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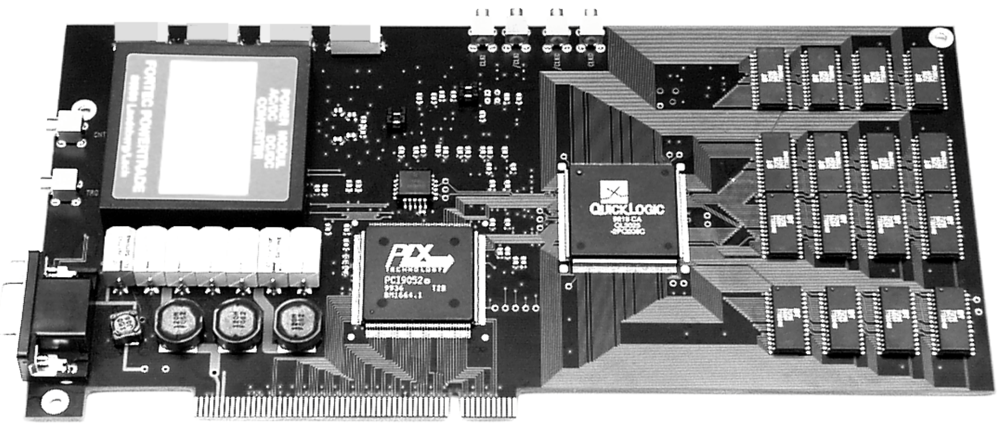
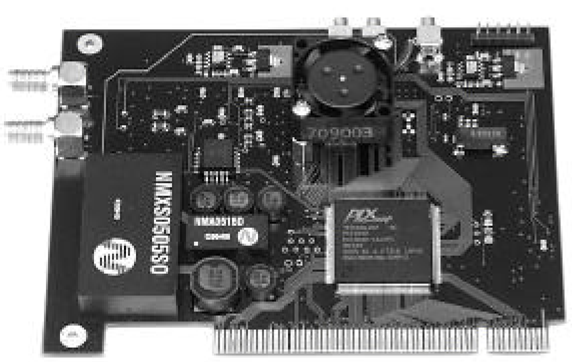
MSA-200 MSA-300 MSA-1000
Ultrafast Photon Counters / Multiscalers

- **MSA-1000: Resolution 1 ns / memory location**
- **MSA-200 / 300: Resolution 5 ns / memory location**
- **High counting efficiency: No dead time between bins**
- **Ultra-fast accumulation: No dead time between sweeps**
- **Ultra-fast input discriminator: Input pulse width < 1 ns**
- **Direct interfacing to most detectors**
- **Count rate up to 1000 MHz (MSA-1000)**
- **Up to 512 k points / curve (MSA-200/300)**
- **Parallel operation of several modules supported**
- **Optional step motor controller**





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Overview

The MSA-200, MSA-300 and MSA-1000 are fast multiscaler cards. The devices count all pulses whose amplitude is greater than a selectable discriminator threshold and stores them into subsequent memory locations of the device memory. The time resolution is 5 ns for the MSA-200/300 and 1 ns for the MSA-1000. Subsequent sweeps are accumulated directly in the MSA hardware thus avoiding any dead time between the sweeps. The capacity of the memory locations is 8 bit or 255 counts. When this value is reached the memory is read automatically and the measurement is continued until the specified number of sweeps are accumulated. The maximum recording time is 131 us (128k points) for the MSA-1000 and 2.6 ms (512k points) for the MSA-200 and the MSA-300.

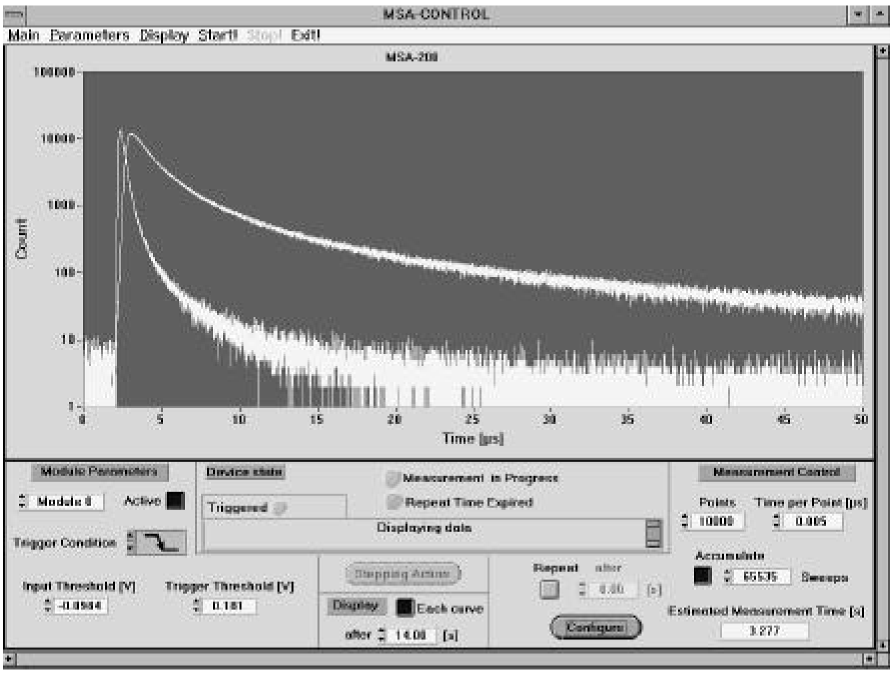
Ultra-fast input discriminators allow for direct counting of fast single electron pulses from photomultiplier tubes and channel plates.

Up to four MSA cards can be operated in one computer and controlled by the same software. Clock cascading provides for synchronous data acquisition.

All MSAs are PC plug-in cards. The MSA-300 and the MSA-1000 have PCI connectors. The older MSA-200 has a ISA connector. The MSA-200 was discontinued and replaced by the MSA-300 in 2001.

All module functions are controlled by the MSA Standard Software. The software runs under Windows 95, 98 and NT and allows setting of device parameters, loading and saving of measurement data and system parameters, evaluation of measurement data and arithmetic operations between different curves. A monochromator can be controlled directly by the MSA Standard Software via the optional step motor controller card STP-240.

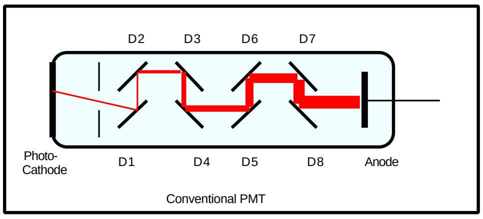
To facilitate programming of special user software DLL function libraries for WINDOWS and for the Windows CVI system of National Instruments are available.



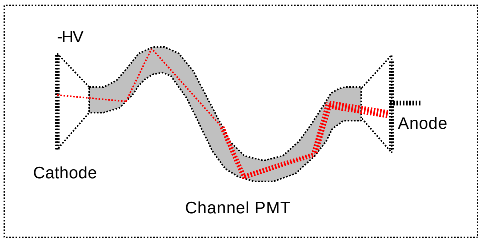
Introduction

Detectors for Photon Counting

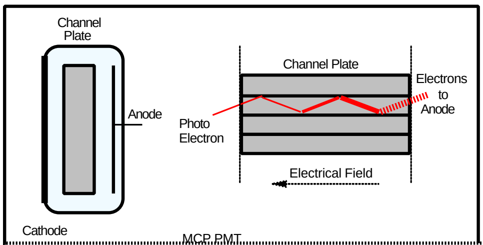
The most common detectors for low level detection of light are photomultiplier tubes. A conventional photomultiplier tube (PMT) is a vacuum device which contains a photocathode, a number of dynodes (amplifying stages) and an anode which delivers the output signal.



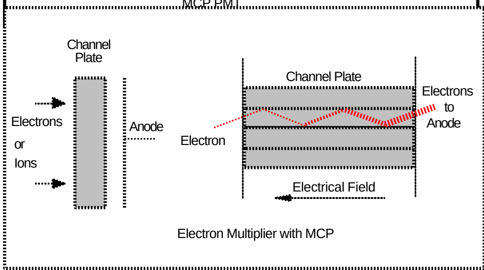
Conventional PMT



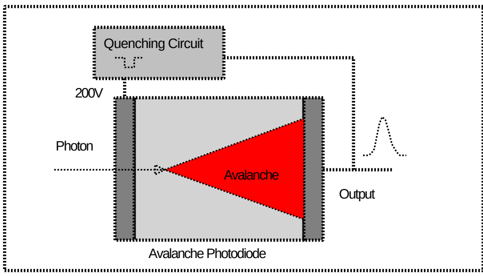
Channel PMT



MCP PMT



Electron Multiplier with MCP



Avalanche Photodiode

By the operating voltage an electrical field is built up that accelerates the electrons from the cathode to the first dynode D1, from D1 to D2 and to the next dynodes, and from D8 to the anode. When a photoelectron emitted by the photocathode hits D1 it releases several secondary electrons. The same happens for the electrons emitted by D1 when they hit D2. The overall gain reaches values of 10^6 to 10^8. The secondary emission at the dynodes is very fast, therefore the secondary electrons resulting from one photoelectron arrive at the anode within a few ns or less. Due to the high gain and the short response a single photoelectron yields a easily detectable current pulse at the anode.

A similar gain effect is achieved in the Channel PMT and in the Microchannel PMT. These PMTs use channels with a conductive coating the walls of which act as secondary emission targets.

The gain systems used in photomultipliers are also used to detect electrons or ions. These ‘Electron Multipliers’ are operated in the vacuum, and the particles are fed directly into the dynode system, the multiplier channel or onto the multichannel plate.

Cooled avalanche photodiodes can be used to detect single optical photons if they are operated close to or slightly above the breakdown voltage. The generated electron-hole pairs initiate an avalanche breakdown in the diode. Active or passive quenching circuits must be used to restore normal operation after each photon.

X ray photons can be detected by normal PIN diodes. A single X ray photon generates so many electron-hole pairs in the diode so that the resulting charge pulse can be detected by an ultra-sensitive charge amplifier. Due to the limited speed of the amplifier these detectors have a time resolution in the us range. They can, however, distinguish photons of different energy by the amount of charge generated.

The output pulse of a detector for a single photoelectron is called the ‘Single Electron Response’ or ‘SER’. Some typical SER shapes for PMTs are shown in the figure below.

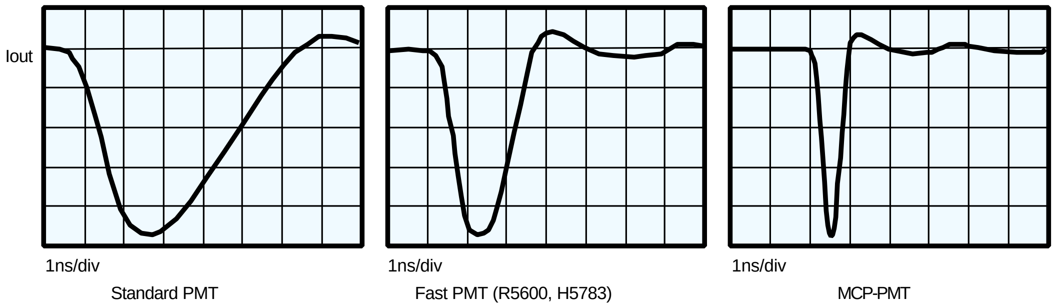
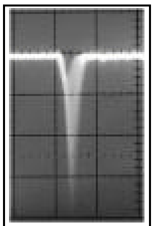


Fig. 3: Single Electron Response of Different PMTs



Amplitude jitter of SER pulses

Due to the random nature of the detector gain, the pulse amplitude is not stable but varies from pulse to pulse. The pulse height distribution can be very broad, up to 1:5 to 1:10. The figure right shows the SER pulses of an R5600 PMT.

The following considerations are made with G being the average gain, and Iser being the average peak current of the SER pulses.

The peak current of the SER is approximately

$$Iser = \frac{G \cdot e}{FWHM}$$

(G = PMT Gain, e=1.6 $\cdot$ 10^{-19} As, FWHM= SER pulse width, full width at half maximum)

The table below shows some typical values. I_{SER} is the average SER peak current and Vser the average SER peak voltage when the output is terminated with 50 Ω. Imax is the maximum continuous output current of the PMT.

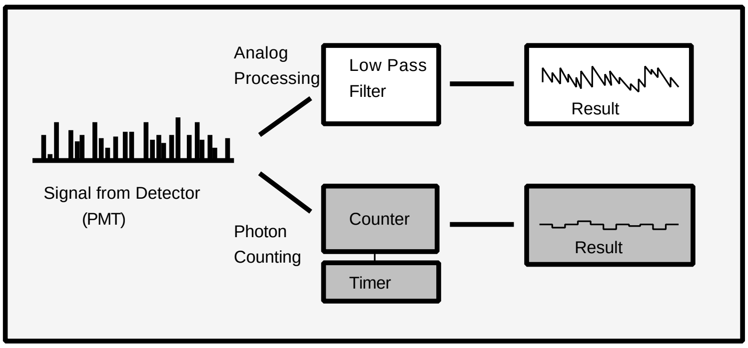
PMT	PMT Gain	FWHM	I_{SER}	V_{out} (50 Ω)	I_{max} (cont)
Standard	10^7	5 ns	0.32 mA	16 mV	100uA
Fast PMT	10^7	1.5 ns	1 mA	50 mV	100uA
MCP PMT	10^6	0.36 ns	0.5mA	25 mV	0.1uA

There is one significant conclusion from this table: If the PMT is operated near its full gain the peak current I_{SER} from a single photon is much greater than the maximum continuous output current. Consequently, for steady state operation the PMT delivers a train of random pulses rather than a continuous signal. Because each pulse represents the detection of an individual photon the pulse density - not the signal amplitude - is a measure for the light intensity at the cathode of the PMT.

Obviously, the pulse density is measured best by counting the PMT pulses within subsequent time intervals. Therefore, photon counting is a logical consequence of the high gain and the high speed of photomultipliers.

Photon Counting - The Logical Solution

The figure below shows the differences between photon counting and analog signal acquisition of PMT signals.



Analog acquisition of the PMT signal is done by smoothing the random pulse train from the PMT with a low pass filter. If the filter bandwidth is low enough the PMT signal is converted in a more or less continuous signal.

Photon Counting is accomplished by counting the PMT pulses within subsequent time intervals by a counter/timer combination. The duration of the counting time intervals is equivalent to the filter time constant of the analog processing. If these values are of the same size both methods deliver comparable results.

