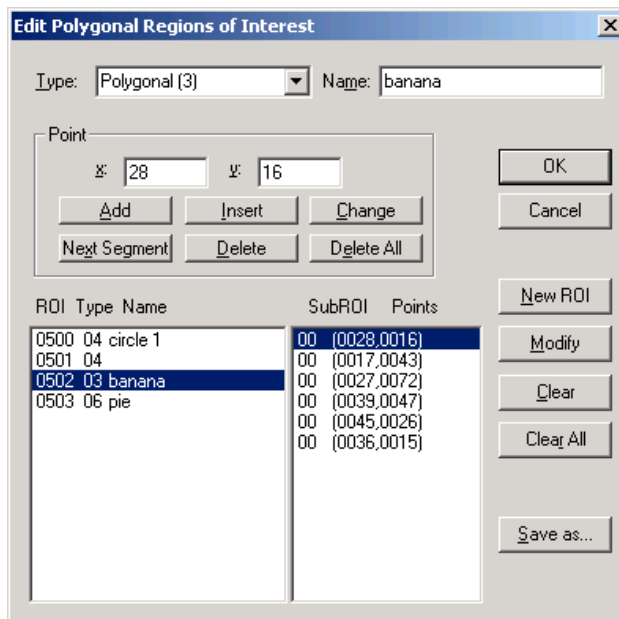
Fig. 6.6: Polygonal ROI Editing dialog box

For polygonal, circular, annular and pie ROI's there is a special dialog to select and edit all the parameters. The ROI definition parameters can be saved into a .CTL file and reloaded using the File menu like any control file. Note that the selected ROI can be advanced in any activated spectra display by pressing the "+" and "-" key from the numeric keypad.

X-Projection, Y-Projection

Projections of ROI's in dual parameter spectra to the x- and y-axes are now implemented. There are new menu items "X-Projection" and "Y-Projection" in the Region menu. They create new single spectra displays showing the respective projection of the selected ROI in a dual parameter spectrum in the active window.

Fit...

By selecting the Fit... menu item or the respective icon, a single Gaussian peak fit with linear background is performed for the currently marked region. The fitted curve is displayed and a dialog box shows the results:
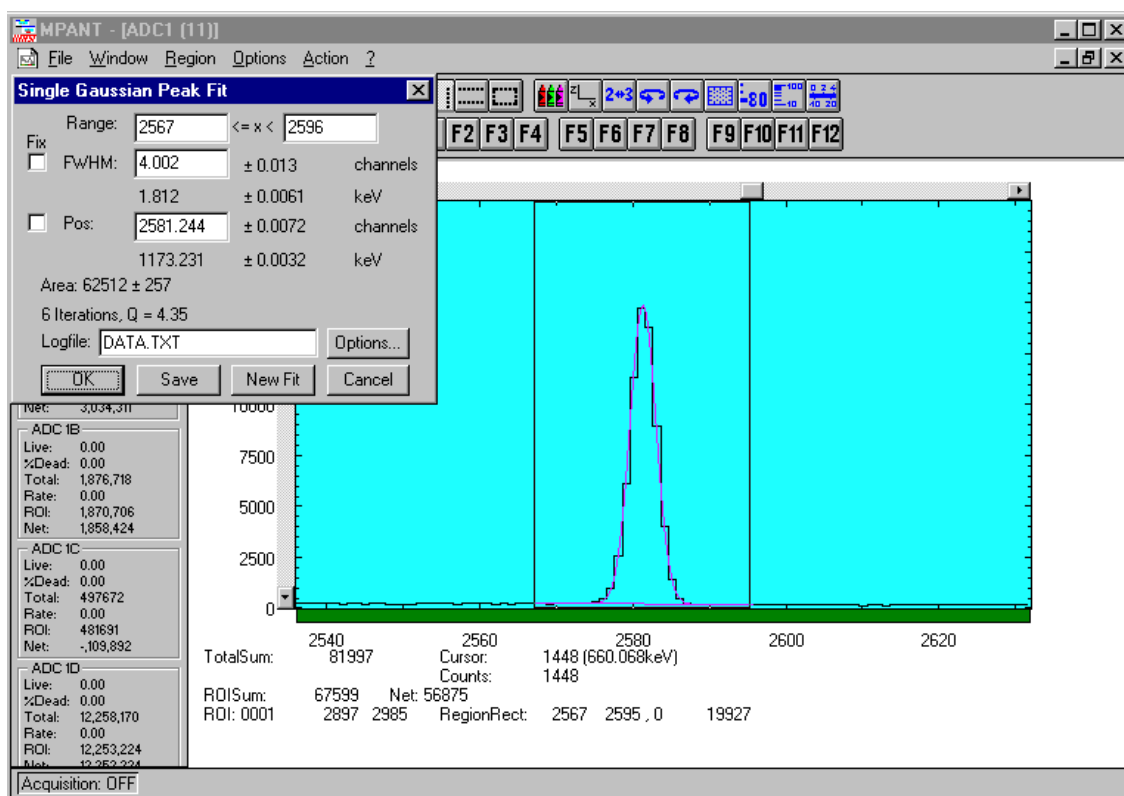
Fig. 6.7: Single Gaussian Peak Fit

The full width at half maximum FWHM and Position of the Gaussian can be changed and a New Fit can be performed, they even can be fixed to the entered value by marking the respective checkbox. The Position and FWHM are displayed in channels and also in calibrated units, if a calibration is available. The area of the Gaussian is also shown. For all values also the standard deviations are given. The value of Q is the normalized chi**2. To take into account the systematic error of the line shape, you may multiply the errors with the square root of Q. Click on Save to append a line containing the results to a Log file with the specified name. OK closes the dialog and lets the fitted function in the display also if it is refreshed, whereas after Cancel the curve no longer will be shown in a refreshed display. Options... opens a new dialog box to define the information in the log file:
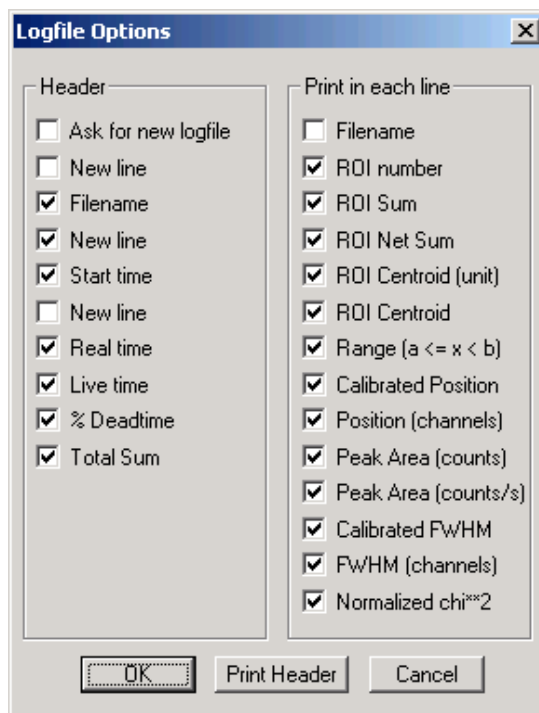
Fig. 6.8: Log file Options for the Single Gaussian Peak Fit

The several quantities are written in standard text format with Tabs as separators and a Newline character at the end of each line, so the file can be read with standard calculation programs like EXCEL. Click on Print Header to write a header line.

Fit ROIs

With the Fit ROIs item, for all ROI's a Single Gaussian Peak Fit is performed and the results are dumped into the log file.

Auto Calib

Makes a Gauss fit for all ROI's in the active Display for which a peak value was entered, and performs a calibration using the fit results.

6.4. Options Menu

The Options Menu contains commands for changing display properties like scale, colors etc., hardware settings, calibration and comments.

Colors...

The Colors menu item or respective icon opens the Colors dialog box.
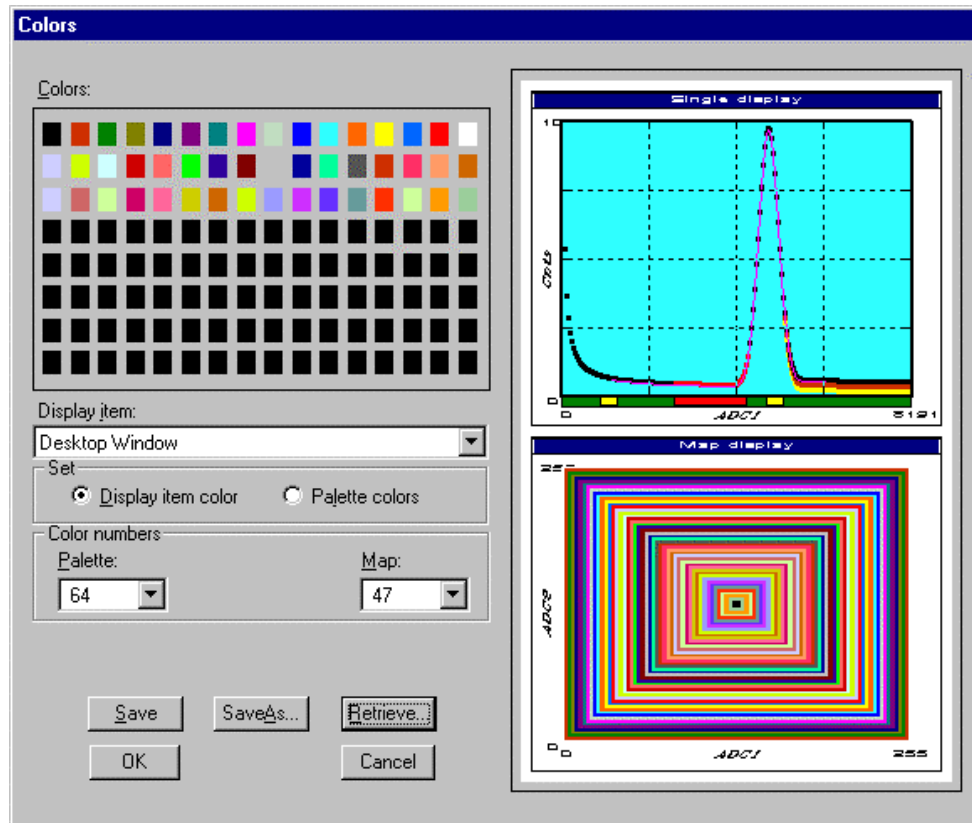
Fig. 6.9: Colors dialog box

It changes the palette or Display element color depending on which mode is chosen. The current color and palette setup may be saved or a new one can be loaded.
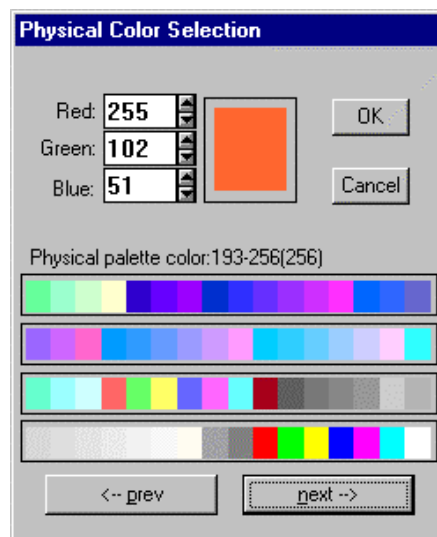
Fig. 6.10: Color Palette dialog box

To change on of the colors, select "Palette colors" and click on one of the colors. In the Color Palette dialog box the RGB values can be edited or for a 256 color video driver one of the Physical palette colors can be chosen.

