MCS8A-1

1(2) Input 80 ps Multi-stop TDC,

Multiscaler, Time.Of-Flight

User Manual

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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.

Table of Contents

1 Introduction 9
2 Installation procedure 11
2.1 Hard- and Software Requirements 11
2.2 Driver Installation 12
2.3 Software Installation 14
2.4 Hardware Installation 14
2.5 Getting Started 15
2.5.1 Initial calibration 15
2.5.2 1st Basic Measurements 15
2.5.3 2nd Introductional Measurement 17
2.5.4 Pulse-Width Measurement 18
2.5.5 Fluorescence livetime imaging microscopy 22
2.5.6 Installing more than one MCS8A module 23
2.6 Models and Upgrade Options 23
3 Hardware Description 25
3.1 Overview 25
3.2 START / STOP Inputs 25
3.3 SYNC Outputs 27
3.4 TAG Inputs 29
3.5 ‘GO’-Line 29
3.6 FEATURE I/O Connector 30
3.7 Time Base / Reference Clock 30
3.8 200 MHz Counter / Timer 31
4 Functional Description 33
4.1 Introduction 33
4.2 Modes of Operation 33
4.2.1 Stop-After-Sweep Mode 33
4.2.2 Endless Mode 35
4.2.3 Tagged Spectra Acquisition 35
4.3 FIFO Concept 36
5 Software Description 37
5.1 Server functions 37
5.1.1 Initialization files 38
5.1.2 Action menus 38
5.1.3 File menu 38
5.1.4 Settings dialog 41
5.1.5 Scaler Setting 45
5.1.6 System Definition 46
5.1.7 Calculated Spectra dialog 48
5.1.8 Conditions 49
5.1.9 Scaler spectra 53
5.2 File formats 56
5.3 Control Language 60
5.4 Controlling the MCS8 Windows Server via DDE 66
5.4.1 Open Conversation 66
5.4.2 DDE Execute 66
5.4.3 Close Conversation 68
5.5 Controlling the MCS8 Windows Server via DLL 70
6 MPANT Software 71
6.1 File Menu 72
6.2 Window Menu 75
6.3 Region Menu 76
6.4 Options Menu 81
6.5 Action Menus 92
7 Programming and Software Options 94
8 Appendix 95
8.1 Performance Characteristics 95
8.1.1 General 95

8.1.2 Time base 95
8.2 Specifications 96
8.2.1 Absolute Maximum Ratings 96
8.2.2 Recommended Operating Conditions 96
8.2.3 Signal Connectors 96
8.3 Diagrams 99
8.3.1 Discriminator Sensitivity and Monitor Output 99
8.3.2 SYNC_1 Output 100
8.3.3 SYNC_2 Output 101
8.4 Physical 102
8.5 Accessories 102
Optional: 102
8.6 Trouble Shooting 104
8.7 Personal Notes 105

Table of Figures

Fig. 1.1: MCS8A-1 transport case 9
Fig. 2.1: Device Manager 12
Fig. 2.2: Driver Installation 12
Fig. 2.3: Choosing the right folder 13
Fig. 2.4: Device Manager after successful driver installation 13
Fig. 2.5: MCS8A-1 rear panel 14
Fig. 2.6: MCS8 Settings window 15
Fig. 2.7: Axis Parameter window 16
Fig. 2.8: Input Thresholds and ROI Presets window 17
Fig. 2.9: Spectrum of a 10 MHz clock signal 17
Fig. 2.10: MCS8 Settings – Acquisition Delay 18
Fig. 2.11: Spectrum with 76.8 ns acquisition delay 18
Fig. 2.12: Inputs setup for a pulse width measurement 19
Fig. 2.13: MCS8 Settings for a pulse width measurement 19
Fig. 2.14: MAP and Isometric View of a pulse width measurement 20
Fig. 2.15: MAP View display options 20
Fig. 2.16: Single Display Options 21
Fig. 2.17: Single View of a pulse width measurement 21
Fig. 2.18: Single Display Options 21
Fig. 2.19: Editing MCS8.INI for the FLIM application 22
Fig. 2.20: Editing MCS8.INI for 2 devices 23
Fig. 3.1: MCS8A-1 front panel 25
Fig. 3.2: START / STOP inputs 26
Fig. 3.3: MONITOR signal of a STOP input 26
Fig. 3.4: Fast-NIM SYNC_1 output schematic 28
Fig. 3.5: TAG input schematic 29
Fig. 3.6: Schematic of the FEATURE I/O connector 30
Fig. 3.7: 200 MHz Counter / Tag bit Connector 31
Fig. 3.8: 200 MHz Counter – Simplified Control Logic 32
Fig. 4.1: Simplified timing diagram 34
Fig. 4.2: FIFO concept 36
Fig. 5.1: MCS8 Server Window 37
Fig. 5.2: MCS8.ini File 38
Fig. 5.3: Data Operations dialog for MPA data (left) and selected spectra (right) 39
Fig. 5.4: Replay Settings dialog 39
Fig. 5.5: About MCS8 dialog box and Installed Options 40
Fig. 5.6: Settings dialog 41
Fig. 5.7 Inspect MCS8 Dialog 43
Fig. 5.8: Input Thresholds Dialog 43
Fig. 5.9: Principle of “Software CFT” 44
Fig. 5.10 Scaler Settings dialog box 45
Fig. 5.11 Left: MCS8-Scaler Status utility, right: as ratemeter 45
Fig. 5.12: System Definition dialog box 46
Fig. 5.13: System Definition dialog box, two MCS8 modules 47
Fig. 5.14: Remote control dialog 47
Fig. 5.15: Dual parameter and Calculated spectra dialog box 48
Fig. 5.16: Multi Display Setting 48
Fig. 5.17: Calculated Spectrum Setting 49
Fig. 5.18: Conditions 50
Fig. 5.19: Conditions 50
Fig. 5.20: ROI Conditions dialog 51
Fig. 5.21: Combine Conditions dialog 51
Fig. 5.22: Test acquisition with calculated spectra 52
Fig. 5.23: Creating a scaler spectrum 53
Fig. 5.24: Setting parameters of a scaler spectrum 53
Fig. 5.25: Scaler spectrum 54
Fig. 5.26: Using a condition in a scaler spectrum for a calculated spectrum 54
Fig. 5.27: Calculated spectrum with a condition set on a ROI in a scaler spectrum 55

Fig. 5.28: Opening the DDE conversation with the MCS8 server in LabVIEW....66
Fig. 5.29: Executing a MCS8 command from a LabVIEW application....67
Fig. 5.30: Getting the range of spectrum data with LabVIEW....67
Fig. 5.31: Getting the data with LabVIEW....68
Fig. 5.32: Closing the DDE communication in LabVIEW....68
Fig. 5.33: Control Panel of the demo VI for LabVIEW....69
Fig. 6.1: MPANT main window....71
Fig. 6.2: MPANT Map and Isometric display....72
Fig. 6.3: File New Display dialog....73
Fig. 6.4: Compare dialog....74
Fig. 6.5: Compare two spectra....74
Fig. 6.6: Print dialog....75
Fig. 6.7: Slice and rectangular ROI Editing dialog....78
Fig. 6.8: Polygonal ROI Editing dialog....78
Fig. 6.9: Single Gaussian Peak Fit....79
Fig. 6.10: Evaluation of a non-Gaussian peak....80
Fig. 6.11: Log file Options....80
Fig. 6.12: Colors dialog....81
Fig. 6.13: Color Palette dialog....82
Fig. 6.14: Single Display Options dialog....82
Fig. 6.15: Map Display Options dialog....83
Fig. 6.16: Isometric Display Options dialog....83
Fig. 6.17: Axis Parameters dialog....84
Fig. 6.18: Scale Parameters dialog....85
Fig. 6.19: Calibration dialog....86
Fig. 6.20: Comments dialog....87
Fig. 6.21: Settings dialog box....88
Fig. 6.22: Data Operations dialog....89
Fig. 6.23: System Definition dialog box....89
Fig. 6.24: Spectra dialog....90
Fig. 6.25: Slice dialog....90
Fig. 6.26: Replay dialog....90
Fig. 6.27: Tool Bar dialog....91
Fig. 6.28: Function keys dialog....91
Fig. 6.29: MPANT with four systems enabled....93
Fig. 8.1: 13mV input pulses and cor. SYNC_1 MONITOR outputs....99
Fig. 8.2: 10mV input pulses and cor. SYNC_1 MONITOR outputs....99
Fig. 8.3: 10 MHz signal at SYNC_1 output....100
Fig. 8.4: 100 MHz signal at SYNC_1 output....100
Fig. 8.5: 195.3125 MHz signal at SYNC_1 output....100
Fig. 8.6: 10 MHz signal at SYNC_2 output....101
Fig. 8.7: Counter Cable BNC or Lemo....103

WARNINGS

The metal case of the MCS8 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 MCS8. 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 Model MCS8A-1 is a 80 ps 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.

For MCS8A devices with an optional lower time resolution of 100 ps all timing data apply accordingly.

A unique feature is the MCS8A'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.

Fig. 1.1: MCS8A-1 transport case

Pulse-width evaluation with 80ps 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 MCS8'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.

In standard operation a sweep is started by a user supplied start (trigger) pulse. Then subsequent events detected at the STOP input 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 MCS8A-1 can evaluate stop events at a rate of 12.5 GHz state changes per second. In the pulse-width mode pulses as narrow as 80ps can be evaluated at a pulse repetition rate of up to 6.25 GHz. The MCS8A-1 is designed with fully digital circuitry capable of accepting at least 131,072 events at peak (burst) input rates of up to 12.5 Gbit/s for each input.

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The MCS8A-1 has been optimized for the best pulse pair resolving while providing state-of-the-art time resolution available in digital designs. Two 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.

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

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

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

The single sweep time range enables the user to take data of up to 8.3 days (53bit setting) or 6 minutes (42 bit setting plus 16 TAG bits enabled) with a time resolution of 80 ps.

An internal oven stabilized 10 MHz reference clock is optional. Via the reference I/O the already excellent stability of the internal oven controlled crystal oscillator can be further improved by connecting an external reference clock source such as a GPS or rubidium-disciplined oscillator with an arbitrary frequency in a range between about 5 and 100 MHz in steps of 1 MHz.

The FIFO memory buffers enable to MCS8A-1 to continuously transfer data rates of approximately 240 MByte/s to the connected computer. Available are FIFOs as large as 4 GB.

Selection of data width per event of 32 or 64 bits allows for optimized FIFO and USB bandwidth usage.

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.

The MCS8A-1 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 MCS8A-1) providing a powerful graphical user interface for setup, data transfer and spectral data display.

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. The Windows software can run on a Linux system using a modified Wine.

1 I/O: Input / Output
2 ROI: Region Of Interest
3 FWHM: Full Width at Half Maximum

2 Installation procedure

2.1 Hard- and Software Requirements

For operating the MCS8A-1 you need a standard PC with a high-speed USB 2.0 or USB 3.0 port and Microsoft Windows XP or higher. USB 1.0 ports do not work. The maximum throughput rate is approximately 32 Mbyte/sec on a USB 2.0 port and 240 Mbyte/sec on a USB 3.0 port. This throughput rate is somewhat dependent on the computer hardware and operating system.

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 or USB 3.0 / USB 3.1 port.

Older PCs that do not have USB 3.0 on the motherboard can use a PCI / PCIe card providing USB 3.0 / USB 3.1 Gen1 ports.

First check you have all shipped equipment available:

- Carrying case
- MCS8A-1 module
- Power supply module 100…240 V AC / 12 V DC out
- Power line cord
- USB 3.0 (A/A) cable
- User manual
- CD with operating software
- 2 cables BNC-SMA, RG316
- 1 cable SMA-SMA, RG316 (30 cm) for tests SYNC1 → START
- 1 SMA-BNC adapter
- D-sub15 HD plug with plastic cap
- D-sub37 plug with plastic cap

Please connect the power to the MCS8A never before the PC power is on and the Windows OS is running!

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.

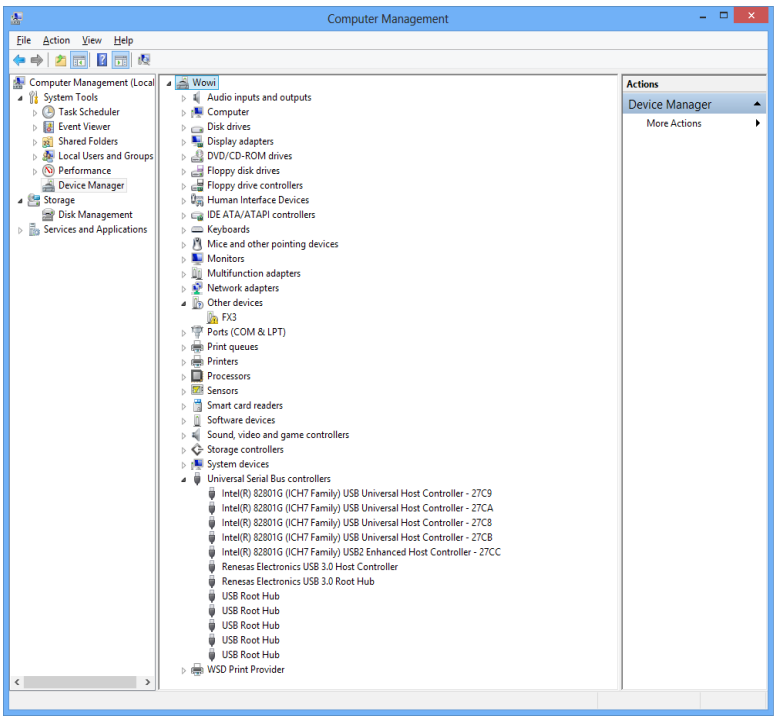


Fig. 2.1: Device Manager

The new device is displayed as ”FX3” in a class ”Other devices”. Please right-click it and select ”Update driver” from the drop-down menu.

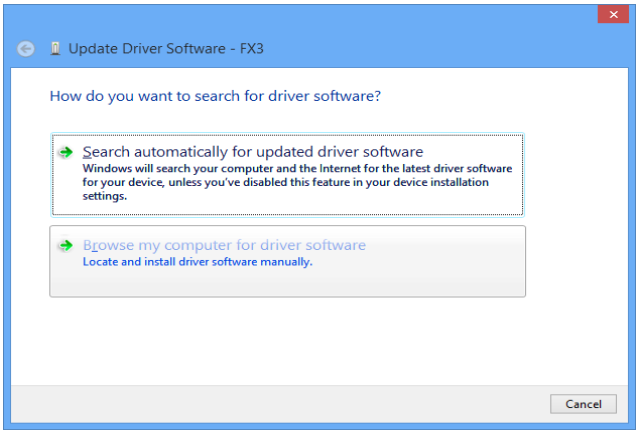


Fig. 2.2: Driver Installation

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 7 or 8 or 10 the driver\fastusb3 on the CD.

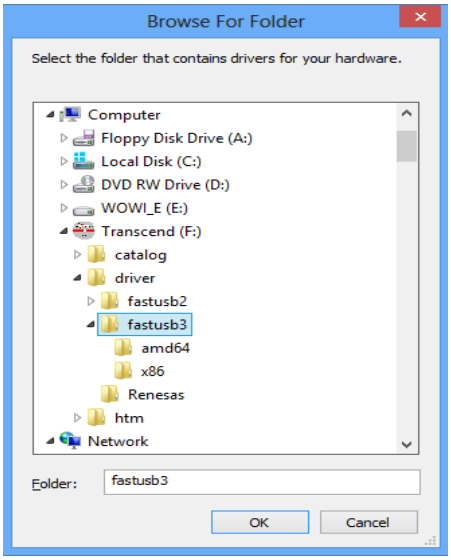


Fig. 2.3: Choosing the right folder

Please don't go deeper into the folder structure, the processor type (x86, amd64, etc.) is found automatically. After pressing "OK" the driver installation will proceed. The device manager will then show a "FAST ComTec USB3 Device" in a class "libusb (WINUSB) devices" as shown in Fig. 2.4.

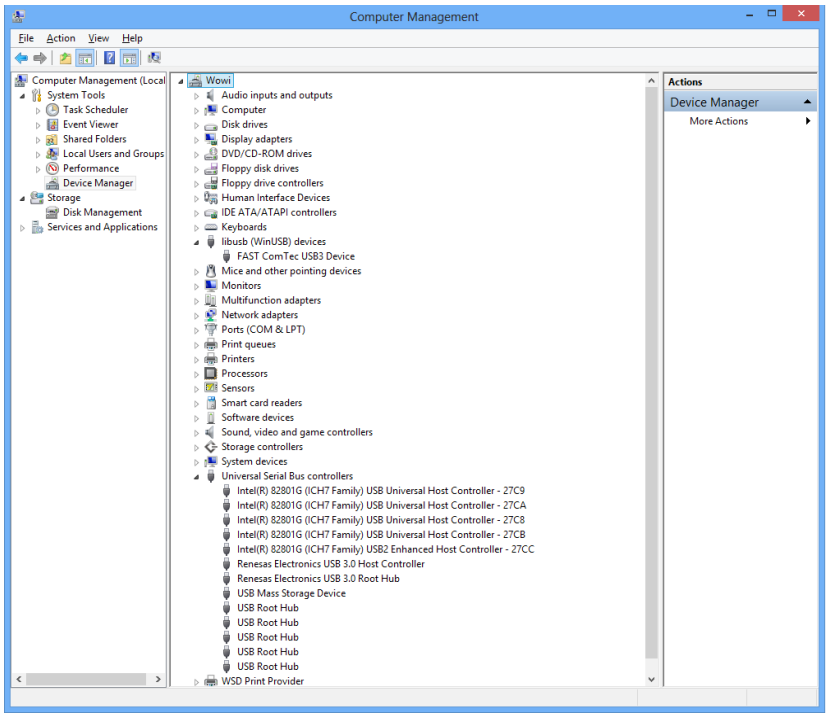


Fig. 2.4: Device Manager after successful driver installation

If there is an exclamation mark at the driver and there is an error message that the device could not start, please remove the power from the MCS8 device and reconnect it. If you don't see the device at all, it is possible that the USB3 driver must be updated. For a Renesas USB3 controller there is an update program on the software disk in the driver\Renesas folder.

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

To install the MCS8 software on your hard disk insert the installation medium (CD or USB Stick) and start the installation program setup.exe for the 32-bit software or setupx64.exe for the native 64-bit software.

A directory called C:\MCS8 for the 32-bit software or C:\mcs8x64 for the native 64-bit software is created on the hard disk and all MCS8 and MPANT files are transferred to this directory. Drive C: is taken as default drive and \mcs8x64 as default directory. It is not mandatory that the MCS8 operating software is located in this directory. You may specify a different directory during the installation or may copy the files later to any other directory.

The Setup program will install a shortcut on the desktop. The icon directly starts MCS8.EXE. The server program will automatically call the MPANT.EXE program when it is executed. The MCS8 Server program controls the MCS8 module but provides no graphics display capability by itself. By using the MPANT program, the user has complete control of the MCS8 along with the MPANT display capabilities.

To run the MCS8 software, simply double click on the “MCS8 Server Program“ icon. To close it, close the MCS8 server in the Taskbar.

2.4 Hardware Installation

Fig. 2.5: MCS8A-1 rear panel

Installation of the MCS8 is as easy as connecting a cable. As the USB 3.0 interface is compatible to USB 2.0 it is just a question of the maximum transfer speed which cables or host ports are used. Connect the power supply to the “POWER” connector and an USB cable to the “USB” port. At the host computer plug in the USB cable into a high-speed capable USB port. Since USB is a hot-pluggable interface the sequence of applying power and connecting the USB port is not important.

When the power is applied the “POWER ON” LED on the rear of the MCS8 should be lit. There is also a “POWER” LED o the front.

When the software and driver are already installed the computer will detect the MCS8 automatically as soon as it is connected.

2.5 Getting Started

2.5.1 Initial calibration

First step is to start the MCS8 software by double clicking the corresponding icon. This will automatically start the MCS8 server and the MPANT program. All hardware settings are accessible from the MPANT program which actually is the graphical user interface and which will appear now on your screen.

At the first start of the software after power up it takes some time to load the firmware and a calibration of the input delays is done automatically.

2.5.2 1st Basic Measurements

To ease getting familiar with the use of the MCS8A-1 we will now setup a first basic measurement. No external signal is needed, only a connection between the SYNC 1 connector and the START connector.

Start the MCS8 software by double clicking the corresponding icon. This will automatically start the MPANT program.

Now we first have to setup the MCS8A-1. What we will want to do is to setup the system such that we use the internal 10 MHz signal and acquire a spectrum of 4096 time bins using the START input channel.

Click on *Options – Hardware Settings…* or to find the MCS8 Settings window pop up. Set the Range to

4096 time bins (Bin width = 1), which corresponds to a time range of 327.6 ns. Enable *Sweep preset* and set it to e.g. 20,000,000. Verify that *Timepreset* is not checked (ref. Fig. 2.6). For the Sync1 signal select 10 MHz.

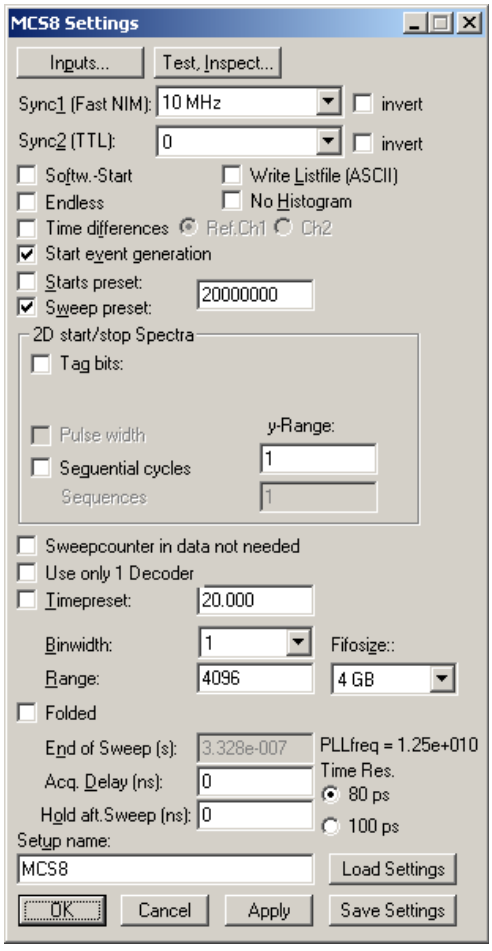


Fig. 2.6: MCS8 Settings window

Now click on *Inputs*…. Select *START (A2)* and deselect all other input channels. Check that *Falling Edge* is selected for *Start* (ref. Fig. 2.8). Set the threshold level of the Start input to FAST NIM. 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. 2.7).

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 seperated by 1250 bins 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. 2.9).

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.

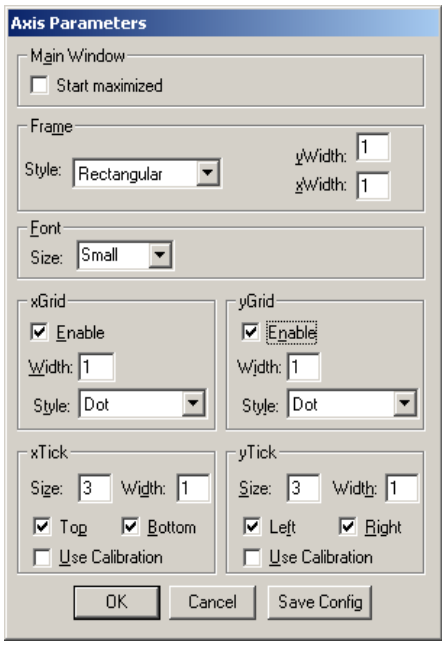


Fig. 2.7: Axis Parameter window

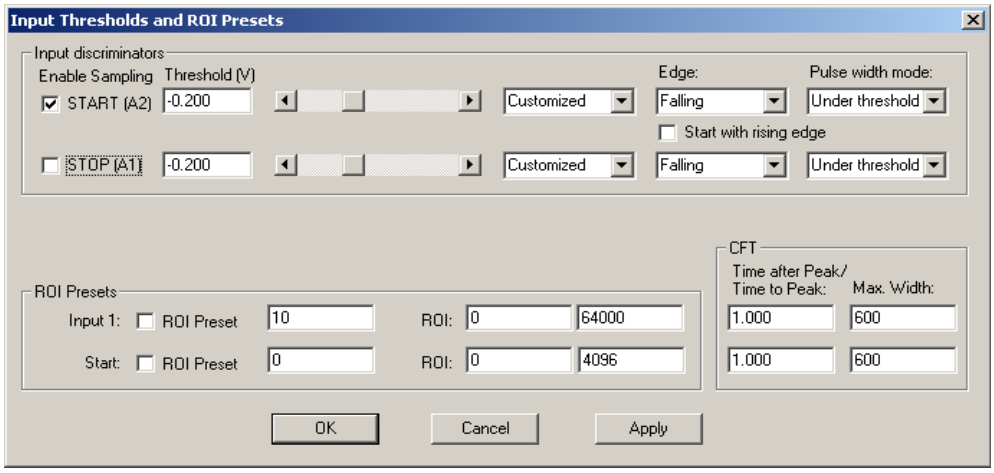


Fig. 2.8: Input Thresholds and ROI Presets window

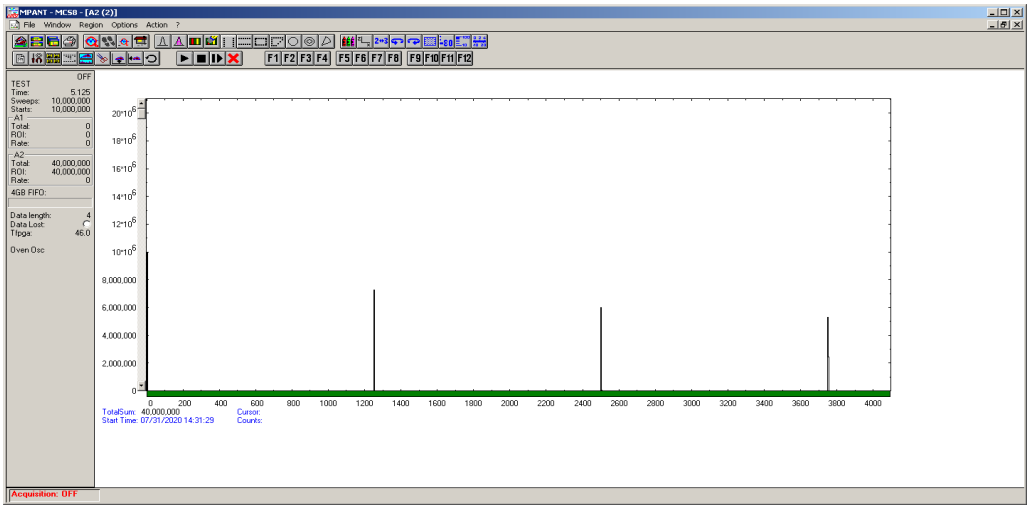


Fig. 2.9: Spectrum of a 10 MHz clock signal

2.5.3 2nd Introductional Measurement

Now we will introduce another feature of the MCS8A-1: 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 76.8 ns (settable in steps of 5.12 ns only) after the START event. Go to the MCS8 Settings window again and insert '76.8' in the Acq. Delay field (ref. Fig. 2.10). 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 76.8 ns.

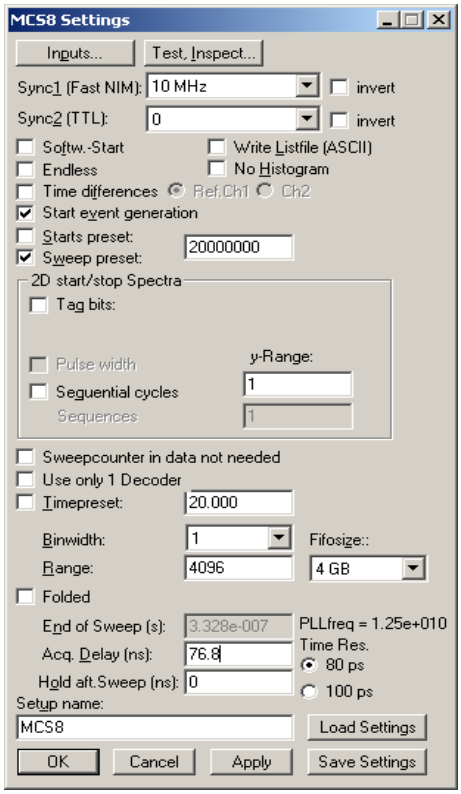


Fig. 2.10: MCS8 Settings – Acquisition Delay

Start acquisition and compare the delayed spectra data (ref. Fig. 2.11) with the above spectra that began instantly with the START pulse. The first peak in the new spectrum is at channel 290 corresponding to time bin 1250 in Fig. 2.9.