There are, however, some significant differences:

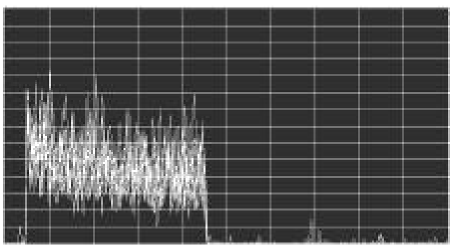
The time resolution of Photon Counting is determined by the risetime of the detector pulses and by the transit time spread of electron avalanche in the detector. For Analog Processing the time resolution is given by the considerably bigger width of the detector pulses.

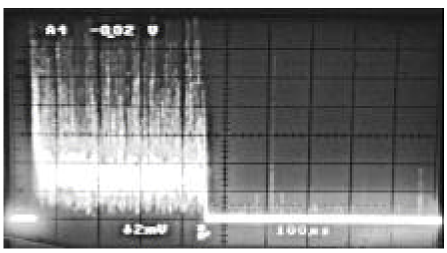
A problem in many PMT applications is the poor gain stability. The PMT gain strongly depends on the supply voltage and is influenced by load effects and ageing. For analog processing the size of the recorded signal depends on the number of photons and the PMT gain. Although the presence of the PMT gain in the result provides a simple means of gain control, it is a permanent source long term instability. Photon Counting - in first approximation - directly delivers the number of photons per time interval. The PMT gain and its instability does not influence the result.

Photon Counting is insensitive to low frequency noise. There is also no baseline drift due to spurious currents in the PMT or in the PMT voltage divider. Analog Signal Acquisition is very sensitive to these effects.

Due to the random nature of the gain process in the PMT, the SER pulses have a considerable amplitude jitter. In first approximation, Photon Counting is not influenced by this effect. For analog processing however, the amplitude jitter contributes to the noise of the result.

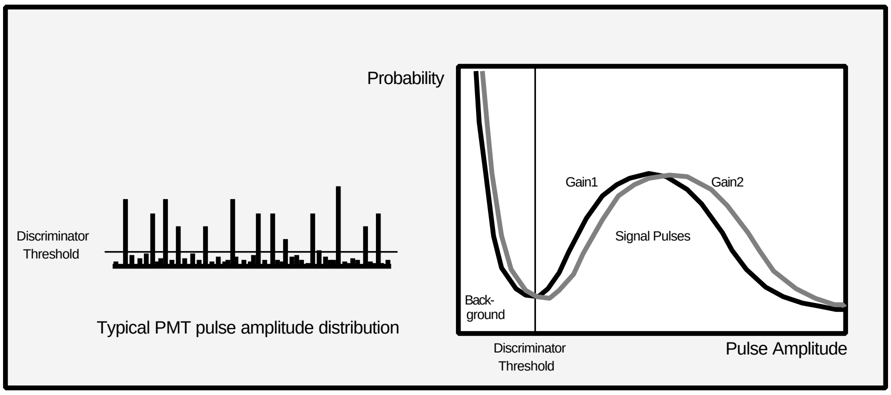
An example is shown in the figure below. The same signal was recorded by photon counting (left) and by an oscilloscope (right). The counter binning time and the oscilloscope risetime were adjusted to approximately the same value.





Recording of the same signal by a photon counter (left) and an oscilloscope (right).

Furthermore, most light detectors deliver numerous small background pulses which have no relation to the signal. A typical pulse amplitude distribution of a PMT is shown in the figure below. Although the single photon pulses have a considerable amplitude spread they are clearly different from the background noise. By appropriate setting the discriminator threshold the background is effectively suppressed without loss of signal pulses.

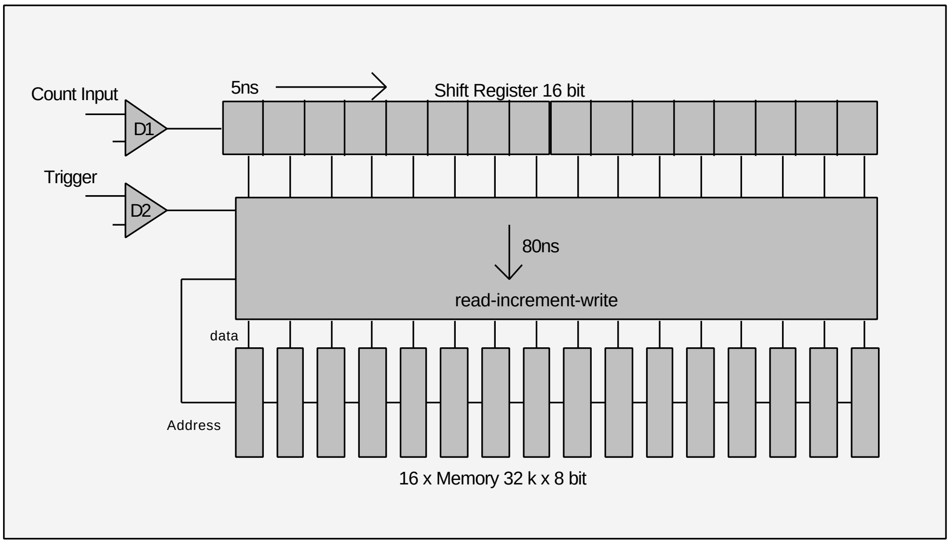


An additional source of noise are occasional detector pulses with very high amplitudes. These pulses are caused by cosmic ray particles, by radioactive decay or by tiny electrical discharges in the vicinity of the photocathode. Because these events are very rare they have no appreciable effect on Photon Counting. Analog Processing, however, is seriously affected by these high amplitude pulses.

Photon counting is sometimes believed to be a very slow method unable to detect fast changes in signal shape or signal size. This ill reputation comes from older systems with slow discriminators and slow preamplifiers that were unable to reach high count rates. State-of-the-art photon counters have fast discriminators responding directly to the fast SER pulses. Therefore, these devices are able to count photons at the maximum steady state load of a PMT. In pulsed applications peak count rates exceeding 100 MHz are reached. At these count rates measurement results can be obtained within a fraction of a millisecond. Therefore, photon counting should always be taken into consideration before an analog data acquisition method is used for optical signals.

Architecture of the MSA Modules

The block diagram of the MSA modules is shown in the figure below.



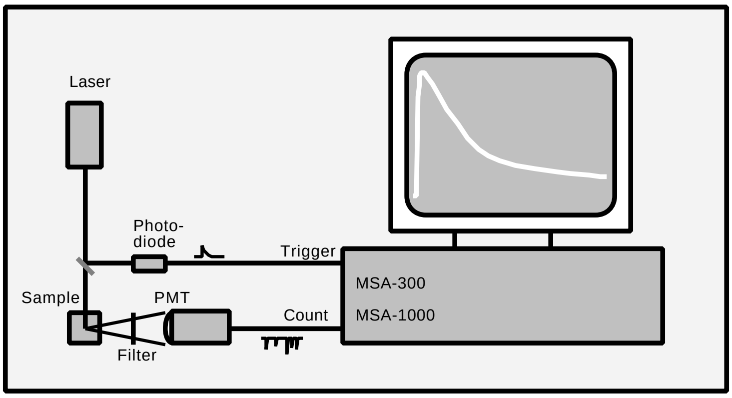
The devices use a fast 16 bit shift register for fast acquisition and a fully parallel 128 bit memory structure for direct accumulation. The measurement is started by a trigger pulse at the input of the discriminator D2. The input pulses are detected by the discriminator D1 and are pushed into the 16 bit shift register with the system clock, i.e. with 200 MHz in the MSA-200/300 and with 1 GHz in the MSA-1000. If D1 detects a pulse edge a ‘1’ is pushed into the shift register, otherwise a ‘0’. Each 80 ns (16 ns for the MSA-1000) the register bits and the memories are read. If a shift register bit contains a ‘1’ the associated memory byte is incremented and stored back to the memory. Than, the memory address is incremented to accept the data of the next 16 time channels. When the recording arrives at the last time channel (which is set by the software) the sequence is repeated until the desired number of sweeps has been accumulated or an overflow occurs in one of the memory channels. Since there is no time required to read out the data between the subsequent sweeps a dead-time-free accumulation can be achieved up to very high signal repetition rates. This makes the MSA cards exceptionally useful for a wide variety of high-repetition rate applications.

The discriminators have response times in the sub-ns range. Therefore, fast detectors can be connected directly to the count and trigger input.

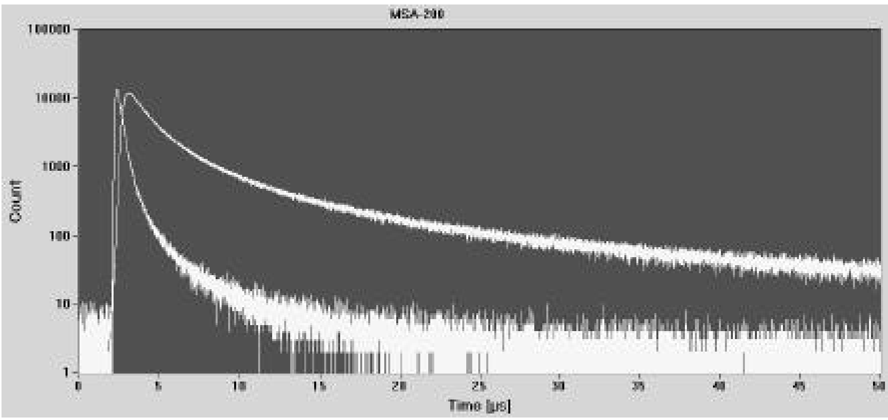
Applications

Luminescence Decay Measurements

A typical arrangement for luminescence decay measurements is shown in the figure below.



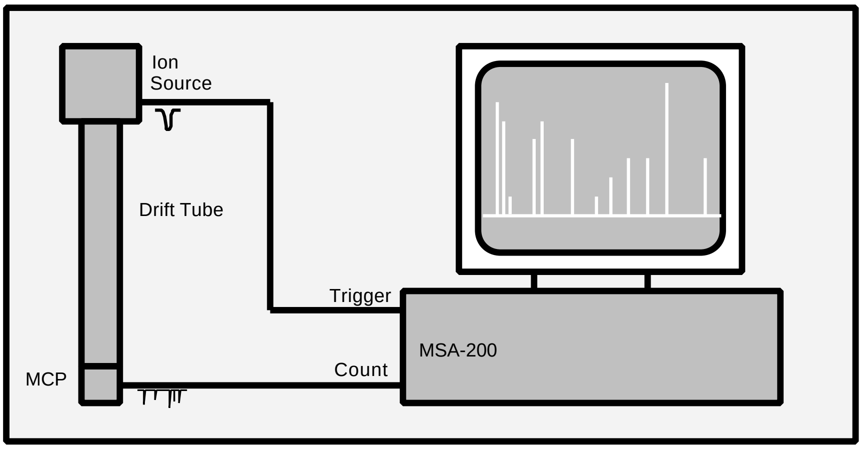
The sample is excited by a pulsed laser and the luminescence signal is detected by a PMT in the photon counting mode. The PMT pulses are recorded by the MSA, which is triggered from the laser by a photodiode. Due to the deep memory of the MSA a time scale from the ns to the ms range can be covered in one measurement. Although the 5ns resolution of the MSA-200/300 and the 1 ns resolution of the MSA-1000 is not sufficient to fully resolve the fluorescence of most organic molecules the device is very efficient to record the phosphorescence and the delayed fluorescence. For inorganic samples with luminescence decay times in the us range the MSA is an excellent choice.
The dead-time-free accumulation allows to exploit the full repetition rate of diode pumped lasers or ns flashlamps and therefore to achieve short measurement times. For the result shown below 65536 sweeps where accumulated in less than 10 seconds.



To control any external parameter during the measurement, the optional step motor controller STP-240 can be used (please see individual data sheets or http://www.becker-hickl.com). To obtain a higher spectral resolution the filter in the figure above can be replaced with a monochromator. The monochromator drive is included in the MSA software. The luminescence can either be recorded at a selected wavelength or, by programming via the ‘Configure’ function, a sequence of decay curves at subsequent wavelengths can be recorded.

Time-of-Flight Measurements

In time-of-flight mass spectrometers ions are accelerated in an electric field and sent to a detector at a fixed distance. Because the velocity of the ions depends on the mass different ions can be separated by the time they need to reach the detector. The principle is shown in the figure below.

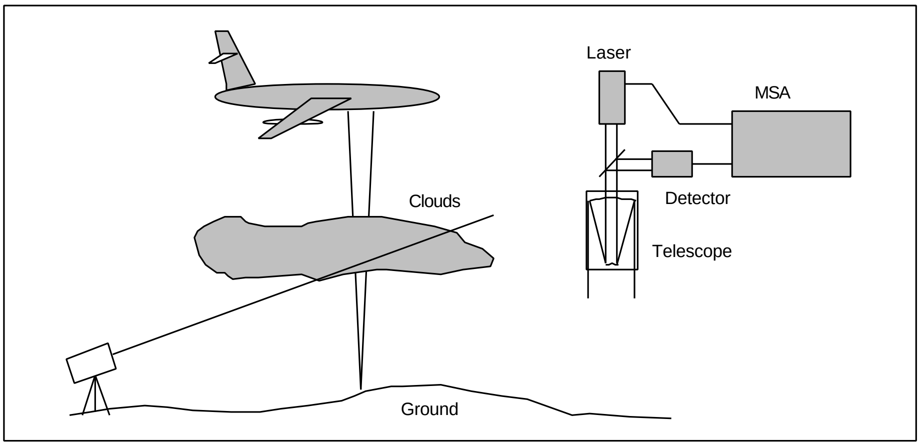


Time-of-flight mass spectrometer

Packages of ions are released by a pulsed source, sent through a drift tube and detected by an MCP detector. The output pulses of the MCP are recorded by the MSA module. The different ions show up as peaks in the counting result.
The flight times are usually in the us range. The overall acquisition time is limited to some 10 s because the sample from which the ions come evaporates so that the ion generation ceases after some time.
Furthermore, the ions should be released in many small portions rather than in a few big ones to be resolved by the detector as individual pulses. It is therefore essential to run the system at a repetition rate as high as possible. With the MSA-200, -300 or -1000, the repetition rate is limited only by the maximum flight time of the heaviest ions (usually some 10us). Therefore, repetition rates of more than 10 kHz can be achieved.

LIDAR

LIDAR methods are used for remote sensing of distant objects or simply for distance measurements. The figure below shows the principle and some typical applications. From the measurement of the backscattered light the distance of a target or of other scattering objects in the light path can be derived. By measurements at different wavelengths environmentally relevant gases (SO_2, NO_x) can be detected. The temperature of water can be measured by the intensity ratio of different Raman lines.