Display...

The Display menu item or the corresponding icon opens for single spectra the Single view dialog box.

Here the graphic display mode of single spectra can be chosen. The '**Type**' combo box gives a choice between dot, histogram, spline and line. The '**Symbol**' combo box gives a choice between None, Circle, Triangle down, Triangle up, Cross, Snow-flake and Diamond. The symbols can be filled by checking **Fill**, error bars can be displayed by checking **Error Bar**.

'Dot' means that each spectra point is shown as a small rectangle or the specified symbol, the size can be adjusted with the **size** combo box. 'Histogram' is the usual display with horizontal and vertical lines, 'spline I' means linear interpolation between the points, and 'line' means vertical lines from the ground to each spectra point.

If the displayed spectra range contains more channels as pixel columns are available in the video graphic display, usually only the maximum value of the channels falling into that pixel columns is displayed. But it can also explicitly specified by marking the checkboxes „**Max Pixel**", „**Mean Pixel**" or „**Min Pixel**" which value will be displayed. It is also possible to display all three possible values in different colors that can be chosen in the colors dialog. For the „Mean Pixel" a Threshold value can be entered; channel contents below this value then aren't taken into account for the mean value calculation.
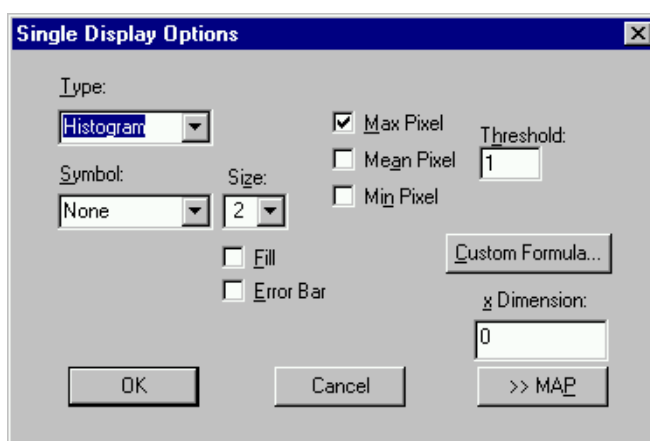
Fig. 6.11: Single View dialog box

The button labeled **Custom Formula...** is visible only if you have a special DLL named FMPA3.DLL. It allows communicating with MPANT for customer- calculated spectra. This DLL including source code is now part of the DLL software interface that is available as an option.

Installation: Copy the FMPA3.DLL into the working directory (usually C:\MPA4T). Use: This DLL allows to calculate spectra and to display it with the MPANT program. Select a single spectrum and open the Display options dialog. Press then the button labeled "Custom formula...". A dialog box "Custom-transformed spectra" is opened. Here the formula for the calculation can be selected and the parameters can be edited. A new display window showing the calculated spectra can be created. Error Bars can be activated in the display options dialog, for the calculation of the error bars also the DLL is used. Example: The supplied DLL is for acquisitions marked by a tag bit in a high bit of the ADC interface. It allows to calculate the Sum=x+x', Difference=x-x' and relative difference Delta=F*(x-x')/(x+x') of spectra marked by the tag bit.
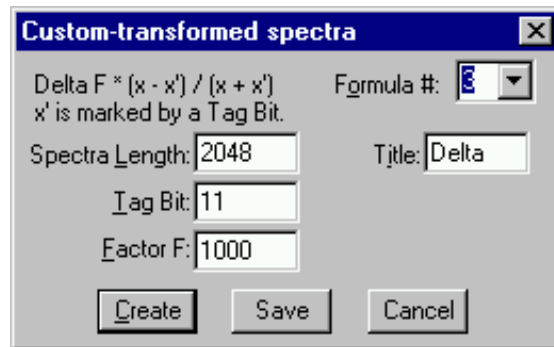
Fig. 6.12: Custom-transformed spectra dialog

It is possible to change to a two dimensional view of the spectrum by specifying the x Dimension and clicking the button ">> MAP" from the Single View dialog.

For MAP displays the Display Options dialog is changed and allows a choice between four Graphic types: **bitmap dot**, **vector dot**, **bitmap contour** and **vector contour**. Bitmap Dot is recommended as a standard, because it makes a good and fast display. The checkbox **Invert Roi Pixel** allows changing the color inside ROI's to make it better visible. Vector Contour paints colored contour lines. To calculate the lines takes a lot of time and causes the mouse pointer changing to an hourglass. But it gives very impressive colored pictures suited especially for presentation and when looking carefully at spectra details.
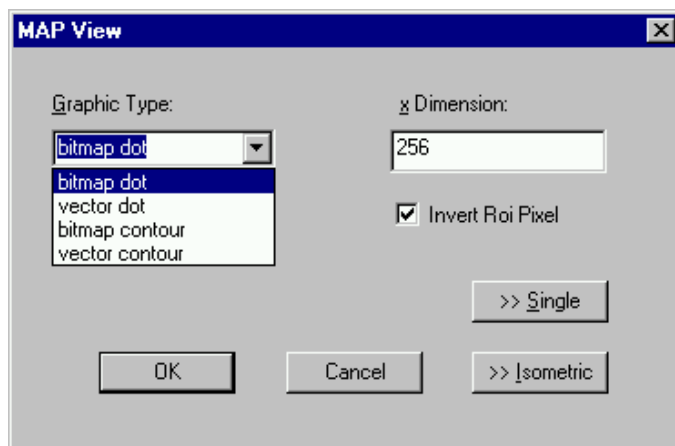
Fig. 6.13: MAP View dialog box

From the MAP View dialog it is possible to change to Single view by clicking ">> Single" or change to Isometric View by clicking ">> Isometric". For pulse width measurements with a y-dimension of two for the two edges a button will be displayed for switching into the "overlapped" single view, see section 2.5.5.
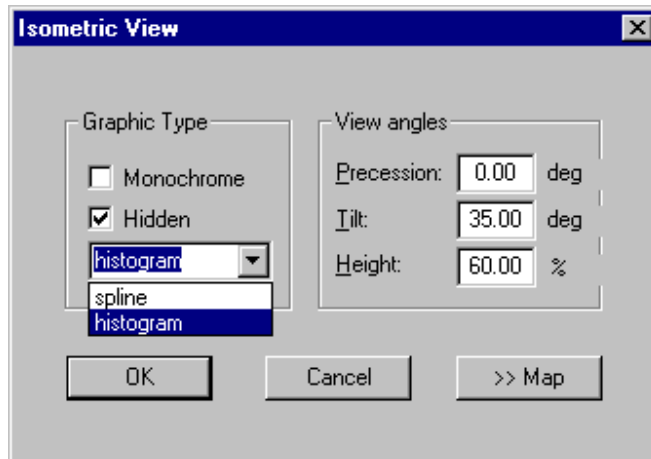
Fig. 6.14: Isometric View dialog box

In isometric mode several single spectra are drawn behind each other. The **Precession** angle around the vertical axis can be chosen in multiples of 90 degrees. The **Tilt** angle is between the x and y-axis and can be chosen between 15 and 89 degrees. The **Height** specifies the percentage of the z-axis length respective to the whole drawing, it can be entered between 0 and 99. With **hidden** it can be specified whether the hidden parts are not drawn. If "Monochrome" is checked, the spectra are painted monochrome, otherwise in color.

Axis...

By the Axis... menu item or the respective icon, the Axis Parameters dialog box is opened.
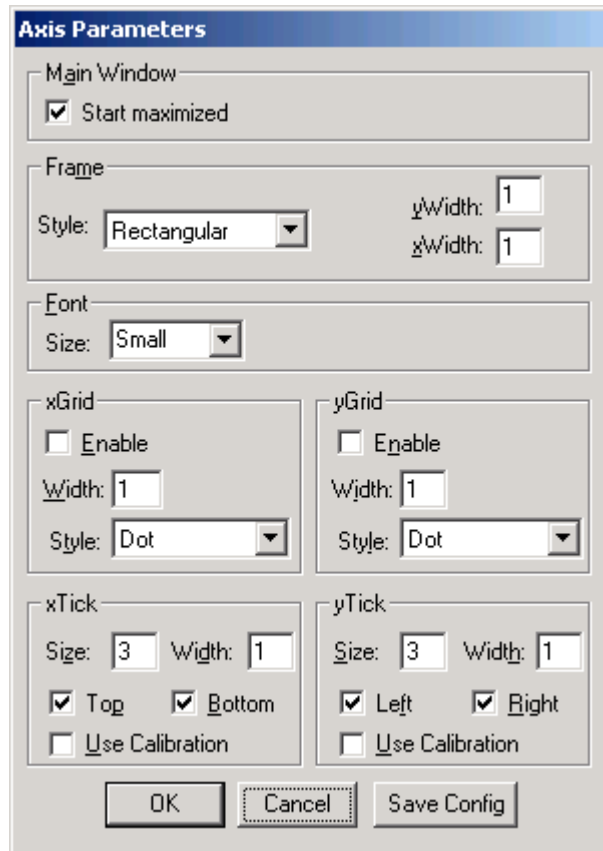
Fig. 6.15: Axis Parameter dialog box

It provides many choices for the axis of a display. The frame can be rectangular or L-shape, the frame thickness can be adjusted (xWidth, yWidth). The font size can be chosen between Small and Large. A grid for x and y can be enabled, the style can be chosen between Solid, Dash, DashDot and DashDotDot. Ticks on each of the four frame borders can be enabled, the tick length and thickness can be chosen. The style of the axis labeling depends on enabled ticks at the bottom respective left side: If no ticks are enabled there, only the lowest and highest values are displayed at the axis, otherwise the ticks are labeled. 'Use calibration' changes the axis ticks and labels into calibrated values. A checkbox "Start maximized" allows to define if the MPANT main window should start in maximized size. It is necessary to save the MPANT options to make these settings permanent.