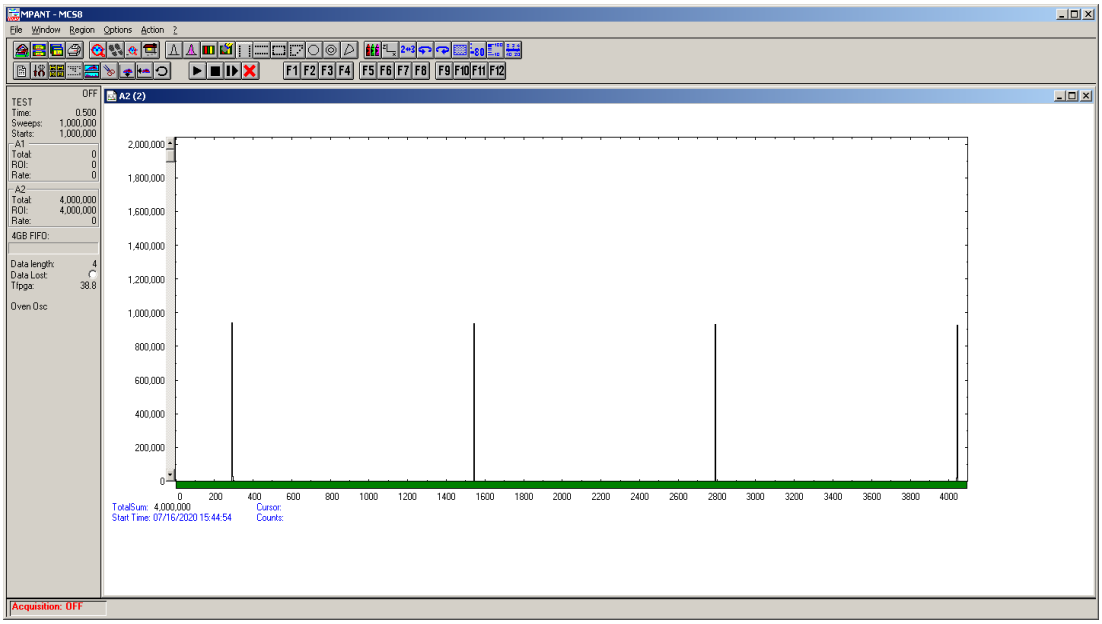


Fig. 2.11: Spectrum with 76.8 ns acquisition delay

2.5.4 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 Start with ‘Both Edges’ to be sampled (ref. Fig. 2.12). 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 100 ns. And, we start the sweeps with the first falling edge (‘Start with rising edge’ is not checked).

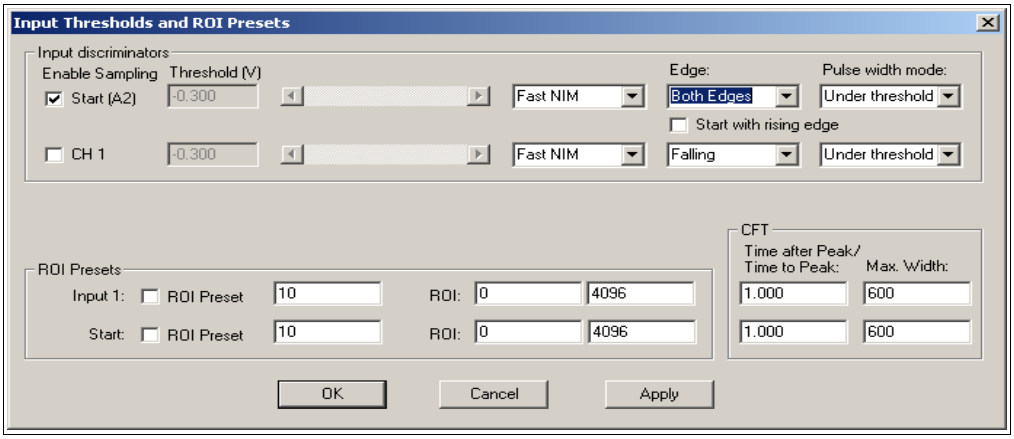


Fig. 2.12: Inputs setup for a pulse width measurement

Back in the ‘MCS8 Settings’ window make sure that ‘Pulse width’ is checked with an ‘y-Range’ of 2 for the falling and the rising edge (ref. Fig. 2.13). The acquisition delay should be ‘0’.

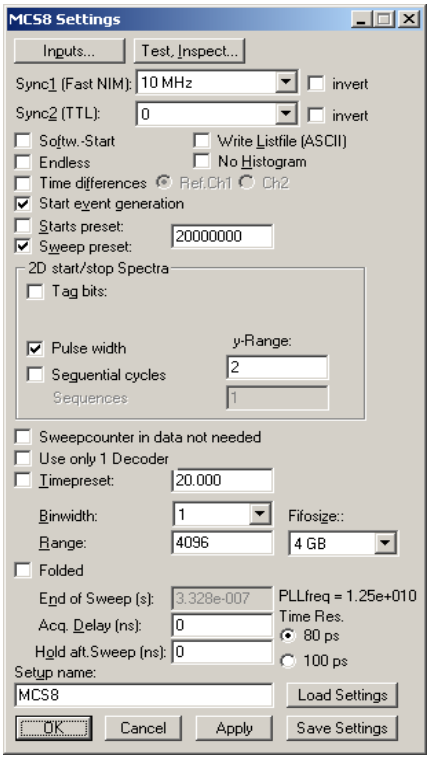


Fig. 2.13: MCS8 Settings for a pulse width measurement

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

you can toggle between the 2- and a 3-dimensional view.

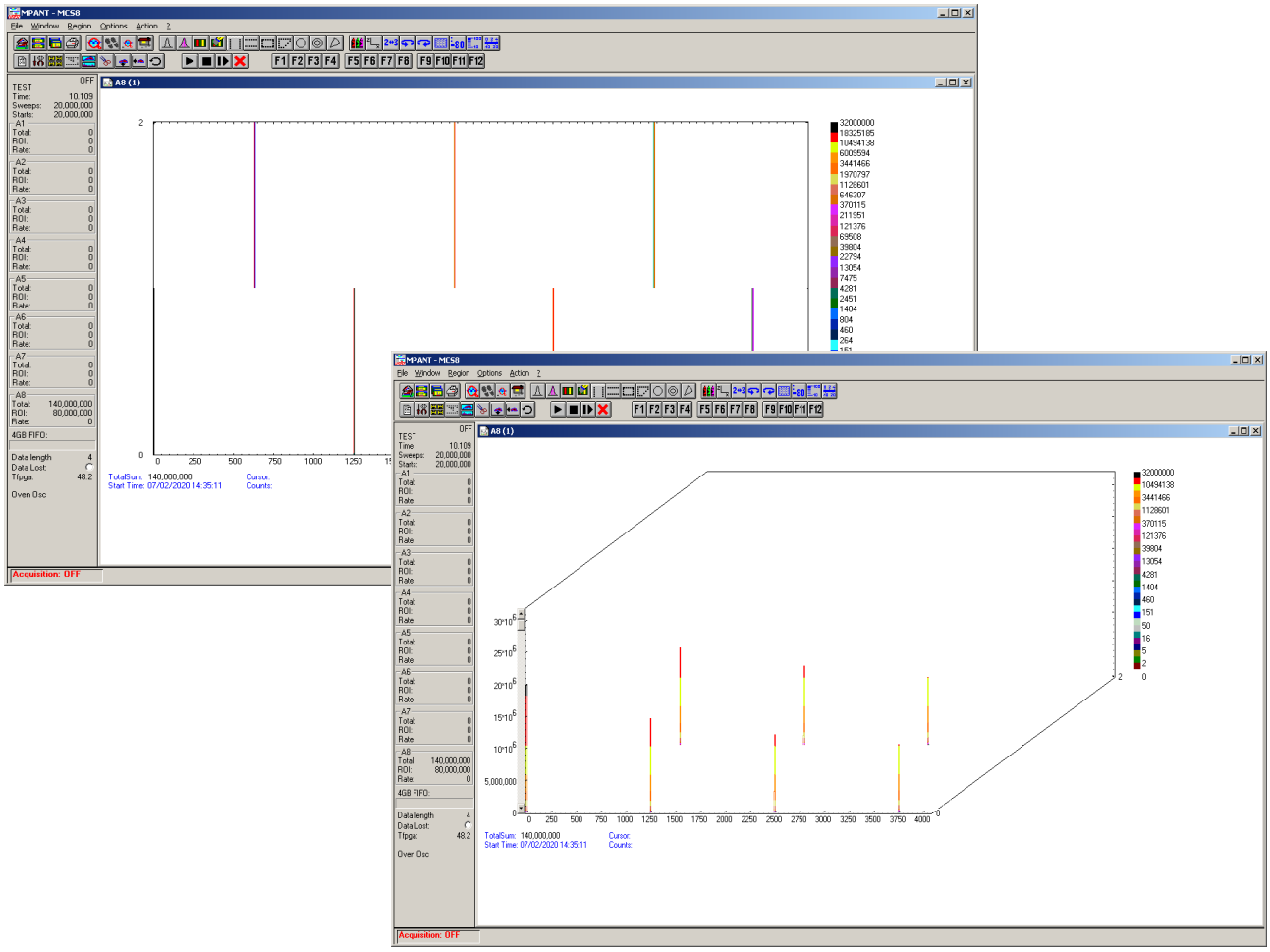


Fig. 2.14: MAP and Isometric View of a pulse width measurement

Go back to the 2-dimensional MAP view and then, click on *Options* – *Display…* and select '>> *Overlapped*' (Fig. 2.15).

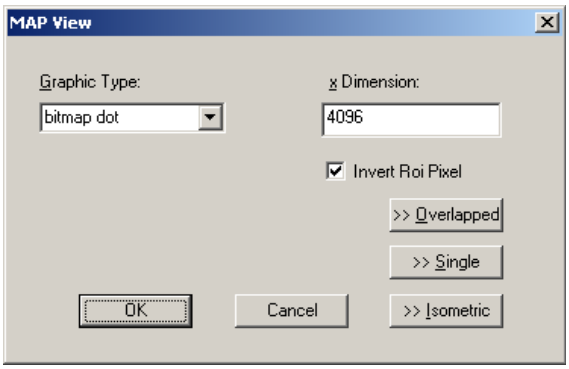


Fig. 2.15: MAP View display options

The spectrum display changes to a 2-dimensional spectrum with rising and falling edges that are drawn overlapped (ref. Fig. 2.17). With the Display Options window you can choose which edges should be in the fore- and background (Fig. 2.16). 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.

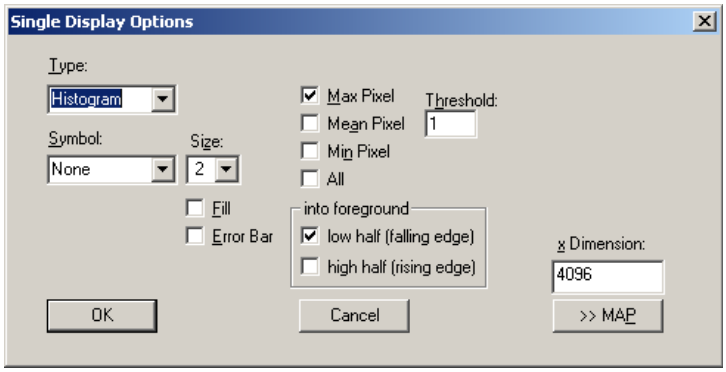


Fig. 2.16: Single Display Options

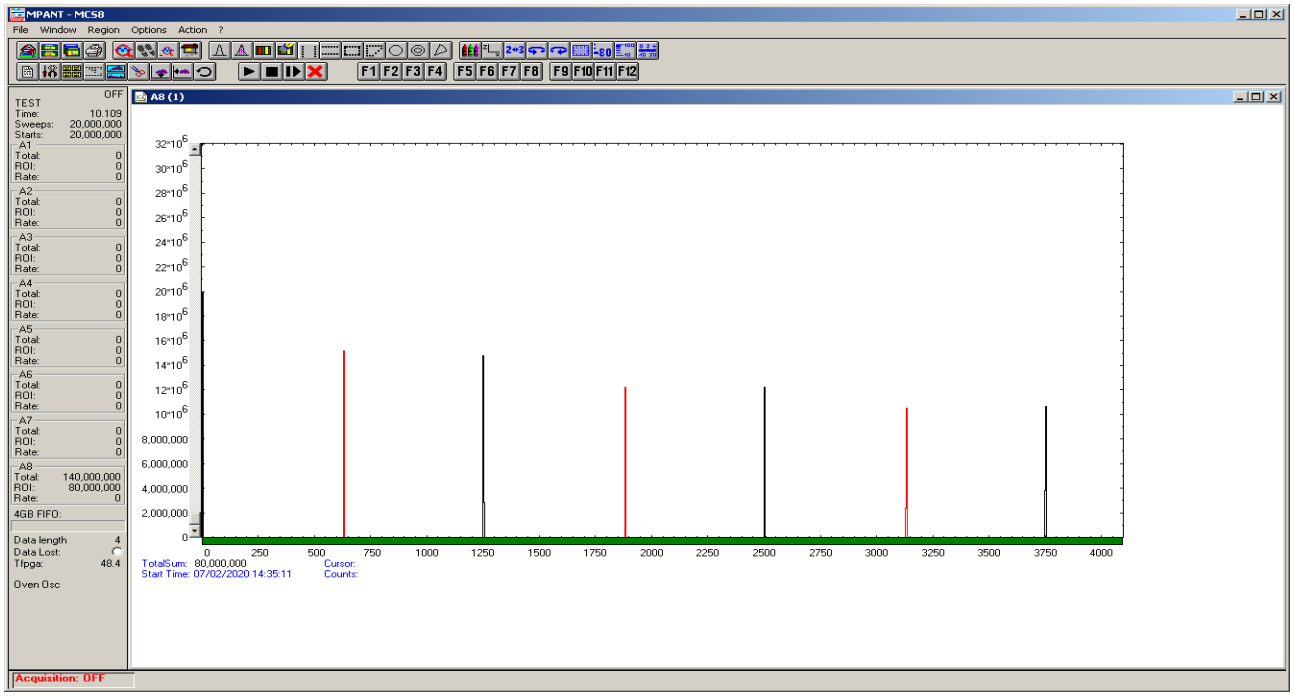


Fig. 2.17: Single View of a pulse width measurement

2.5.5 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 MCS8A-1, an external clock frequency of 76 MHz must be used.

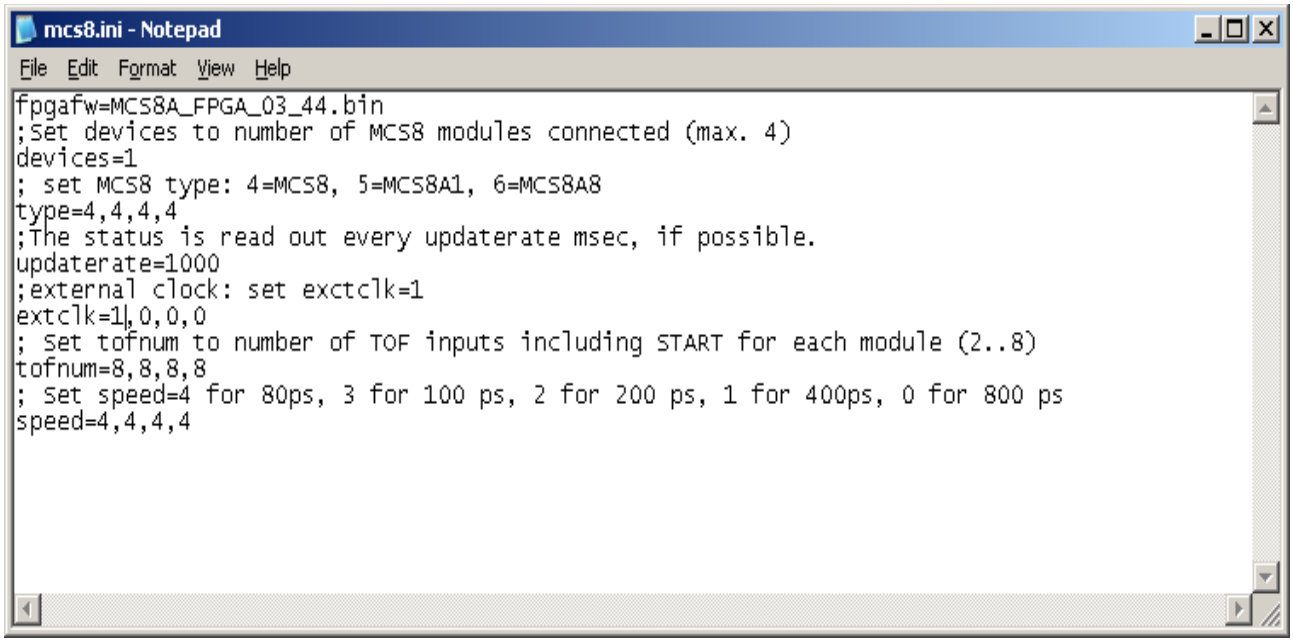


Fig. 2.19: Editing MCS8.INI for the FLIM application

First, edit the MCS8.INI file and set extclk=1 to indicate that an external clock is used, see Fig. 2.19.

After starting the software you will be prompted to connect the external clock signal to the CLOCK I/O connector at the rear. If the signal level is ok, the frequency will be recognized as 76 MHz and the MCS8 clock is now synchronized to the laser frequency. Now 164.5 time bins of a width of 80 psec will exactly correspond to the period of the 76 MHz laser frequency. It means that every two periods can be folded together and this way a time resolution of 40 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 165, bin 2, bin 166, ... , bin 163, bin 329, bin 164. The next 329 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 168448 bins corresponding to 2 x 256 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 240 MB/sec / 4 bytes = 60 MHz. The maximum burst rate is 300 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. Two up/down counters can also be used to count position movements from stepping motors for recording the beam position. Folding and interleaved folding is supported in the software, see chapter 5.1.4 .

2.5.6 Installing more than one MCS8A module

The software is able to operate up to 4 MCS8A modules with a single computer. Just connect them at an USB port, switch on the power, and install the driver when you are prompted. When starting the software, you will be asked to edit the MCS8.INI file as more than one MCS8A modules are found, and the notepad editor will be automatically started with MCS8.INI loaded. Edit the line "devices=1" accordingly and save the file.

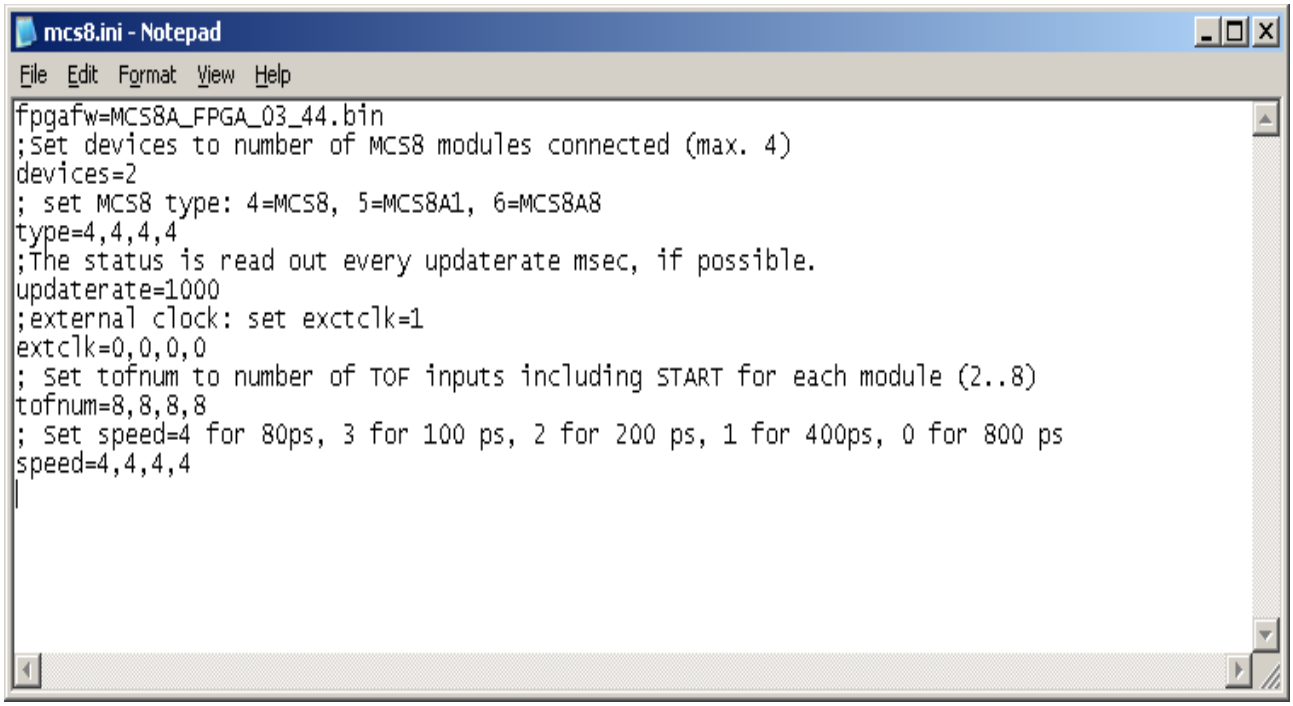


Fig. 2.20: Editing MCS8.INI for 2 devices

That is all you have to do, next time when you start the software all modules will be found and can be operated.

2.6 Models and Upgrade Options

The MCS8A-1 is available with one physical stop input beside the start input. The resolution is 80 ps, available are also 100 ps, 200 ps, 400 ps or 800 ps. The size of the FIFO can be 1 GB, 2 GB or 4GB. See the following table showing the available models.

Model	Description
MCS8A1T0	1+1 Input, 12.5 GHz TOF-Multiscaler, 80ps, 2GB Fifo, USB 3.0, field upgrade
MCS8A1T1	1+1 Input, 10 GHz TOF-Multiscaler, 100ps, 2GB Fifo, USB 3.0, field upgrade
MCS8A1T2	1+1 Input, 10 GHz TOF-Multiscaler, 200ps, 2GB Fifo, USB 3.0, field upgrade
MCS8A1T4	1+1 Input, 10 GHz TOF-Multiscaler, 400ps, 2GB Fifo, USB 3.0, field upgrade
MCS8A1T8	1+1 Input, 10 GHz TOF-Multiscaler, 800ps, 2GB Fifo, USB 3.0, field upgrade
MCS8D1Ty	1+1 Input, y=0,1,2,4,8 (80, 100, 200, 400, 800 ps) 1GB Fifo, no TAG, no oven
MCS8FIFO2	FIFO expansion to 2 GB, included in MCS8A1
MCS8FIFO4	FIFO expansion to 4 GB
MCS8TAG	16bit TAG input option, included in MCS8A1
MCS8OVX	Option oven controlled oscillator for MCS8, included in MCS8A1
MCS8DLL	DLL for LabVIEW/“C“/Visual Basic for MCS8

It is very easy to upgrade an MCS8A-1 for improved time resolution, or FIFO size. Buy a new Licence key and select in the start menu under Programs.. FAST ComTec MCS8.. the item ”Upgrade MCS8 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.

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

Model	**Description**
MCS8UP	Additional cost for in-field upgrade (+ price difference of versions involved)
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.
MCS8COUNT	6 x 200 MHz Counter (48 bit)

3 Hardware Description

3.1 Overview

The MCS8A-1 is a USB 3.0 device with a super-speed USB 3.0 port. It is able to measure multiple events in up to 1(2) input channels at a time resolution of 80 ps. The logic is capable to accommodate an incredible burst edge rate of 12.5 GHz. Such a burst can last for up to 10.48 µs before any event might be lost. And that 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 MCS8A's capability to measure falling and rising edges simultaneously. Thus, Time-over-Threshold or pulse width measurements are easily accomplished.

Fig. 3.1: MCS8A-1 front panel

Each input channel has its own on-board 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. These provide also improved built-in test capabilities.

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.

And there is the optional 4 GB large FIFO that extends the onboard storage capabilities.

The MCS8A-1 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.

The metal case of the MCS8A-1 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.

3.2 START / STOP Inputs

The START (trigger) and STOP 1 (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.

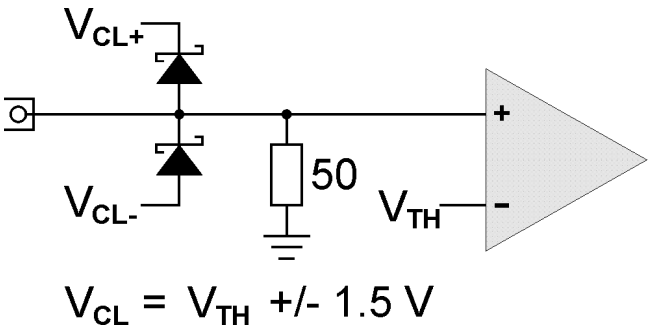


Fig. 3.2: START / STOP inputs

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 -1.0 V...+1.5 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 200 mV and slew rate varies from 2 V/ns to 10 V/ns the delay can vary for up to 30 ps, which is ⅓ 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 390.625 MHz cor. 2.56 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 2.56 ns sampling the delay of the monitor signal relative to the input pulse will vary by 2.56 ns as well. The minimum output pulse width will be 2.56 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 2.56 ns the detection probability will be below ‘1’ i.e. ”pulse width [ns]/ 2.56”. 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 80 ps and still are 100% detected.

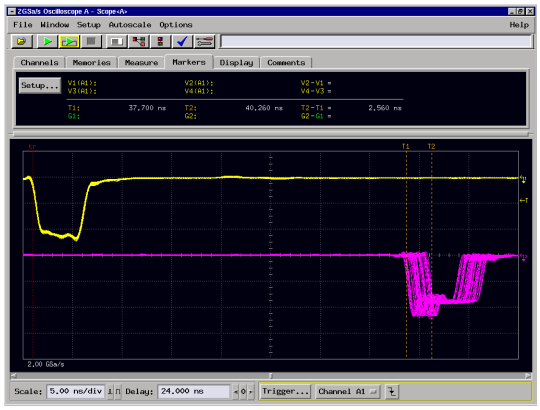


Fig. 3.3: MONITOR signal of a STOP input

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 SYNC Outputs

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

- 0 static "0"
- 10 MHz 10 MHz
- 100 MHz 100 MHz
- 200 MHz 200 MHz
- 195.3125 MHz or 156.25 MHz for 80 ps or 100 ps resolution
- 390.6250 MHz or 312.50 MHz for 80 ps or 100 ps resolution
- PLL Ref Clock 10 MHz or external clock
- START monitor of the discriminated START input sampled at 390.625 MHz
- STOP monitor of the discriminated STOP input sampled at 390.625 MHz
- GO GO-line state
- START-OF-SWEEP 2.56 ns pulse at the beginning of a new sweep
- ARMED ready for START
- Sweep_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] 2.56ns = 2^0 x 2.56 ns periodic timer signal active only when sampling
- TIME[1] 5.12ns = 2^1 x 2.56 ns periodic timer signal active only when sampling

… …

- TIME[29] 2.75s = 2^{30} x 2.56 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[11] bit 11 of the sweep counter

All these signals may be output on the fast-NIM SYNC_1 output on the front panel and most of them on the TTL SYNC_2 output on the FEATURE connector as well. They can also be inverted. The signals with higher frequencies than 100 MHz are not available at the TTL SYNC_2 output. It is recommended to use the TTL SYNC_2 signals for monitoring the Start and Stop signals only during setup, but not during a real acquisition. Due to its relatively high signal amplitude the TTL Sync_2 output might negatively influence experimental setups and thus, worsen the spectra quality due to crosstalk.

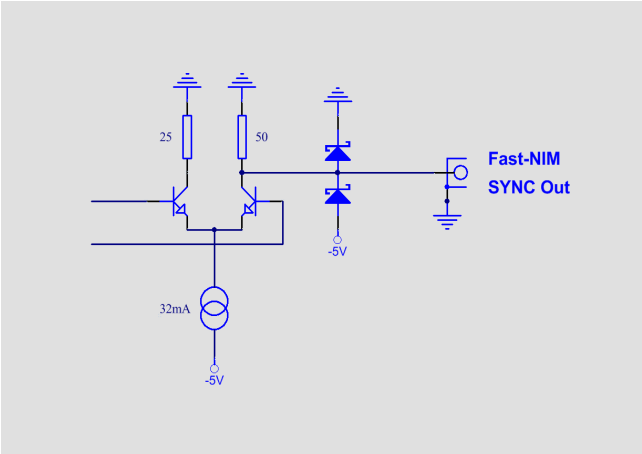


Fig. 3.4: Fast-NIM SYNC_1 output schematic

The sweep counter is incremented when a new sweep is started / triggered. 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 (-0.8 V), e.g. while a sweep is running ‘ON’ will result in –0.8 V (=’TRUE) output. You can switch to negative logic by selecting ‘inverted’ in the corresponding settings.