The dynamic range of LIDAR signals is usually very high. Therefore, as many laser shots as possible have to be accumulated to get a good signal-to-noise ratio for the weak portions of the signal. Therefore, it is essential to achieve a repetition rate as high as possible. Again, with the MSAs the repetition rate is limited only by the maximum signal propagation time which makes the MSA modules an excellent choice for these applications.

Installation

Requirements to the Computer

The computer must be a PC 486 or Pentium PC with a graphics card of 1024 by 628 resolution or more. There must be enough free slots to insert the required number of MSA (and STP) modules. Although not absolutely required, we recommend to use a computer with a speed of at least 300 MHz for convenient working with the MSA.

The computer should have at least 64 Mb memory. The standard software requires approximately 2 Mb hard disk space. To store the measurement data files, some Mb more should be available.

Installation of the MSA Standard Software

The MSA modules come with the ‘MSA Standard Software’, a comfortable software package that allows for measurement parameter setting, measurement control, step motor control, loading and saving of measurement and setup data, and data display and evaluation. For data processing with other software packages a conversion program to the ASCII format is included.

Two versions of the MSA Standard Software are delivered with the module - one is for Windows 3.1, the other for Windows 95/98 and Windows NT. To facilitate the development of user-specific software a DLL library for Windows 95 and Windows NT is available on extra order.

The installation of the MSA Standard Software is simple. Start the WINDOWS version for which the MSA is to be installed and start setup.exe from the installation disk.

You can install the software also from the Becker & Hickl web site, e.g. if you want to upgrade your system with a new computer and a new MSA software version has been released in the meantime. In this case proceed as described under ‘Update from the Web’.

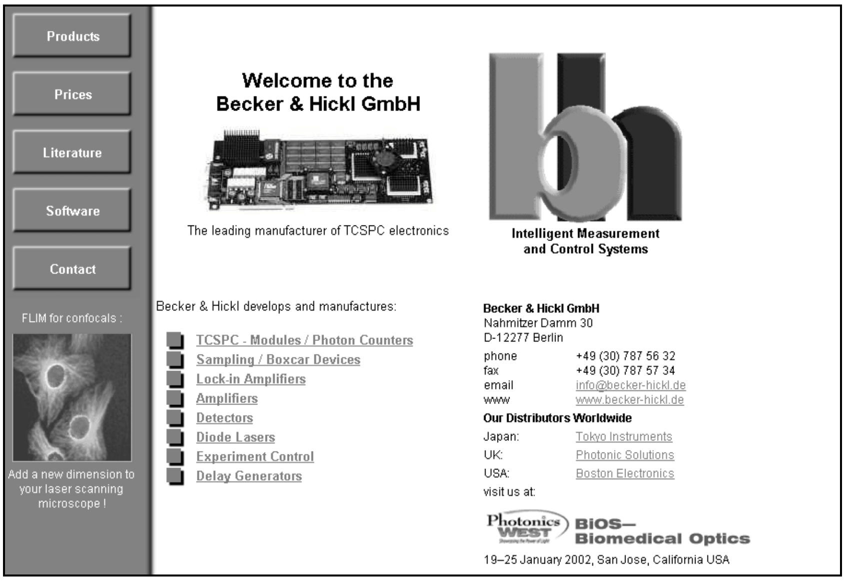
The MSA software is based on 'LabWindows/CVI' of National Instruments. Therefore the so-called 'CVI Run-Time Engine' is required to run the MSA software. The 'Run-Time Engine' contains the library functions of LabWindows CVI and is loaded together with the MSA software. The installation routine suggests a special directory to install the Run-Time Engine. If the required version of the Run-Time Engine is already installed for another application, it is detected by the installation program and shared with the existing LabWindows CVI applications.

Software Update

If you install a new MSA software version over an older one only the files are copied which have a newer date. This, to a certain extend, avoids overwriting setup files such as auto.set (the last system settings) or msa200.ini (the hardware configuration). Consequently, you cannot install an older software version in the place of a newer one. If you want to do this (normally there is no reason why you should), run the ‘Uninstall’ program before installing.

Update from the Web

The latest software versions are available from the Becker & Hickl web site. Open www.becker-hickl.de, and click on ‘Software’.



Click on ‘Download’, ‘Windows 95/98/NT/2000’ or ‘Windows 3.1’. Choose the MSA software and you will get a ZIP file containing the complete installation. Unpack this file into a directory of your choice and start setup.exe. The installation will run as usual.

For a new software version we recommend also to download the corresponding manual. Click on ‘Literature’, ‘Manuals’ and download the PDF file. Please see also under ‘Applications’ to find notes about typical applications of the bh photon counters.

Installation of the MSA Module

Upgrading PCs with measurement modules often causes problems such as system crashes, malfunctions of special hardware or software components or other mysterious effects. To our experience such problems normally arise from interrupt and memory conflicts between different components. Therefore, the MSA modules have been designed without using interrupts and direct memory access. Thus the installation of the MSA usually does not cause any problems.

To install the device, switch off the computer and insert the MSA module into a free slot. To avoid damage due to electrostatic discharge we recommend to touch the module at the metallic back shield. Then touch a metallic part of the computer with the other hand. Then insert the module into a free slot of the computer. Keep the MSA as far as possible apart from loose cables or other computer modules to avoid noise pick-up.

MSA-300 and MSA-1000

The MSA-300 and the MSA-1000 have a PCI interface. Windows has a list of hardware components, and on the start of the system, it automatically assigns the required hardware resources to the components of this list. When the computer is started first time with the MSA inserted Windows detects the MSA and updates the list of hardware components. Therefore it asks for driver information from a disk. Although this information is not actually required for the MSA you should select the driver information file from the driver disk delivered with the module.

If you don’t have the driver disk, please download the driver file from www.becker-hickl.com or www.becker-hickl.de, ‘Software’, ‘Windows 95/98/NT/2000’ or ‘Windows 3.1’, ‘Device drivers for bh modules’.

You can also proceed without the driver , but this can be tricky in some Windows versions. Click on ‘Continue’ or a similar button when a driver is demanded for. Don’t click on ‘Abort’ or something like that. This forces Windows to ignore the MSA at all so that it cannot be accessed by the software.

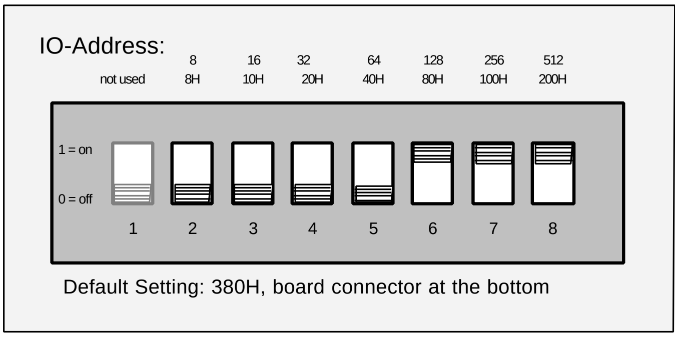
MSA-200

The MSA-200 has a DIP switch to set the I/O address of the module. Changes of the module address for a single MSA-200 (see section below) are not normally required. However, for the operation of more than one MSA-200 module in one computer the module addresses must be different, and the address values must be declared in the MSA200.INI file (see ‘Changing the Module Address of the MSA-200’). If you purchase several MSA-200 modules for operation in one PC we can deliver the modules and the MSA200.INI file in a ready-to-use configuration.

Should there be any malfunction after installing the MSA-200 either the capacity of the power supply is exceeded or - which is more probable - another module in the PC has the same I/O address as the MSA-200. In this case change the module address as described under 'Module Address'. If there are only the standard modules (hard disk, floppy drives, COM ports, LPTs, VGA) in your computer the default address range (380h to 398h for one MSA module) should be free.

If there is more than one MSA module inserted in the computer or if the computer contains other measurement devices which occupy the MSA default address, the MSA module addresses must be changed.

Each module is controlled by a block of 16 subsequent I/O addresses. The start address of this block is the 'Module Base Address'. The module base address is set by a DIP switch on the MSA-200 board (see figure below). The address value is switched on if the switch is in 'on' position.



The software (standard software or library functions) reads the addresses of the used modules from the configuration file MSA200.INI. Therefore, the DIP switch setting and the addresses in MSA200.INI must be the same. The MSA200.INI file is shown in the table below. It can be edited with any ASCII editor (e.g. Norton Commander).

```
; MSA200 initialization file
; MSA parameters have to be included in .ini file only when parameter
; value is different from default.
; module section (msa_module0-3) is required for each existing MSA module

[msa_base]
simulation = 0          ; 0 - hardware mode(default) ,
                        ; >0 - simulation mode (see msa_def.h for possible values)

[msa_module0]

base_adr= 0x380         ;base I/O address for ISA module (0 ... 0x3FC,default 0x380)
pci_card_no= 0          ; number of module on PCI bus if PCI version of MSA module
                        ;   0 - 3, default -1 ( ISA module)
active= 1               ;module active - can be used  (default = 0 - not active)
trigger = 0             ; external trigger condition
                        ;       none(0)(default),active low(1),active high(2)
inp_threshold= -0.1            ;input threshold level
                                      ; (-1.0 ... 1.0V , default -0.1)
trig_threshold= -0.1           ;trigger threshold level
                                      ; (-1.0 ... 1.0V , default -0.1)
frames = 32768          ; number of 80ns frames to collect ( 1 ... 32768(default))
sweeps=1                ; number of accumulation sweeps (1(default) ... 65535)

[msa_module1]

base_adr= 0x280         ;base I/O address for ISA module   (0 ... 0x3FC)
pci_card_no=1           ; number of module on PCI bus if PCI version of MSA module
                        ;   0 - 3, default -1 ( ISA module)
active= 0               ;module not active - cannot be used

[msa_module2]

base_adr= 0x2a0         ;base I/O address for ISA module   (0 ... 0x3FC)
pci_card_no=2           ; number of module on PCI bus if PCI version of MSA module
                        ;   0 - 3, default -1 ( ISA module)
active= 0               ;module not active - cannot be used


[msa_module3]

base_adr= 0x2c0         ;base I/O address for ISA module   (0 ... 0x3FC)
pci_card_no=3           ; number of module on PCI bus if PCI version of MSA module
                        ;   0 - 3, default -1 ( ISA module)
active= 0               ;module not active - cannot be used
```

The configuration file contains a first part which is common for all modules, and a module specific part. The common part is specified by the headline

```
[msa_base],
```

the module specific parts by the headlines

```
[msa_module0]
[msa_module1]
[msa_module2]
[msa_module3]
```

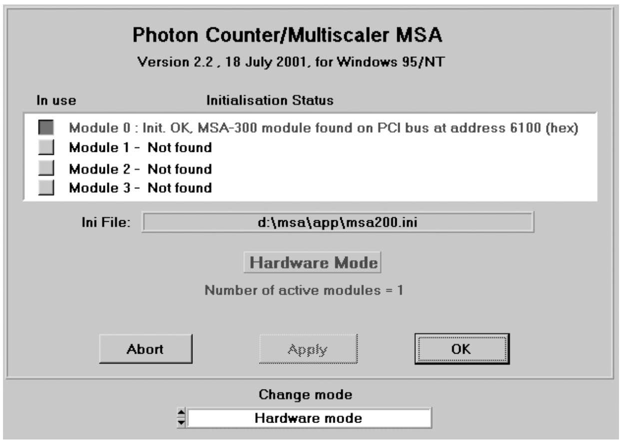
Die Base addresses of the modules are declared in the module specific part by `base_adr=0x...` (hexadecimal) or by `base_adr=....` (decimal). The default values are

`base_adr = 0x380` for the 1st module
`base_adr = 0x280` for the 2nd module
`base_adr = 0x2A0` for the 3rd module
`base_adr = 0x2C0` for the 4th module

Each module can be set ‘active’ or ‘inactive’ by `‘active=1’` or `‘active=0’`. All modules which are present in the system must be declared as ‘active’. On the other hand, if a module is not present, `'active=0'` should be set to avoid that the software attempts to initialise this module and displays an error.

Starting the MSA Software

When you start the MSA software the initialisation window shown right appears.



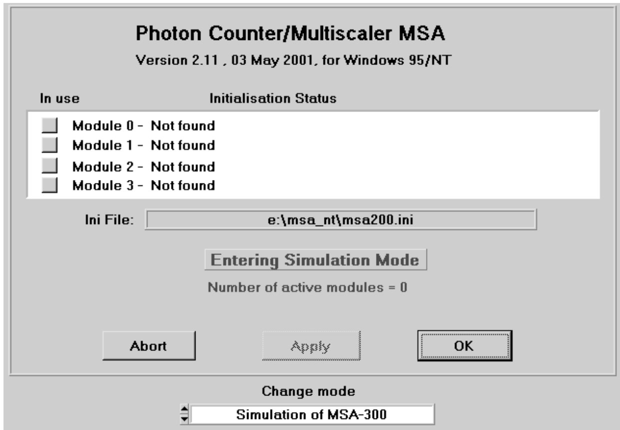
The installed modules should be marked as 'In use' and 'Initialized OK'.

Click on 'OK' to open the main window of the MSA software.

In case of non-fatal hardware errors you can start the main window by selecting the hardware mode in the 'Change Mode' panel. Please note that this feature is intended for trouble shooting during repair rather than for normal use.

Using the MSA Software without the MSA Module

You can use the MSA software also without the MSA module. The startup window will display the error message that no MSA modules are found.



Click on the 'in use' buttons for a number of modules you want the software to emulate. Than click on 'Change Mode' and select the module type, click on 'Apply' and 'OK'. The software starts in the 'Simulation Mode' and you can do everything except a real measurement.

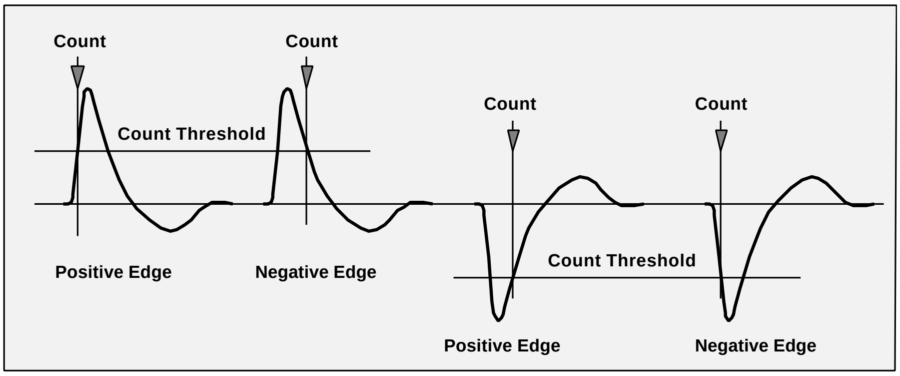
Building up Measurement Apparatus with the MSA Modules

Count Input

The detector pulses are fed to the COUNT input of the MSA module. The input amplitude should be in the range between 20 mV and 1 V. Amplitudes above 1.5 V are clipped by safety diodes at the module input. Pulses up to 30 V (max. 1 us) and DC voltages up to 5 V will not damage the module. However, input amplitudes above 2.5 V should be avoided, since they can cause false counting due to reflections or crosstalk between different modules.