Scaling...

The Scaling menu item or the corresponding icon opens the Scale Parameters dialog box.
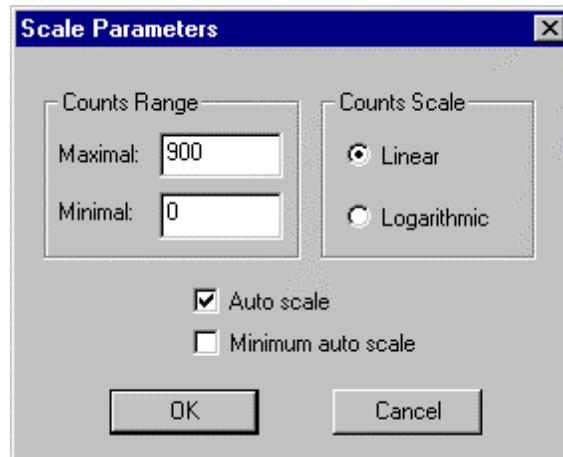
Fig. 6.16: Scale Parameters dialog box

It allows to change the ranges and attributes of a Spectrum axis. By setting the Auto scaling mode, the MPANT will automatically recalculate the y-axe's maximum value for the visible Spectrum region only. To keep the same height of the visible region for a longer time, deselect the Auto scaling mode. Then with the scroll bar thumb one can quickly change the visible region scale, otherwise the scale will be changed automatically. The Minimum auto scale mode helps to display weak structures on a large background.

Lin / Log scale

For a Lin scale all data intervals have the same size. With Log scale the intervals will be small for small y values and large for large y values. All options have effect only on the active Display.

Calibration...

Using the Calibration menu item or the corresponding icon opens the Calibration dialog box.
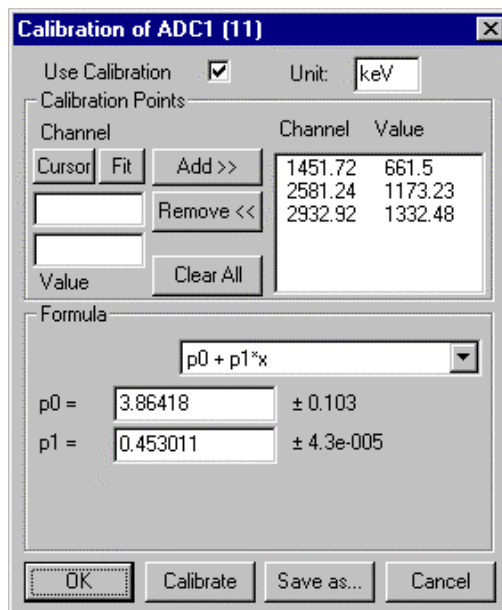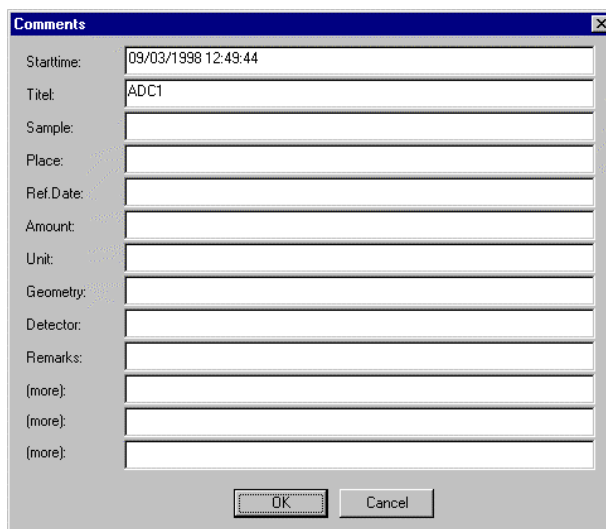
Fig. 6.17: Calibration dialog box

Choose between several calibration formulas. Enter some cursor positions and the corresponding values. The actual cursor position can be entered by pressing 'Cursor' or the last fitted peak position by pressing 'Fit'. Click on Add to insert the calibration position into the list, then on Calibrate. The obtained coefficients can be inspected together with the statistical error, or they can be changed and entered by hand. If 'use calibration' is on, the calibrated values are displayed together with the channel position of the cursor. For MAP spectra the dialog is slightly different and allows to select by two radio buttons between the calibration of x- and y-axis. For a selected parameter there is only one calibration: If any ADC is already calibrated in a single spectrum and it is used also in a MAP spectrum, the calibration is the same here.

Comments...
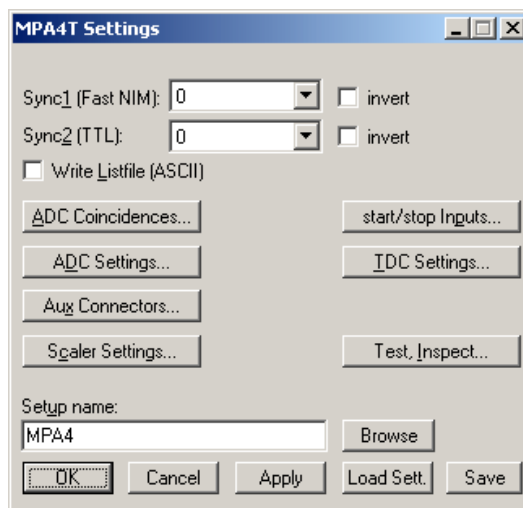
Up to 13 comment lines with each 60 characters can be entered using the Comments dialog box. The content of these lines is saved in the data header file. The first line automatically contains the time and date when a measurement was started. The second line contains the title of the spectra. Note that editing this line changes the spectra name. This is the only method to change the name of physical ADC spectra. The description of each comment line can be changed by editing the file COMMENT.TXT.

Fig. 6.18: Comments dialog box

Hardware...

The Range, Preset dialog box allows to make all the respective MPA4T settings (ref. chapter 5.1.4).

Fig. 6.19: Settings dialog box

Data...

The Data Operations dialog box allows to edit all the respective settings (ref. chapter 5.1.3).
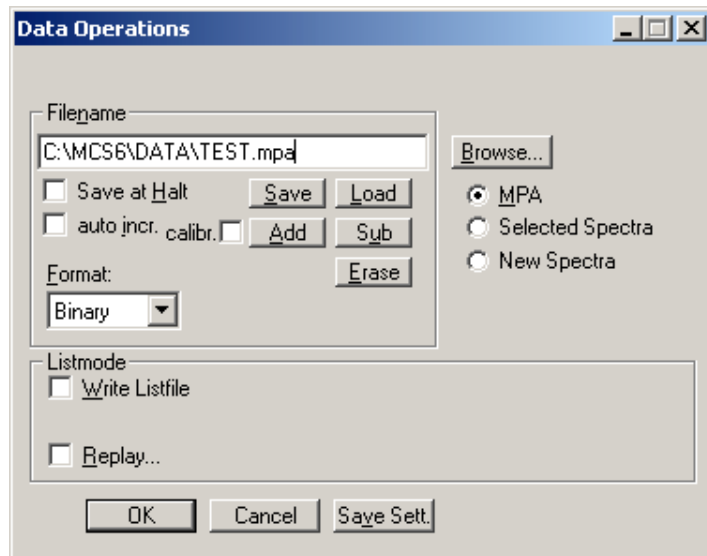
Fig. 6.20: Data Operations dialog box

System...

The System Definition dialog box allows to make all the respective settings (See chapter 5.1.9).
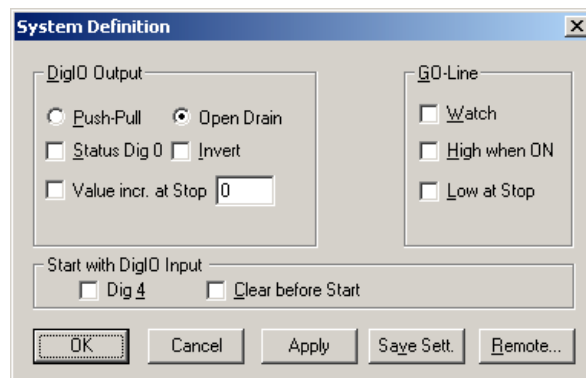
Fig. 6.21: System Definition dialog box

Spectra...

The Spectra dialog box allows editing the list of calculated and dual parameter spectra, see chapter 5.1.10.
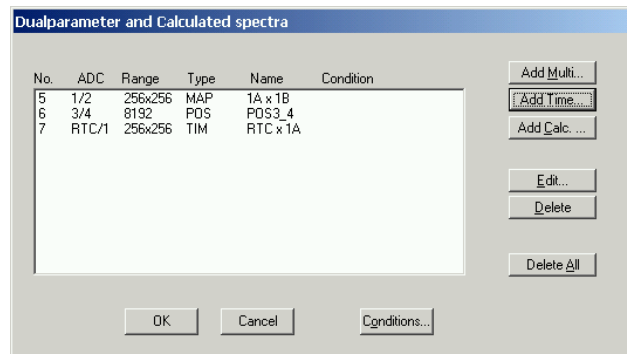
Fig. 6.22: Spectra dialog box

Slice...

The Slice option allows to create new single spectra displays, showing a slice in a dual parameter spectrum. Click on a dual parameter spectra display to make it the active window, then select the Slice menu item or toolbar icon. The Slice dialog box is displayed.

Select "x=const" or "y=const" for the slice direction, and the coordinate. Clicking the "create" button creates the new display window. In the title bar of the new window the name of the dual parameter spectra and the slice coordinate is shown.