3.4 TAG Inputs

A unique feature of the MCS8 is a 16-bit TTL TAG input with a time resolution of 5.12 ns.

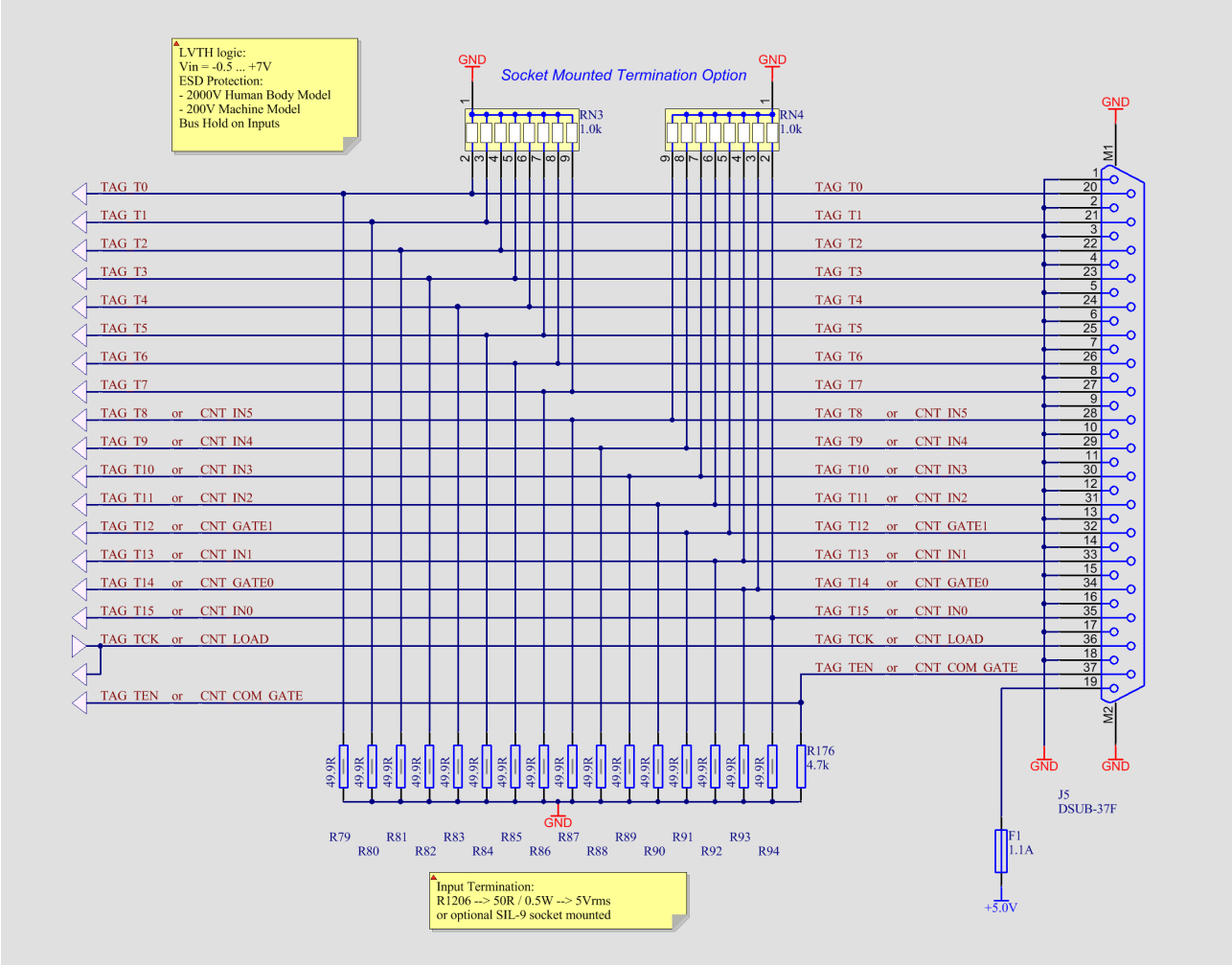


Fig. 3.5: TAG input schematic

When in use the TAG inputs are stored with each detected event at a resolution of 5.12 ns.

3.5 ‘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.

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 MCS8, a low voltage will halt the measurement. When output to the ‘GO’ line is enabled, starting a measurement (i.e. the MCS8 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. 3.6.

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

3.6 FEATURE 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. 3.6) 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.

NOTE:

Please contact factory if changes to the resistors are needed.

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

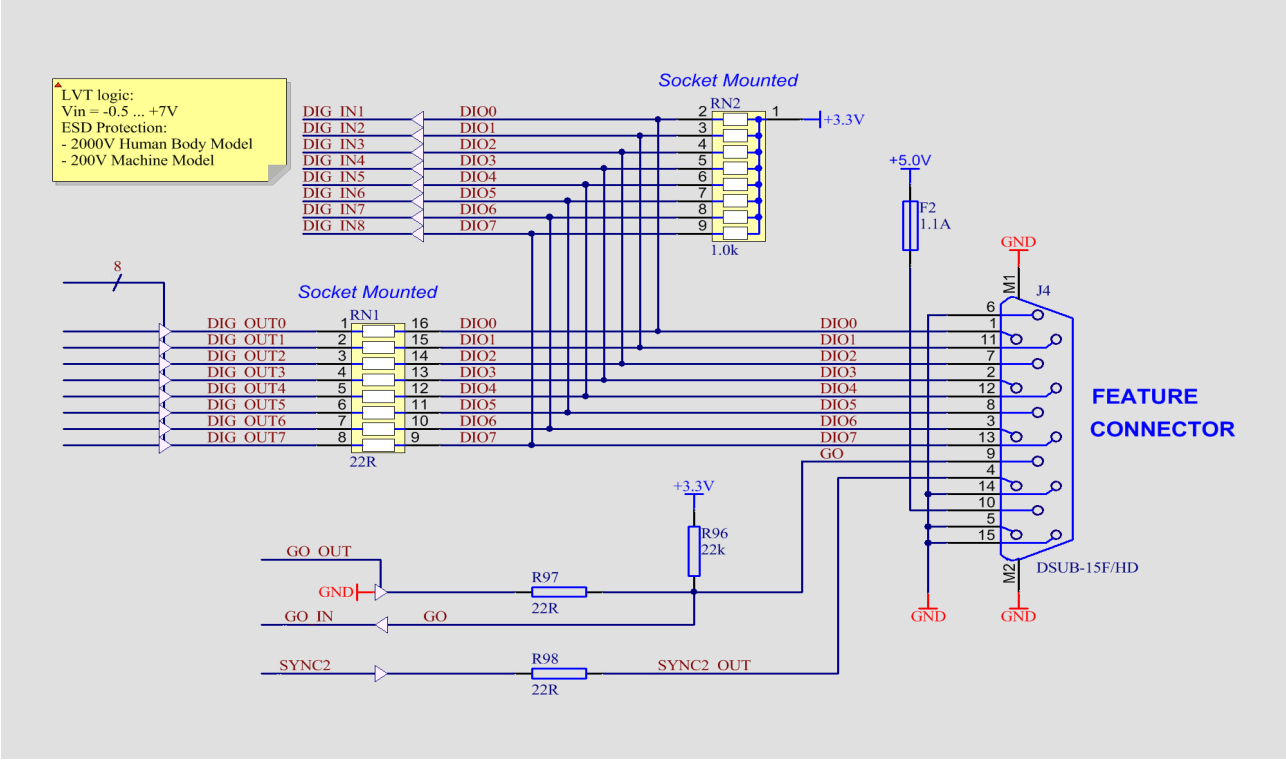


Fig. 3.6: Schematic of the FEATURE I/O connector

3.7 Time Base / Reference Clock

The internal reference is a 10 MHz crystal oscillator. This can be output at the rear side CLOCK I/O BNC connector. Or an external clock signal may be used. This external reference frequency might be in the range from 5 to 100 MHz in steps of 1 MHz.

To derive the outstanding temperature and long-term stability the MCS8 is optionally equipped with an on-board ovenized crystal oscillator (OCXO). This OCXO stabilizes the 12.5 GHz PLL (phase locked loop) synthesizer that clocks the 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 chapter 8.2.3 for the signal impedance and amplitude. The input impedance is 1.3 kOhm. As this may cause a problem due to reflections when using an external clock from a clock generator with a long cable, it is then recommended to use a 50 Ohm resistance and a Tee connector.

3.8 200 MHz Counter / Timer

The MCS8 optionally includes six 48bit synchronous 200 MHz counters. 2 counters are presettable.

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

The counters actually either count the software selected rising or falling COUNT input edges (counter mode) or work as 200 MHz timers.

For two counters counting can be individually gated or switched between up- and down-counting by individual GATE inputs. Also a common gate is provided. The usage can be individually selected.

Also a common LOAD is individually selectable. This actually clears the chosen counters.

The system wide GO-Line may also control the counting action. This can be set individually for each counter.

If counters are used, only up to 8 tag bits are useable as they share the same connector.

IMPORTANT: TAG_CLK/CNT_LOAD and TAG_TEN/CNT_COM_GATE are high impedance inputs with bus-hold circuitry. If used, they must be driven by a low impedance source, for example use a T-connector with a 50 Ohm resistor.

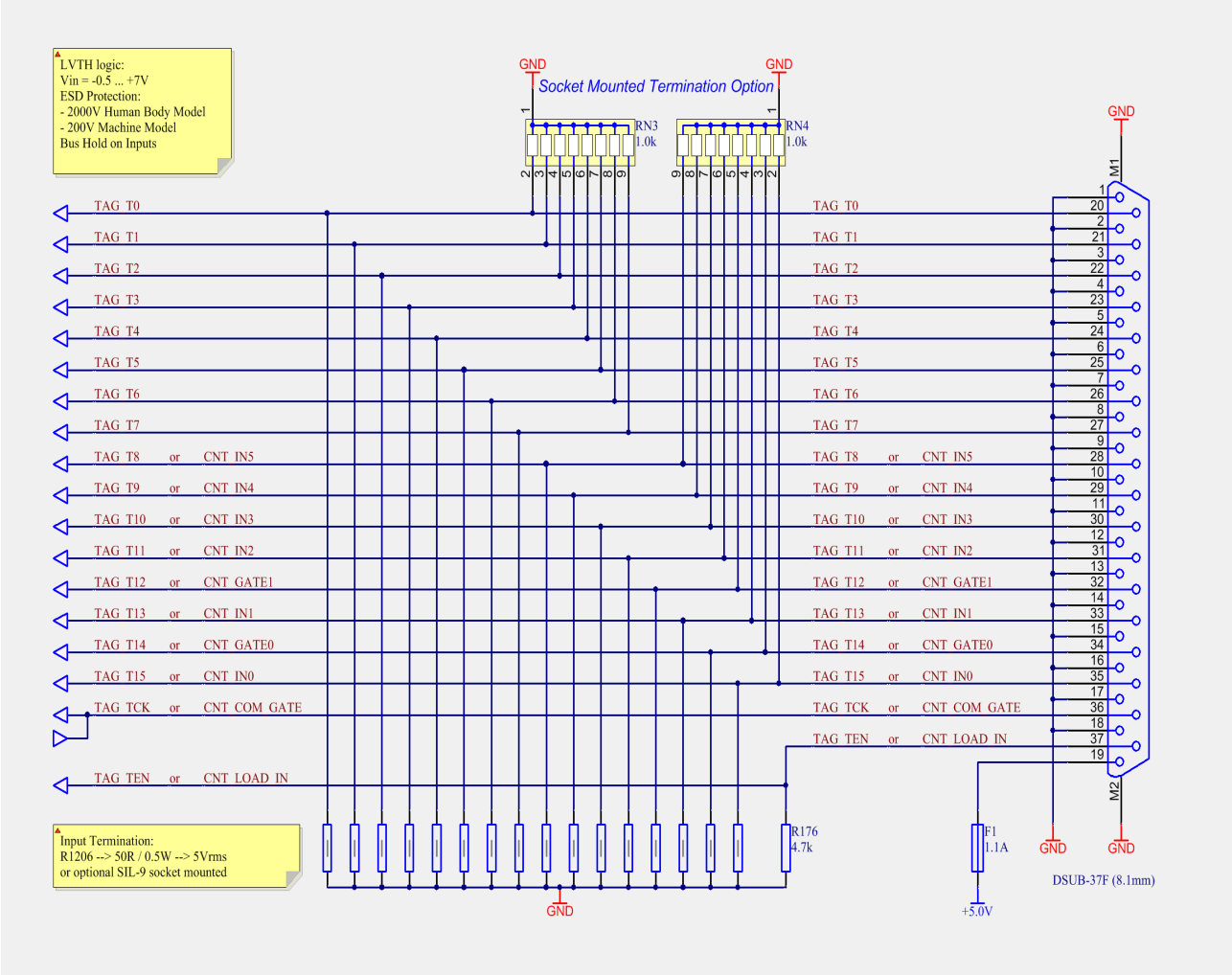


Fig. 3.7: 200 MHz Counter / Tag bit Connector

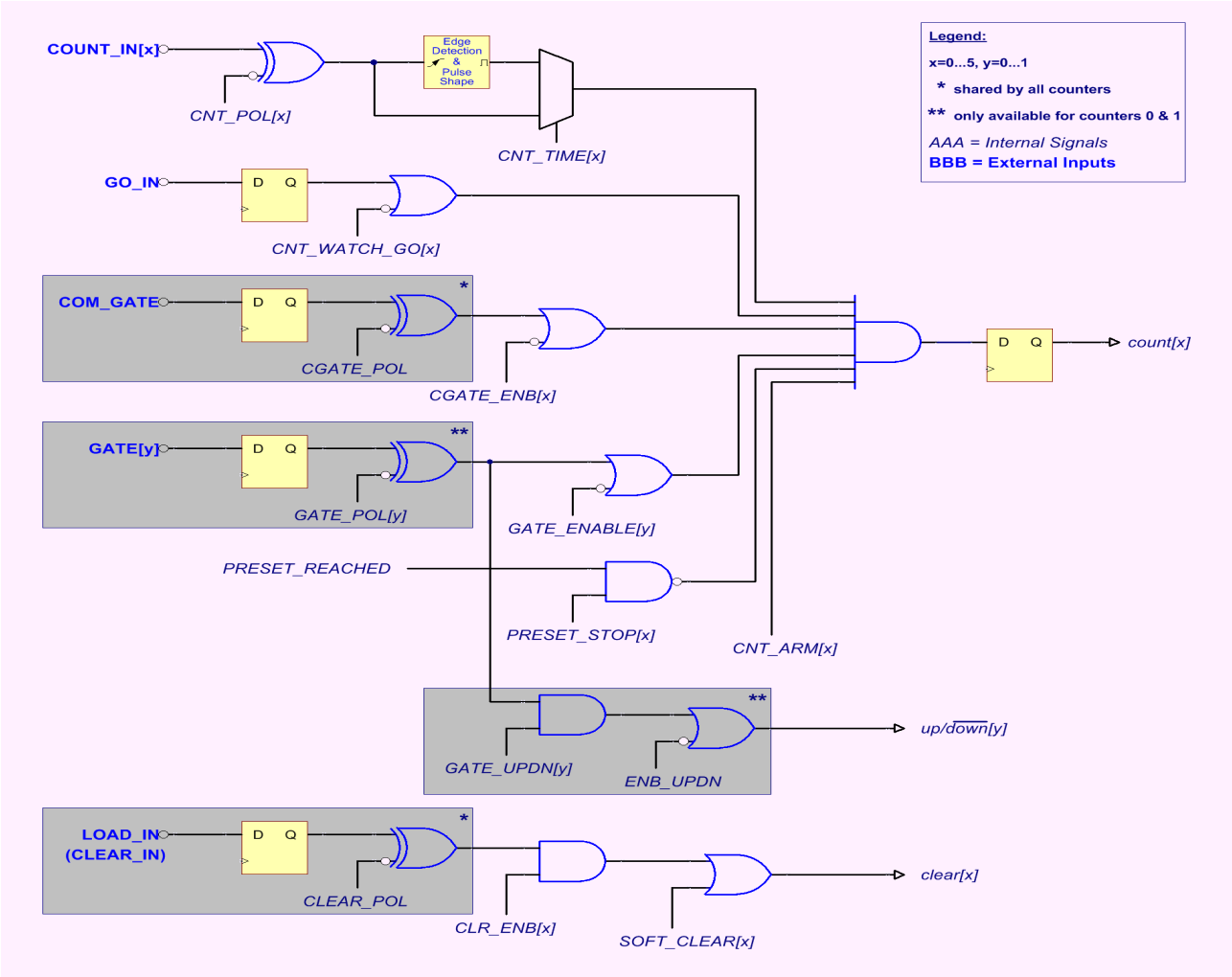


Fig. 3.8: 200 MHz Counter – Simplified Control Logic

4 Functional Description

4.1 Introduction

The MCS8A-1 measures the arrival time of STOP input events relative to a previous START signal. The resolution or time bin width is 80 ps. The full dynamic range is 53 bits which results in the incredible maximum sweep time of 8.3 days. 30 bits of the timer are also accessible via the SYNC outputs (TIME[0…29], ref. Chapter 3.3). The measured data is transferred into the computer in list-mode, i.e. as they are acquired per each input channel.

A STOP event can be either a falling, a rising or even both edges.

A unique feature of the MCS8A-1 is that the START channel can be sampled as well and thus can be used as a second input channel.

Since the time base for the 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 correlation's between the input channels can be acquired with one single instrument. Time differences or correlation's between specific events in up to 2 different channels can be measured. And this always at the full 80 ps resolution even for long time periods.

4.2 Modes of Operation

4.2.1 Stop-After-Sweep Mode

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

When the MCS8A-1 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 2.56 ns to accept only STOP events that arrive after the selected delay.

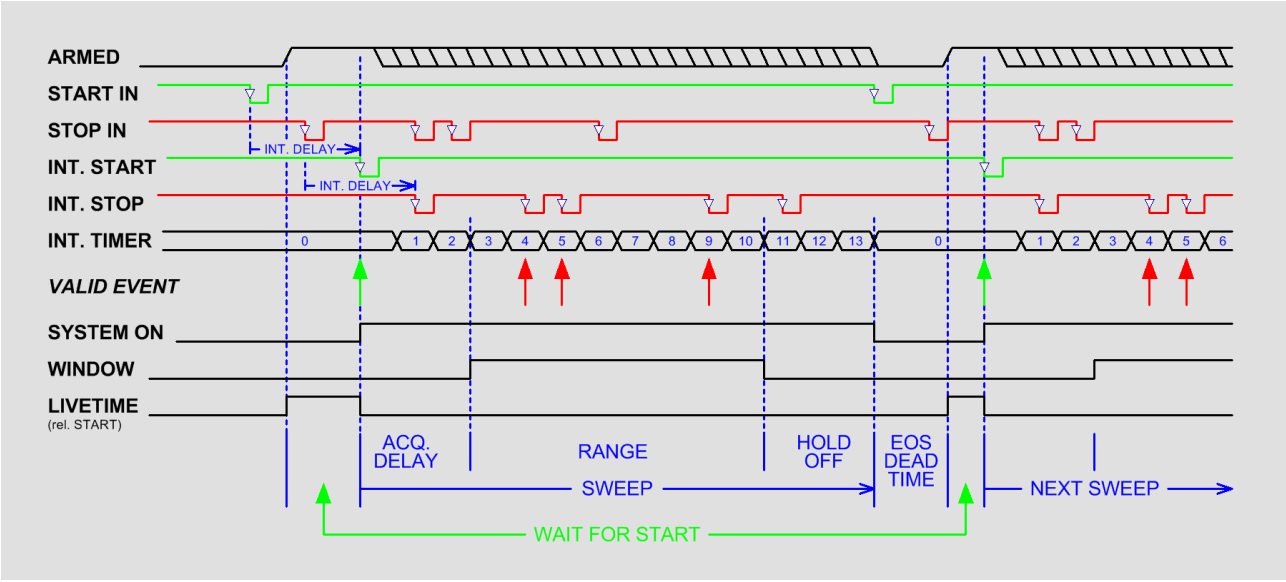


Fig. 4.1: Simplified timing diagram

When the selected measurement time range – selectable in steps of 2.56 ns - has elapsed the sweep and so the data acquisition ends. After a short (<50 ns) end-of-sweep dead time the MCS8A-1 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 2.56 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 2.56 ns units each.

Acq.Delay + TimeRange + Hold-Off ≤ 2^{48} x 2.56 ns = 8.3 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 delay 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 2.56 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 53 bit or 8.3 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 5.12 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 80 ps bin width. This allows also for ultra fast coincidence measurements with very little external logic required.

A tag clock is provided on the tag connector that can be used as a strobe signal.

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, see chapter 5.2 .

4.3 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 12.5 Gevents/s) should be acceptable for a period of time as long as possible. In the case of the MCS8 each individual START / STOP input has its own 2.56 ns x 4k FIFO. These are able to store burst rates of as high as 12.5 G edge events per second for up to 10.5 µs before any event might be lost. Each FIFO word is comprised of the complete event structure in a 2.56 ns period. It is worth noting that these ultra fast FIFO's are really independent for each channel.

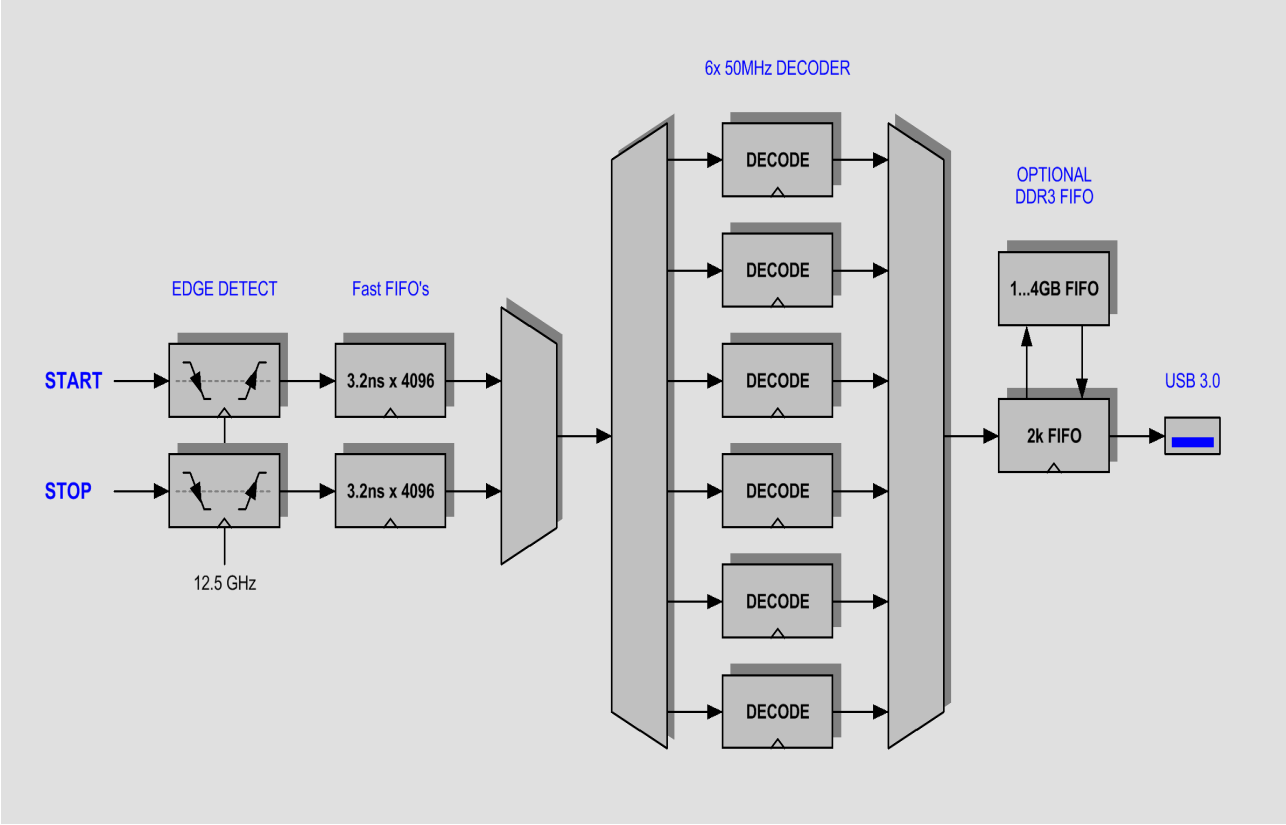


Fig. 4.2: FIFO concept

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 by 6 decoder machines working in parallel at a sum rate of over 300 MHz. As this parallel decoding has the consequence that data are mixed, it is possible to use only one decoder to assure better ordered data in the list file. This is usefull especially if coincident data from different inputs are evaluated, for example for a position-dependent detector. When using only one decoder the maximum sum count rate is limited to 50 MHz. Since the bandwidth of the USB 3.0 transmission is limited to something like 240 MB/s a large second FIFO is provided that is able to store a high number of data.

The optional up to 4 GB large DDR3 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 4 GB / 8 = 512 Mevents can be buffered. For 32 bit = 4 byte data up to 1 G events, can be stored in a 4 GB DDR3 module.

5 Software Description

The software is a layer of several parts. A driver (WINUSB.SYS) provides the communication via the USB port. A server program (MCS8.EXE) controls the hardware and the data. A graphical user interface (MPANT.EXE) controls the server via a DLL (DMCS8.DLL) and provides graphical displays. This chapter describes now the server program.

The window of the MCS8 server program is shown here. It enables the full control of the MCS8 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.

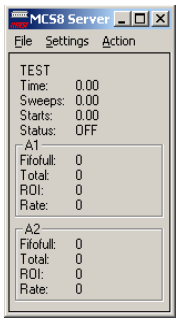


Fig. 5.1: MCS8 Server Window

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. Usually you will control everything from MPANT, but it is possible to work with the server alone and independently from MPANT.

Fig. 5.1 shows the opened server window. The upper part of the window contains parameters that belong to all channels. The filename (TEST), “Time” is the run time of the acquisition in seconds as measured by the PC clock, “Sweeps” is the number of sweeps counted by the hardware sweep counter, “Starts” is the number of start events counted by the software that can be lower than the sweeps during a running acquisition as the events in the FIFO buffer are not yet ealuated, “Status” is the acquisition status (ON / OFF / READ OUT). The lower part contains in boxes labeled with the channel name (A1, A2, ..) counters belonging to each channel. “Fifofull” is the number of recognized FIFO full events. “Total” is the number of counts in the spectrum as counted by the software. “Rate” is the number of counts per second within the ROI (region of interest) that is defined in the settings. The ROI is usually spanned over the total spectrum and rate is then the total count rate. “ROI” is the sum of counts within the ROI, default value is the total sum.

5.1.1 Initialization files

At program start the configuration files MCS8.INI and MCS8A.SET are loaded.

Parameters that can be set by editing the MCS8.INI file are the update rate in msec for the refresh of the status. The number of input channels and resolution is set automatically by changing the MCS8.INI file when the software is started for the first time.

Oven oscillator: If you have the optional internal oven stabilized oscillator, it is found and used automatically. The oscillator can be changed in the “Test, Inspect...” dialog.

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

Change the MCS8.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 message box to connect the external clock signal to the BNC connector labeled "CLOCK I/O" at the back side. If you later exit and restart the software, let it connected. But after power down please let it disconnected at first. When using the internal clock the same connector outputs the internal 10 MHz signal.

The file MCS8A.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. MCS8 *TEST* to load TESTA.SET). The command line parameter can be used either by calling the program from a “DOS box” or by changing the properties of an icon on the desktop that points to the program.