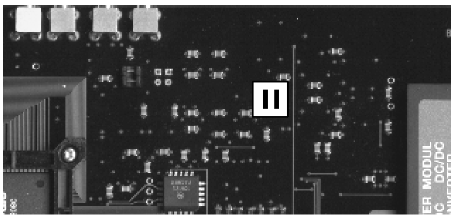
To count pulses with amplitudes less than 20 mV we recommend to use preamplifiers. BH delivers amplifiers which are powered from the sub-D connector of the MSA module (please see individual data sheets or http://www.becker-hickl.com).

In all MSA modules the Count input is edge triggered. A count is initiated when the input signal crosses the trigger threshold in the selected direction, see figure below.

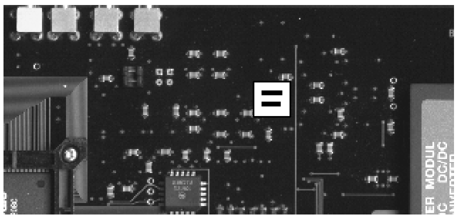


Selecting the Counting Input Pulse Edge

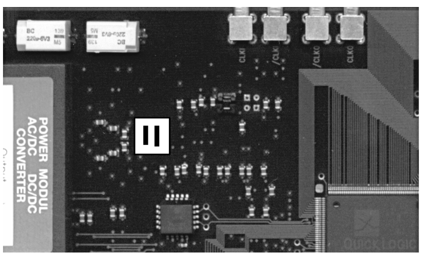
The COUNT input can be configured to count at the positive or negative edge of the input pulse. For the MSA-200 and MSA-300 the active edge is selected by the jumpers shown in the figure below. In the MSA-1000 the active edge is selected by software. The default setting is 'negative edge', as required for photomultipliers.



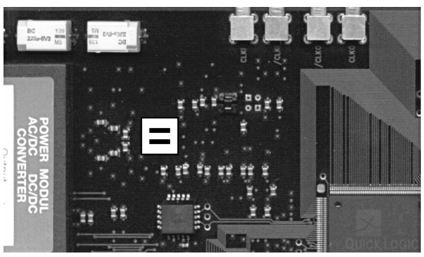
MSA-200
Input set to 'Negative Edge



MSA-200
Input set to 'Positive Edge



MSA-300
Input set to 'Negative Edge

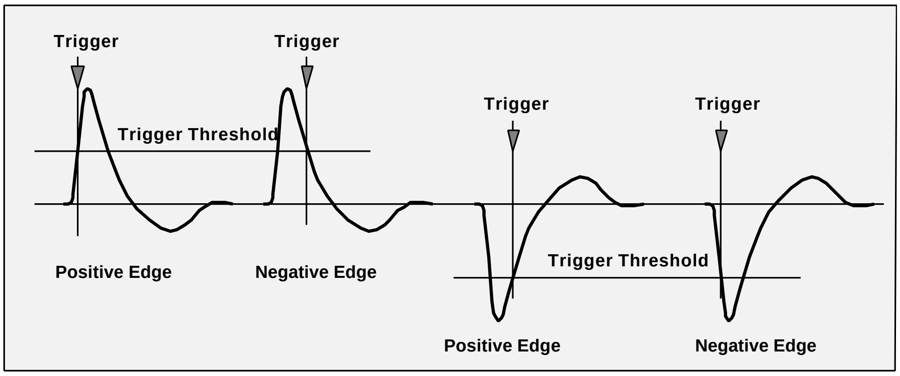


MSA-300
Input set to 'Positive Edge'

Trigger Input

The trigger input is used to start a measurement by an external event (laser shot, spark discharge etc.). Although a measurement can be started by simply giving a software command, triggering is required for measurements at fast time scales and for accumulating a signal over several signal periods.

A trigger event is initiated when the trigger input signal crosses the trigger threshold in the selected direction, see figure below.

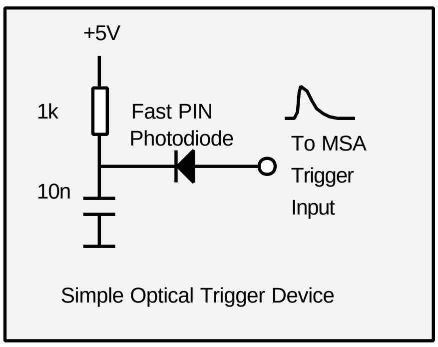


The trigger input amplitude should be in the range between 20 mV and 1 V. Amplitudes above 1.5 V are clipped by safety diodes at the module input. Pulses up to 30 V (max. 1 us) and DC voltages up to 5 V will not damage the module. However, input amplitudes above 2.5 V should be avoided, since they can cause false triggering or false counting due to reflections or crosstalk between different modules.

For trigger pulses with amplitudes less than 20 mV we recommend to use preamplifiers. BH delivers amplifiers which are powered from the sub-D connector of the MSA module (please see individual data sheets or http://www.becker-hickl.com).

Do not attempt to trigger the MSA by electrical trigger signals from nitrogen or excimer lasers. The jitter between these signals and the light pulse can be much higher than the 1ns or 5ns resolution of the MSA. Furthermore, the connection to the laser can couple noise from the laser discharge into the MSA. A simple photodiode circuit that can be used to trigger the MSA by laser pulses is shown in the figure below.

Suitable photodiode modules (PDM-400) are available from Becker & Hickl (please see individual data sheet or http//www.becker-hickl.de).

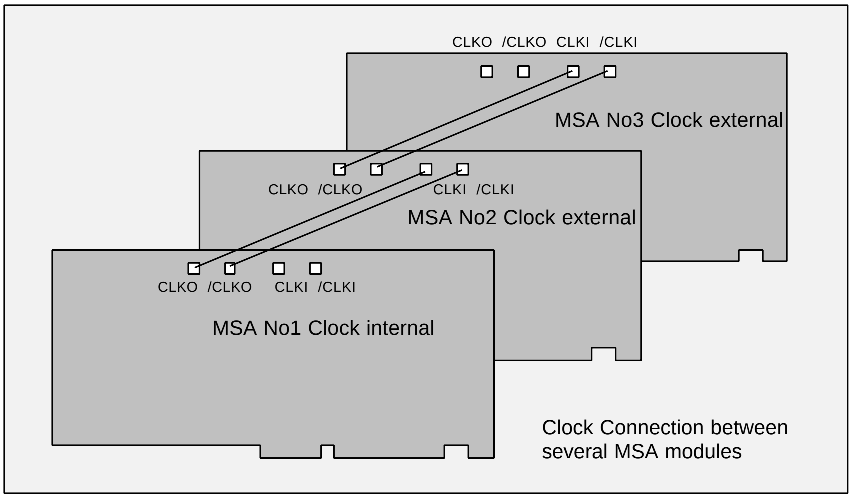


External Clock - Cascading MSA Modules

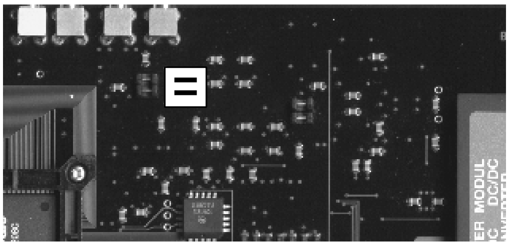
If several MSA modules are used together it is recommended to operate all modules from the same clock. This assures that all modules have the same time scale and avoids timing uncertainties between the modules.

MSA-200 and MSA-300

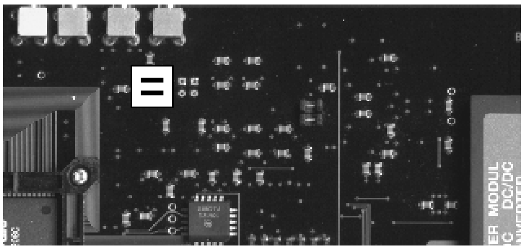
The clock connections between several MSA-200 or MSA-300 modules are shown in the figure below.



The clock is generated by the first module and tied through all other modules via the CLKI and CLKO connectors. The clock configuration for the first module is ‘internal’, for all other modules ‘external’. The clock configuration jumpers are shown in the figure below.



Clock Internal

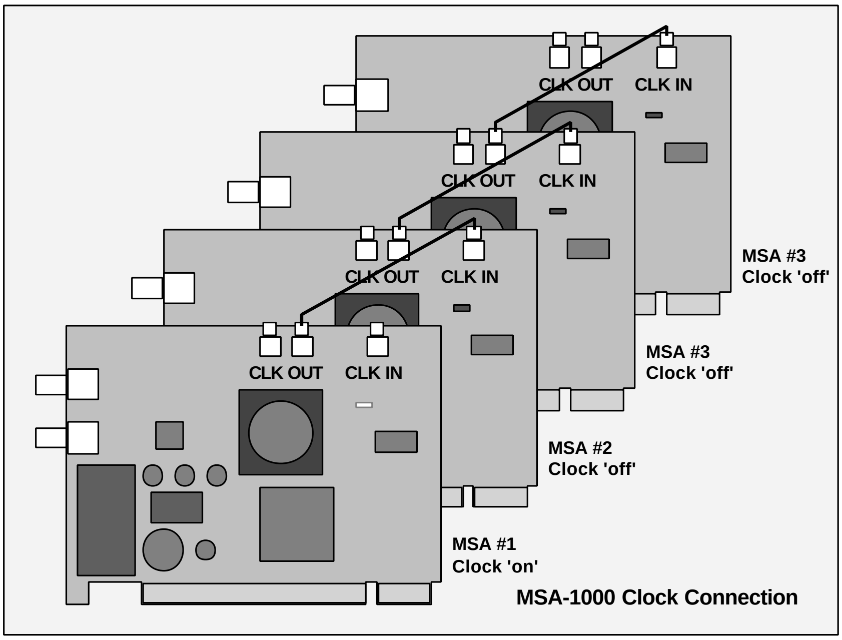


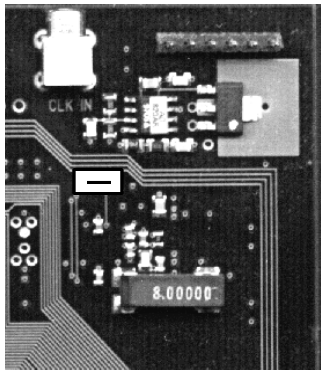
Clock External

The clock signals are differential ECL signals with a frequency of 200 MHz. If you use another clock source than an MSA please make sure that the signals have ECL levels and that the frequency is between 160 and 200 MHz. The clock inputs can be damaged if signals > 0V or < -5V are connected. The clock signals are also used for the PC bus interface. Therefore, a MSA module does not work if the clock is missing or if the clock frequency is outside the specified range.

MSA-1000

The MSA-1000 has two clock outputs and one clock input. The clock connection for cascading several MSA-1000 modules is shown in the figure below.





Clock generator of the MSA-1000:
Jumper: Generator off
No Jumper: Generator on

The first module generates the normal clock of 1 GHz. The clock generators of the other modules are shut down, and each module gets the clock from the previous one. Either clock output can be used to drive the subsequent clock input. The clock outputs have a 180 degree phase shift which can be used to compensate for the phase shift in the connection cables.

The clock signals are sine waves with a frequency of 1 GHz. If you use another clock source than an MSA-1000 please make sure that the signals have 200 to 800 mV peak-peak amplitude and a frequency from 800 to 1000 MHz. The clock inputs can be damaged if signals >3 V peak-peak are connected. Please note, that the clock signals are also used for the PC bus interface. Therefore, a MSA-1000 module does not work if the clock is missing or if the clock frequency is outside the specified range.

Please make sure that no external clock signal is connected if a module works with its internal clock generator. This would mix both clocks and result in a chaotic behaviour.

Dead Time Considerations

Dead time is a basic concern in any multiscaler measurement. Unfortunately, a dead-time-free recording system doesn't exist. Only knowledge about dead time effects can help to avoid surprises and disappointment.

Generally, there are three different kinds of dead time - dead time between subsequent sweeps, dead time between subsequent time bins, and dead time between counts.

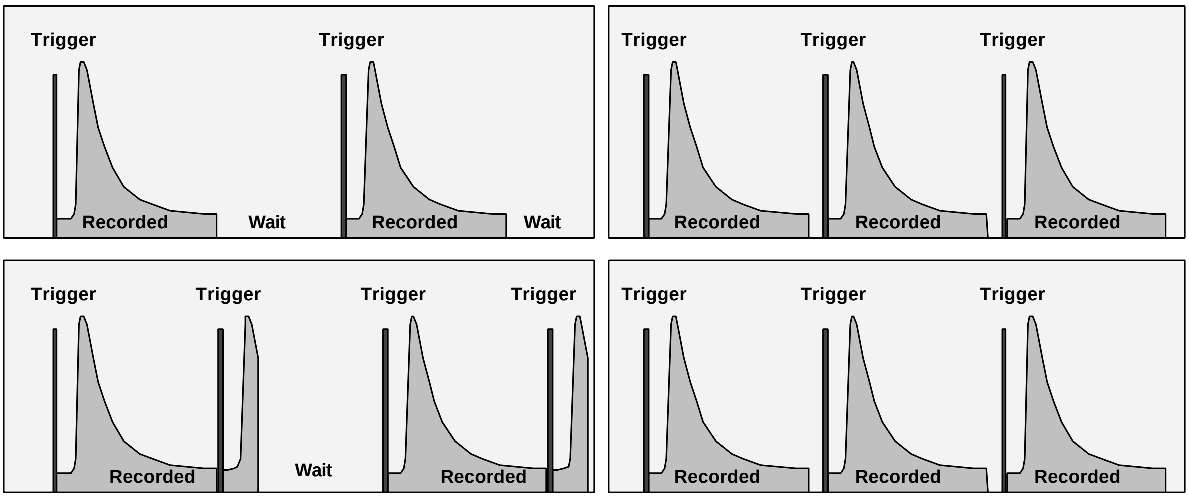
Dead Time between Sweeps

Dead time between subsequent sweeps of the acquisition limits the repetition rate of the signal periods that can be used. If the signal repeats faster than the multiscaler can start the next sweep cycle the events from one ore more signal periods are lost.