The slice position can be changed using the scroll bar in the Slice dialog, or by entering the value in the edit field and pressing the button, which is labeled "Set" after creation of the slice view.

Clicking its close field can close the Slice dialog. Created slice spectra displays remain visible and their coordinates can be changed later using the Slice utility again. The position of the Slice dialog with respect to the MPANT main window can be saved in the MPANT.CFG file. Rectangular ROI's are visible in the slice spectra display and can be created here.

Fig. 6.23: Slice dialog box

Replay...

The menu item Options – Replay... opens the Replay settings dialog (ref. chapter 5.1.3).
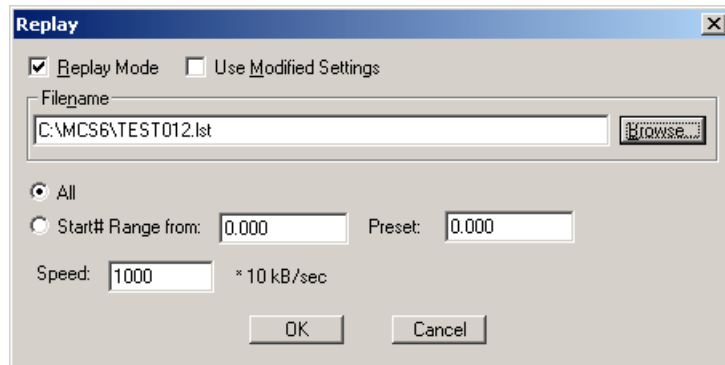
Fig. 6.24: Replay dialog box

Tool Bar...
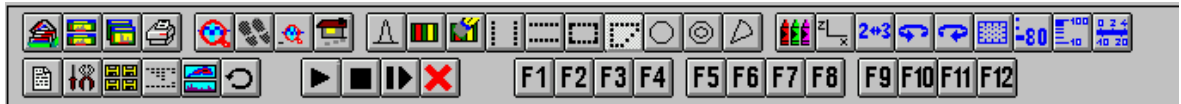
Selecting the Tool Bar Menu item opens the Tool Bar Dialog Box. It allows arranging the icons in the Tool Bar.
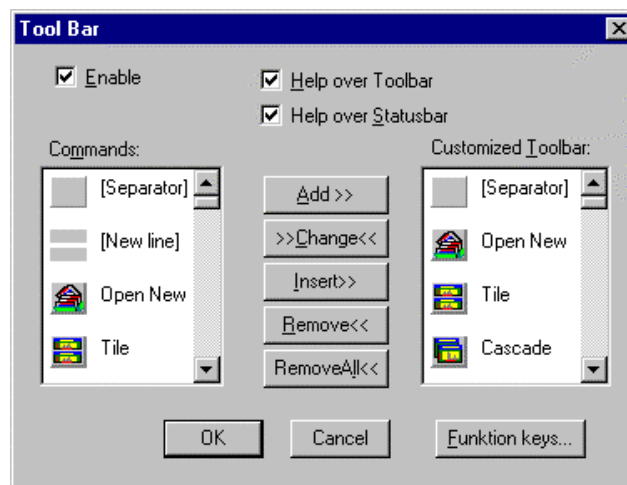
Fig. 6.25: Tool Bar dialog box

If it is enabled, an array of icons in the MPANT Menu is shown. Clicking the left mouse button with the cursor positioned on an icon, the user can perform a corresponding MPANT Menu command very quick.

It is also possible to include icons for free programmable function keys F1...F12 into the Toolbar. The function keys can be programmed in the Function keys dialog. It can be accessed either by clicking the "Function keys..." button or directly from the options menu.
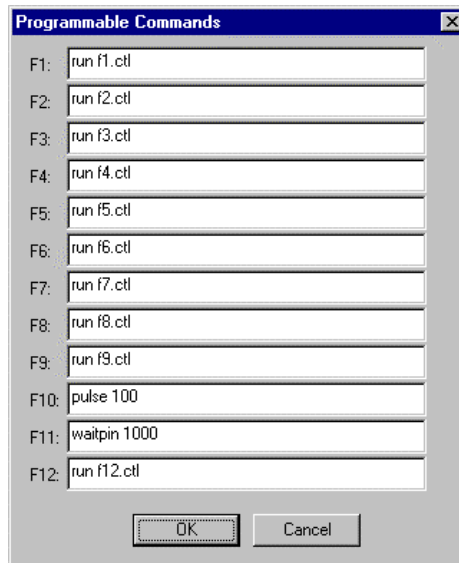
Fig. 6.26: Function keys dialog box

The functions can be executed by clicking the corresponding icon in the toolbar or by the corresponding function key on the keyboard simultaneously with the CTRL key. The MPANT window must be the active on the desktop and have the focus.

Status bar

With this menu item the Status bar at the bottom of the MPANT main window can be switched on or off. A corresponding check mark shows if it is active or not. The Status bar usually shows if an acquisition is active. When the left mouse button is pressed while the mouse cursor is within a toolbar icon, it displays a short help message what the meaning of the toolbar icon is.

Status window

The same way it is possible to hide or show the status window at the left side of the MPANT main window.

Save As...

Saves all parameters defined in the Options menu to the MPANT.CNF or a user defined config file.

Open...

Loads a new configuration.

6.5. Action Menu

The Action Menu or corresponding toolbar icons contain the commands to start, stop, continue and erase a measurement. If more than one systems are formed, also more actions menus are available, otherwise they are grayed.

Start

The Start toolbar button erases the data and starts a new measurement.

Halt

The Halt toolbar button stops a measurement.

Continue

The Continue toolbar button continues a measurement.

Erase

The Erase toolbar button erases the data.

7. Programming and Software Options

The MPA4T can be controlled by user-written programs using the DLL software interface with example programs for Visual Basic, LabVIEW and C that is available as an option. Furthermore, LINUX software is available as an option containing a driver, library and console test program. A Windows software similar to the LINUX package that runs without the server using a stand-alone DLL is also available on demand for customers who own one of the two available library packages.

Auto-Correlation: an optional available expansion of the Server program allows to acquire data into a two-dimensional array M(i,j). The channel (i,j) is incremented when in a single sweep the channel i and i+j has an event. The two dimensional MAP can be viewed in MPANT even during the acquisition. Use the display options and switch to MAP and later to ISOMETRIC.
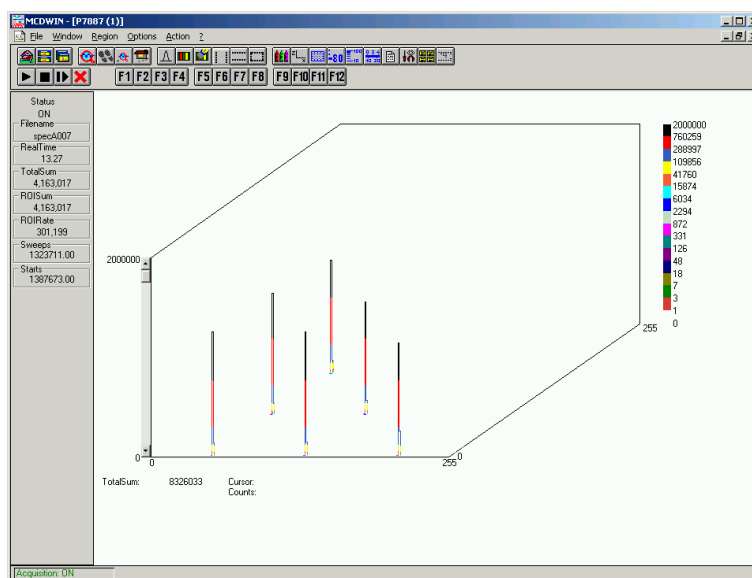
Fig. 7.1: Autocorrelation software option

8. Appendix

8.1. Performance Characteristics

8.1.1. TOF General

Resolution[10] FWHM[11]:
at 1 ms $\cong$ 10,000,000 chs over 60 min: ....typ. 135 ps
at 100 ms $\cong$ 1,000,000,000 chs over 60 min: ....typ. 160 ps
at 1 sec $\cong$ 1,000,000,000 chs over 60 min: ....typ. 340 ps
(see also the spectra in Fig. 8.6, Fig. 8.7 and Fig. 8.8)

Dynamic range: ....2^{54} x 100 ps = 500.4 h =20.85 d

Differential non-linearity: .... << ± 1 %

Trigger delay: (rel. to 1st detectable STOP) .... none

Input delay (rel. to TAGs): (selectable in steps of 3.2 ns) .... 0 … 48 ns

Dead time:
end-of-sweep to re-arm ("stop-after-sweep" mode) .... 96 ns
end-of-sweep to re-start (in "endless" mode) .... none
between time bins .... none

Loss less burst time: (individually for each input channel) .... > 6.5 µs

Decoder rate: .... > 33 MHz

Sweep repetition time: .... (Acq. Delay + Range + Hold Off + 96 ns)

8.1.2. MPA General

ADC port data width:
.... 16 bit / 64k
.... optional 32, 48 or 64 bit

Data throughput: .... 30 MB/s (1 USB port) or 35 MB/s (2 USB ports)

Coincidence time window:
.... 20ns … 1.3ms
.... in steps of 20ns

DRDY timeout:
.... 20ns … 1.3ms
.... in steps of 20ns

Real / Livetime resolution: (any ADC port) 1ms

8.1.3. Time base

Reference oscillator type:
.... ovenized crystal oscillator
Nominal frequency: ....10.000 MHz
Frequency stability:
in operating temperature range: .... ≤ ± 0.03 ppm
vs. Supply voltage change ±5 %: .... $\leq \pm 5.0 \cdot 10^{-9}$
vs. Short term: .... $\leq \pm 1.0 \cdot 10^{-10}$ /s
Ageing: .... $\leq \pm 2.0 \cdot 10^{-9}$ /day
.... $\leq \pm 2.0 \cdot 10^{-7}/1^{st}$ year

---

[10] Input signal is a highly stable 10MHz GPS disciplined sine wave oscillator in a laboratory surrounding

[11] Full width at half maximum. All FWHM data is derived from a gaussian fit.