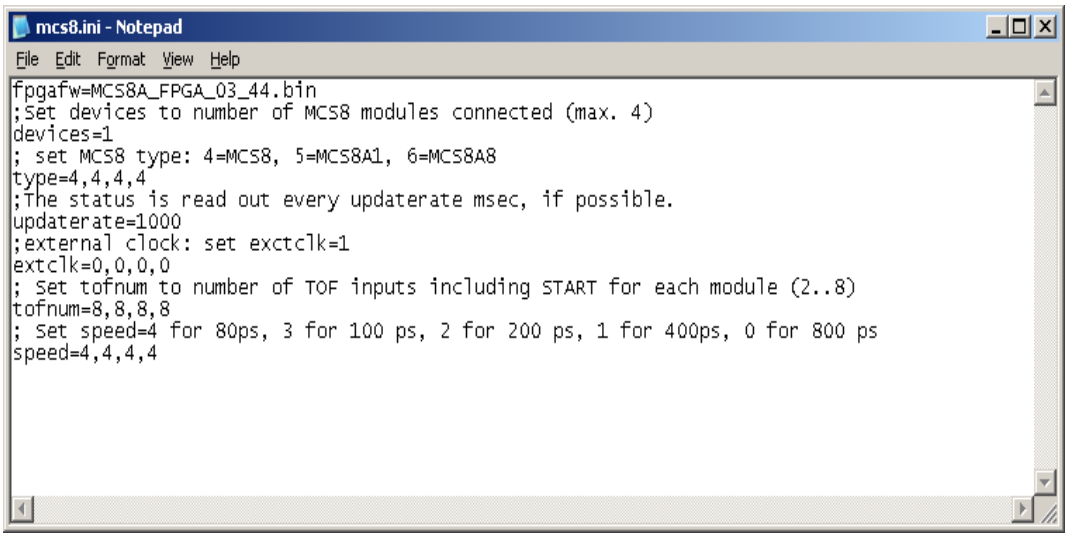


Fig. 5.2: MCS8.ini File

5.1.2 Action menus

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 Action1 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.

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 file name can be entered. If the checkbox **auto incr.** is crossed, a 3-digit number is appended to the file name that is automatically incremented with each saving. The format of the data can be ASCII (extension for separated spectra .ASC), binary (.DAT), and 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.

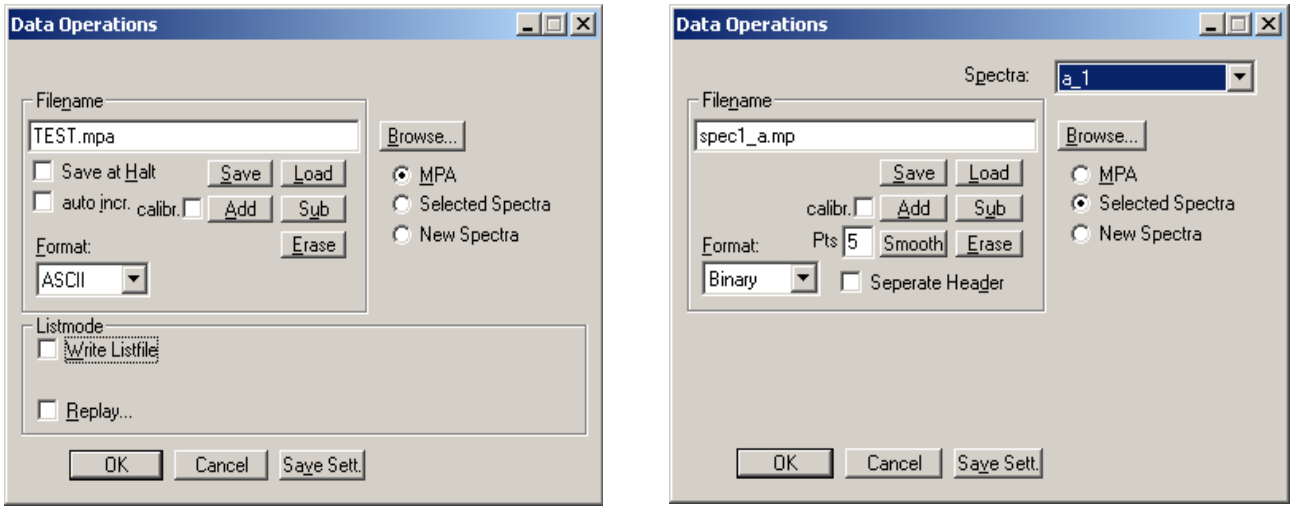


Fig. 5.3: Data Operations dialog for MPA data (left) and selected spectra (right)

The menu item File – Replay... opens the Replay dialog. It enables evaluation of list data.

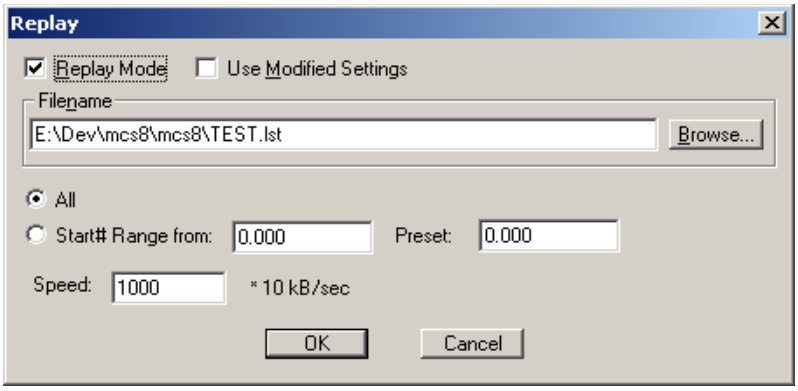


Fig. 5.4: Replay Settings dialog

Enable **Replay Mode** using the checkbox and specify a **File name** 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 MCS8 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 MCS8 system. A click on the "**Installed...**" button opens a dialog showing all installed features.

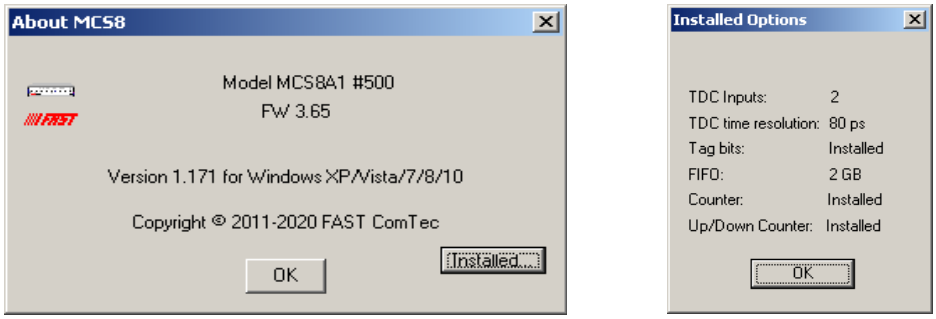


Fig. 5.5: About MCS8 dialog box and Installed Options

The MPANT menu item in the file menu starts the MPANT program if it is not running.

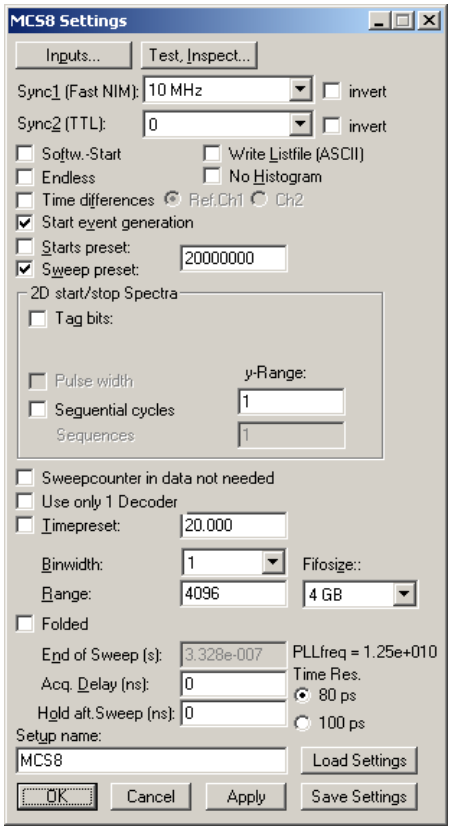


Fig. 5.6: Settings dialog

5.1.4 Settings dialog

The Hardware... item in the Settings menu opens the MCS8 Settings dialog box. 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. The Sweep length is defined by the **Range** times the **Bin Width**. 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.

Via the **Sync out** - combo boxes you can specify the signal you want to observe. See chapter 3.3 . You can observe the **START** and **STOP1…STOP7** signals. Use it as a monitor and vary the input thresholds to find the best threshold settings. The Sync Outs can deliver **10 MHz**, **100 MHz, 200 MHz, 97.656 MHz, 195.3125 MHz, 390.525 MHz, PLL Ref Clock, START..STOP7, GO, START_OF_SWEEP, ARMED. SWEEP_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[29]** are the Bits 0..29 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 32 basic dwell times i.e. after about 2.56 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.

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.

A List file can be written by checking the corresponding checkbox **Write Listfile**. If **No Histogram** is checked, no histogramming is made. 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 80 ps option is installed, the **Time resolution** can be selected between 80 ps and 100 ps.

If the MCS8 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 **”Interleaved”** appear.

The data word length of MCS8A data can be 4 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 5.2 . 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 "**Inspect**" button a special dialog is opened that allows to inspect the data format in detail. You see in addition information about the voltages and temperatures of the FPGA and the MCS8. Pressing the Read button can refresh that information. It is also possible here to test and select the oscillator.

A checkbox “**Test Pulses 1 kHz on all inputs**” can be used to test all inputs. Set a range of 16 k, set a sweep preset of 10000, and start a short acquisition. You will then see 16 equally spaced peaks in each spectrum with a total of 10000 counts. This internal “test pulser” can be used for test purposes and to make sure that the all input threshold DACs are working. The resulting spectra look like the signal would be a pulse train with pulses equally spaced by 40 ns, but actually there is only one pulse in each sweep. The rate is 1kHz in each input channel, only the delay after the start pulse is changed by 40 ns with the next pulse.

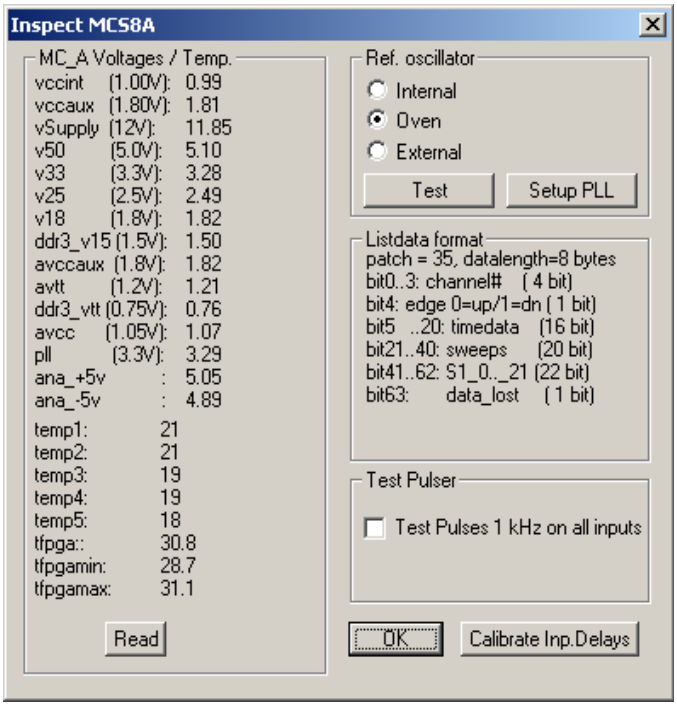


Fig. 5.7 Inspect MCS8 Dialog

The **Inputs...** button opens the Input Thresholds and ROI Presets dialog box. For all inputs you can **Enable Sampling** and you can specify for the START and STOP1..STOP7 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 -2 .. +2 V (scroll bar or edit field). It is also possible to choose both edges. 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.

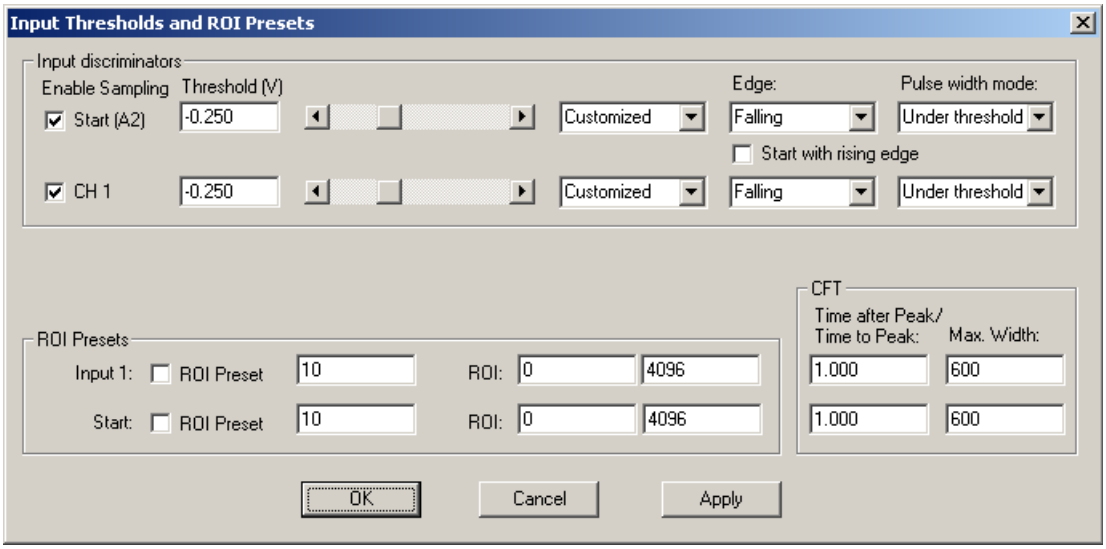


Fig. 5.8: Input Thresholds Dialog

As the edge information is contained in bit 4 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 2.5.4).

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 MCS8 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.

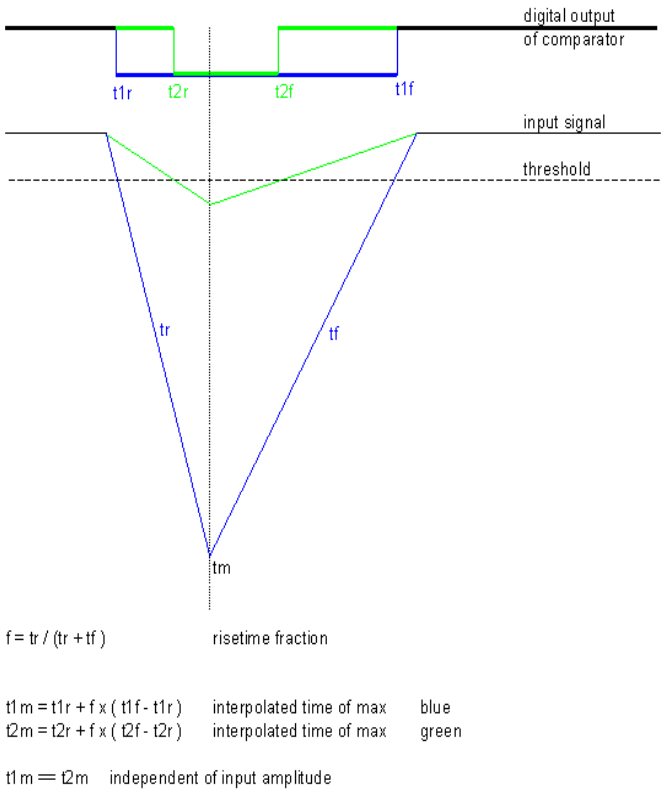


Fig. 5.9: Principle of “Software CFT”

5.1.5 Scaler Setting

The “Scaler...” button in the settings overview opens the respective dialog box to define the use of the six 200 MHz Scaler / Counters. This is an option, see chapter 3.8 . A utility program mcs8scal.exe is started automatically and shows the scaler values, optionally as a rate meter. The scalers can be individually named, the values are saved into the data file. For synchronizing of start and stop of the scalers with the acquisition it is possible to enable “Count gated with GO”. Then also the three check boxes concerning the GO-line in the system definition dialog should be crossed, see chapter 5.1.6 . IMPORTANT: When using the Extern Common Gate or the Extern Clear, use a T-connector with a 50 Ohm resistor at these inputs. As these are high impedance inputs with bus-hold circuitry, they must be driven with a low impedance source. Part of scaler data can be inserted into the list data stream by crossing either the “Scaler 1 in data word” or “Scaler 1 and 2 in data word” checkbox, see chapter 5.2 . It is then also possible to create scaler spectra and use ROIs within it as conditions for other calculated spectra, see chapter 5.1.9 .

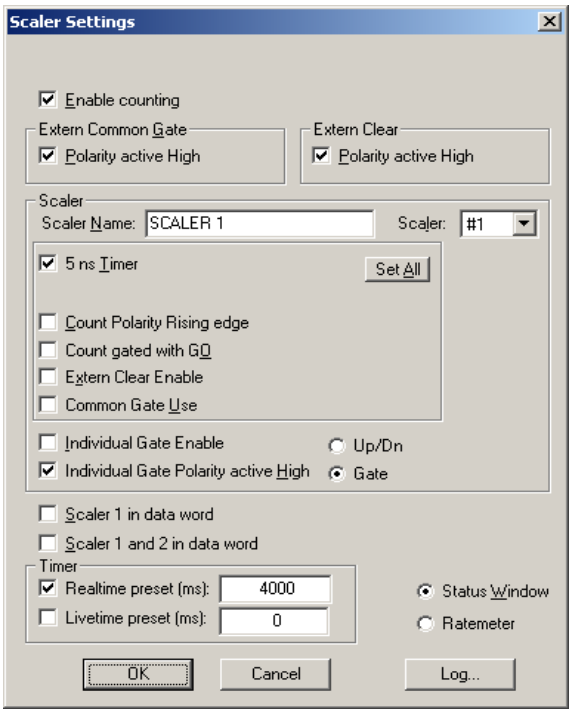


Fig. 5.10 Scaler Settings dialog box

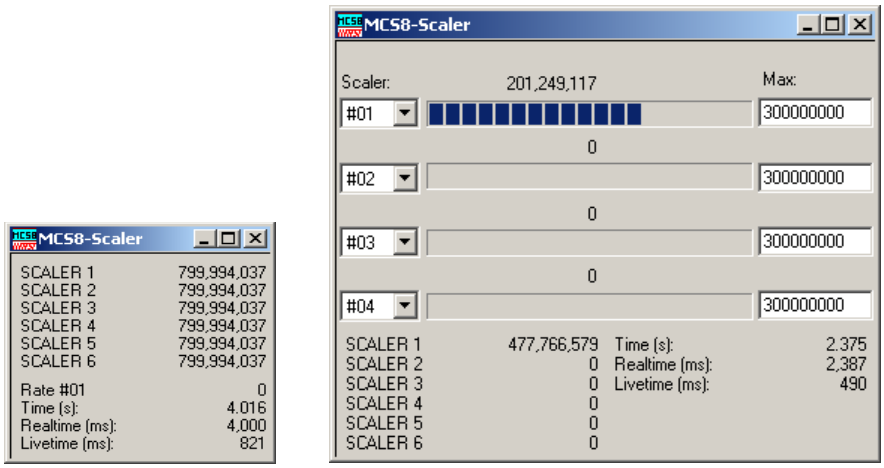


Fig. 5.11 Left: MCS8-Scaler Status utility, right: as ratemeter

5.1.6 System Definition

The “System...” item in the settings menu opens the System Definition dialog box. It is possible to select between 80 ps and 100 ps time resolution here. 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 MCS8 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. 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 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.

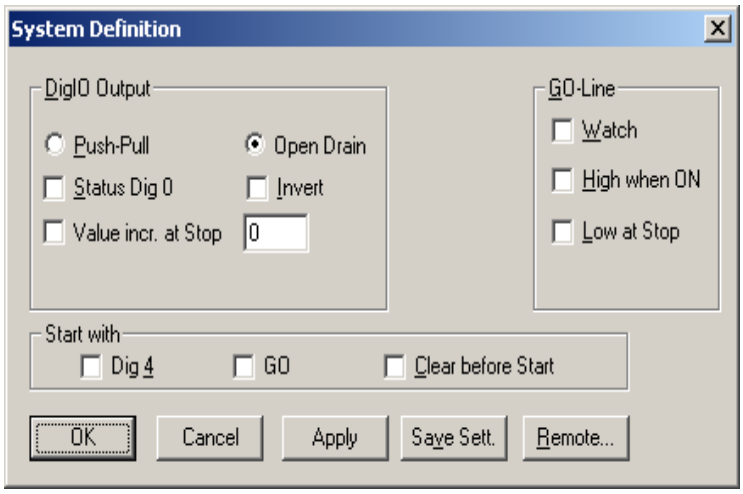


Fig. 5.12: System Definition dialog box

If more than one MCS8 modules are used, the system definition dialog box comes up as shown in Fig. 5.13. 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 MCS8 a preset is reached.

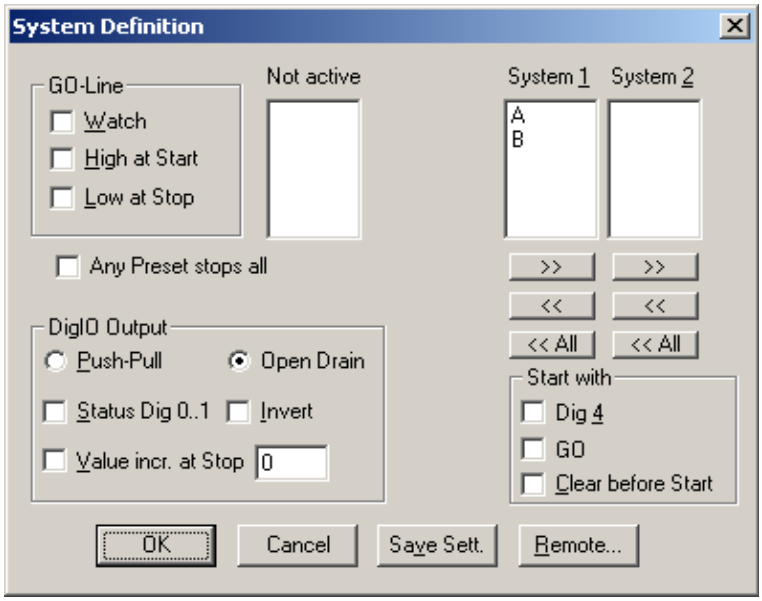


Fig. 5.13: System Definition dialog box, two MCS8 modules

In the shown setting a single system is formed. The modules A and B 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.

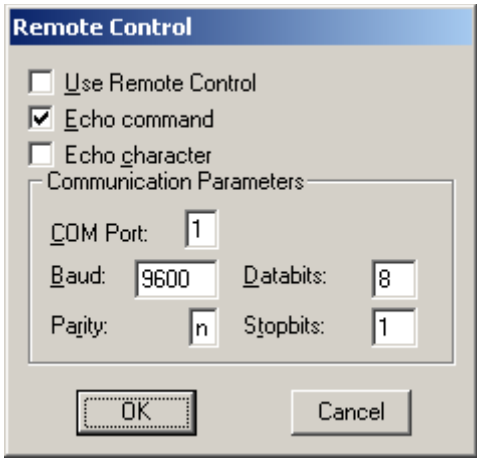


Fig. 5.14: Remote control dialog

OK accepts all settings. **Cancel** rejects all changes. Pressing “**Save Settings**” stores all settings in the file **MCS8A.SET** using the control language (see the following section). This file is loaded at program start automatically and the parameters set.The **Remote...** button opens the Remote control dialog box. Here all settings can be made for the control of the MCS6A 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.

5.1.7 Calculated Spectra dialog

The data from the 8 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 channels. The MCS8 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 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 MCS8 server is called. Here additional dual parameter and calculated spectra can be added, modified and deleted from the list.

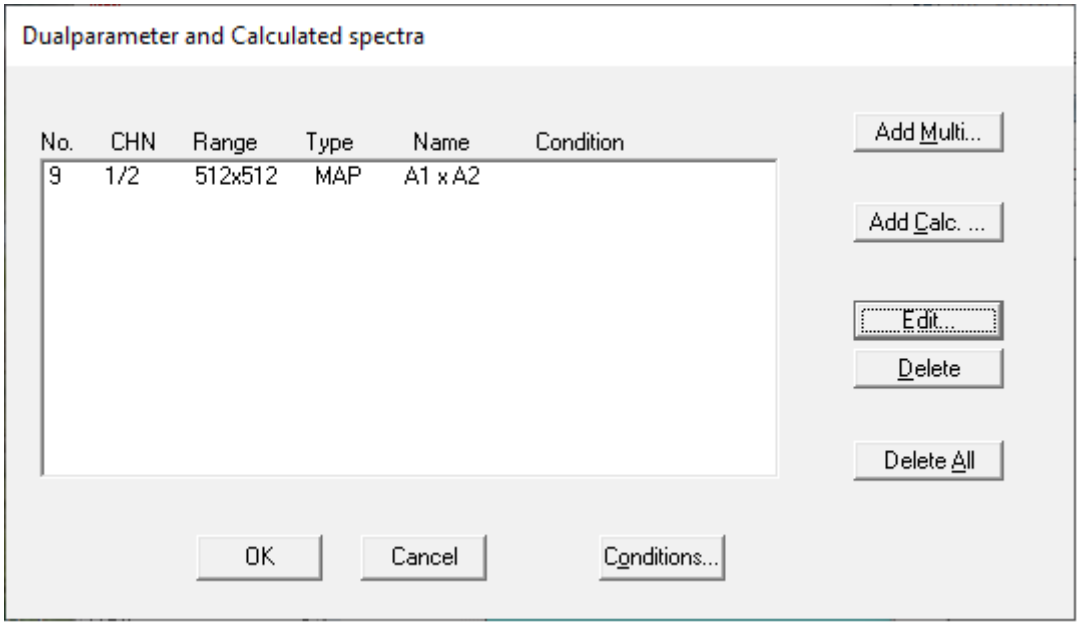


Fig. 5.15: Dual parameter and Calculated spectra dialog box

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

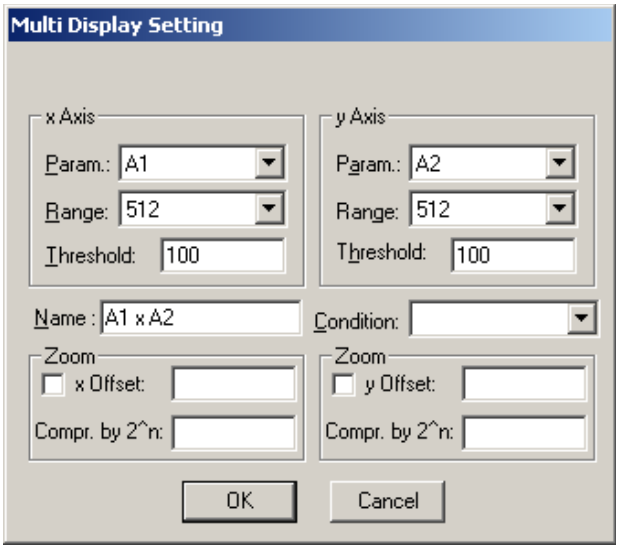


Fig. 5.16: Multi Display Setting

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

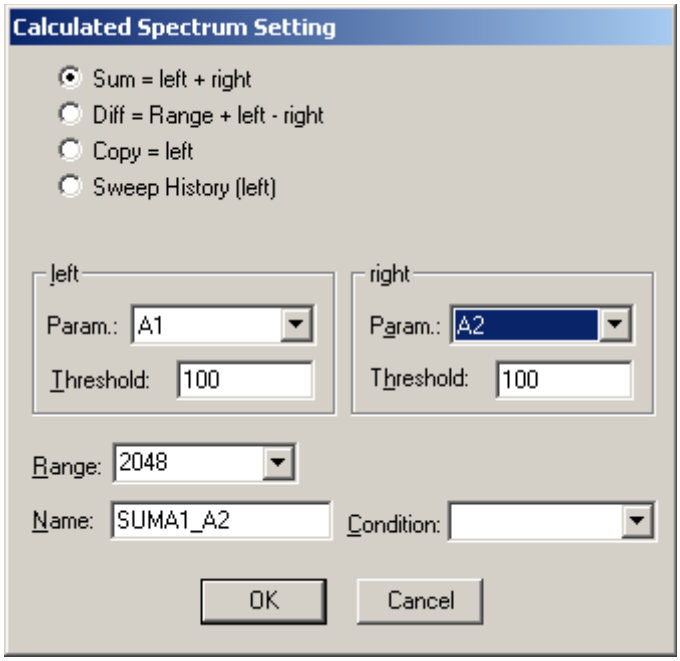


Fig. 5.17: Calculated Spectrum Setting

You have a choice between several formulas to combine two parameters: **Sum** = left + right makes a sum spectrum, and **Dif** = 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.