Many multiscalers must readout their memory after each sweep because they are not able to add the events of subsequent sweeps directly in the high speed memory. The result is a considerable reduction of the useful signal repetition rate.

In the MSA devices, the photons from subsequent sweeps are added directly in the high speed memory. Basically the MSAs are able to start the next sweep within a few ns after the end of the previous sweep. In practice the recording starts with the next trigger pulse, and there is an unused time interval from the end of the sweep to the next trigger. To keep this time short, the distance of the trigger pulses should be just a little bit longer than the sweep duration.

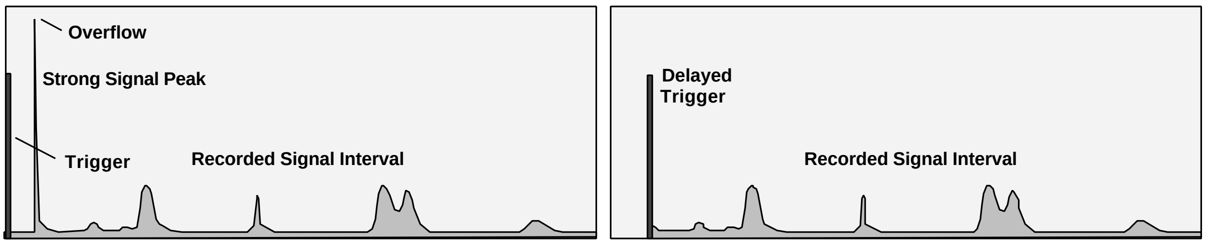
The situation is shown in the figure below. By optimising the signal repetition rate or the recording length long waiting for trigger or wasting of parts of signal periods can be avoided.



Recording sequence with waiting for trigger (left) and optimised sequence (right)

The counting capability of each MSA memory location is 255 counts or 8 bit. Please don't wonder about this 'small' value. Because 16 locations are be accessed at the same time the true width of the memory bus is 128 bits!

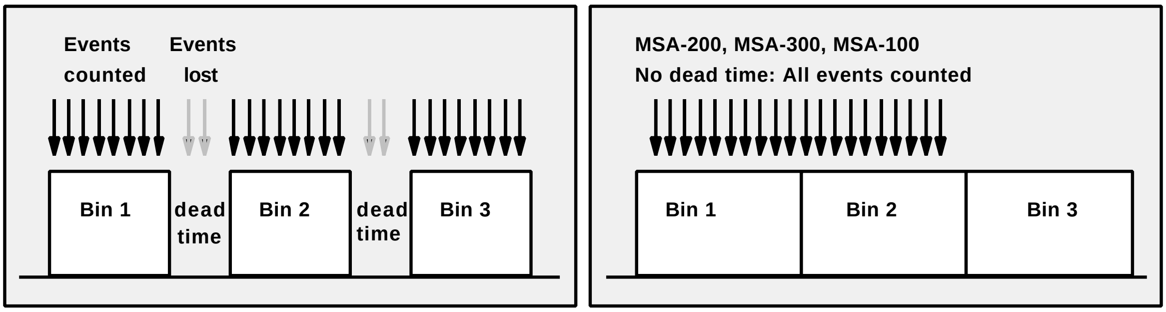
When one memory location reaches 255 counts the acquisition is interrupted, and the memory is read. Worst case, this can happen after 255 sweeps. Even in this case the readout time does not noticeably increase the measurement time. Nevertheless, such frequent overflows can often be avoided. In most cases (Time-of-Flight, LIDAR) the portion of the signal which causes the excessive counts is at the beginning of the signal period and need not actually be recorded. Thus, the solution is to trigger the measurement with a delayed trigger (or to use the 'Start Delay' function of the MSA-1000) so that the critical part of the signal is not recorded.



Avoiding frequent overflow at an initial signal peak by delayed triggering

Dead Time between Bins

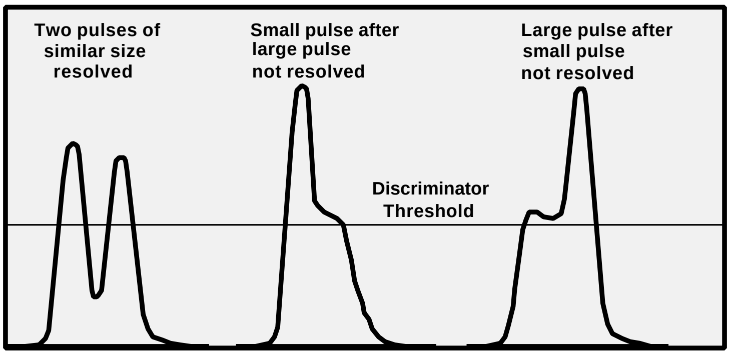
Dead time between the subsequent bins - or points - of the recording results in a counting efficiency lower than one independently of the signal count rate. Although an overall efficiency of one cannot be achieved anyway because there is no perfect detector, additional counting loss in the multiscaler should be avoided. All MSA versions use an input circuit that avoids dead time between subsequent time bins at all.



Counting loss due to dead time between subsequent bins

Dead Time between Counts

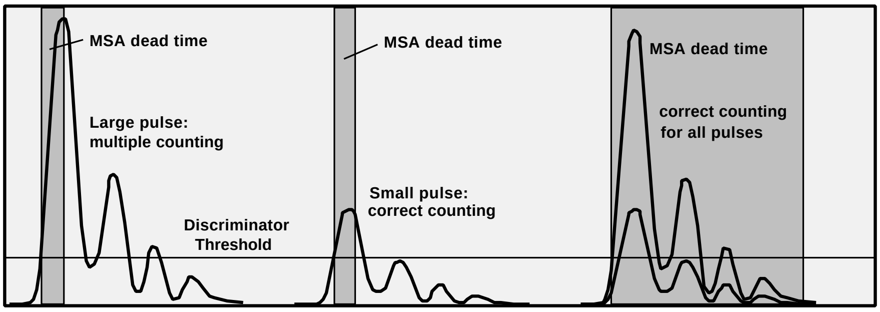
The most important source of dead time between subsequent counts is the detector. Even if the detector is able to detect the next photon within a few ns (a single photon APD isn't) the output pulses from the two photons cannot be resolved if the distance is in the order of the pulse width. For a PMT the situation is further complicated by the pulse height spread of the single photon pulses. A small pulse shortly after a large one or vice versa is more difficult to resolve than two pulses of equal size. For PMTs or PMT-scintillator combinations often a 'Pulse Pair Resolution' is given which means the average resolution for a large number of pulses.



Effect of pulse height fluctuation on pulse resolution

The peak count rate that can be achieved is about 200 MHz for the fastest PMTs (R6500, R7400, H5783) and 50 to 100 MHz for standard PMTs. Thus, the average dead time between counts is 5 ns and 10 to 20 ns respectively.

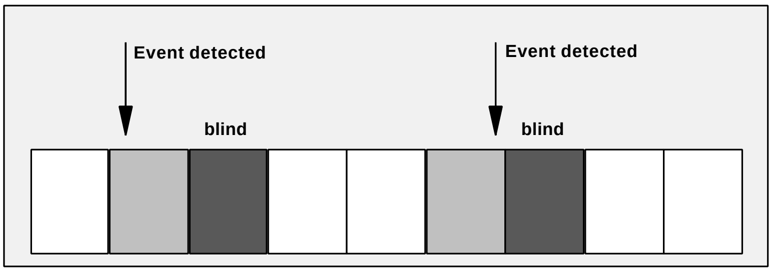
The dead time between subsequent counts in the MSA is usually shorter than the dead time due to limited pulse resolution in the PMT. Interestingly, some dead time in the MSA is required to assure correct counting of PMT pulses. The reason is shown in the figure below.



A reasonable MSA dead time avoids multiple counting of pulses with ringing

The shape of PMT SER pulses is usually far from ideal. Almost all detector deliver pulses with some ringing in the pulse tail. The ringing can cause multiple counting of large detector pulses. Increasing the discriminator threshold is not a good solution because it suppresses the small pulses. With a dead time in the order of the pulse duration correct counting for all pulses is achieved.

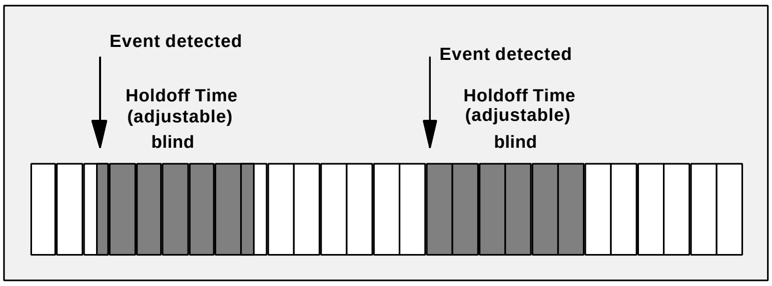
The dead time behaviour of the MSAs is different for the MSA-200/300 and the MSA-1000. The MSA-200 and MSA-300 has a constant dead time of 5ns after each bin with a valid count. In other words, if there is a count in one 5ns bin in the next 5ns bin no event can be recorded.



Dead time behaviour of the MSA-200/300: The next bin after a detected event is blind

The 5ns dead time does not impair the counting efficiency with PMTs but is usually enough to avoid multiple counting of misshapen detector pulses.

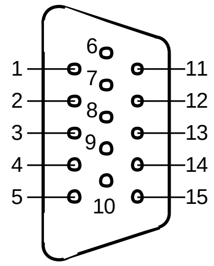
The MSA-1000 has an adjustable ‘Holdoff Time’ after the detection of each photon. This allows to optimise the relation of counting efficiency and multiple counting for a given detector.



Dead time behaviour of the MSA-1000: Multiple counting is inhibited by an adjustable Holdoff Time

Power Supply Connector (MSA-200 and MSA-300 only)

For the power supply of external amplifiers or detectors a 15 pin sub-d connector is provided at the MSA-200 and MSA-300 boards. The signals at this connector are connected as described below:



Sub-D Connector
Seen onto the contacts
(Back View)

Pin	Function
1	+5 V, max. 100 mA via 1.0 Ω
2	TTL I/O (spare)
3	TTL I/O (spare)
4	not connected
5	GND
6	- 5 V, max. 100 mA via 1.0 Ω
7	TTL I/O (spare)
8	TTL I/O (spare)
9	TTL I/O (spare)
10	+12 V, max. 200 mA
11	Do not connect, -12V in other B&H devices
12	not connected
13	DAC1, Uncommitted DAC Output
14	DAC1, Uncommitted DAC Output
15	GND

Choosing and Connecting the Detector

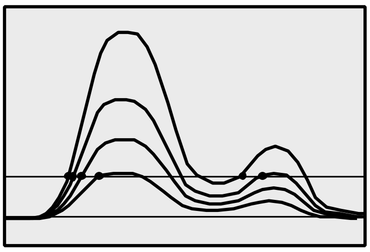
Conventional PMTs

A wide variety of PMTs is available for the MSA. Most PMTs can be connected to the MSA modules without a preamplifier. However, to improve the noise immunity and the safety against detector overload we recommend to use the HFAC-26 preamplifier of bh. This amplifier incorporates a detector overload indicator which responds when the maximum detector current is exceeded.

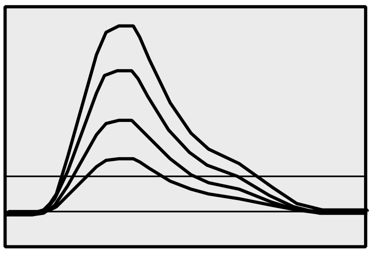
For the MSA-200 or MSA-300 the time resolution of the PMT is usually not a concern. Therefore you can select the PMT by the desired spectral range, the cathode sensitivity, the dark count rate and the pulse height distribution. Even simple side window PMTs (R928, R931 etc.) often give good results. Generally, the PMT should be operated at a gain as high as possible. This helps to suppress noise signals from lasers, the computer or from radio transmitters.

For the MSA-1000 the rise time of the PMT pulse should be less than 1 ns. Most conventional PMTs have output pulse rise times of several ns so that the time resolution of the MSA-1000 cannot be fully exploited.

The output pulses of photomultipliers do not have a defined pulse height - the amplitude changes from pulse to pulse. Even good photomultipliers specified for photon counting have an amplitude spread of 1:2 and more. With standard PMTs the amplitude spread can easily reach 1:5 or 1:10. As the figure below shows, double counting can occur if the pulses have a broad amplitude distribution and a bad pulse shape. In the MSA-1000 the adjustable ‘Holdoff Time’ can be used to avoid multiple counting of misshapen pulses. Nevertheless, the input pulses should be free of reflections, after-pulses and ringing. If the pulse shape cannot be improved by optimising the detector circuitry the use of a low-pass filter or amplifier of suitable bandwidth can solve the problem.



Input Pulse has Reflections: Double Counting at high Amplitudes



Clean Input Pulse: Correct Result

The Hamamatsu H5783 with a PMA-100 low cost amplifier

Hamamatsu R5600, R7400 and Derivatives

The R5600 and R7400 tubes made by Hamamatsu are a small (15 x 15 mm) PMT with a correspondingly fast response. Based on this PMT are the H5783 and H5773 Photosensor modules and the PMH-100 detector head of bh. The H5783 incorporates a small size PMT and the HV power supply. It requires a +12 V supply and some gain setting resistors only. The +12 V is available from the MSA-200 or MSA-300 module. The SER pulses have 2 ns FWHM and a rise time of less than 1 ns. For optimum results, use the '-P' type, which is specified for photon counting. The H5783-P can be connected directly to MSA modules. However, to improve the safety against detector overload we recommend to use the HFAC-26-10 preamplifier of bh. This amplifier incorporates an detector overload indicator which responds when the maximum detector current is exceeded.

A more comfortable solution is the PMH-100 module from Becker & Hickl. This module contains a H5773-P, a fast preamplifier and an overload indicator LED. The PMH-100 has a ‘C Mount’ adapter for simple attaching to the optical setup. Its simple +12 V power supply and the internal preamplifier allow direct interfacing to all bh photon counting devices.