Jitter: .... << 2 ps$_{rms}$
Phase noise: ....(10 Hz) -105 dBc/Hz
....(100 Hz) -130 dBc/Hz
....(> 1 kHz) -140 dBc/Hz
Warm-up time: ....≤ 1 min. @ 25 °C
....≤ 2 min. @ 0 °C

Sampling frequency: (nominal) .... 10 GHz

8.2. Specifications

8.2.1. Absolute Maximum Ratings

Input voltage: any ADC port input: .... -0.5 to +5.5 V[12]
any ADC GATE input: .... -0.5 to + 7 V[13]
any Counter input: ....-0.5 to +6 V
any AUX I/O port .... TBD
any multi I/O port (DIG I/O 0…7): .... -0.5 to + 5.5 V[14]
GO-Line: .... -0.5 to + 5.5 V[15]
any TTL TAG input port: ....-0.5 to + 5.5 V
any LVDS TAG input port: ....-0.5 to + 2.9 V
any discriminator input: ....-3.0 … +4.0 V

Differential input voltage: any START / STOP discriminator input: .... $(V_{IN} - V_{Threshold}) = \pm 2.0V$

DC input current: any ADC port input: ....± 10 mA
any ADC GATE input: ....± 10 mA
any Counter input: ....± 10 mA
any AUX I/O port .... TBD
any multi I/O port...± 10 mA
any TTL TAG input port...± 40 mA
any LVDS TAG input port..± 20 mA
any discriminator input: ....± 100 mA

DC output current: any Counter Carry Output ....± 50 mA

Input power: any Counter input (termination resistors): ....0.25 W
any TTL TAG input port (termination resistors):....................0.25 W

8.2.2. Recommended Operating Conditions

Power supply: .... +12V / 5A

Operating temperature range: .... 0 to + 50°C

GO-Line load: .... min. 1 kΩ to +5.0V
or ....min. 2 kΩ to GND

---

[12] Max. DC undershoot below GND must be limited to –0.5 V or 10 mA. During transitions internal device pins may undershoot to –2.0 V and overshoot to +7.0 V, provided it lasts less than 10 ns and the forcing current is limited to 200 mA.

[13] Max. undershoot below GND may be exceeded as long as the max. current is limited to 50mA

[14] Max. DC undershoot below GND must be limited to –0.5 V or 10 mA. During transitions internal device pins may undershoot to –2.0 V and overshoot to +7.0 V, provided it lasts less than 10 ns and the forcing current is limited to 200 mA.

[15] Max. DC undershoot below GND must be limited to –0.5 V or 10 mA. During transitions internal device pins may undershoot to –2.0 V and overshoot to +7.0 V, provided it lasts less than 10 ns and the forcing current is limited to 200 mA.

8.2.3. Signal Connectors

START / STOP (discriminator) inputs

Connector:	....female SMA
Edge sensitivity:	(software selectable) .... falling / rising / both
Voltage range:	.... V_{IN} = -2.0 … +3.0 V
Threshold voltage:	.... V_{th} = ±1.5 V
Clamp voltage:	....V_{CL} = V_{th} ± 1.5 V
Impedance:	.... 50 Ω ± 3 Ω
Input reflection:	(ref. Fig. 8.1) .... ≤ 12.5%
Sensitivity:	(ref. chapter 8.3.1)... < 10 mV
Hystheresis:	.... approx. 5 mV
Offset voltage:	.... ±10 mV
Bias current:	....30 µA
Equivalent input bandwidth:	(0…400mV input, t_R=t_F=25ps, 20/80%)................................. 8 GHz
Toggle rate:	(>50% output swing) .... 12.5 Gbps
Slew rate requirement:	.... > 50 V/µs
Overdrive dispersion:	(V_{OD} = 50 mV … 1.0 V) .... 10 ps
	(V_{OD} = 10 mV … 200 mV) .... 15 ps
Slew rate dispersion:	(2 V/ns … 10 V/ns) .... 15 ps
Pulse width dispersion:	(100 ps … 5 ns) .... 15 ps

Fast NIM Sync_1 output

Connector:	.... female SMA
Impedance:	.... back-terminated 50 Ω
Output signal:	fast NIM / current mode .... -16 mA into external 50 Ω
Output HIGH voltage:	(50 Ω load) ....typ. -0.0 V
Output LOW voltage:	(50 Ω load) ....typ. -0.8 V
Output short circuit current:	V_{OUT} = GND ....typ. -32 mA
Fall time:	(ref. Fig. 8.10) .... < 200 ps
Rise time:	.... ~ 300 ps

Sync_2 output

Location:	.... ref. FEATURE (multi) I/O port connector
Impedance:	.... ~ 50 Ω
Output HIGH voltage:	$I_{OutHIGH}$ = -24mA .... min. 2.4 V
	.... typ. 1.6 V into 50 Ω
Output LOW voltage:	I_{OutLOW} = 48mA .... max. 0.45 V
Recommended current:	V_{OUT} = LOW ....< 180 mA
	V_{OUT} = HIGH...< -90 mA

| Rise time: | (ref. Fig. 8.11) .... ~ 1 ns |
| Fall time: | .... ~ 1 ns |

Reference clock I/O

Connector:	.... BNC
Input frequency:	(software selectable) .... 10 / 20 / 40 / 80 MHz
Output frequency:	.... 10 MHz
Impedance:	....(dc blocked) 50 Ω
Output HIGH voltage:	(50 Ω load) .... typ. 2.0 V
Output LOW voltage:	(50 Ω load) .... typ. 0.4 V
Input amplitude:	(clipped sine or sine wave)..typ. 3.3 V_{PP}

The clock I/O circuitry is widely adjustable to individual needs. Contact factory for details.

ADC ports

Connectors:	.... 25 pin female D-SUB
Input Impedance:	....10 kΩ pull-up
Output impedance:	(series resistor)...33 Ω / 0.063 W
Input HIGH voltage:	.... min. 2.0 V
Input LOW voltage:	....max. 0.8 V
Output HIGH voltage:	I_{OH} = -1.0 mA .... min. 2.4 V
	I_{OH} = -4.0 mA .... min. 2.2 V
Output LOW voltage:	I_{OL} = 1.0 mA..max. 0.4 V
	I_{OL} = 8.0 mA..max. 0.7 V
DRDY to DACC time:	....min. 211 ns
	4 ADC's simultaneously in a row............................... max. 897 ns[16]

ADC GATE inputs

Connector:	....................................15 pin high-density female D-SUB
Input Impedance:	....10 kΩ pull-up
Input HIGH voltage:	.... min. 2.0 V
Input LOW voltage:	....max. 0.8 V
Gate setup time:	Gate to DRDY .... - 211 ns
Gate hold time:	Gate after end of DRDY .... ~ 0 ns

Digital I/O 0...7

Location:	.... ref. FEATURE (multi) I/O port connector
R PULL :	(default) ....1.0 kΩ
R I/O:	(default) ....22 Ω
Input HIGH voltage:	(at PIN_i)[17] .... min. 2.0 V

---

[16] ADC data in a port row (1..4 or 5...8) is queued for transfer. Thus, simultanously firing ADC's may delay the interface response by 211 ns. Interface operates at 19 MHz or 53 ns. Max. DRDY-to-DACC = 4 x 211 ns + 53 ns = 897 MHz.

Input LOW voltage:	(at PIN$_i$)	max. 0.8 V
Output HIGH voltage:	(at POUT$_i$) I$_{OutHIGH}$ = -4.0mA	min. 2.4 V
Output LOW voltage:	(at POUT$_i$) I$_{OutLOW}$ = 8.0mA	max. 0.4 V

DAC output:

Location:		ref. FEATURE (multi) I/O port connector
Voltage range:		0 … + 2.5 V
Resolution:		14 bit
Short-circuit current:		40 mA
Load current:		± 1 mA
Capacitive load stability:	R$_L$ = ∞	max. 200 pF
	R$_L$ = 5 kΩ	max. 1000 pF
DC output impedance:		0.5 Ω
Relative accuracy:		± 4 LSB
Differential non-linearity:	(guaranteed monotonic)	-1 / +2 LSB
Offset error:	(measured at code 64)	± 4 mV
Gain error:		± 0.1 % FSR
Output settling:	(¼ to ¾ scale change to ± 1 LSB)	typ. 8 µs
Glitch energy:		typ. 12 nV s
Glitch impulse peak amplitude:		typ. 15 mV

GO-Line

Location:		BNC
		ref. FEATURE (multi) I/O port connector
Line type:		open drain / wired-AND
Pull-up resistor:		22kΩ to +5.0 V
Input HIGH voltage:		min. 2.0 V
Input LOW voltage:		max. 0.8 V
Output LOW voltage:	I$_{Out LOW}$ = 8mA	max. 0.4 V

Auxiliary I/O 1..3

Connector:		BNC
Pull-up resistor :	(ref. Fig. 3.13)	10 kΩ
Serial termination resistor:	(ref. Fig. 3.13)	33 Ω
Input HIGH voltage:	(at IC pad)[18]	min. 2.0 V
Input LOW voltage:	(at IC pad)	max. 0.8 V

---

[17] Note: input and output voltages are measured at the internal logic pads not at the external connectors. Thus, the corresponding pull and series resistors must be considered to get the external voltages

[18] Note: input and output voltages are measured at the internal logic pads not at the external connectors. Thus, the corresponding pull and series resistors must be considered to get the external voltages

---

Output HIGH voltage:	(at IC pad) $I_{OutHIGH}$ = -4.0mA .... min. 2.4 V
Output LOW voltage:	(at IC pad) I_{OutLOW} = 8.0mA .... max. 0.4 V

Counters 1…8

Connector:	.... 15 pin high-density female D-SUB
Count frequency:	.... max. 100 MHz
Location of Carry outputs:	.... ADC GATE connector
Input Impedance:	.... 50 Ω / 0.25 W
Input pulse width:	(high or low)..min. 5 ns
Input HIGH voltage:	.... min. 2.0 V
Input LOW voltage:	.... max. 0.8 V
Output impedance:	(series resistor, Carry outputs)..................................... 33 Ω / 0.1 W
Output HIGH voltage:	I_{OH} = -0.1 mA .... min. 3.1 V
Output LOW voltage:	I_{OL} = 0.1 mA.. max. 0.2 V