5.1.8 Conditions

If the RTC and Coincidence options are enabled, press Conditions... from the "Dualparameter and Calculated Spectra" dialog to define or edit ROI Conditions in the Conditions dialog.

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

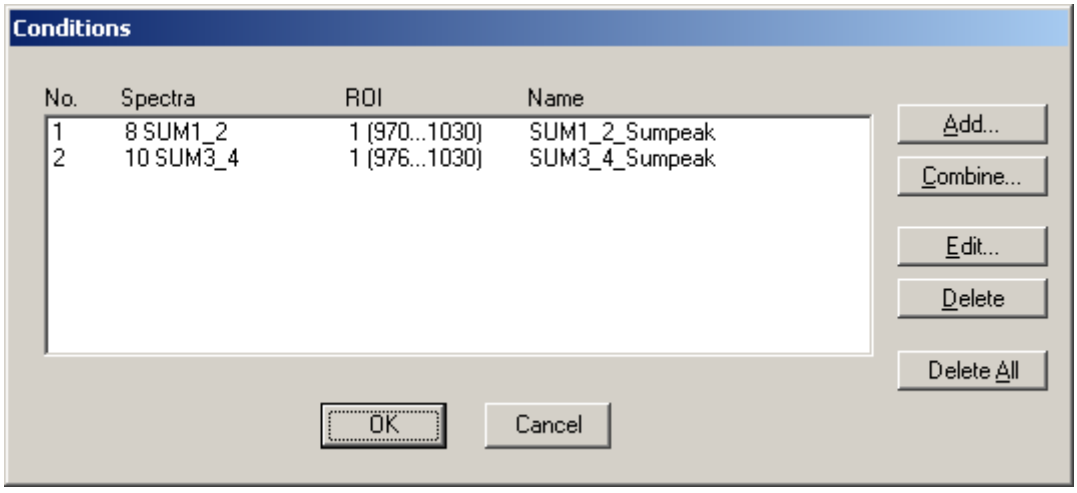


Fig. 5.18: Conditions

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

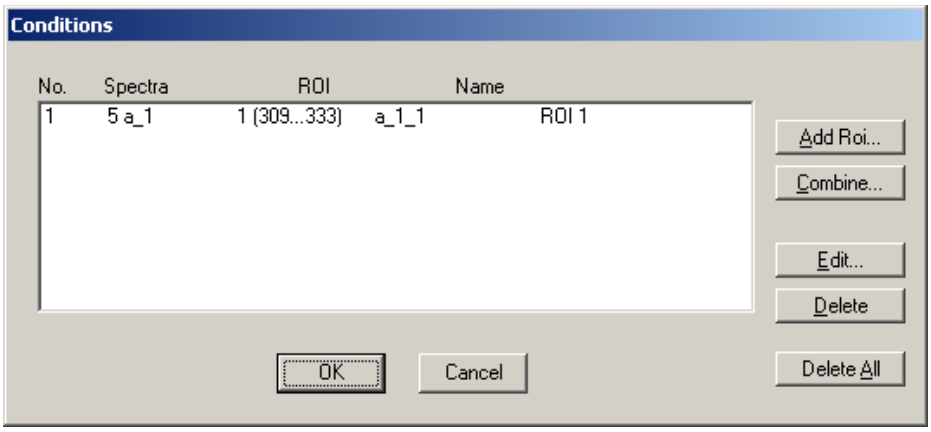


Fig. 5.19: Conditions

To define a new condition, press **Add Roi...** to open the ROI Condition dialog.

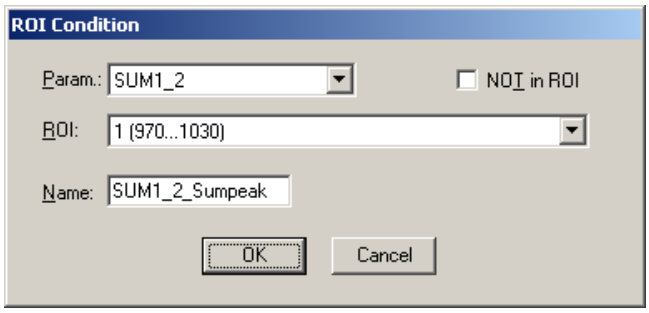


Fig. 5.20: ROI Conditions dialog

Here it is possible to define a Condition as an event inside or outside of an ROI in any parameter spectrum i.e. a calculated parameter or a "copy" of a primary spectrum. 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.

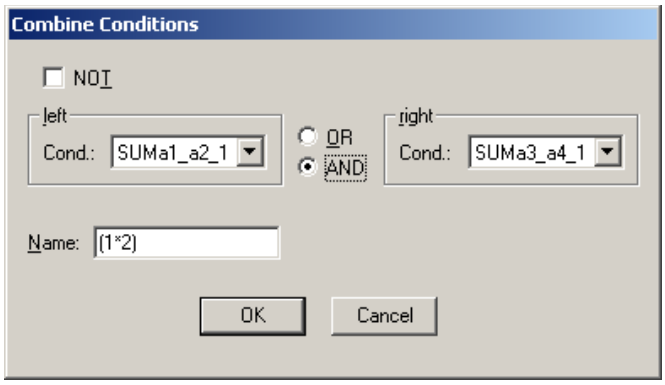


Fig. 5.21: Combine Conditions dialog

Here a Condition can be defined 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 "*".

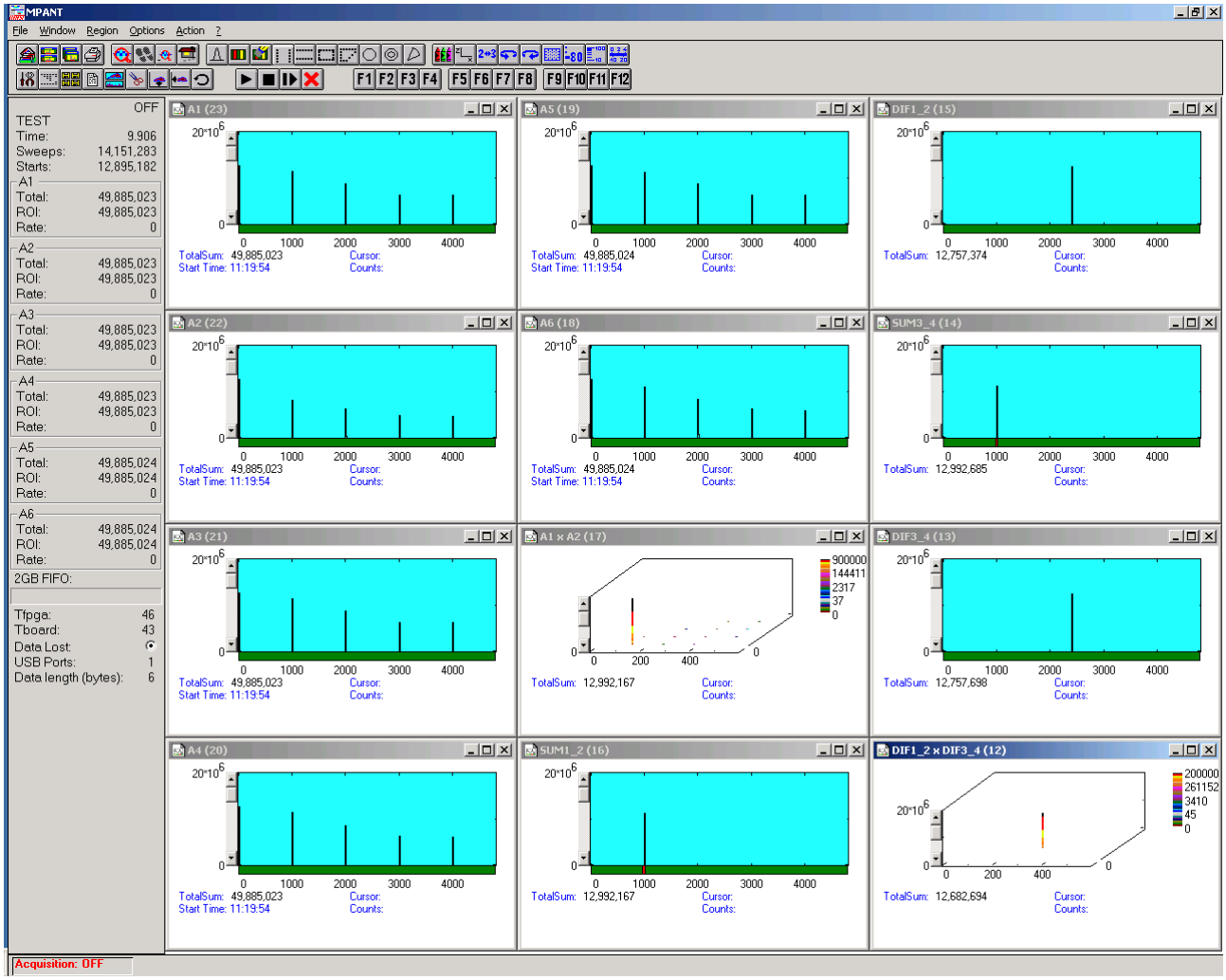


Fig. 5.22: Test acquisition with calculated spectra

Fig. 5.22 shows an acquisition with calculated spectra. The settings could be used as an example for a two-dimensional position dependent detector.

5.1.9 Scaler spectra

If the scaler / counter option is installed, it is possible to have a part of the bits of either the first of the six scalers or of the first two of them in the list data, see chapter 5.1.5 and 5.2 . It is then possible to create spectra that contain scaler data. As an example, check “Scaler 1 in data word” in the scaler settings, see Fig. 5.15. In the dialog for creating spectra then a button “Add Scaler” is visible, and it is possible to create a scaler spectrum, see Fig. 5.23 and Fig. 5.24.

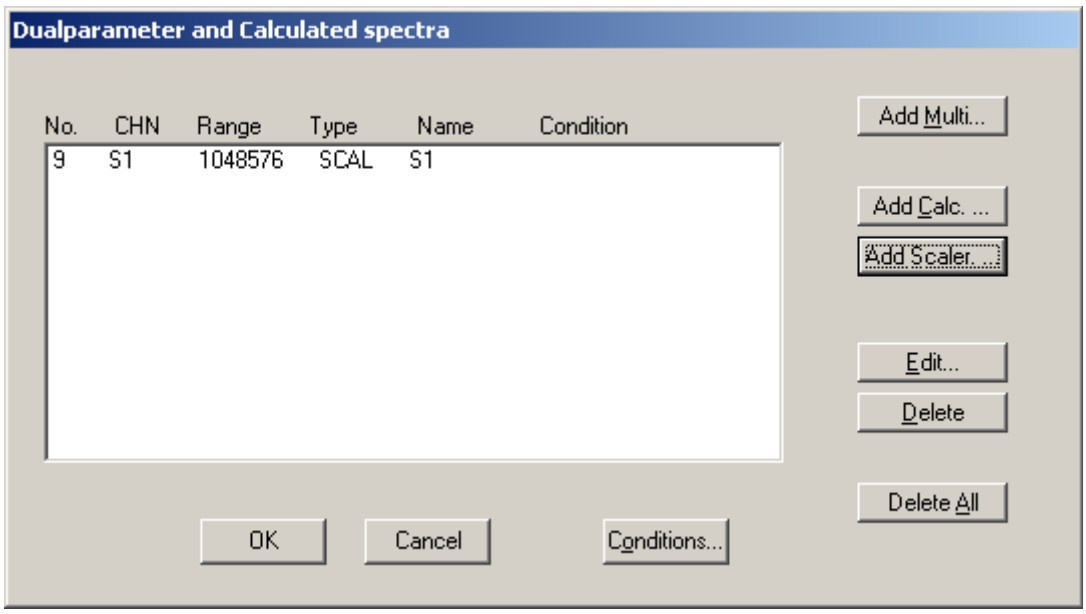


Fig. 5.23: Creating a scaler spectrum

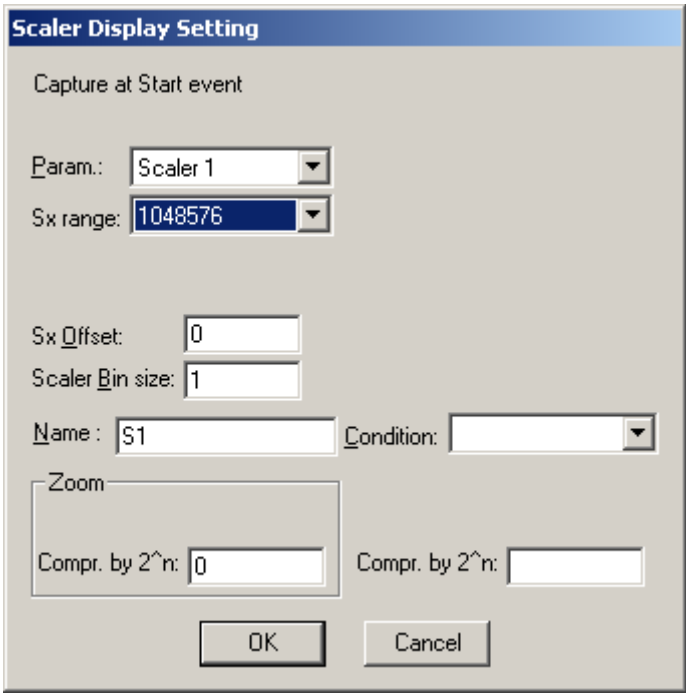


Fig. 5.24: Setting parameters of a scaler spectrum

An example of such a spectrum using the 5 ns timer for S1 is shown in Fig. 5.25.

Fig. 5.25: Scaler spectrum

It is possible to create ROIs in a scaler spectrum and use it as condition for other spectra, an example is shown in Fig. 5.26 and Fig. 5.27.

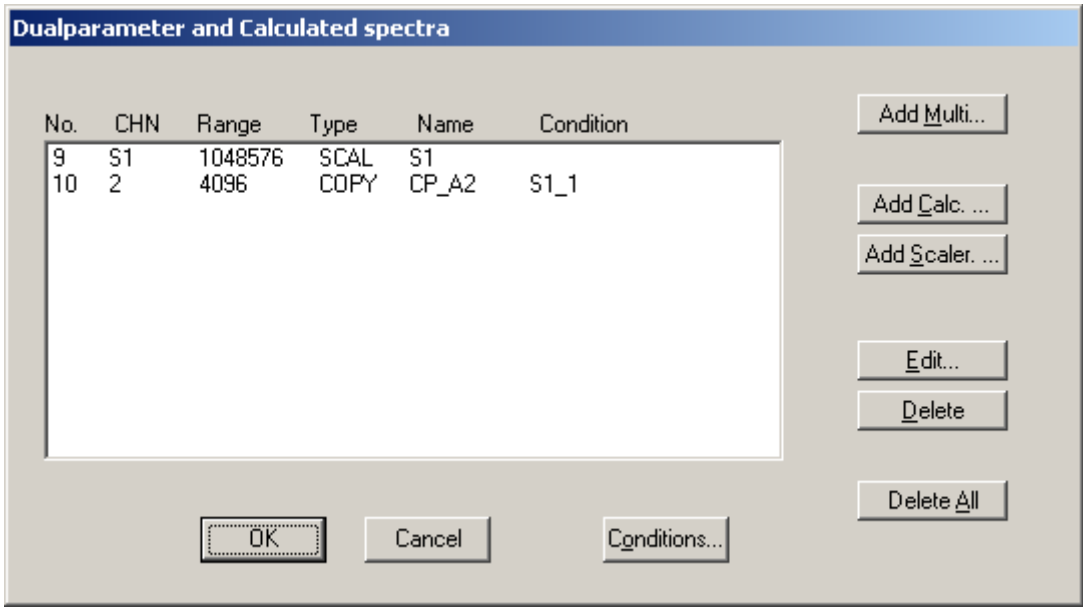


Fig. 5.26: Using a condition in a scaler spectrum for a calculated spectrum

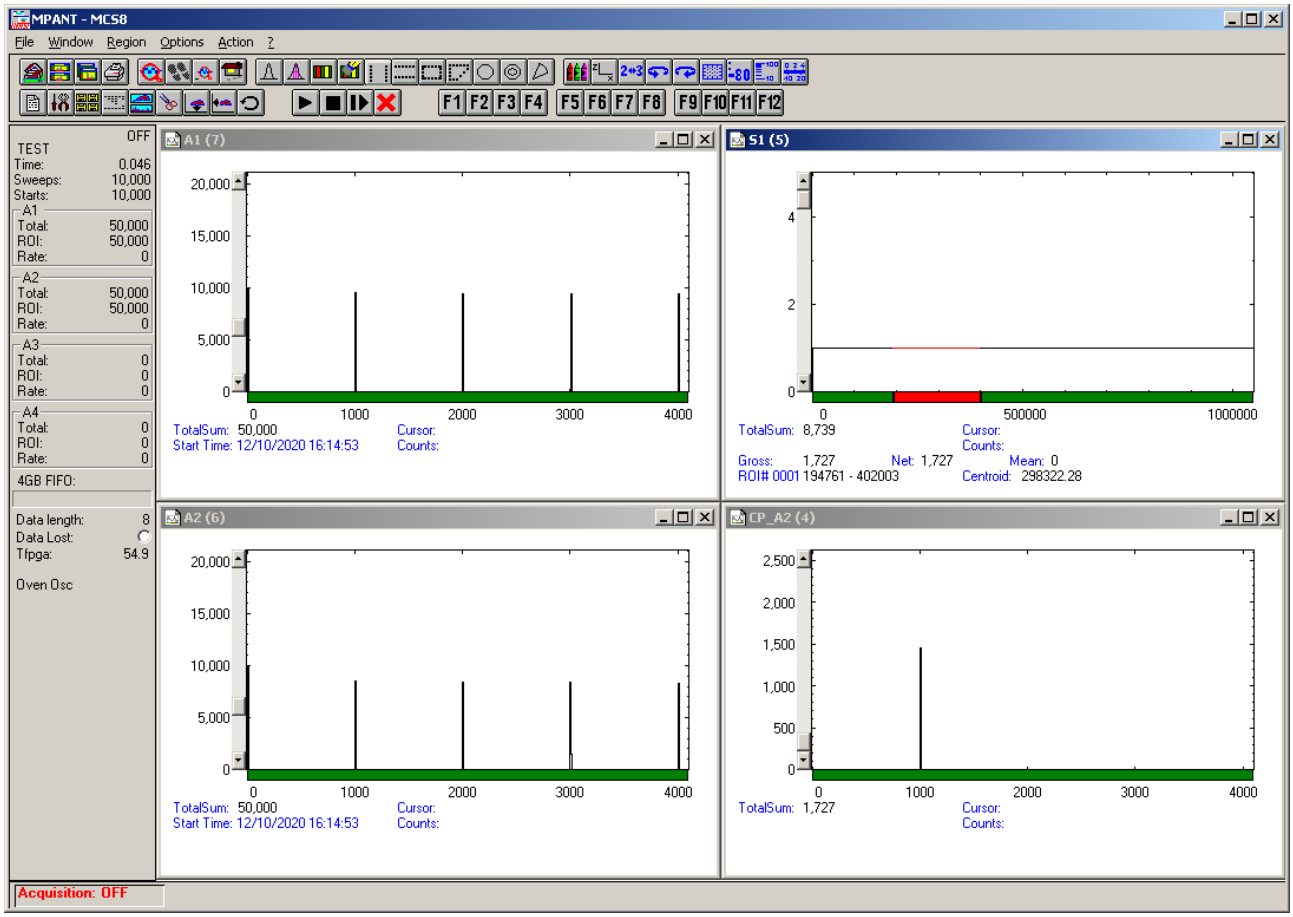


Fig. 5.27: Calculated spectrum with a condition set on a ROI in a scaler spectrum

An example for such an application could be a neutron time of flight defined by a counter that is resetted by a chopper, or a FLIM application with two up/down counters defining the position of a laser on a target.

5.2 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 spectrum 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 5.3

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:

```
;MCS8 #1004 Sversion=1.005 Fversion=0.13
time_patch=1c
;datalength=4 bytes
;bit0..3: channel# 1..8 ( 4 bit)
;bit4: edge 0=up / 1=dn ( 1 bit)
;bit5 ..20: timedata    (16 bit), max sweep length 6.5536 us
;bit21..30: sweeps      ( 10 bit)
;bit31:     data_lost   ( 1 bit)
[DATA]
00200016
00200639
00200fbb
00209c56
0020a259
0020abfb
00400016
..
```

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 4 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.

Now lets try to understand the first data word 00200016. This is is a 32 bit word in hex format. The last nibble is 6, this means binary 0110. Bit0 is 0, Bit1 is 1, Bit2 is 1, Bit3 is 0 (from right to left). This is the channel

number 6, which is the START channel as described in the following table. The next nibble is 1, binary 0001. Bit4 is 1. This is the edge information, a pulse going down. Bits 5 to 7 are 0. The next 3 nibbles are 000. These are bits 8 to 19 The next nibble is 2, binary 0010. Bit20 is 0, Bit 21 is 1. The time data bit 5 to 20 are zero. Bit 21 and higher bits are the sweep number 1. Bit 31 is zero, the data lost flag.

Bit 0 to 4 contain the channel number for all data formats.

The following scheme is used for coding the channel number:

Channel Numbers ==> Data Type

0	ZERO WORD	
1	COUNTER	Real/Livetime, 6 Counter
2	COUNTER	High data part for 4 byte datalength
3	unused	
4	unused	
5	unused	
6	START	
7	*- reserved -*	
8	START / STOP 2	
9	STOP 1	
10	STOP 3	
11	STOP 4	
12	STOP 5	
13	STOP 6	
14	STOP 7	
15	STOP 8	

Bit 4 is the edge information, 1 means falling edge. 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*
1c	*4 bytes*	*1 (Bit[31])*	*-*	*10 (Bit[20:30] = Sweeps[0:9])*	*16*	*5.24 us*
18	*4 bytes*	*1 (Bit[31])*	*-*	*-*	*28*	*0.027 s*
15	*8 byte*	*1 (Bit[63])*	*16 (Bit[47:62] = Tag[0:15])*	*26 (Bit[21:46] = Sweeps[0:25])*	*16*	*5.24 us*
11	*8 byte*	*1 (Bit[63])*	*16 (Bit[47:62] = Tag[0:15])*	*20 (Bit[27:46] = Sweeps[0:19])*	*22*	*335.54 us*
d	*8 byte*	*1 (Bit[63])*	*8 (Bit[55:62] = Tag[0:8])*	*20 (Bit[35:54] = Sweeps[0:19])*	*30*	*85.899 ms*
9	*8 byte*	*1 (Bit[63])*	*-*	*20 (Bit[43:62] = Sweeps[0:19])*	*38*	*21.990233 s*
5	*8 byte*	*1 (Bit[63])*	*16 (Bit[47:62] = Tag[0:15])*	*-*	*42*	*351.843721 s = 0.10 h*
1	*8 byte*	*1 (Bit[63])*	*5 (Bit[58:62] = Tag[0:4])*	*-*	*53*	*200.16h = 8.34 d*

With the scaler option it is possible to have also part of scaler data in the list data word, see Fig. 5.10. In this case the following Time_patch values are available in addition:

Time_patch value (hex)	*Data length*	*Data lost bit*	*Scaler bits*	*Sweep counter*	*Time bits*	*Max. sweep length*
31	*8 byte*	*1 (Bit[63])*	*22(Bit[41:51]= S1[0:10], Bit[52:62] = S2[0:10])*	*20 (Bit[21:40] = Sweeps[0:19])*	*16*	*5.24 us*
35	*8 byte*	*1 (Bit[63])*	*22(Bit[41:62] = S1[0:21])*	*20 (Bit[21:40] = Sweeps[0:19])*	*16*	*5.24 us*
21	*8 byte*	*1 (Bit[63])*	*24(Bit[39:50]= S1[0:11], Bit[51:62] = S2[0:11])*	*10 (Bit[29:38] = Sweeps[0:9])*	*24*	*1.342 ms*
29	*8 byte*	*1 (Bit[63])*	*24(Bit[39:62]= S1[0:23])*	*10 (Bit[29:38] = Sweeps[0:9])*	*24*	*1.342 ms*
25	*8 byte*	*1 (Bit[63])*	*22 (Bit[41:51] = S1[0:10], Bit[52:62] = S2[0:10])*	*-*	*36*	*5.4976 s*
2d	*8 byte*	*1 (Bit[63])*	*22 (Bit[41:62] = S1[0:21])*	*-*	*36*	*5.4976 s*

The software adds at the end of a list file a small block containing counter values. The format follows the scheme of usual data, it can be distinguished by the channel number, which is 1 or 2 for the high data part of data values when using a word length of 4 bytes.

For 8 byte data length it is also possible to let the firmware insert such a counter data block in regular time intervals.

The lowest 4 Bits 0 to 3 is the channel number, 1 or 2 for counter data.