The PMH-100 Detector

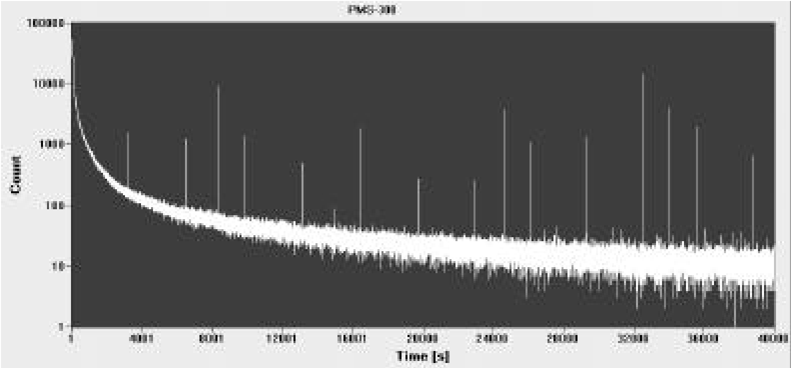
MCP PMTs

MCP-PMTs achieve excellent time resolution in the TCSPC (Time-Correlated Single Photon Counting) mode. The FWHM of the SER is less than 500ps. However, MCPs are expensive and are easily damaged. Their life time is limited due to degradation of the microchannels under the influence of the signal electrons. Because the excellent timing performance of an MCP cannot be exploited with an MSA module there is no reason why you should use such an expensive detector. If an MCP is used with one of the MSAs for whatever reason it should be connected via an HFAC-26-01 preamplifier.

Reducing the Dark Count Rate of PMTs

For high sensitivity applications a low dark count rate is important. Attempts to decrease the dark count rate by increasing the discriminator threshold are not very promising. Except for very small pulses, the pulse height distribution is the same for dark pulses and photon pulses. Thus, with increasing discriminator threshold the photon count rate decreases by almost the same ratio as the dark count rate. To achieve a low dark count rate, the following recommendations can be given:

- The simplest (but not the cheapest) solution is to cool the detector. A decrease in temperature of 10 degrees Celsius typically reduces the dark count rate by a factor of eight. For PMTs which are sensitive in the infrared range (Ag-O-Cs, InGaAs) cooling is absolutely required.
- Use a PMT with a cathode area and with a cathode not larger than necessary and not more red sensitive than required for your application.
- Keep the PMT in the dark even if the operating voltage is switched off. After exposing to daylight the dark count rate is drastically increased. It can takes several hours or even days until the PMT reaches the original dark count rate. An example for an H5773P-01 is shown below.

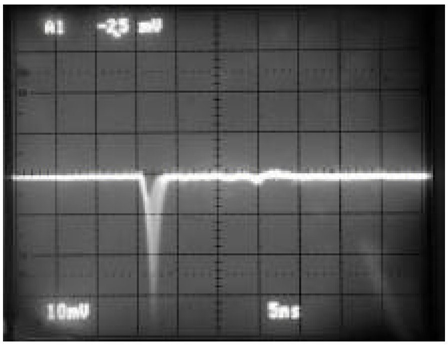


Decrease of dark count rate (counts per second) of a H5773P-01 after exposing the cathode to room light. The device was cooled to 5°C. The peaks are causes by scintillation effects.

- Do not overload the PMT. This can increase the dark count rate permanently. Extreme overload conditions are sometimes not noticed, because the count rate saturates or even decreases at high light levels.
- Keep the cathode area clear from lenses, windows and housing parts. The cathode area is at high voltage and contact with grounded parts can cause scintillation in the glass of the PMT. The effect shows up as short bursts of counts with extremely high rate.
- The same effect is caused by cosmic ray particles and radiation from radioisotopes. Materials likely to contain radioactive isotopes should be avoided in the vicinity of the PMT.
- Keep the cathode area absolutely clean.

Checking the SER of PMTs

If you do not know the amplitude or shape of the Single Electron Response of your PMT you can measure it with a fast oscilloscope. The oscilloscope must have sufficient bandwidth (>400 MHz) to show the rise time of the pulses. Connect the PMT output to the oscilloscope. Do not forget to switch the oscilloscope input to DC, 50 Ω. Set the trigger to ‘internal’, ‘normal’, ‘falling edge’. Start with no light at the PMT. Switch on the high voltage and change the trigger level of the oscilloscope until it is triggered by the dark pulses. This should happen at a trigger level of -5 mV to -50 mV. When the oscilloscope triggers, give some light to the PMT until you get enough pulses to see a clear trace.



The single photon pulses have an amplitude jitter of 1:5 or more. This causes a very noisy curve at the oscilloscope display. Nevertheless, the pulse shape can be roughly estimated from the displayed curves. A typical result is shown in the figure right.

Please don't attempt to check the single electron response of an MCP with an oscilloscope. Because there is no control about the output current, the MCP easily can be damaged. Furthermore, the measurement is of little value because the pulses are too short to be displayed correctly by a conventional oscilloscope. If you really cannot withstand the temptation to measure the SER, use an HFAC-26-01 preamplifier.

Safety rules for PMTs and MCPs

To avoid injury due to electrical shock and to avoid damage to the MSA module, please pay attention to safety rules when handling the high voltage of the PMT.

Make sure that there is a reliable ground connection between the HV supply unit and the PMT. Broken cables, lose connectors and other bad contacts should be repaired immediately.

Never connect a photomultiplier tube to an MSA module when the high voltage is switched on! Never connect a photomultiplier to the MSA if the high voltage was switched on before with the PMT output left open! Never use switchable attenuators between the PMT and the MSA! Never use cables and connectors with bad contacts! The same rules should be applied to photodiodes (at the trigger input) that are operated at supply voltages above 30V. The reason is as follows: If the PMT output is left open while the HV is switched on, the output cable is charged by the dark current to a voltage of some 100V. When connected to the MSA the cable is discharged into the MSA input. The energy stored in the cable is sufficient to destroy the input circuitry. Normally the limiter diodes at the input will prevent a destruction, but the action will stress the diodes enormously. So don't tempt fate!

To provide maximum safety against damage we recommend to connect a resistor of about 10 kOhm from the PMT anode to ground inside the PMT case as close to the PMT anode as possible. This will prevent cable charging and provide protection against damage due to bad contacts in connectors and cables.

Avalanche Photodiodes

Avalanche photodiodes (APDs) have a high quantum efficiency in the near infrared. Although this looks very promising, some care is recommended. Only a few APD types are really suitable for photon counting. To achieve a high count rate, an active quenching circuit for the APD is required. Furthermore, the diode must be cooled. The dark count rate per detector area unit is much higher than with a good PMT, even if the APD is cooled to a very low temperature. Good results can be expected if the light can be focused to an extremely small detector area and a correspondingly small APD is used.

Si APD detector heads from EG&G / Perkin Elmer (SPCM-AQR modules) deliver 4 V pulses with 20 to 50 ns duration into 50 Ω. They work with the MSA modules if connected to the ‘Count’ input via a 20dB attenuator. The input should be configured for ‘positive edge’.

When a photon is detected by an APD which is operated in the photon counting mode, a light pulse is emitted by the diode. The intensity is very low so that this pulse usually does not cause any problems. However, if a second detector is connected to another MSA channel crosstalk can result if both detectors are optically coupled.

Preamplifiers

Most PMTs deliver pulses of 20 to 50 mV into 50 Ω when operated at maximum gain. Although these pulses can easily be detected by the MSA input discriminators a preamplifier improves the noise immunity, the threshold accuracy and the safety against damaging the MSA input. Furthermore, it can extend the detector lifetime by reducing the required detector output current for a given count rate and avoiding overload conditions.

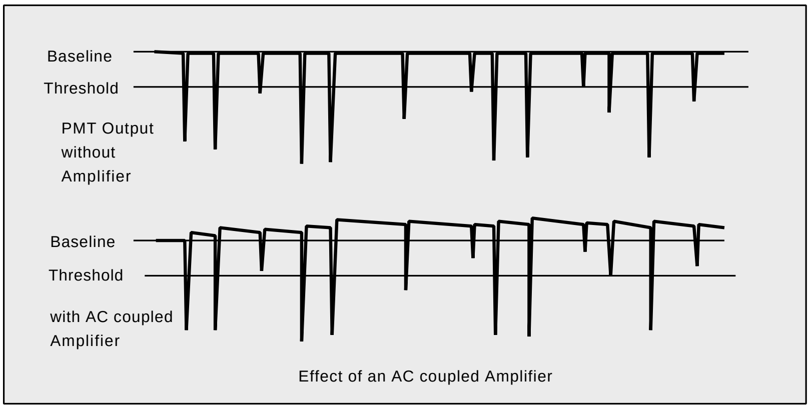
For most applications we recommend our HFAC-26 preamplifier. The HFAC-26 has 20 dB gain and 1.6 GHz bandwidth. The maximum linear output voltage is 1 V. Therefore, it amplifies the single photon pulses of a typical PMT without distortions. Furthermore, the HFAC-26 incorporates a detector overload detection circuit. This circuit measures the average output current of the PMT and turns on a LED and activates a TTL signal when the maximum safe detector current is exceeded.

Thus, even if the gain of the amplifier is not absolutely required the overload warning function helps you to make your measurement setup ‘physicist proof’. The HFAC-26 amplifier is shown in the figure right.

HFAC-26 Amplifier

The HFAC-26 is available with different overload warning thresholds from 100 nA (for MCPs) to 100 uA (for large PMTs).

As already mentioned, the single photon pulses of a photomultiplier have a considerable amplitude jitter. Even if the discriminator threshold is optimally adjusted some of the pulses will fall below the discriminator threshold and therefore be not counted. The loss in the counting efficiency due to this effect is normally not important. However, in conjunction witch AC coupled HF preamplifiers problems can arise at high count rates (> 1 MHz). The effect is shown in the figure below.



Effect of an AC coupled Amplifier

Due to the AC coupling, the signal voltage at the amplifier output swings beyond the baseline and returns with a time constant defined by the lower cutoff frequency of the amplifier. At high count rates this results in a signal shift which, in turn, results in a loss of some of the smaller PMT pulses. Because the loss depends on the count rate it causes a nonlinearity of the measured intensity or a distortion of the measured waveforms.

The effect increases with increasing width of the detector pulses. For fast PMTs (PMH-100, R5600) it is barely detectable and usually not distinguishable from the normal counting loss due to the limited pulse resolution of the detector. If the effect of AC coupling is a concern it can be minimised by using an AC coupling time constant much (1 order of magnitude) smaller than the reciprocal count rate or - for pulsed signals with a low duty cycle - much longer than the duration of the light pulse.

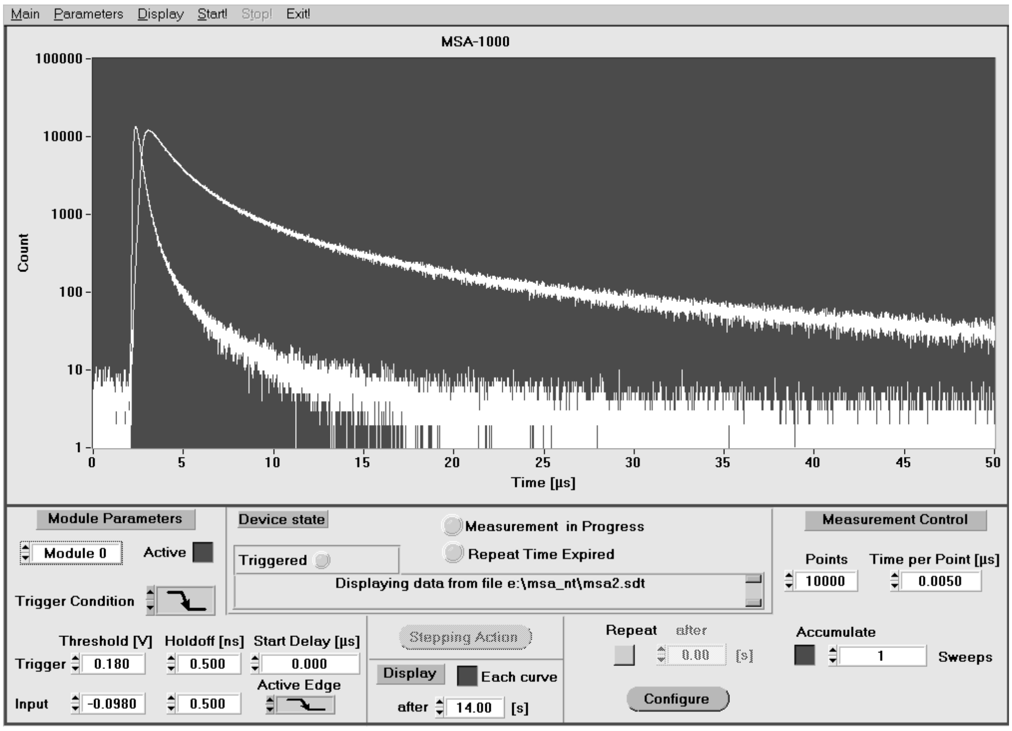
Distortions due to AC baseline shift are avoided with DC coupled amplifiers. DC coupled amplifiers are, however, slower and have a higher noise than the typical AC coupled HF amplifiers. Furthermore, the gain at low frequencies can cause problems due to line frequency pickup. For DC coupled amplifiers please see individual data sheets or http://www.becker-hickl.com.

Software

The MSA standard software is able to control up to four MSA modules of the same type. Two versions of the software are available: One for Windows 3.1 and Windows 95, the other for Windows 95 and Windows NT. Both versions run on Pentium or 486 PCs. At least 64 Mb of memory should be available. For convenient working the speed of the computer should be 300 MHz or more. The VGA resolution must be 1024 by 628 or more.

The MSA standard software includes the setting of the measurement parameters, the control of the measurement, the loading and saving of measurement data and parameters, the display of the results and the application of mathematical operations to the result curves. Furthermore, the software is able to control a stepping motor in conjunction with the B&H stepping motor controller card STP-240.

After starting the MSA software the main window appears. It incorporates a curve window for measurement data display, information about the present state of the module, facilities to set the measurement parameters and a menu bar to call functions such as load/save, print, a curve display with cursor movement and mathematical functions, setting of system and display parameters and start/stop of a measurement. The screen after the start of the program is shown in the figure below.



Menu Bar

The menu bar incorporates the following items:

Main Parameters Display Start Stop Exit

Under these items the following functions are available:

Main:	Load, Save, Convert, Print
Parameters:	Step Device Configuration, Display Parameters, Trace Parameters, EEPROM Parameters

Display:	Curve display with cursor and zoom functions, mathematical operations
Start:	Start of a measurement
Stop:	Stop of a measurement
Exit:	Exit from the MSA software

A detailed description of the menu bar functions is given in the section 'Functions of the Menu bar'.

Curve Window

In the curve window the measurement results are displayed. During the measurement intermediate results are displayed in programmable intervals (see 'Display Control').
The number of curves displayed, the colours, the curve style and the display scale are controlled by the 'Trace Parameters' and the 'Display Parameters'.