TTL TAG inputs 0…15

Location:	.... ref. TTL TAG input port connector
R PULL-DOWN:	....110 Ω
Input HIGH voltage:	.... min. 2.0 V
Input LOW voltage:	.... max. 0.8 V
Time resolution:	....6.4 ns
Sampling uncertainty:	TAG to cor. STOP: .... ± 6.4 ns
Pulse width:	.... >12.8 ns

TTL TAG clock output

Location:	.... ref. TTL TAG input port connector
Output frequency:	....156.25 MHz
Output period:	....6.4 ns
Output HIGH voltage:	$I_{Out\ HIGH}$ = 128mA.. min. 2.0 V
Output LOW voltage:	$I_{Out\ LOW}$ = 64mA .... max. 0.4 V
Output HIGH current:	.... max. −128 mA
Output LOW current:	.... max. 256 mA

LVDS TAG inputs 0…15

Connector:	.... 68 pin HD-SMC (male)
	.... ERNI type 114807 SMC 68m
Location:	(optional only) .... internal
R differential:	....100 Ω
	detail of each input: .... 100 Ω to GND and 100 Ω to +2.5 V
Input differential volt.:	.... min. ±100 mV
	.... typ. ±350 mV

Input common-mode volt.: (diff. ±350 mV)... min. 0.2 V
.... typ. 1.25 V
.... max. 1.8 V

Time resolution: ....6.4 ns

Sampling uncertainty: TAG to cor. STOP: ....± 6.4 ns

Pulse width: .... >12.8 ns

LVDS TAG clock output

Connector: .... ref. LVDS TAG inputs

Output frequency: ....156.25 MHz

Output period: ....6.4 ns

Output differential volt.: R_{Diff} = 100 Ω .... min. 250 mV
....typ. 350 mV
....max. 400 mV

Output common-mode volt.: R_{Diff} = 100 Ω .... min. 1.125 V
.... typ. 1.2 V
....max. 1.375 V

8.3. Diagrams

8.3.1. START / STOP Input Reflection

Below one sees a fast negative pulse edge and its reflection on a START / STOP input. In the lower window the reflected signal is magnified in time. The red cursor lines indicate the reflected pulse amplitude.
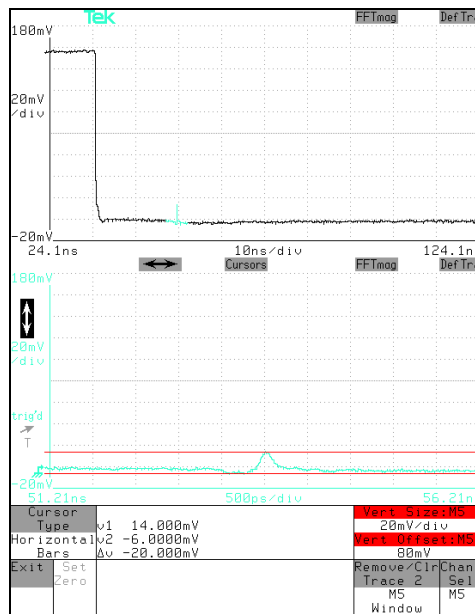

Fig. 8.1: START/STOP input pulse reflection

8.3.2. Discriminator Sensitivity and Monitor Output

In the pictures below STOP 1 is monitored on the SYNC_1 output. When the input signal height falls below 10 mV, adjustment of the threshold level gets tricky and the monitor signal shows a large uncertainty in pulse width. Keep in mind that the hysteresis is about 5 mV.
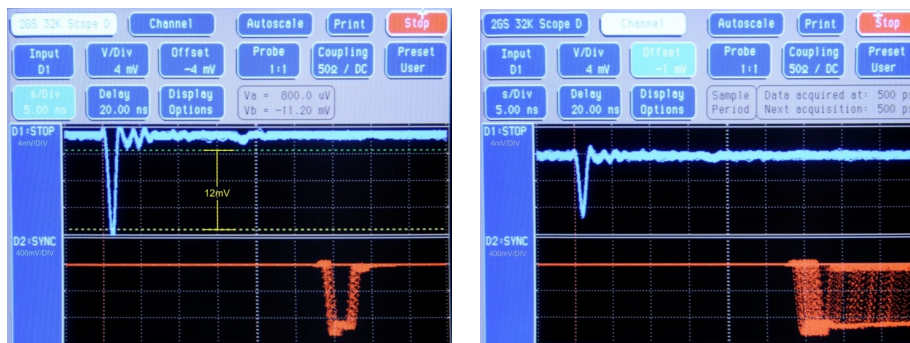
Fig. 8.2: 12mV and 8mV input pulses and cor. SYNC_1 MONITOR outputs[19]

---

[19] These pictures are taken with a 2 GS/s, 500 MHz digital scope

---

And from the acquired spectra it can be seen that with input signal amplitudes below 10 mV the noise floor is increasing. But still with the 8 mV pulses the noise is about 6 orders of magnitude below the signal.
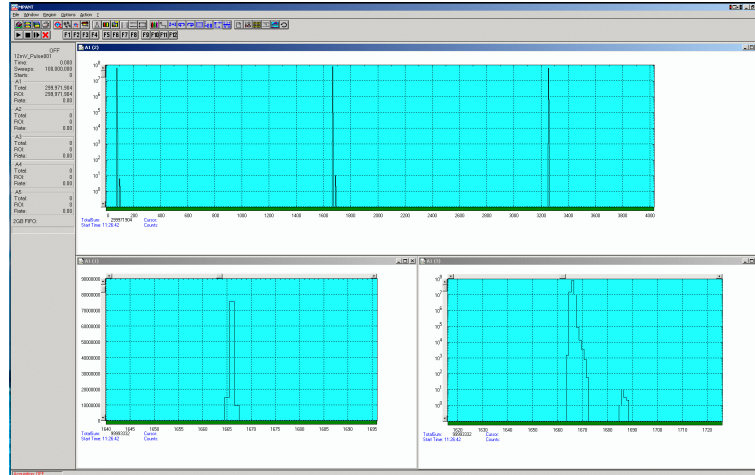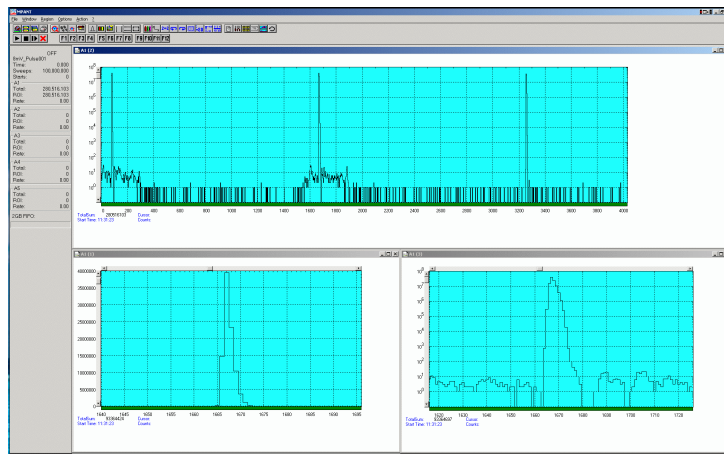

Fig. 8.3: Spectrum of 12 mV pulses

Fig. 8.4: Spectrum of 8 mV pulses

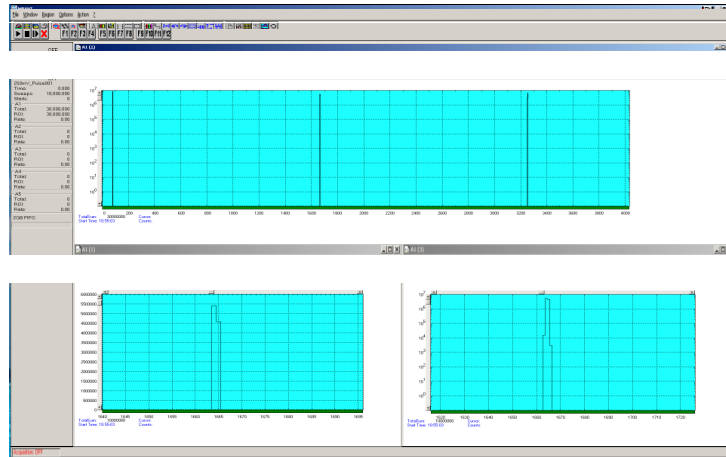Compare the perfect spectrum of the same signal with the original, not attenuated pulse height of 250 mV (Fig. 8.5).
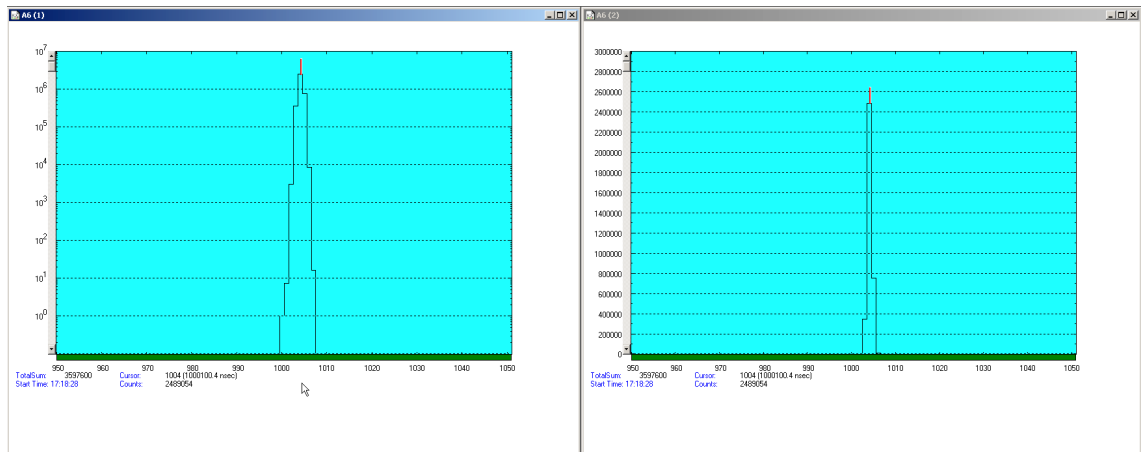
Fig. 8.5: Spectrum of 250 mV pulses