Bits 4 :7 is the counter number:

Counter Number	
0	Scaler 1
1	Scaler 2
2	Scaler 3
3	Scaler 4
4	Scaler 5
5	Scaler 6
6	Realtime
7	Livetime
8	Sweep Counter
9	*- reserved -*
10	*- reserved -*
11	*- reserved -*
12	*- reserved -*
13	*- reserved -*
14	*- reserved -*
15	*- reserved -*

All counter values have a length of 48 bit. When using a data length of 4 byte, the lower 24 bits are in the first 32 bit data word in bits 8 : 31, the upper 24 bits in the next data word that is marked by a channel number of 2. When using a data length of 8 byte, Bits 8 : 55 contain the 48 bit counter value. The Real- and Livetime is in units of 5.12 ns for a time resolution of 80 ps, otherwise in units of 6.4 ns. An example of counter data in list file with 8 byte data word length and counters enabled is shown here:

0000097786796661
00000974343b0171
000000000186a081

000004d8d7570001
000004d8d7570011
000004d8d7570021
000004d8d7570031
000004d8d7570041
000004d8d7570051

Here is an example of counter data in a list file with 4 byte data word length and counters not enabled:

08932661
00000062
00733571
00000072
0003e881
00000082

5.3 Control Language

A sequence of commands that are stored in a file with extension .CTL can be executed by the MCS8 server program or MPANT with the “Load ” or “Run” command. Also the configuration files MCS8A.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:

- Define one of programmable toolbar icons F1..F12 in the MPANT program with the command and click the icon, see Options..Function keys in the MPANT menu.
- 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 5.4. The application name for opening the DDE connection with the standard MCS8 server program MCS8.EXE is MCS8, the topic is MCS8-. 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 MCS8A.SET contains a complete list of commands for setting parameters. An example is:

```
[MCS8A] 500             ; Device and serial number
range=4096              ; Spectrum length
periods=2               ; Number of periods for folding
fstchan=0               ; acquisition delay = number of first bin / 64
holdafter=0             ; hold after sweep in units of 64 basic dwelltimes
sweepmode=227ea080 ; (hex) 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)
                        ; 0xF = Corr.+diff (Ch2)
                        ; bit 4: Softw. Start
                        ; bit 5: "Don't show" tagbits
                        ; bit 6: Endless
                        ; bit 7: Start event generation
                        ; 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
                        ; bit 12: abandon Sweepcounter in Data
                        ; bit 13: "one-hot" mode with tagbits
                        ; bit 14: start ref (diff.mode) (MCS8)
                        ; bit 15: MCS8, MCS8A1: enable start input sampling
                        ; bit 16..bit 22 ~(input channel enable)
                        ; MCS8A: bit 16..bit 23 ~(input channel enable)
                        ; bit 26: 100 ps time resolution instead of 80 ps
                        ; bit 27: Folded
                        ; bit 28: Interleaved
                        ; bit 29: MCS8A: don't use trigger, use CH1 to start sweep
```

```
                        ; bit 30: Use only 1 decoder
calreg0=fe00            ; result of input delay calibration, l
                        ; lower 8 bits: start channel (always 0),
                        ; higher 8 bits, first channel after start
calreg1=0               ; second, third channel
calreg2=0               ; ..
calreg3=0               ; ..
swpreset=1000000        ; Sweep-Preset value
prena=4                 ; bit 0: realtime preset enabled
                        ; bit 1:
                        ; 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
                        ; bit 10: ROI7 preset enabled
                        ; bit 11: ROI8 preset enabled
syncout=0               ; LOWORD: sync out; bit 0..5 NIM syncout, bit 8..13 TTL syncout
                        ; bit7: NIM syncout_invert, bit15: TTL syncout_invert
                        ; 0="0", 1=5 MHz, 2=50 MHz, 3=100 MHz, 4=1/(80 ps or 100 ps * 64),
                        ; 5=1/(80 ps or 100 ps * 32), 6=PLL ref clock, 7=Input 0(Start), 8=Input 1,
                        ; 9=Input 2, 10..13=Input 3..7, 15=GO in, 16=Start_of_sweep, 17=Armed,
                        ; 18=SWEEP_ON, 19=WINDOW, 20=HOLD_OFF, 21=EOS_DEADTIME
                        ; 22=TIME[0],...,51=TIME[29], 52...63=SWEEP[0]..SWEEP[11]
cycles=18               ; cycles for sequential mode
sequences=1             ; for sequential mode (default 1)
                        ; specifies how often to repeat
                        ; after performing cycles acquisitions
tagbits=16              ; number of tagbits
vdac0=8fa               ; (hex) dac0 value (start) voltage=2.048 * (1-vdac/2048)
                        ; bit 16: start with rising edge
                        ; (bit 14, 15) : 0=falling, 1=rising, 2=both, 3=both+CFT
vdac1=8fa               ; dac1 value
vdac2=8fa               ; dac2 value
vdac3=8fa               ; ...
vdac4=8fa
vdac5=8fa
vdac6=8fa
vdac7=8fa               ; …dac7 value
dac0v=-0.2              ; dac0 value = -0.2 V (start)
dac1v=-0.2              ; dac1 value = -0.2 V (STOP1)
..
dac7v=-0.2              ; dac7 value in Volt
dacv=-0.1               ; set dac1..dac7 to -0.1 V, all dacs without dac0 (start)
dacv+=0.001             ; increase all dac values without dac0 by 1 mV
dac0v+=0.001            ; increase dac0 value by 1 mV (start)
rtpreset=20.000         ; Timepreset (seconds)
digio=0                 ; 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 3: Push-Pull output, not possible
                        ; bit 4:  Start with Input Dig 4
                        ; bit 5:  Start with Input GO
                        ; 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
```

```
digval=0            ; digval=0..255 value for samplechanger
autoinc=0           ; 1=Enable auto increment of filename
savedata=0          ; 0=No Save at Halt
                    ; 1=Save at Halt
                    ; 2=Write list file, no save at Halt
                    ; 3=Write lit file, Save at Halt
mpafmt=asc          ; data fromat used in MPA files
                    ; (dat=binary, asc=ASCII, csv=CSV)
sephead=0           ; 1=Seperated Header file (extension .MP) and
                    ; Data file (extension dat, asc or spe) for seperated spectra
fmt=asc             ; data format used in seperated spectra (extension .MP)
                    ; (dat=binary, asc=ASCII, csv=CSV)
smoothpts=5         ; number of points to average for a smooth operation
wndwidth=155        ; width of server window
wndheight=273       ; height of server window
sysdef=0            ; 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
                    ; ...
                    ; bit6=1, bit7=1: dev#3 in system 4
                    ; bit 31: any preset stops all
[CHN1]              ; the following section concerns parameters of CHN1
range=4096          ; Spectrum length
active=1            ; Spectrum definition words for CHN1..8:
                    ; active & 0xF  ==0 not used
                    ;                ==1..4 enabled, system 1..4
                    ; 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 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
                    ;           ==10 SW-HIS, Sweep History
                    ; bit 8..11 xsh, bit 12..15 ysh or bit 8..15 xsh
                    ; HIWORD(active) = condition no. (0=no condition)
bitshift=0          ; LOWORD: Binwidth = 2 ^ (bitshift)
                    ; HIWORD: Threshold for Coinc
cftfak=2580100      ; LOWORD: 256 * cft factor (t_after_peak / t_to_peak)
                    ; HIWORD: max pulse width for CFT
evpreset=10         ; ROI preset value
roimin=0            ; lower ROI limit
roimax=4096         ; upper limit: roimin <= channel < roimax
caloff=0.000000     ; calibration parameter: offset
calfact=0.080000    ; calibration parameter: factor
calfact2=0
calfact3=0
calunit=nsec        ; calibration unit
caluse=1            ; bit 0=1: use calibration, higher bits: calibration formula
roi=0 9986 ;starts  ; rectangular ROI from 0 to 9986 with name “starts” (lower left, upper right corner)
[CHN2]              ; the following section concerns parameters of CHN2
...
```

The following commands perform actions and therefore usually are not included in the MCS8A.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 MCS8A.SET
mpaname=filename     ; Defines the mpa filename
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                 ; Sets actual multichannel analyzer to MC_B (STOP2)
                     ; … MC_H (ch8)
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 7 going low.
                      ; After a timeout a Messagebox warns and waits for pressing OK
                      ; Can be used for connecting a sample changer.

waitpin3 4000         ; waits for going the level at pin 3 going low. All Dig I/O ports 0..7
                      ; can be used this way.

loadcnf configfile    ; Loads a configuration stored in a config file like mcs8a.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.

oncycle command       ; The command is executed in sequential mode after each cycle.
                      ; can be used together with 'waitpin' command to synchronize with a
                      ; beam- or target mover.

oncycle off           ; Switches off the 'oncycle' feature.

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.

closeall              ; close all spectra windows in MPANT

openall               ; open all spectra windows in MPANT

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_A          ; 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_A means 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 SP_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..).

selnamedroi roiname ; select a named roi with (unique) name roiname in MPANT

yproj CH_1 ; create a projection of the selected ROI in first shown spectrum window in MPANT

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 MC_A via the serial port and make it actual.

...

MC_H? ; Sends the status of MC_H via the serial port and
; make it actual.

? ; Send the status of the actual channel

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.

5.4 Controlling the MCS8 Windows Server via DDE

The MCS8 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 MCS8 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 MCS8 server program.

5.4.1 Open Conversation

application: MCS8

topic: MCS8-

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 MCS8 and the topic is MCS8-.

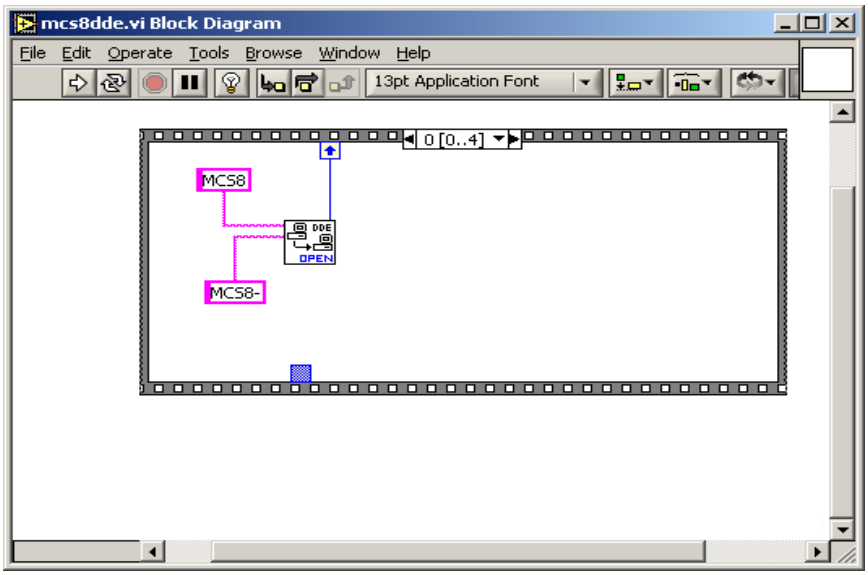


Fig. 5.28: Opening the DDE conversation with the MCS8 server in LabVIEW

5.4.2 DDE Execute

The DDE Execute command can be used to perform any action of the MCS8 program. Any of the Control command lines described in section 5.3 can be used. For example a sequence of control commands saved in a file TEST.CTL can be executed by specifying the command

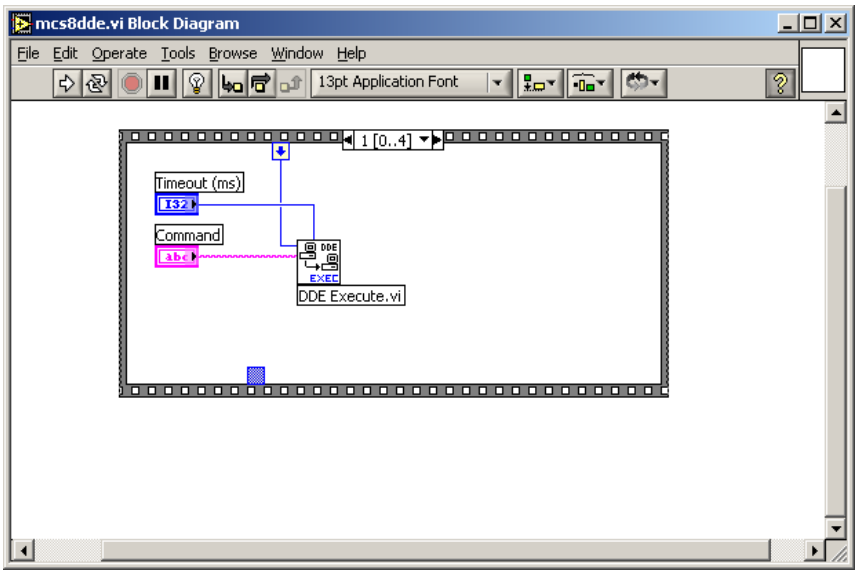


Fig. 5.29: Executing a MCS8 command from a LabVIEW application

RUN TEST.CTL

The MCS8 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.

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.

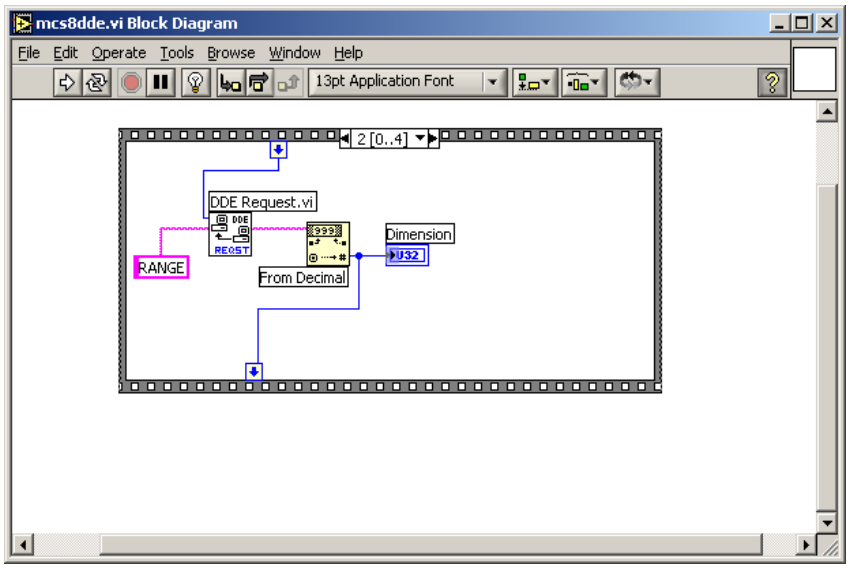


Fig. 5.30: Getting the range of spectrum data with LabVIEW

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.

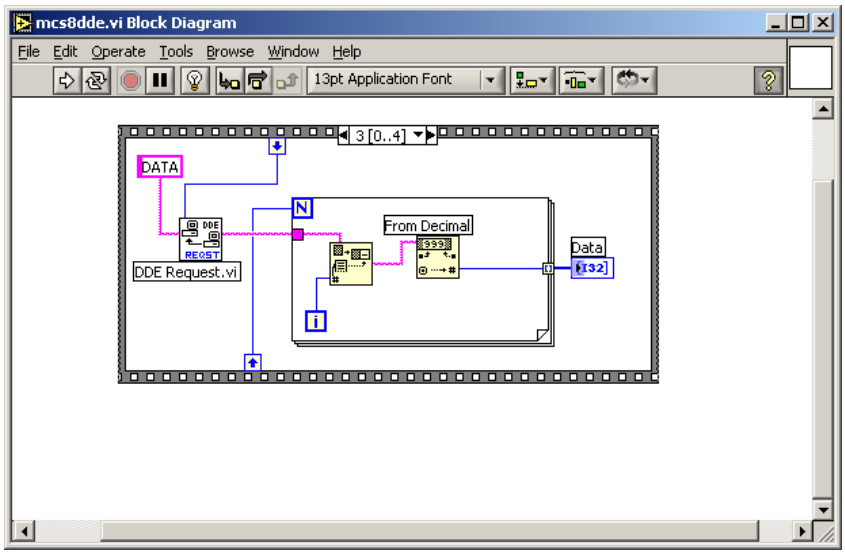


Fig. 5.31: Getting the data with LabVIEW

5.4.3 Close Conversation

After finishing the DDE communication with the server program, it must be closed.

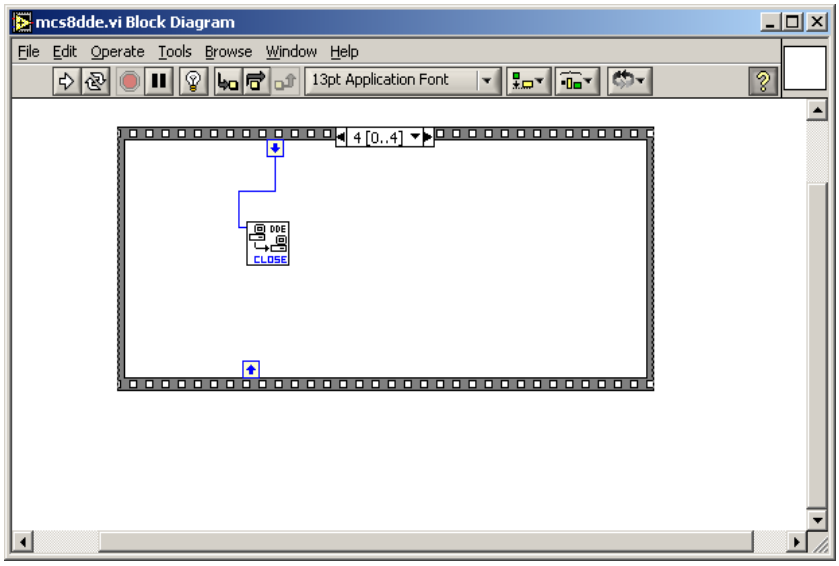


Fig. 5.32: Closing the DDE communication in LabVIEW

The following figure shows the “Panel” of the described VI for LabVIEW.

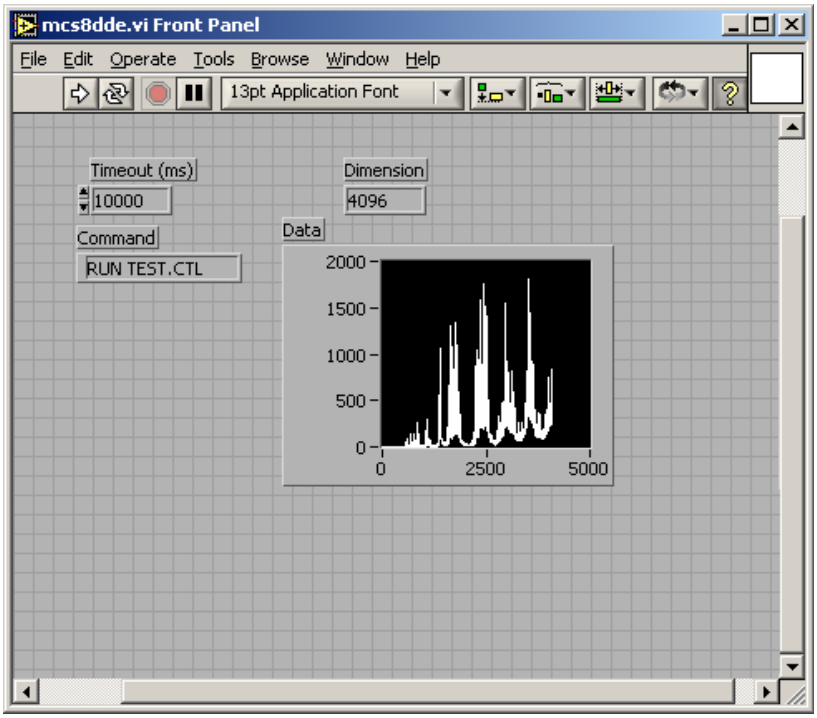


Fig. 5.33: Control Panel of the demo VI for LabVIEW

5.5 Controlling the MCS8 Windows Server via DLL

The MCS8 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 MPANT software that provides all necessary graphic displays.

NOTE:

The complete documented source code of the DLL including a library with fundamental VI’s and an example VI for LabVIEW and an example Visual Basic and C program is available as an option.

The DLL DMCS8.DLL is an interface providing functions to communicate with the server program. Most of these functions send messages to the server as you do it when operating the server program by sending Windows messages via mouse clicks. Please do not expect any functions in this DLL for controlling the hardware directly. All software using the DLL interface requires that the server program is running. The DLL was mainly developed as an interface between the server program and MPANT, not as a nice developing tool for customers. But by looking at the programming examples and some hints in the DLL documentation it should be easy to develop own programs that are able to control the server like MPANT does.

The server program has a built-in command interpreter. The syntax of these commands is described in chapter 5.3, and in the MPANT on-line help (look for: "How to use the command language.."). It is recommended to send commands like "range=16384" to the server via the RunCmd DLL function, i.e. RunCmd(0, "range=16384"); if you want to set parameters like a spectra length. The alternative method is to store all settings parameters into the DLL by calling the DLL function StoreSettingData(setting, 0); and then calling NewSetting(0); to send a message to the server to read new settings from the DLL. This method will not work for changing a spectra length to avoid the problem of any undefined memory pointers. The range parameter should be changed by the server program only (or by sending a "range=.." command). The recommended usage of the DLL is reading parameters like Status, Settings, Strings, Cnt numbers, ROI boundaries using the corresponding DLL functions, but for any actions or setting any parameters the command interpreter should be used.

It is important that the DLL is loaded first by the Server program and that it is loaded from the same path by all programs using it. Otherwise it does not work to access the shared memory. The dmca4.dll is installed by the installation program into the standard Windows folder for 32-bit or 64-bit DLLs, respectively. Please make sure that there is nowhere else any file dmcs8.dll.

6 MPANT Software

The window of the MPANT program is shown here. It enables the full control of the MCS8 via the server program to perform measurements and save data, and shows the data on-line in several windows.

The server program MCS8.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. If you want to use the server without the MPANT display program, you may rename the file “mpant.exe” into “mympant.exe”. It will then not be found by the server and not started. MPANT can be closed at any time without affecting the data acquisition and can be restarted out of the server menu or by a shortcut on the desktop.

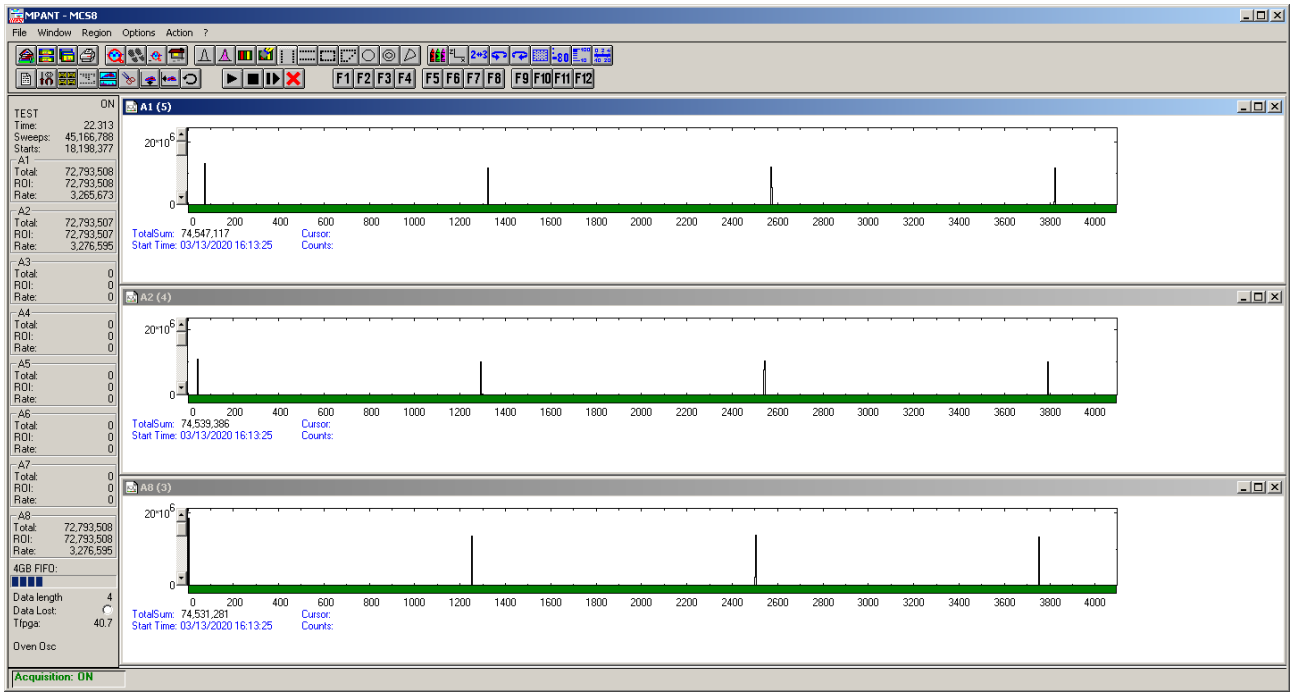


Fig. 6.1: MPANT main window

MPANT has viewing capabilities for single- and two-dimensional spectra. For ROI's the ROISum, Net sum and 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 MCS8. Below the different counting rates you can see the present temperature of the FPGA. A "Data Lost" indicator shows if the FIFO was full at any time during an acquisition, a progress bar shows the filling of the large FIFO.

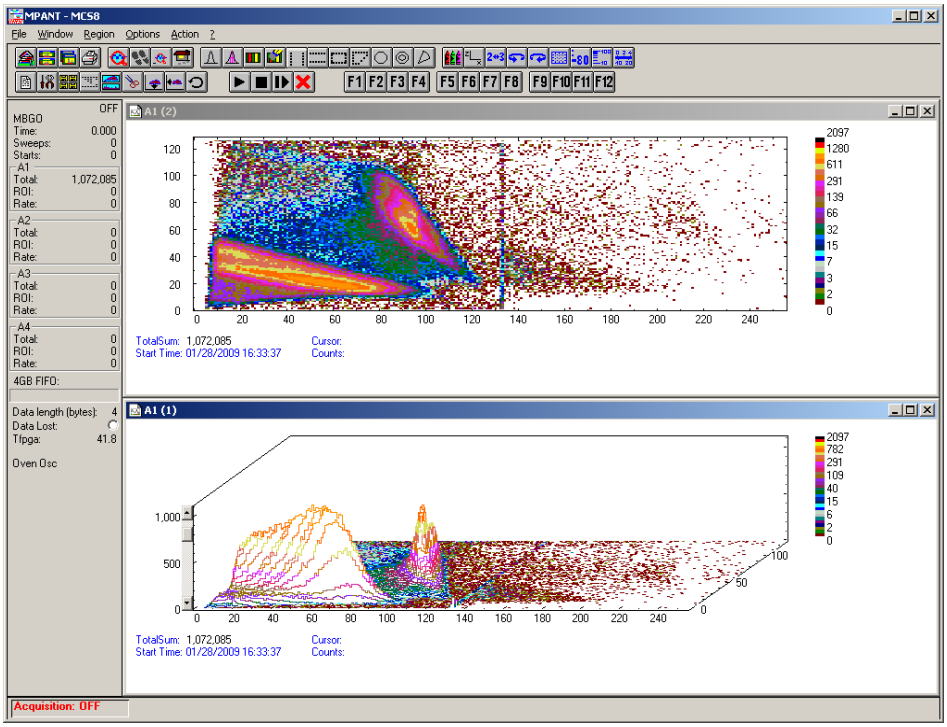


Fig. 6.2: MPANT Map and Isometric display

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 scroll bar 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 seperated 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 Fig. 5.3. When saving data, you have the choice between several formats like 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 Data Operations dialog, see Fig. 5.3. This dialog can also be used to load spectrum data from a file into an existing display window.

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 spectrum for the new display can be selected.

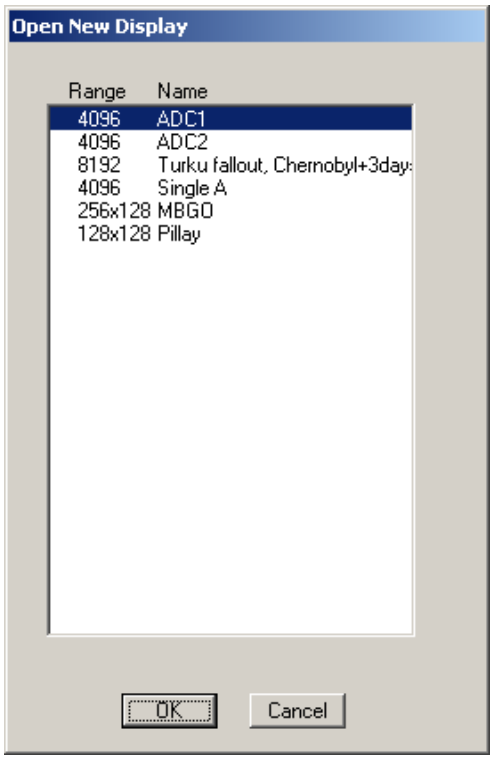


Fig. 6.3: File New Display dialog

Open All

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

Close All

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

Compare...

The Compare... menu item opens a dialog that enables to show two spectra with different colors in the same window. The active display window can be checked as a primary window and there is a list of other spectrum windows that can be inserted as secondary windows.

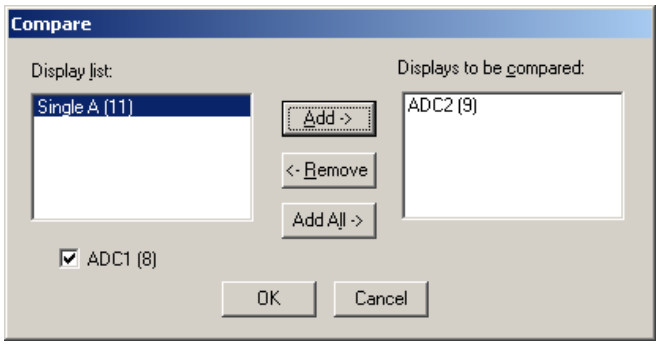


Fig. 6.4: Compare dialog

Using the features of the software it is possible to create a shifted spectrum that has a characteristic peak at the same place as the primary spectrum, see 5.1.7 . This way a view as shown in Fig. 6.5 can be created.

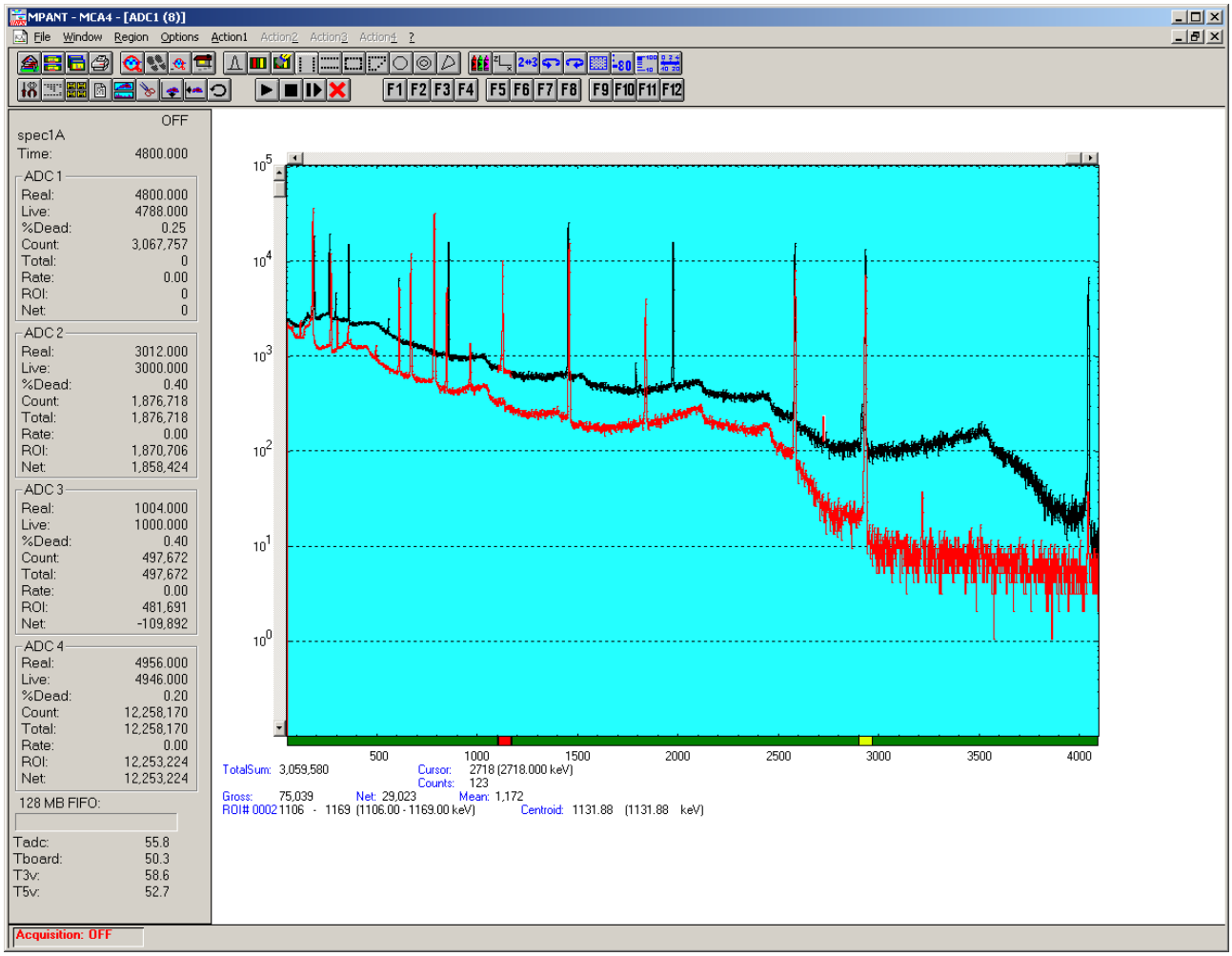


Fig. 6.5: Compare two spectra

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, file name and title can be added. For each page a temporary file PRINT1.WMF, PRINT2.WMF... will be created. This file is in Windows Meta file format and can be exported into some other Windows applications.