Device State

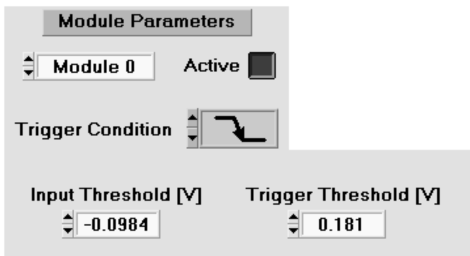
'Device State' informs about the current state of the measurement system.

The 'Measurement in Progress' indicator turns on when a measurement was started.

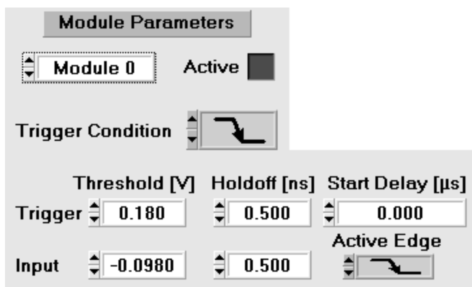
'Repeat Time expired' indicates that for a repeated measurement the repeat time has expired before the last measurement cycle could be finished.

The 'Triggered' indicators turn on when a module was triggered. Up to four trigger indicators are displayed depending on the number of MSA modules in the system. Final results will be not displayed until all active modules have triggered and finished their measurement. Therefore, when using more than one module with trigger conditions different from 'none', make sure that all modules get an appropriate trigger pulse (see also 'Trigger Condition').

Module-Parameters



Module parameters MSA-200/300



Module parameters MSA-1000

Module / Active

Under 'Module/Active' the module is selected to which the displayed module parameters refer. Parameters are displayed and set for modules only which are present in the system and declared as present in the MSA200.INI file. The modules can be switched on and off by the 'active' button.

Trigger Threshold

‘Trigger Threshold’ is the voltage level which must be crossed by the trigger pulse to trigger the device. ‘Trigger Threshold’ can be set from -1 V to +1 V.

The trigger input of the MSA is extremely fast. Therefore, trigger pulses derived from a laser by a fast photodiode are detected without problems.

If several MSA modules are present the trigger threshold can be set independently for different modules. Each module starts its measurement by its own trigger pulse. Final results will be not displayed until all active modules have triggered and finished their measurement. Therefore, when using several modules with trigger conditions different from 'none', make sure that all modules have the correct trigger threshold and get an appropriate trigger pulse.

Trigger Holdoff (MSA-1000 only)

The trigger holdoff function inhibits the trigger input for the specified time after a valid trigger event. Changing the trigger holdoff can avoid false triggering if the trigger signal has reflections or a trigger signal with a frequency of more than 100 MHz is used.

Trigger Condition

‘Trigger Condition’ defines the condition for the start of the measurement. With ‘None’ the recording starts immediately after pushing the ‘Start’ button of the menu bar. If 'Rising Edge' or 'Falling Edge' is selected, the measurement is initiated by the 'Start' button, but the recording does not start until the specified transition at the trigger input is detected. A reasonable accumulation of several sweeps is possible only if the MSA is triggered synchronously with the signal to be recorded. Therefore, the trigger condition must be ‘rising edge’ or ‘falling edge’ and an appropriate trigger signal must be used.

If several MSA modules are present the trigger condition and the trigger threshold can be set independently for different modules. Each module starts its measurement by its own trigger pulse. Final results will be not displayed until all active modules have triggered and finished their measurement. Therefore, when using several modules with trigger conditions different from 'none', make sure that all modules get an appropriate trigger pulse.

Start Delay (MSA-1000 only)

Start delay is the time from the detection of a valid trigger edge and the start of the sweep. It can be used to suppress the first part of the signal. This part of the signal sometimes causes excessive counting and frequent overflow of some time channels. Suppressing these events can increase the accumulation speed.

Input Threshold

'Input Threshold' is the discriminator threshold of the counting input. Values from -500 mV to +500 mV can be set. The count inputs can be configured to trigger either on the positive or on the negative edge of the input signal (See section 'Counting Inputs'). Normally, for negative detector pulses the negative edge configuration and a negative input threshold, for positive detector pulses the positive edge configuration and a positive input threshold is used.

The ‘Count’ input of the MSA is extremely fast. Therefore, the pulses from fast PMTs with a duration of only 1 to 4 ns are seen with their true amplitude, which often abandons the use of a preamplifier.

Input Holdoff (MSA-1000 only)

The ‘Count Holdoff’ function inhibits the count input for the specified time after a valid count event. It is used to avoid multiple counting of input pulses by reflections, afterpulses or ringing. Please see also ‘Dead time between counts’.

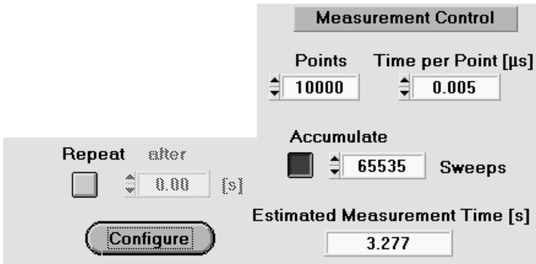
Input Edge (MSA-1000 only)

A count event can be initiated either on the rising (positive) edge or on the falling (negative) edge of the input pulse. Normally the leading edge of the detector pulse is used for counting, i.e. the negative edge is used for negative pulses and the positive edge for positive pulses.

Measurement Control

The MSA modules count input pulses whose amplitude is greater than the input discriminator threshold and stores them into subsequent memory locations of the device memory. In the MSA-200/300 and in the MSA-1000 each memory location represents a 5 ns and a 1 ns interval respectively. One sweep can be up to 512 k or 2.6 ms long for the MSA-200/300 and 128 k or 131 us long for the MSA-1000.

Accumulate



If 'Accumulate' is set several signal periods (‘sweeps’) are accumulated. In this case the recording is restarted with the next trigger pulse after the end of the previous sweep and the result is added to the current memory contents.

The photons of the subsequent sweeps are accumulated directly in the memory of the MSA. When the result in one of the memory channels reaches 255, the memory is read and the results are accumulated in a buffer in the PC memory. I the worst case (i.e. if one particular channel counts a photon in every sweep) this happens once for 255 sweeps. However, in practice the probability to count a photon in a particular channel is much smaller than 1, and much more than 255 sweeps are accumulated without readout.

The maximum number of accumulations is more that 2 billion so that the practical limitation is the measurement time rather than the capability of the MSA.

Repeat

The whole measurement sequence is repeated if the 'repeat' button is pressed. In this case a repetition time ('repeat after ...') can be specified. Furthermore, a measurement sequence can be defined with subsequent measurements, saving the data to files, and step motor actions between subsequent recordings (see ‘Configure’ and 'System Parameters' / 'Stepping Device Configuration' / 'Action').

If the overall measurement time is greater than the specified repeat time the measurement is repeated immediately when the last measurement has been finished.

Please note also, that repeating can be achieved only if all active modules are able to finish their measurement. Therefore, when using trigger conditions different from 'none', all active modules must receive an appropriate trigger pulse.

Points per Curve

'Points' is the number of curve points (time bins) for one curve in the measurement result. The range 'Points per Curve' depends on the selected time scale (see ‘Time per Point’).

Time per Point

The MSA-200/300 and the MSA-1000 use a fixed recording speed of 5 ns and 1 ns per point. Nevertheless, different time scales are available by combining several of the 5 ns or 1 ns channels into one point of the result curve. 'Time per Point' determines the time scale of the result curves.

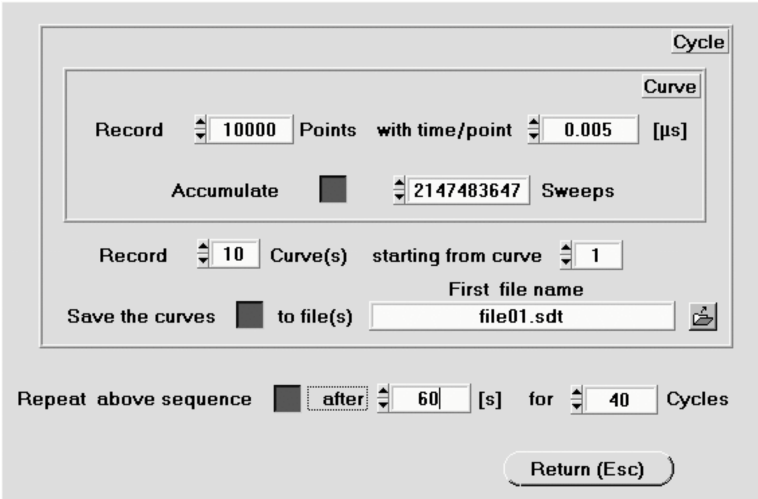
A ‘Time per Point’ greater than 5 ns or 1 ns is recommended to reduce the file size for the measurement of longer time intervals. Furthermore, it allows to record more than one event per curve point and per sweep. Because the maximum recording length is constant the maximum number of curve points depends on the selected ‘Time per Point’.

Estimated Measurement Time

'Estimated Measurement Time' is displayed for information only. It is the sweep time multiplied by the number of accumulations. In practice, this time is achieved only if the next trigger pulse appears immediately after a sweep is finished. Otherwise the measurement time is longer and depends on the trigger repetition rate.

Configuring a measurement sequence

The MSA can be configured to record a sequence of measurements. The sequence is controlled by the parameters in the 'Configure' menu shown below.



The 'Configure menu is opened by clicking on the 'Configure' button in the measurement control part of the main window. The measurement sequence can (but need not) consist of three program loops:

- The inner loop is the recording of a 'curve' with the specified number of sweeps accumulated for each of the activated MSA devices. This is the normal recording sequence which is controlled by the parameters 'points' and 'time / point'.

- The curve recording can be repeated for a number of 'curves' specified by 'Record ... Curve(s)'. The number of available curves depends on the parameter ‘Points / Curve’. At the end of the specified ‘cycle’ the result can automatically be stored to a data file.

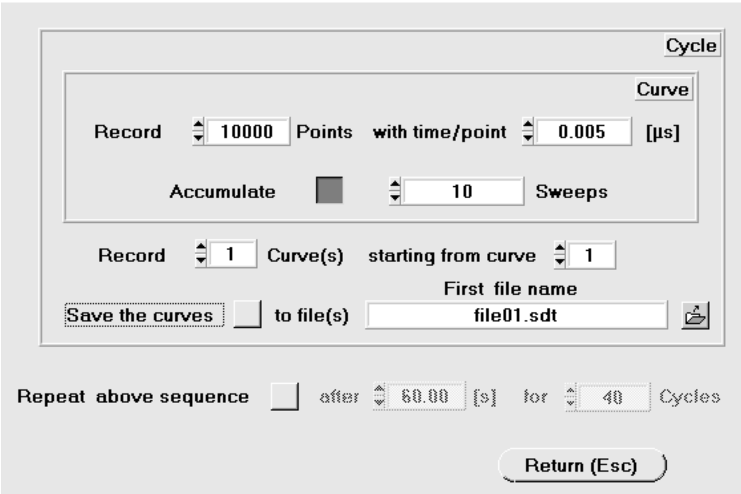
- Finally, the recording of the specified number of curves (‘cycle’) can be repeated in intervals of 'Repeat Time' ('after ... [s]'). The number of repetitions is given by 'for ... Cycles'. If the repeat function is used the ‘Save curves to files’ function must be switched on in order not to loose the data of the previous cycle. The data of the subsequent recording cycles are then stored into subsequent files with subsequent numbers (e.g. file01.sdt, file02.sdt, ...).

The programmed sequence can be combined with step motor actions if the STP-240 step motor controller card is present in the system. Up to two motors can be controlled. The actions are specified under 'System Parameters' / 'Stepping Device Configuration'. Step motor actions can be placed at the beginning of the measurement, after each curve, after each cycle and at the end of the measurement. Depending on what the motors drive a wide variety of complex measurements can be performed.

Measuring into Different Curves

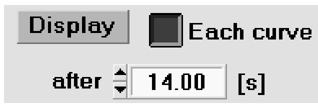
Several measurements can be stored into different blocks of the memory. The destination of the measurement data is controlled via the ‘Configure’ menu.

To record several curves into different blocks of the memory, set ‘Record 1 Curve’ and chose the destination curve number by ‘Starting from Curve ...’. The settings are shown in the figure below.



Display Control

Depending on 'Time per Point', 'Points per Curve' and 'Accumulations' the measurement time can vary in a wide range. Therefore, the display rate can be configured by 'Display Time' and the 'Display after each Curve' button.



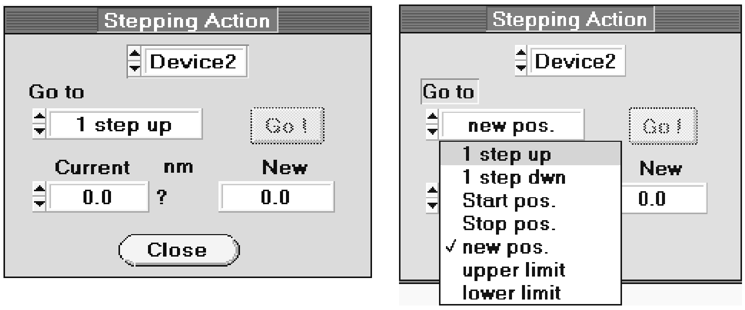
If 'Display after each Curve' is active the results are displayed when the measurement for one curve has been finished. Thus, without 'Accumulate' the result is displayed when the recording reaches the last curve point. With 'Accumulate' the result is displayed when the specified number of sweeps have been accumulated.

Furthermore, a display of intermediate results can be initiated after a specified ‘Display Time’.

For display colours, curve style, selection of displayed curves etc. please see ‘Display Parameters’ and ‘Trace Parameters’

Step Motor Control

If the stepping motor controller STP-240 is present in the system and enabled ('Parameters', 'Stepping device configuration') a window for manual step motor control can be opened by pressing the 'Stepping Action' button. The stepping action window is shown in the figure below (left).



With 'Device 1' or 'Device 2' one of the two motors driven by the STP-240 can be selected. Several actions are available, as shown in the figure above (right). The action is initiated by the 'Go' button.

For stepping device configuration, please see 'Parameters', 'Stepping Device Configuration'.