8.3.3. Peak Resolution at different Time Ranges
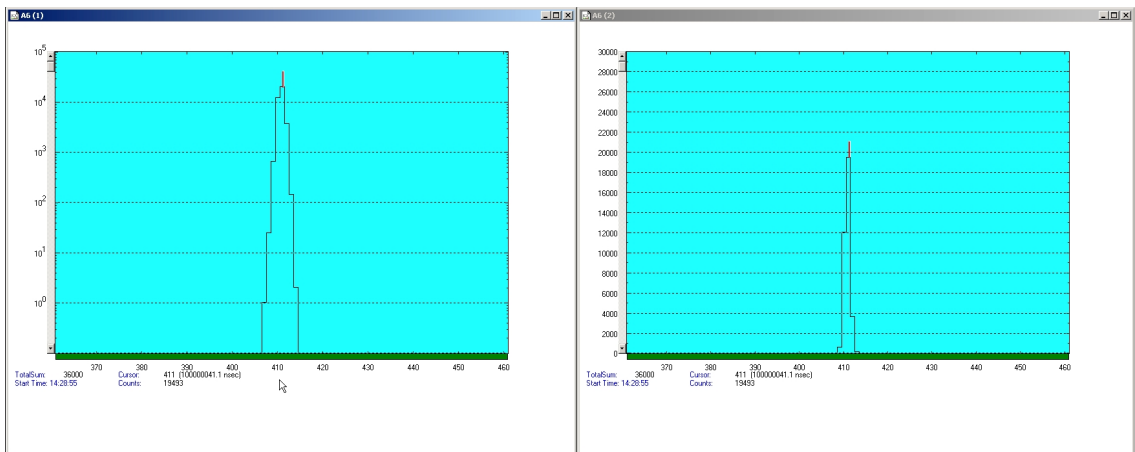

Fig. 8.6: Peak Resolution at 1 ms after the Trigger

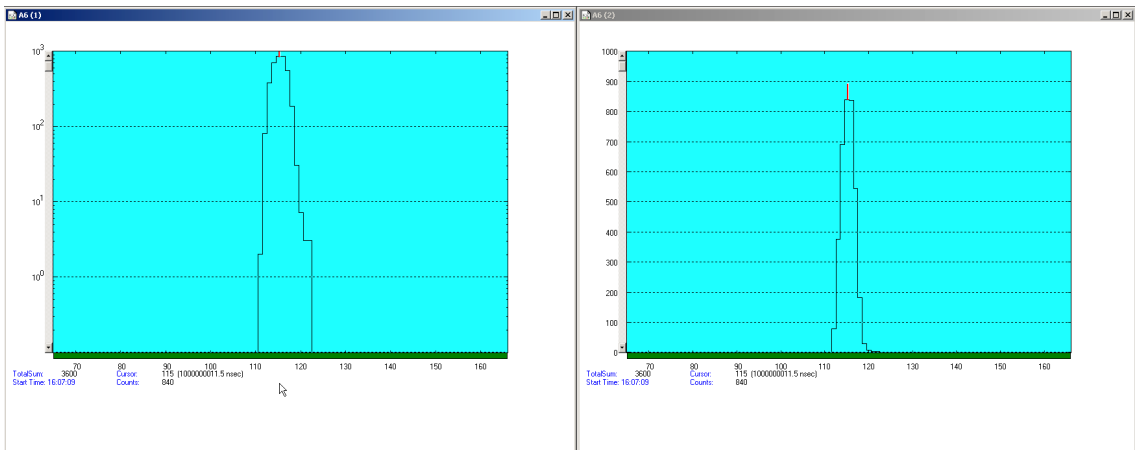**Fig. 8.7: Peak Resolution at 100 ms after the Trigger**

Fig. 8.8: Peak Resolution at 1,000 ms after the Trigger
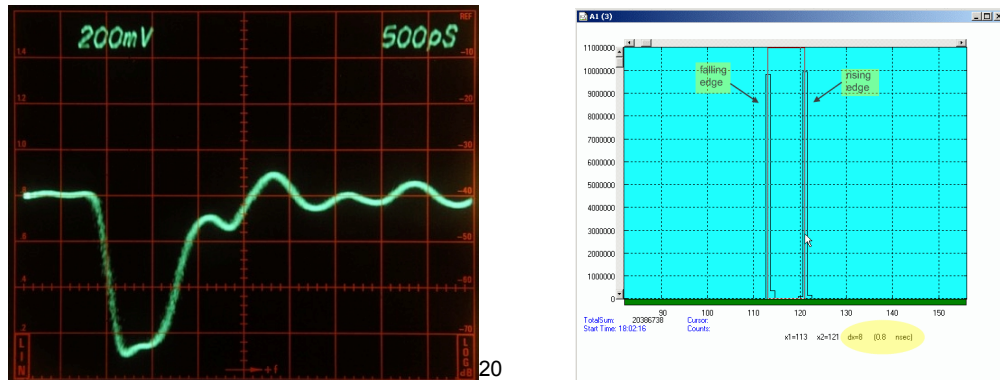
8.3.4. Pulse Width Measurement

Fig. 8.9: Pulse width measurement

8.3.5. Fast-NIM SYNC_1 Output

Fig. 8.10: SYNC_1 output signals[21]: fall time, rise time, 200 MHz clock
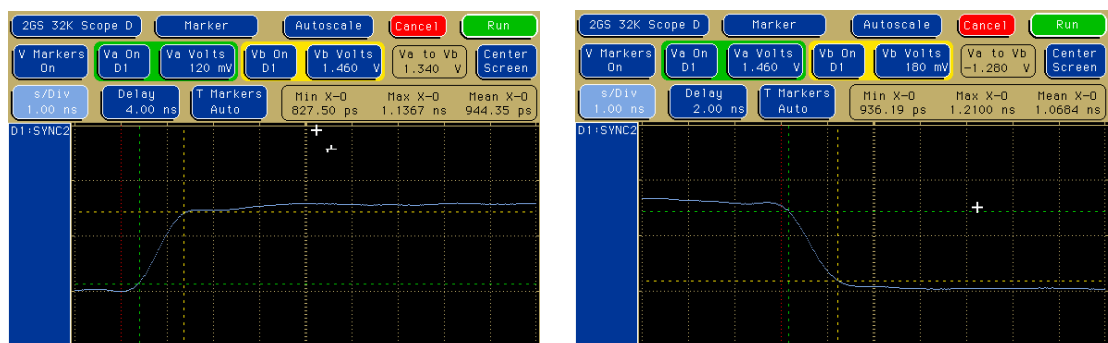
8.3.6. SYNC_2 Output

Fig. 8.11: SYNC_2 output signals: rise time, fall time[22]

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[20] This scope picture is taken with a 12 GHz loop through sampling head

[21] These scope pictures are taken with a 14 GHz, 50 Ω sampling head

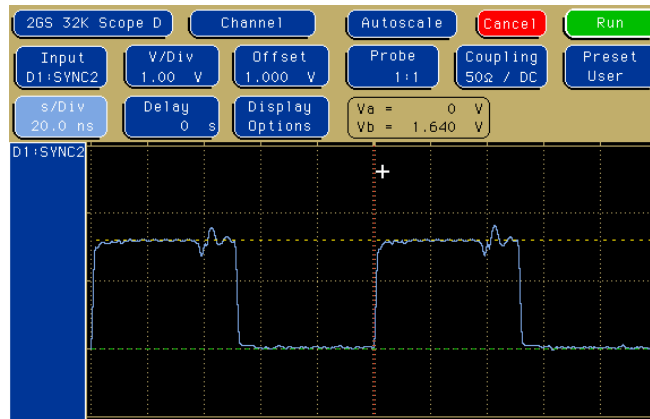[22] These pictures are taken with a 2 GS/s, 500 MHz digital scope

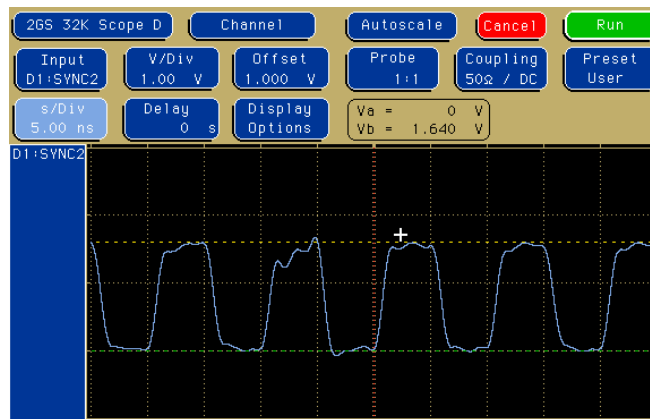**Fig. 8.12: SYNC_2 10 MHz clock output signal**

Fig. 8.13: SYNC_2 100 MHz clock output signal

8.3.7. PRBS Sync Output

A Pseudo Random Bit Sequence (PRBS) generator produces a quasi random sequence of bits with 5ns width each. This can be usefull e.g. for testing of the cables of an experimental setup.
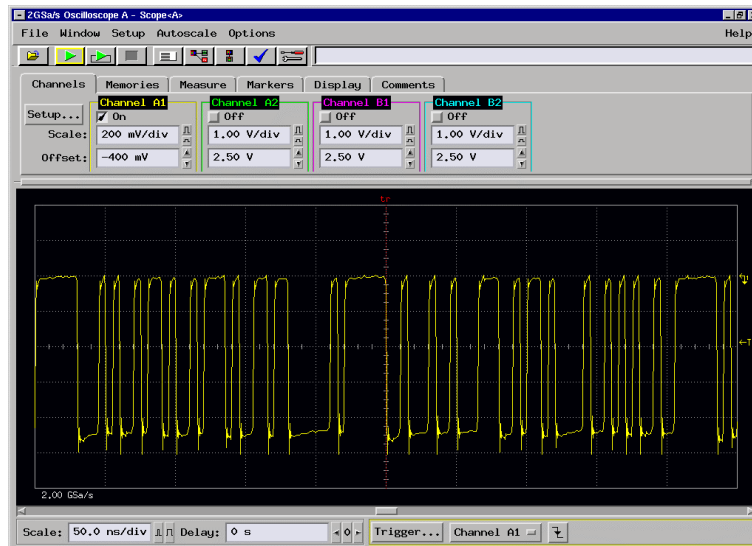
Fig. 8.14: PRBS signal at SYNC_1

Fig. 8.15: Eye diagram using the PRBS output

NOTE: The PRBS signal is not a real noise signal. It is synchronous to the internal reference clock. Thus, you cannot expect a real noise spectrum when fed to a STOP input.