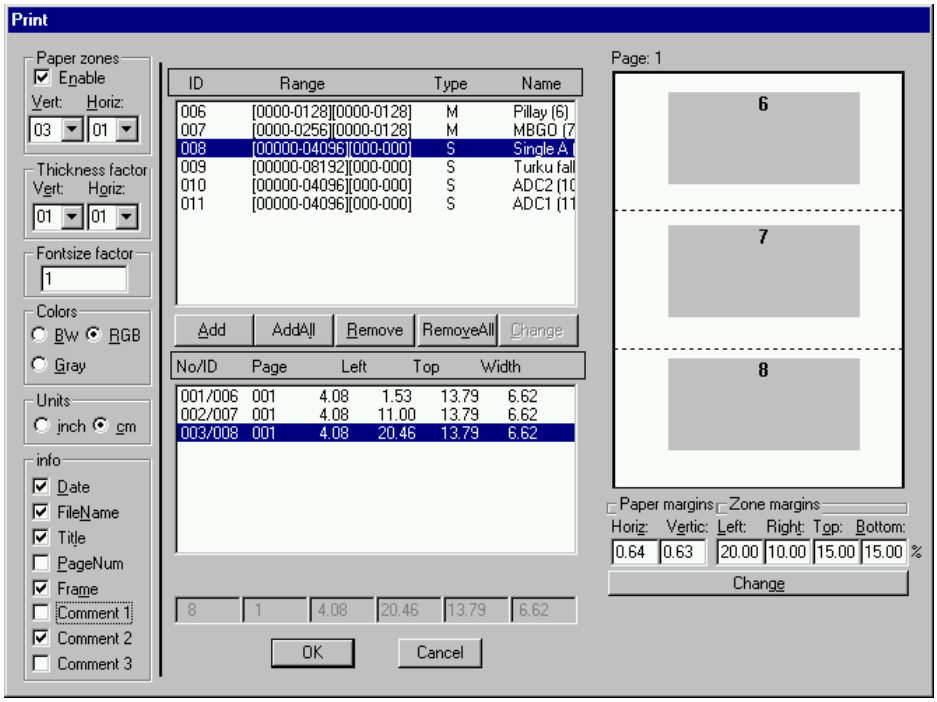


Fig. 6.6: Print dialog

Setup Printer...

The Setup Printer menu item enables to configure the printer.

Exit

The Exit menu item exits the MPANT program. The server and any measurement data remain active, MPANT can be easy restarted out of the file menu of the server program.

6.2 Window Menu

The Window menu enables arranging the Display windows.

Tile

With the Tile menu item or by 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.

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 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. You can also use a mouse wheel for zooming in at out.

Home

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

Shape

Selecting the Shape menu item opens a sub menu 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 enables editing 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.

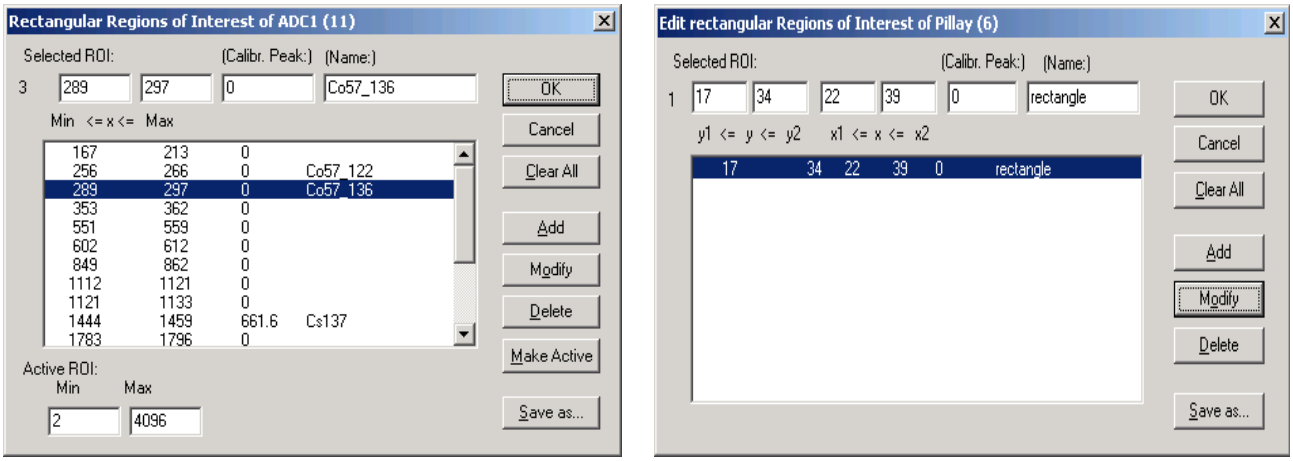


Fig. 6.7: Slice and rectangular ROI Editing dialog

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 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.

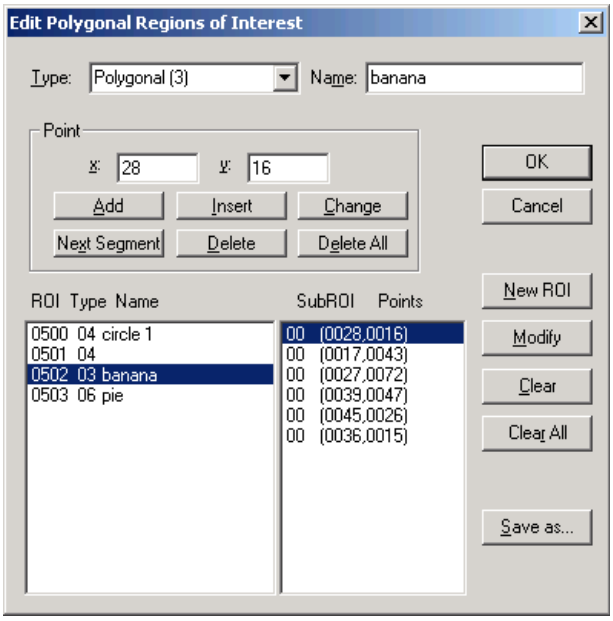
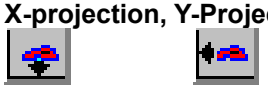


Fig. 6.8: Polygonal ROI Editing dialog

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 implemented. There are 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:

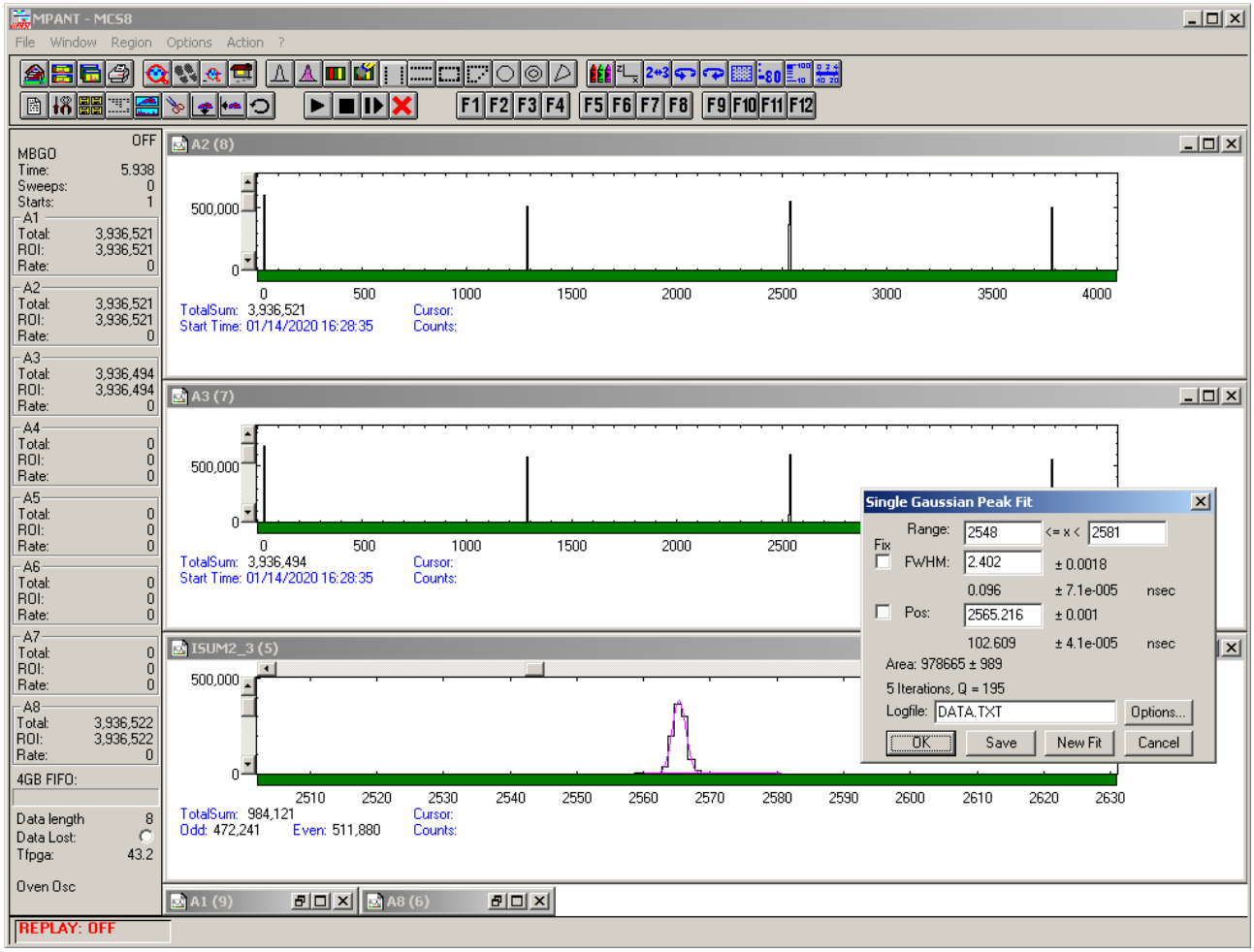


Fig. 6.9: Single Gaussian Peak Fit

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 check box. 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.

Peak Evaluation...

By selecting the Eval... menu item or the respective icon, a general peak evaluation with linear background is performed for the currently marked region. The calculated background curve is displayed and a dialog box shows the results:

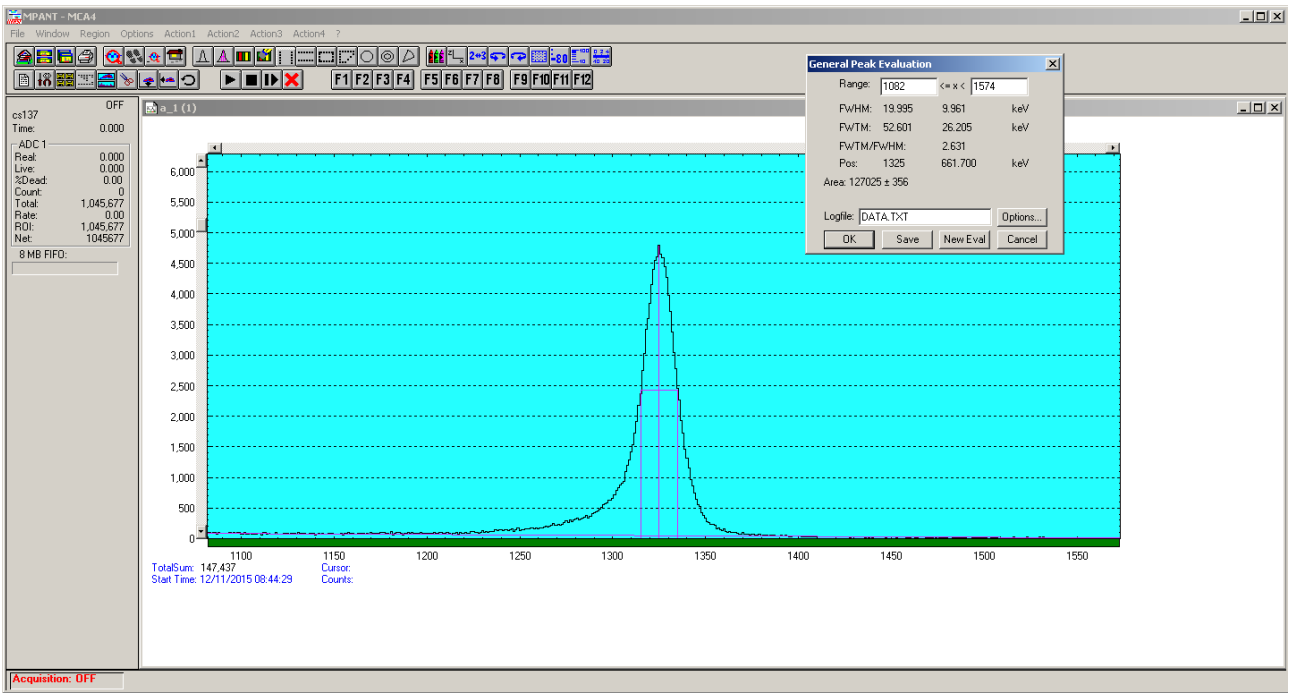


Fig. 6.10: Evaluation of a non-Gaussian peak

The Position and FWHM are displayed in channels and also in calibrated units, if a calibration is available. The area of the peak is also shown, as well as the FWTM and FWTM / FWHM ratio. Click on Save to append a line containing the results to a Log file with the specified name. OK closes the dialog. Options... opens a new dialog box to define the information in the log file:

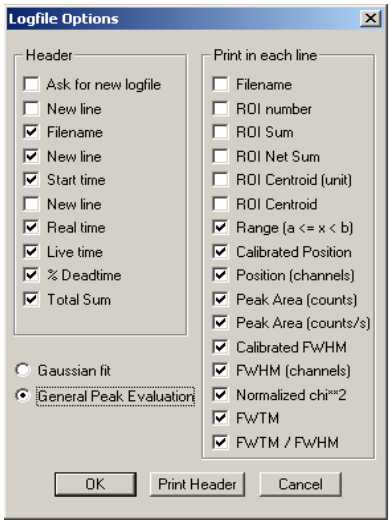


Fig. 6.11: Log file Options

Two radio buttons enable to select between Gaussian fit and general peak evaluation. 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 as a text file. 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 calibration value was entered in the ROI editing dialog, and performs a calibration using the fit results. You have then only to check “use calibration” in the calibration dialog opened with to use it.

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.

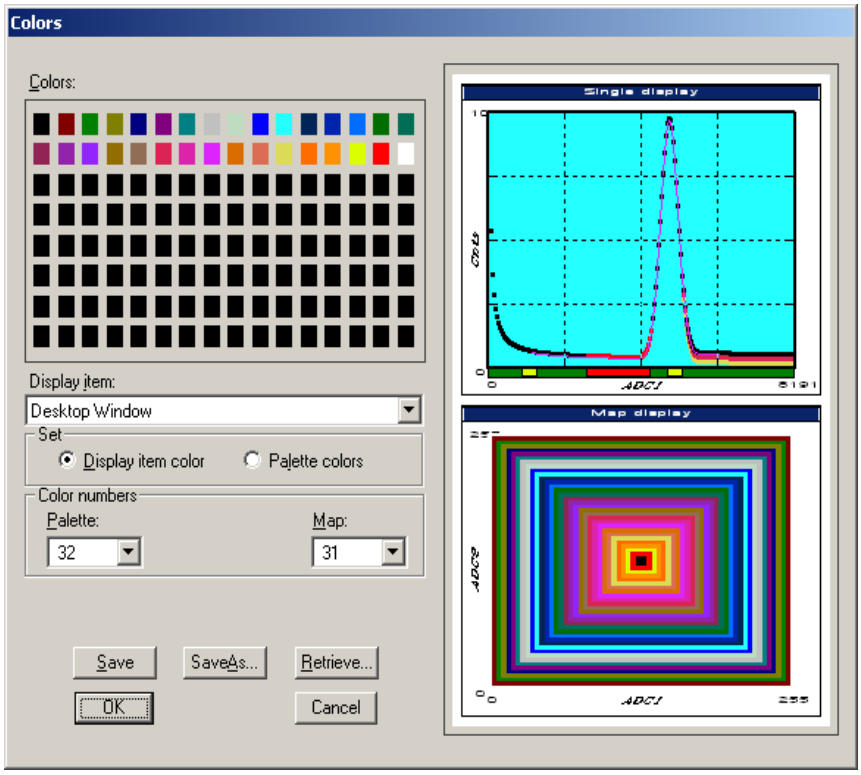


Fig. 6.12: Colors dialog

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.

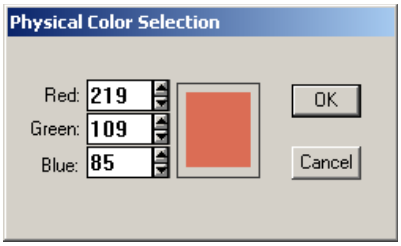


Fig. 6.13: Color Palette dialog

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 check boxes “**Max Pixel**”, “**Mean Pixel**” ,“**Min Pixel**” or “**All**” which value will be displayed. It is also possible to display all three possible Pixel 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. As plotting all values costs a lot of computing time for very large spectra, it is replaces automatically by “Max” and “Min” pixel for spectra with more than 1 million counts.

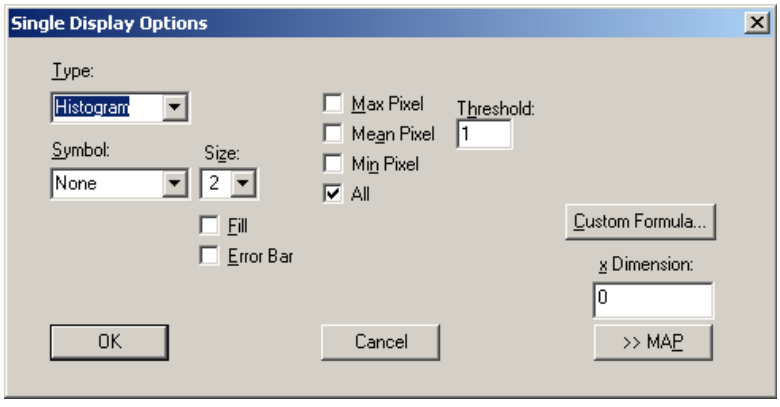


Fig. 6.14: Single Display Options dialog

The button labeled **Custom Formula...** provides spectra that are calculated in a special DLL named FMPA3.DLL. This DLL allows to calculate spectra and to display it with the MPANT program. The source code of this DLL is part of the optional DLL software interface, so it is possible to program customer defined functions.

Installation: Copy the FMPA3.DLL into the working directory. 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 data. 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.

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 Display Options dialog.

For MAP displays the Display Options dialog is changed and enables 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 check box **Invert Roi Pixel** changes the color inside ROI's to make them 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.

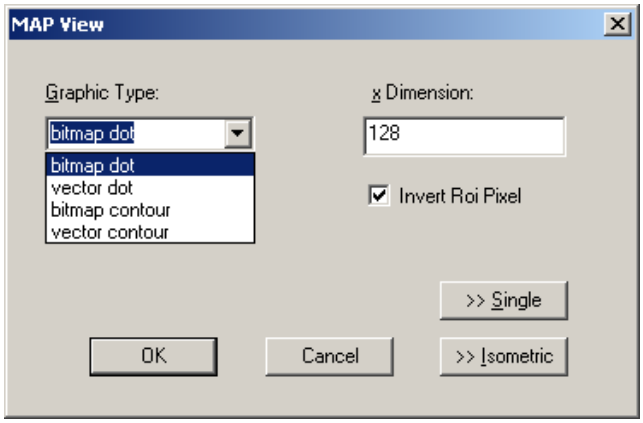


Fig. 6.15: Map Display Options dialog

From the MAP View dialog it is possible to change to Single view by clicking ">> Single" or change to Isometric View by clicking ">> Isometric". This can also be done directly via the respective toolbar icon . 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 2.5.4 .

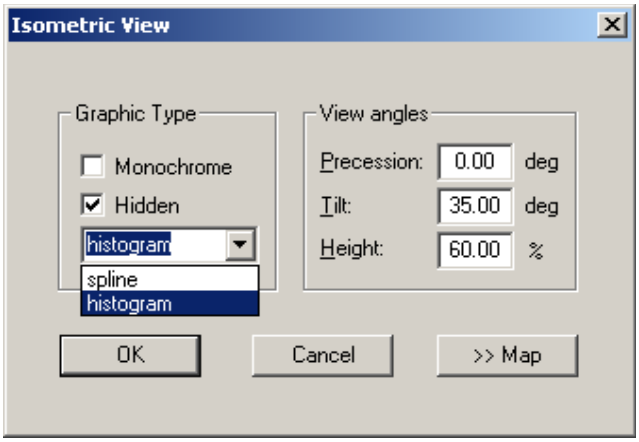


Fig. 6.16: Isometric Display Options dialog

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. This rotation can also be done directly using toolbar icons and . 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.

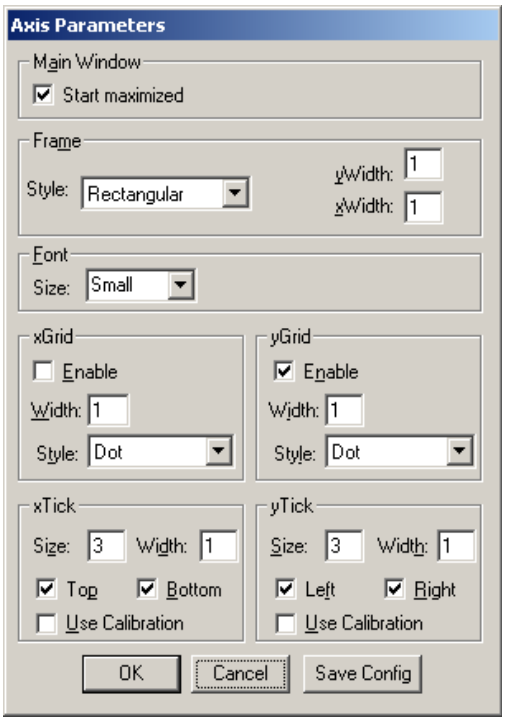


Fig. 6.17: Axis Parameters dialog

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 check box "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.

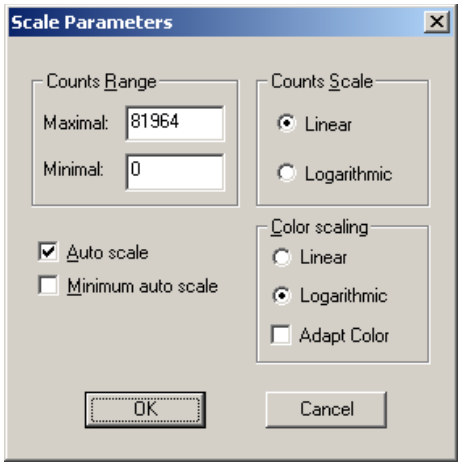


Fig. 6.18: Scale Parameters dialog

It enables changing the ranges and attributes of a Spectrum axis. By setting the Auto scaling mode, the MPANT will automatically recalculate the y-axis 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.

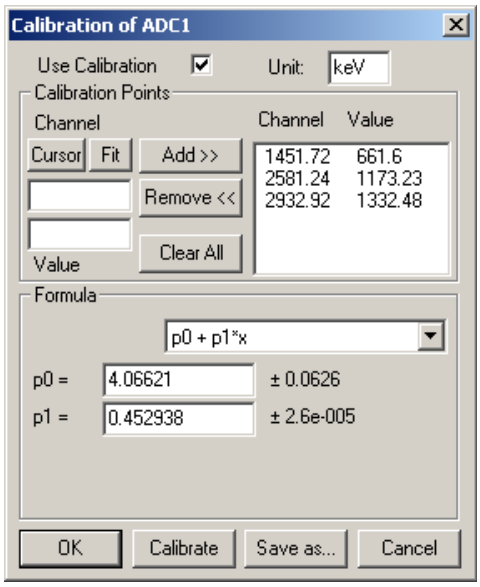


Fig. 6.19: Calibration dialog

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.

The fastest way to get a good calibration is to create ROI's around peaks with known energy and enter the energy in the ROI editing dialog, see Fig. 6.7. Then use the “Auto Calib” function in the region menu. You will immediately get a calibration and the dialog opens as shown in Fig. 6.19.

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.

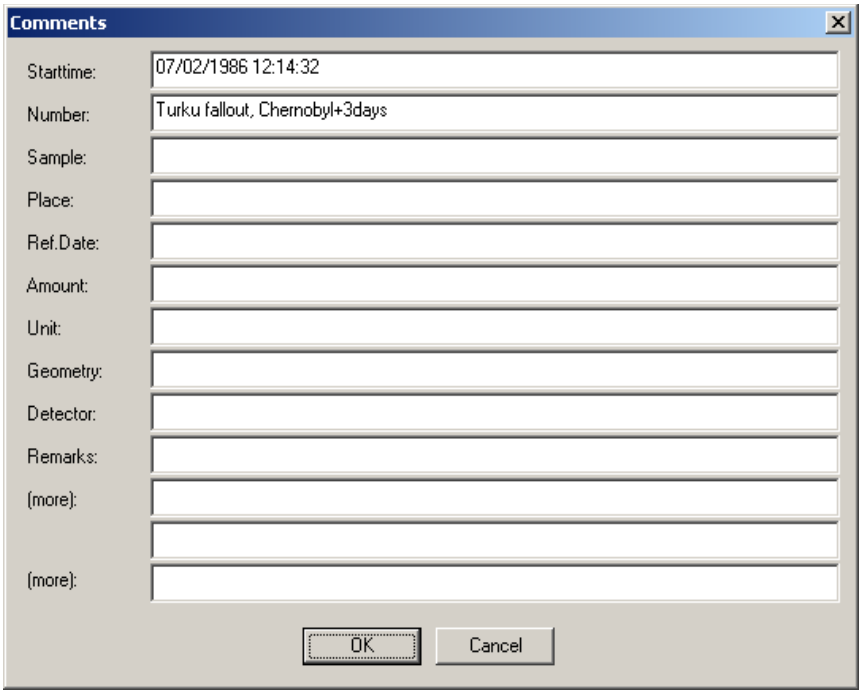


Fig. 6.20: Comments dialog

Hardware...

The Hardware settings dialog box allows to make all the respective settings (ref. 5.1.4).