8.3.8. ADC port DRDY / DACC handshake

In the following scope pictures a FAST ComTec ADC model "7072" was used.


Fig. 8.16: ADC port handshake

The minimum DRDY to DACC delay is approximately 211 ns. Since ADC and MPA4T work asynchronously to each other the response time varies by about 53 ns. The maximum time may also vary depending on the number of ADC data to be recorded simultaneously (ref. Fig. 8.17).

Fig. 8.17: ADC port handshake with 2 simultanously firing ADC's

In Fig. 8.17 two ADC's are connected and firing simultanously. Since the data is queued for transfer data acquisition may be delayed by about 211 ns per synchronously firing ADC in a port row. Thus, the DRDY to DACC delay maybe as long as 211 + 53 + 3 x 211 = 897 ns.
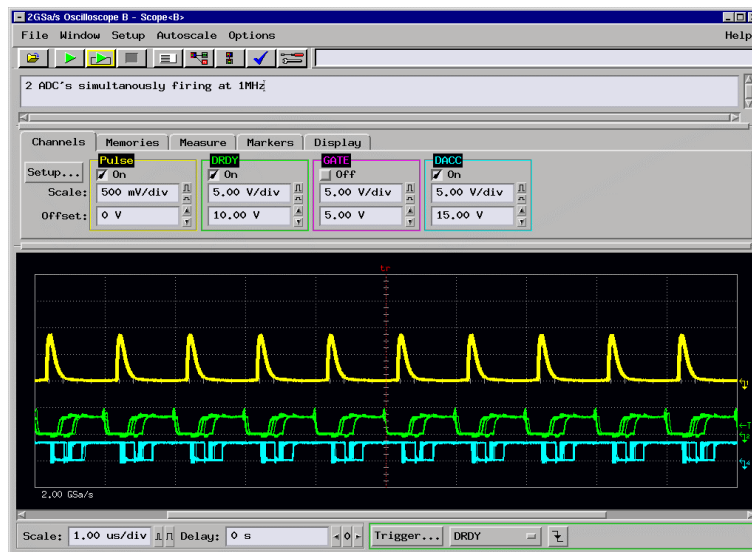
Fig. 8.18 : Handshake with 2 ADC's at a rate of 1MHz each

In Fig. 8.18 again 2 ADC's are connected and simultanously firing only that the event rate now is 1 MHZ each. In the accumulated graphs one can see that data acquisition still works without loss or disruption.

8.3.9. ADC GATE setup and hold time

In the following the "Individual GATE" was used in "COINC" mode which means that GATE must be logic high for the MPA4T to accept an ADC event.

Fig. 8.19: ADC GATE setup time

The GATE signal must be valid at about 210 ns after DRDY goes active which corresponds to a negative setup time.

For the above setup the GATE signal was delayed (i.e. shifted right) as long as no losses of events occurred (observed in the MPANT software).
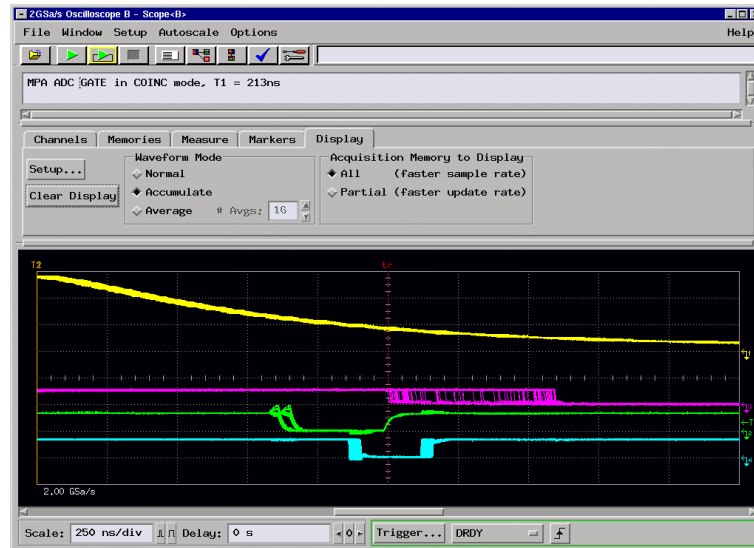

Fig. 8.20: ADC GATE hold time

The ADC GATE signal must be held valid until DRDY is removed.

Here the GATE delay was reduced (i.e. shifted left) as long as no event losses occurred.

NOTE: DRDY is only removed after DACC was set and this may vary largely (see Fig. 8.17).

8.4. Power Requirements

Connector: ....4 pin female

Supply voltage: .... nominal +12 V$_{DC}$

voltage range: .... +11 … +14 V$_{DC}$

Supply power: .... max. 8.5 A

8.5. Metal Case

Case material: ....aluminum

Size: .... 260 mm x 48 mm x 265 mm

Weight: .... net 9.2 kg, 10.5 kg incl. packaging

8.6. Accessories

Included:

- USB 2.0 (A/B) cable, 3 m

- SMA – BNC adapter cable, RG316, 2 m, (6x)

- Power supply 100-240 V$_{AC}$ / 12 V$_{DC}$

- Power supply cord

Optional:

- Cesium-disciplined internal 10 MHz reference oscillator

- TAx dc-coupled very high speed timing pre-amplifiers

- TD2000, 2 GHz timing discriminator

- 50 ps option: Three power splitters together with the software option described in chapter 5.1.12 allow 50 ps time resolution

Fig. 8.21: Power splitters for 50 psec option
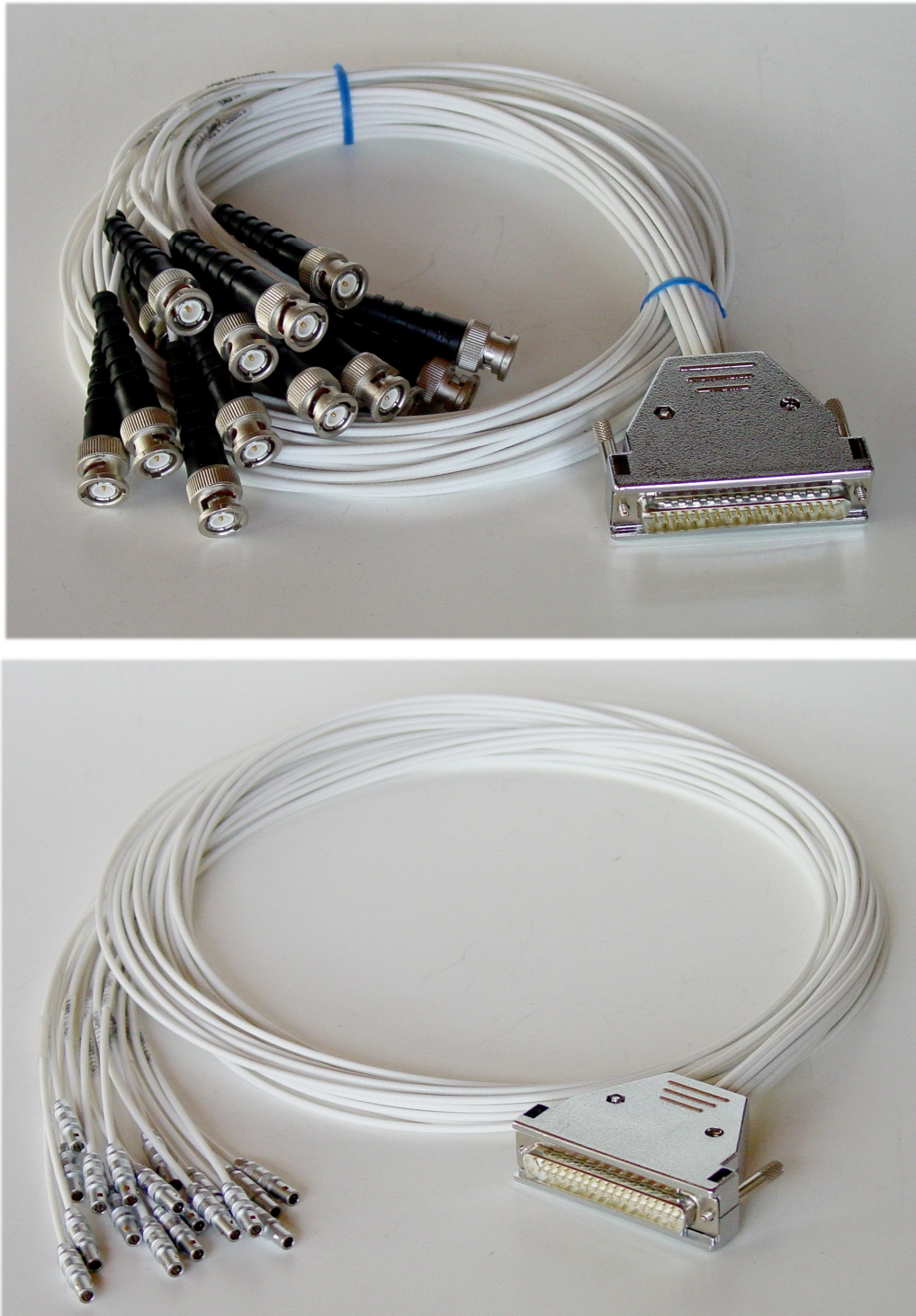
Fig. 8.22: Tagbit / Counter cable

The Tagbit / Counter cable is an adapter from the 37 Pin D-SUB connector to 18 seperated cables with BNC or Lemo connectors and can be used as well for the Tagbits as for the Counters, see Fig. 3.4 and Fig. 3.9. There is a 10 kOhm resistor between pin 19 and pin 37 to enable the tag bits.

8.7.   Trouble Shooting

- The 'POWER ON' LED does not light up:
  1) check that power is applied to the external power supply
  2) check the 12 V supply cable is properly plugged in
  3) check that the external power supply works – check it's output voltage

- No LED's of the input channels will light up a few seconds after power is applied:
  Please remove the power until the 'POWER ON' LED is dark and reapply power

- The MPA4T is not found by the host computer:
  1) Check that USB 1 is properly connected
  2) Remove the MPA4T power supply, wait for about 10 seconds and reapply power

8.8.   Personal Notes