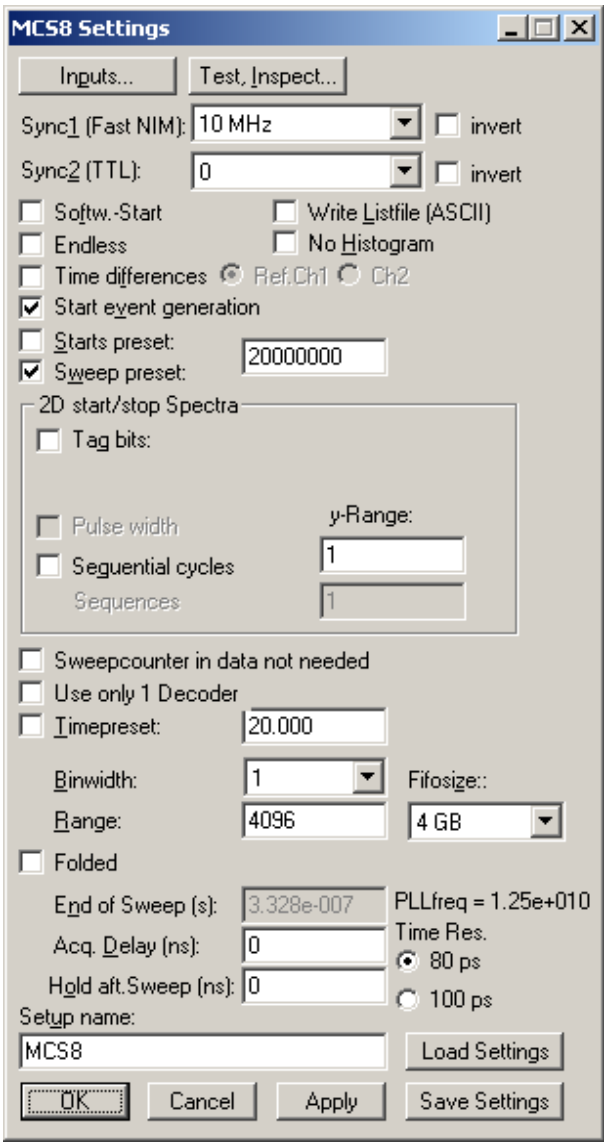


Fig. 6.21: Settings dialog box

Data...

The Data Operations dialog allows to edit format settings and to load and save spectra data, ref. 5.1.3 .

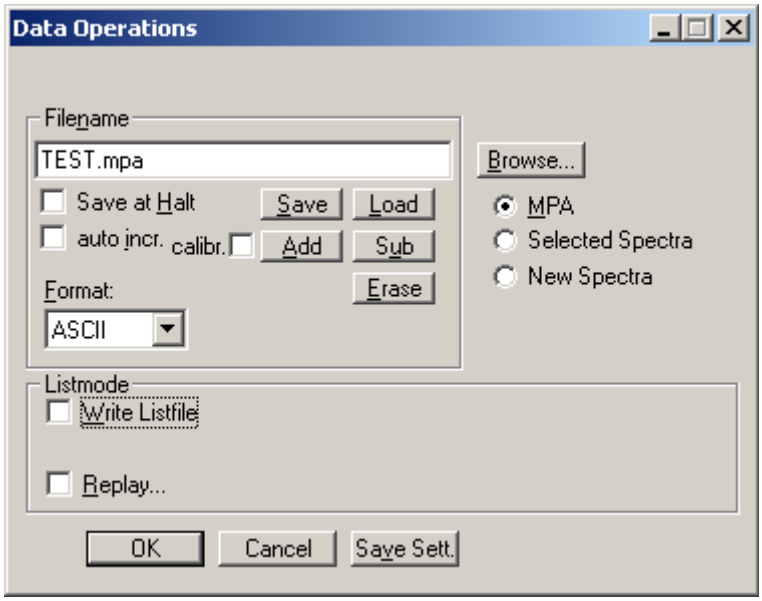


Fig. 6.22: Data Operations dialog

System...

The System Definition dialog box allows to make all the respective settings, see 5.1.6 .

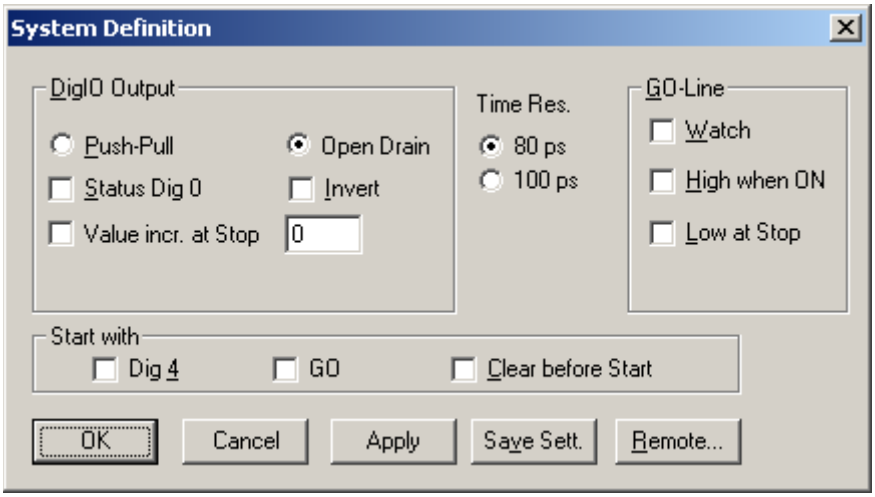


Fig. 6.23: System Definition dialog box

Spectra...

The Spectra dialog box allows editing the list of calculated and dual parameter spectra, see chapter 5.1.7

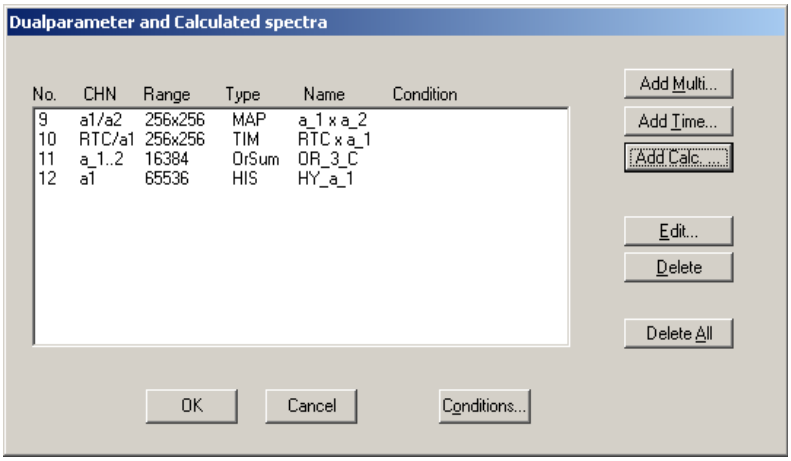


Fig. 6.24: Spectra dialog

Slice...

The Slice option allows to create new single spectra displays, showing a slice in a dual parameter spectrum. Click on a dual parameter spectrum 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. 6.25: Slice dialog

Replay...

The menu item Options – Replay... opens the Replay settings dialog (ref. 5.1.3).

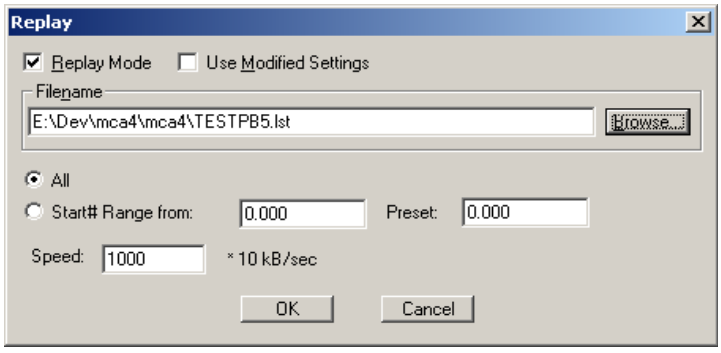
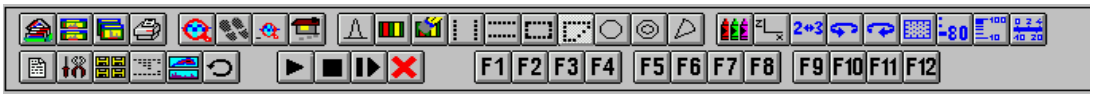


Fig. 6.26: Replay dialog

Tool Bar...



Selecting the Tool Bar Menu item opens the Tool Bar Dialog Box. It enables arranging the icons in the Tool Bar.

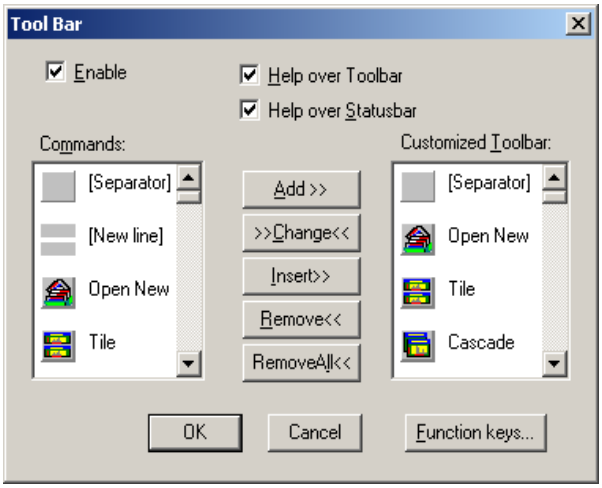


Fig. 6.27: Tool Bar dialog

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 with any one of the commands described in 5.3 . It can be accessed either by clicking the "Function keys..." button or directly from the Options menu.

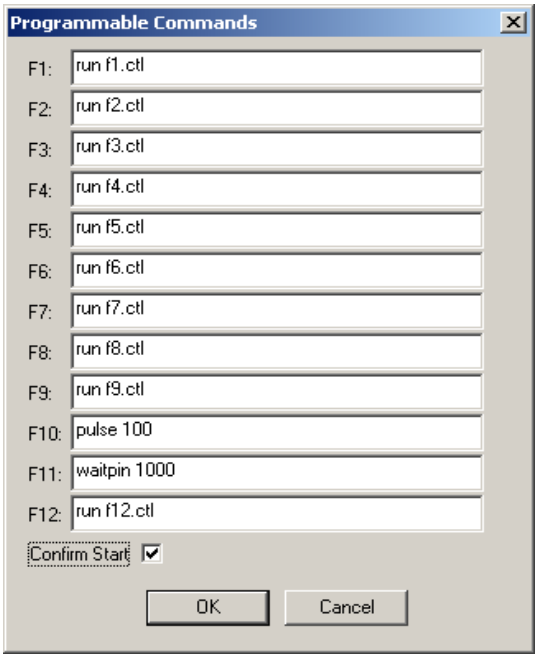


Fig. 6.28: Function keys dialog

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, i.e. it must be the top window. Uncheck the “Confirm Start” check box if you don't like the message box asking for a confirmation before starting a new acquisition.

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 status window at the left side of the MPANT main window can be shown in a small or large size or can be hidden.

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

Open...
Loads a new configuration.

6.5 Action Menus

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.

If more than one systems are defined for starting and stopping combined MCAs together, more groups of start / halt / continue / erase icons appear in the toolbar for the respective systems.

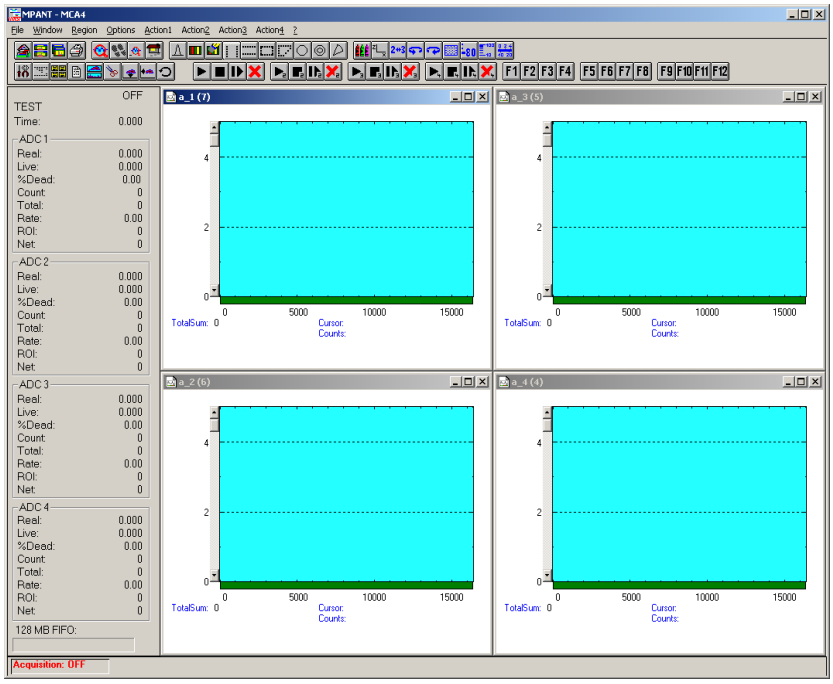


Fig. 6.29: MPANT with four systems enabled

7 Programming and Software Options

The MCS8 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.

The MPANT Windows software runs also on Linux using Wine and libusb, if Wine is expanded by DLLs as described in the readme.txt accompanying the software that can be free downloaded from our website.

8 Appendix

8.1 Performance Characteristics

8.1.1 General

Resolution[4] FWHM[5]:	at 1 ms ≅10,000,000 chs over 60 min: ..... typ. 135 ps
	at 100 ms ≅1,000,000,000 chs over 60 min: ..... typ. 160 ps
	at 1 sec ≅1,000,000,000 chs over 60 min: ..... typ. 340 ps
Dynamic range:	..... 2^{53} x 80 ps = 200.16 h = 8.3 d
Differential non-linearity:	..... << ± 1 %
Trigger delay:	Standard mode: ..... approx. 5 ns Multi-Start mode: ..... none
End-of-sweep deadtime:	(“Stop-after-sweep” mode) ..... <50 ns (“Endless” mode) ..... none
Deadtime between time bins	..... none
Loss less burst time:	(individually for each input channel) ..... > 10.5 µs
Decoder rate:	..... > 300 MHz
Sweep repetition time:	..... (Acq. Delay + Range + Hold Off + 50 ns)

8.1.2 Time base

Reference oscillator:	..... ovenized crystal oscillator
Nominal frequency:	..... 10.000 Mhz initial accuracy at 25°C: ..... ± 500 ppb
Frequency stability:	over operating temperature range: ..... ± 5 ppb vs. temperature slope: ..... ± 0.15 ppb/°C 24-hour drift: ..... ± 0.8 ppb vs. supply voltage change ±5 %: ..... ± 1 ppb total stability over 20 years: ..... ± 2 ppm
Ageing:	one-day ..... ± 0.8 ppb one-month ..... ± 25 ppb one-year ..... ± 150 ppb 20-year ..... ± 500 ppb
Jitter:	RMS period jitter ..... typ. 0.8 ps RMS phase jitter (random) ..... typ. 0.48 ps Peak cycle-to-cycle ..... typ. 6 ps
Phase noise:	..... (1 Hz) -80 dBc/Hz ..... (10 Hz) -108 dBc/Hz ..... (100 Hz) -127 dBc/Hz ..... (1 kHz) -148 dBc/Hz ..... (10 kHz) -154 dBc/Hz ..... (100 kHz) -154 dBc/Hz ..... (1 MHz) -167 dBc/Hz ..... (5 MHz) -168 dBc/Hz
Warm-up time:	to rated stability .....2 min.
Sampling frequency:	(nominal) ..... 12.5 Ghz

4 Input signal is a highly stable 10MHz GPS disciplined sine wave oscillator in a laboratory environment
5 Full width at half maximum. All FWHM data is derived from a gaussian fit

8.2 Specifications

8.2.1 Absolute Maximum Ratings

Input voltage:	any multi I/O port (DIG I/O 0…7):	- 0.5 to + 5.5 V[6]
	GO-Line:	-0.5 to + 5.5 V[7]
	any TAG input port:	-0.5 to + 5.5 V
	any discriminator input:	-3.0 … +4.0 V
Differential input voltage:	any discriminator input:	(V_{IN} – $V_{Threshold}$) = ± 2.0V
DC input current:	any multi I/O port	± 50 mA
	any TAG input port	± 50 mA
	any discriminator input:	± 80 mA

8.2.2 Recommended Operating Conditions

Power supply:	+12V / 2A
Operating temperature range:	0 to + 50°C
GO-Line load:	min. 1 kΩ to +5.0V
or	min. 2 kΩ to GND

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:		$V_{threshold}$ = -1.0 … +1.5 V
Clamp voltage:		V_{Clamp} = $V_{Threshold}$ ± 1.5 V
Impedance:		50 Ω ± 3 Ω
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:		12.5 Gbps
Slew rate requirement:		> 50 V/µs
Overdrive dispersion:	(V_{OD} = 50 mV … 1.0 V)	typ. 10 ps
	(V_{OD} = 10 mV … 200 mV)	typ. 15 ps
Slew rate dispersion:	(2 V/ns … 10 V/ns)	typ. 15 ps
Pulse width dispersion:	(100 ps … 5 ns)	typ. 15 ps

6 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.

7 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.

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:	VOUT = GND ... typ. -32 mA
Fall time:	< 200 ps
Rise time:	~ 300 ps

Sync_2 output

Location:	ref. FEATURE (multi) I/O port connector
Output impedance:	~ 25 Ω
Output HIGH voltage:	$I_{OutHIGH}$ = -100µA ... min. 3.1 V typ. 1.8 V into 50 Ω
Output LOW voltage:	I_{OutLOW} = 100µA ... max. 0.2 V
Recommended current:	V_{OUT} = LOW ... < 128 mA
	V_{OUT} = HIGH ... < -64 mA
Rise time:	~ 1 ns
Fall time:	~ 1 ns

Reference clock I/O

Input frequency:	(auto detected) ... 5 ... 100 MHz
Output frequency:	10 MHz
Input impedance:	(AC coupled) ... 1.3 kΩ
Output impedance:	(DC coupled) ... ~ 25 Ω
Output HIGH voltage:	(50 Ω load) ... typ. 1.8 V
Output LOW voltage:	(50 Ω load) ... typ. 0.2 V
Input amplitude:	(clipped sine or sine wave) ... typ. 3.3 V_{PP}

Digital I/O 0...7

Location:	ref. FEATURE (multi) I/O port connector
R Pull:	(default pull-up to +3.3V) ... 1.0 kΩ
R I/O:	(default series resistor) ... 22 Ω

GO-Line

Location:	ref. FEATURE (multi) I/O port connector
Line type:	open drain / wired-AND
Pull-up resistor:	22kΩ to +3.3 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

TAG inputs 0…15

Location:	ref. TAG input port connector
R PULL-DOWN:	50 Ω
Input HIGH voltage:	min. 2.0 V

Input LOW voltage: ..... max. 0.8 V

Time resolution: ..... 5.12 ns

Sampling uncertainty: TAG to cor. STOP: ..... ± 5.12 ns

Pulse width: ..... >10.24 ns

TTL TAG clock output

Location: ..... ref. TAG input port connector

Output frequency: ..... 195.3125 MHz

Output period: ..... 5.12 ns

Output HIGH voltage: $I_{OutHIGH}$ = -100µA ..... min. 3.1 V
..... typ. 1.6 V into 50 Ω

Output LOW voltage: I_{OutLOW} = 100µA ..... max. 0.2 V

Recommended current: V_{OUT} = LOW ..... < 256 mA

V_{OUT} = HIGH ..... < -128 mA

Octal Counter inputs

Count frequency: ..... max. 200 MHz

Input impedance: ..... 50 Ω / 0.5 W

Input pulse width: (high or low) ..... min. 2.5 ns

Input HIGH voltage: ..... min. 2 V

Input LOW voltage: ..... max. 0.4 V

8.3 Diagrams

8.3.1 Discriminator Sensitivity and Monitor Output

In the pictures[8] below STOP 1 is monitored on SYNC_1 output.

The input signal is drawn yellow and SYNC_1 in green.

Fig. 8.1: **13mV input pulses and cor. SYNC_1 MONITOR outputs**

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 (ref. Fig. 8.2).

Keep in mind that the hysteresis is about 5 mV.

Fig. 8.2: **10mV input pulses and cor. SYNC_1 MONITOR outputs**

8 These pictures are taken with a 2 GS/s, 500 MHz digital scope

8.3.2 SYNC_1 Output

In the pictures[9] below the SYNC_1 output is monitored with different signal selections.

The most important characterizing data of the output are calculated by the scope and are visible in the upper part of the pictures.

Fig. 8.3: **10 MHz signal at SYNC_1 output**

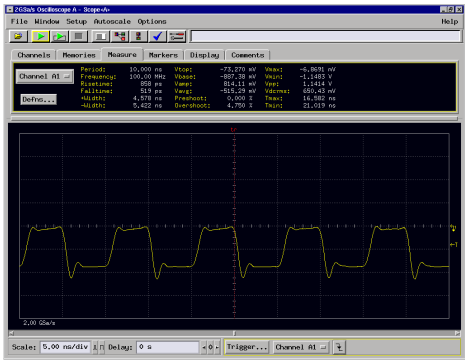


Fig. 8.4: **100 MHz signal at SYNC_1 output**

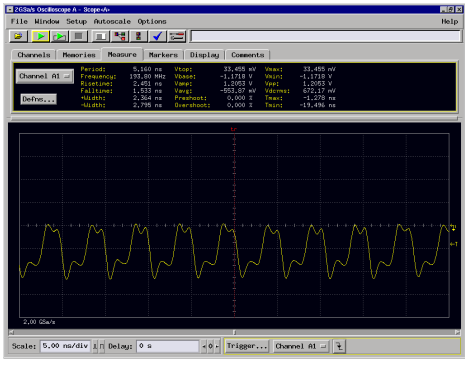


Fig. 8.5: **195.3125 MHz signal at SYNC_1 output**

9 These pictures are taken with a 2 GS/s, 500 MHz digital scope

8.3.3 SYNC_2 Output

In the picture[10] below the SYNC_2 output is monitored.

The most important characterizing data of the output are calculated by the scope and are visible in the upper part of the picture.

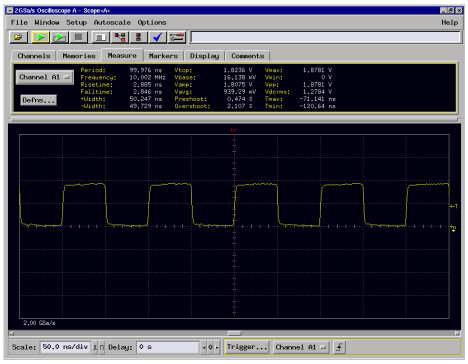


Fig. 8.6: **10 MHz signal at SYNC_2 output**

10 These pictures are taken with a 2 GS/s, 500 MHz digital scope

8.4 Physical

Case material: ..... aluminum
Size: ..... 260 mm x 48 mm x 275 mm
Weight: .....1.7 kg
Shipping case: Paper box with transport case, typ. 440 mm x 350 mm x 160 mm, 5.2 kg

8.5 Accessories

Included:

- USB 3.0 (A/A) cable, USB 2.0 compatible,
- Power supply 100-240 V_{AC} / 12 V_{DC} , min 2.0 A
- Power supply cord (if necessary)
- D-sub15 HD plug with plastic cap
- N+1 cables BNC-SMA, RG316 where N is the number of STOP channels ordered
- 1 cable SMA-SMA, RG316 (30 cm)
- 1 SMA-BNC adapter
- D-sub37 plug with plastic cap

Optional:

- Oven-disciplined internal 10 MHz reference oscillator for MCS8D-x (included with MCS8A-x)
- TAG / Counter cable BNC or Lemo
- TD2000, 2 GHz timing discriminator
- TA1000, TA2000, TA1800, TA2400 amplifier

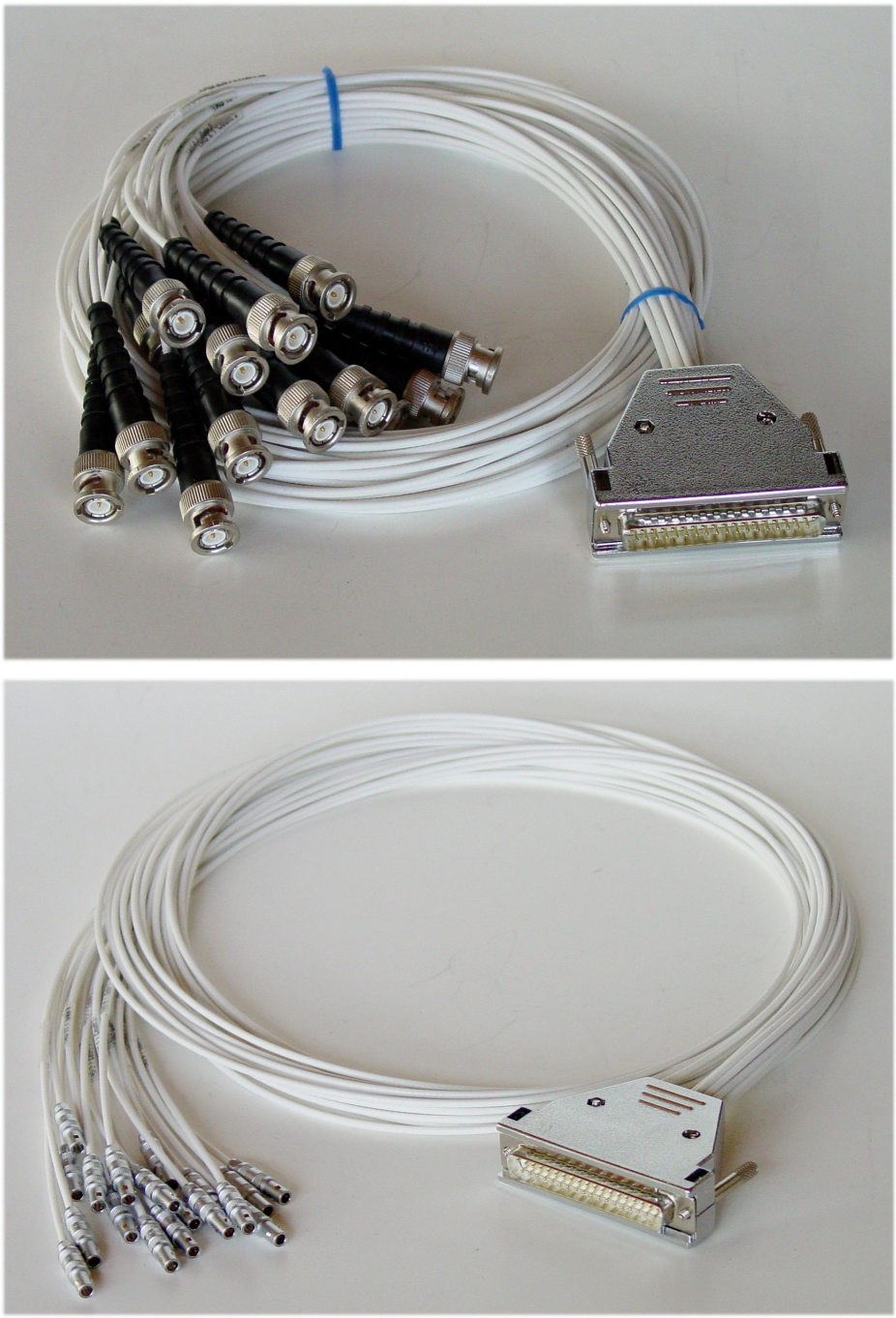


Fig. 8.7: Counter Cable BNC or Lemo

8.6 Trouble Shooting

- The 'POWER ON' LED does not light up:
  1) check that power is applied to the external power supply
  2) check the 12V supply cable is properly plugged in
  3) check that the external power supply works – check it's output voltage
- The MCS8A is not found by the host computer
  1) check that the USB cable is properly plugged in
  2) Remove the MCS8A power supply, wait 10 s and reapply power

When the software is started for the first time, it is normal that several windows pop up indicating that the MCS8.INI file is adapted to the special MCS8A device characterized by the number of Stop inputs and time resolution. It takes also some time to load the firmware and perform calibrations.

When the PC is shut down, also the MCS8A power must be switched off.

If the communication to the MCS8A is lost by any reason, the MCS8A power must be removed for at least about 10 seconds and the software restarted. It is not enough just to remove and plug in the USB cable. This is also the same with MCS6A.

If the customer wants to control the software via the DLL, he should first start the MCS8 software before he starts his own control program. The server can be started from a command prompt in the standard path of the MCS8 software. It is essential the the DLL is loaded first by the MCS8 server program, and that it is loaded then from the same path by his control program. The DLL must be in the folder where it was installed by the setup program, it must not be copied or moved to any other location. It is the standard Windows path for DLLs, for 32 bit DLLs on a 64 bit Windows it is Windows\SysWOW64, otherwise Windows\System32.

8.7 Personal Notes