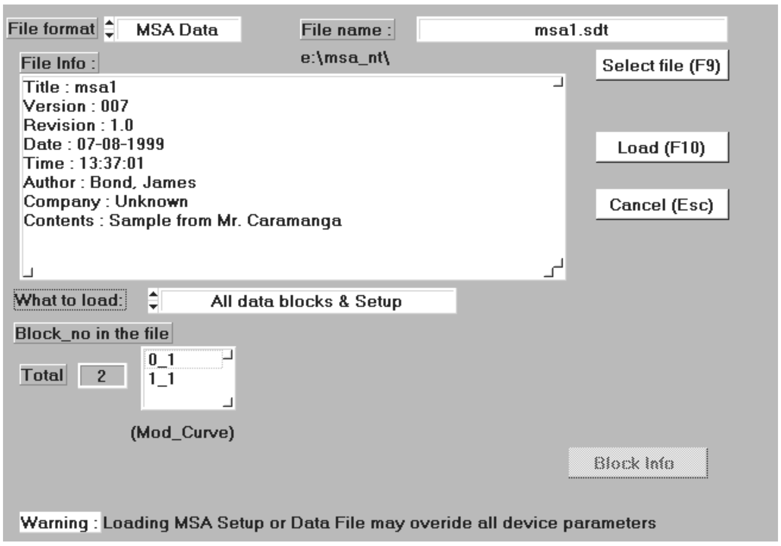
Functions in the Menu Bar

Main: Load, Save, Print

Under 'Main' the functions for loading and saving data and the print functions are available. 'Counter Test' provides a test facility for the hardware functions of the modules.

Load

The 'Load' menu is shown in the figure below.



In the 'Load' menu the following functions are available:

Data and Setup File Formats

You can chose between 'MSA Data' and 'MSA Setup'. The selection refers to different file types.
With 'MSA Data', files are loaded that contain both measurement data and system parameters. Thus the load operation restores the complete system state as it was in the moment of saving.
If you chose 'MSA Setup', files are loaded that contain the system parameters only. The load operation sets the system parameters, but the measurement data is not influenced. Files for 'MSA Data' have the extension '.sdt', files for 'MSA Setup' the extension '.set'.

File Name / Select File

The name of the data file to be loaded can be either written into the 'File Name' field or selected from a list. To select the file from the list, 'Select File' opens a dialog box that displays the available files. These are '.sdt' files or '.set' files depending on the selected file format. Furthermore, in the 'Select File' box you can change to different directories or drives.

File Info, Block Info,

After selecting the file an information text is displayed which was typed in when the data was saved. With 'Block Info' information about single data blocks (curves) is displayed. The blocks are selected in the 'Block no in the file' list.

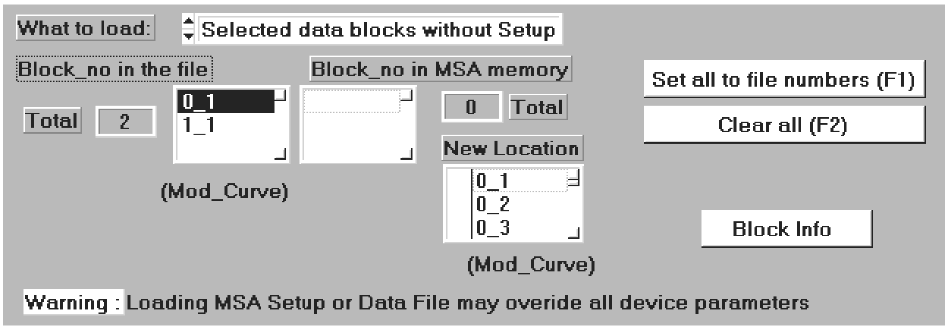
Load, Cancel

Loading of the selected file is initiated by 'Load'. 'Cancel' rejects the loading and closes the 'Load' menu.

Loading selected Parts of a Data File

Under 'What to Load' the options 'All data blocks & setup', 'Selected data blocks without setup' or 'Setup only' are available. The default setting is 'All data blocks & setup', which loads the complete information from a previously saved data file. 'Setup only' loads the setup data only, the measurement data in the MSA memory remains unchanged.

With 'Selected data blocks without setup' a number of selected curves out of a larger .sdt file can be loaded. If this option is used the lower part of the 'Load' menu changes as shown in the figure below.



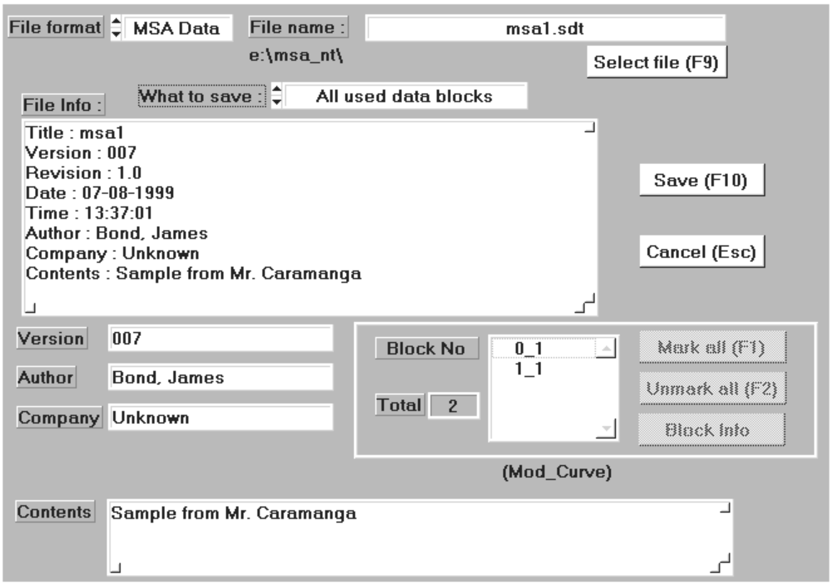
The list 'Block no in the file' shows the curves available in the file. Under 'Block no in the memory' the destination of the data blocks (curves) in the memory is shown. With 'Set all to file numbers' the destination in the memory can be set to the same block numbers as in the file. To set the destination of the data to locations different from the block numbers in the file, block numbers in the 'Block no in the memory' list can be selected and replaced by block numbers selected from the 'New location' list. 'Clear all' clears the 'Block no in the memory' list.

‘Block Info’ opens a new window which gives information about the data in a selected data block. An example for the block information window is given in the section ‘Trace Parameters’.

When partial information is loaded from a data file care should be taken that 'Time per Point' and 'Points per Curve' be identical with the current setting.

Save

The 'Save' menu is shown in the figure below.



In the 'Save' menu the following options are available:

File Format

You can chose between 'MSA Data' and 'MSA Setup'. The selection refers to different file types. With 'MSA Data' files are created which contain measurement data and system parameters as well. Thus the complete state is restored when the file is loaded. If you chose 'MSA Setup' files are created that contain the system parameters only. Loading of such files sets the system parameters only, the measurement data is not influenced.
Files created by 'MSA Data' have the extension '.sdt', files created by 'MSA Setup' have the extension '.set'.

File Name

The name of the data file to which the data will be saved can be either typed into the 'File Name' field or selected from a list. To select the file from the list, 'Select File' opens a dialog box that displays the available files. These are '.sdt' files or '.set' files depending on the selected file format. Furthermore, in the 'Select File' box you can change to different directories or drives.

File Info

After selecting the file an information text can be typed into the 'File info window'. If you have selected an existing file you can edit the existing file information. When you load the file later, this text is displayed. This helps to identify the correct file before loading.

Save / Cancel

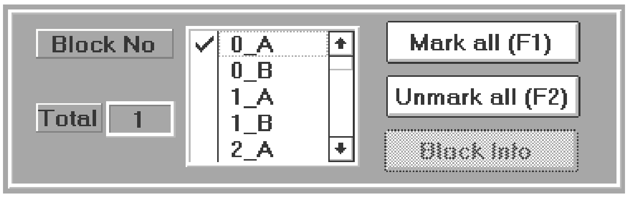
Saving of the selected file is started by 'Save' or F10. 'Cancel' rejects the saving and closes the 'Save' menu.

Saving selected curves

Under 'What to Save' the options 'All used data blocks', 'Only measured data blocks' or 'Selected data blocks' are available. The default setting is 'All used data blocks', which loads all data in the memory. This can be measured data, calculated data or data loaded from another file.

'Only measured data blocks' saves data blocks only which contain data which was measured since the start of the software.

With 'Selected data blocks without setup' a number of selected curves is saved. If this option is used the lower part of the 'Load' menu changes as shown in the figure below.



The list 'Block No' shows the curves which are available in the memory. The desired curves are selected (or deselected) from this list by a mouse click. 'Mark all' selects all curves, 'Unmark all' deselects all curves. 'Block info' displays information about a selected curve.

‘Block Info’ opens a new window which gives information about the data in a selected data block. An example for the block information window is given in the ‘Trace Parameters’ section.

Convert

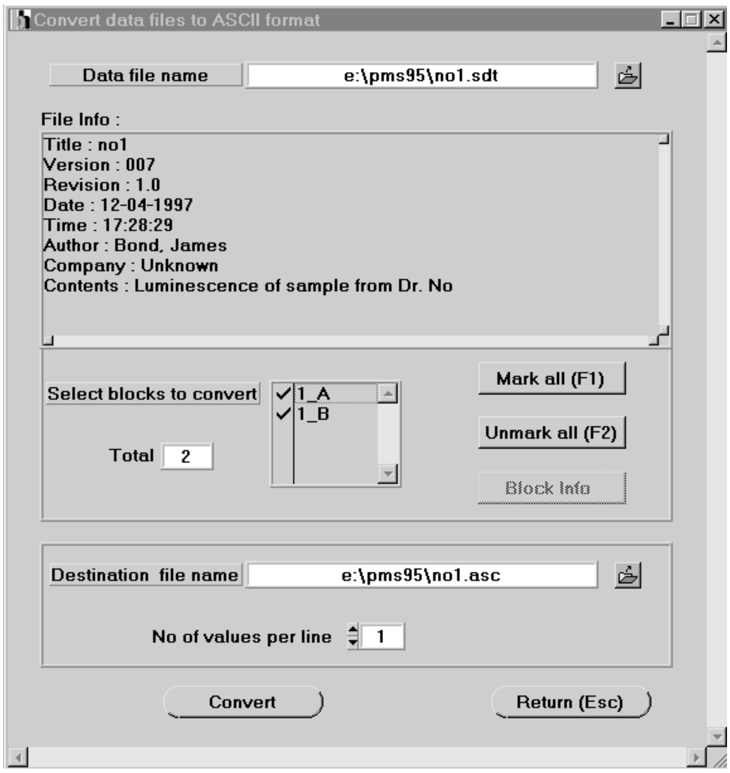
The ‘Convert’ functions are used to convert the .sdt files of the MSA Standard Software into ASCII data files. The ‘Convert’ menu is shown in the figure below.

The file name can be typed in or selected from a list which is opened by clicking on the file symbol near the name field. After selecting the source file, the file information is displayed which was typed in when the file was saved by the ‘Save’ function.

By ‘Select blocks to convert’ special blocks (curves) from the source file can be selected for conversion. At the beginning all curves of the source file are marked. Thus, no selection is required if all blocks of the source file are to be converted.

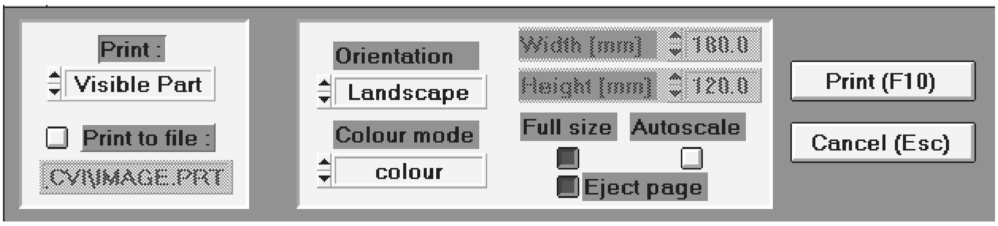
The destination file is specified in the lower part of the convert menu. The file name can be selected from a list which is opened by clicking on the file symbol near the name field. As long as no destination file name is entered or selected the source file name is used with the extension .ASC.

The style of the generated ASCII can be changed by setting ‘Number of values per line’ to the desired value.



Print

The 'Print' function prints the actual screen pattern on the printer. You can print either the whole panel or the visible part only. 'Portrait' or 'Landscape' selects the orientation on the sheet. The dimensions are set by 'Autoscale', 'Full Size' or 'Size X' and 'Size Y'.

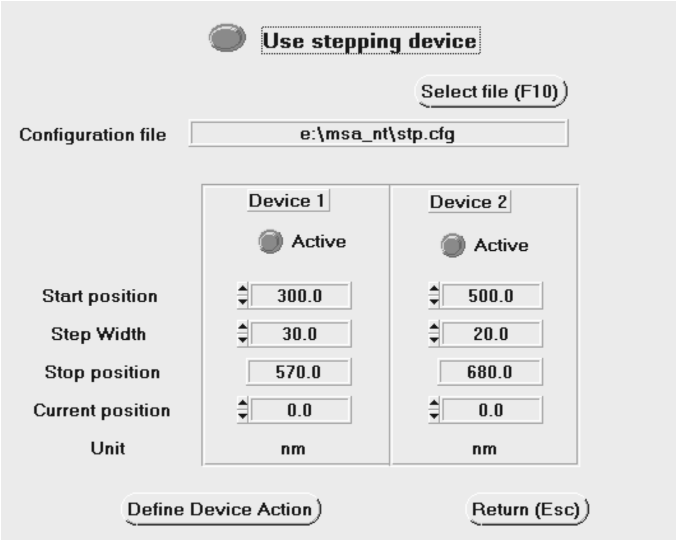


If you want to create a file of a screen pattern you can use the 'Print to File' option. However, another convenient possibility to save a screen pattern is the 'print screen' key. When this key is pressed, Windows stores the screen pattern to the memory from where it (usually) can be loaded into any other program.

Parameters

Stepping Device Configuration

The stepping device configuration menu is shown in the figure below.

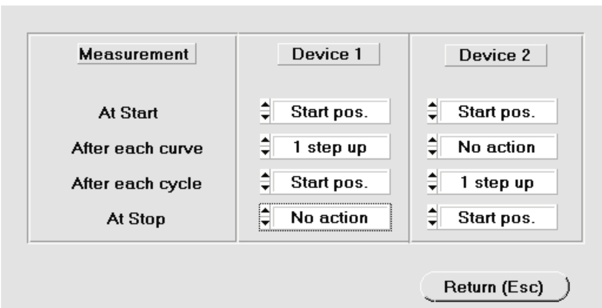


The basic electrical and mechanical parameters of the step motor drive are configured by a configuration file. This file contains the stepping frequency, start and stop ramps, duration of overvoltage pulses, end positions, the unit of the driven axis (e.g. nm for a wavelength drive) and the number of motor steps per unit. The default file name is STP.CFG. Other file names can be used to select between different configurations.

The STP-240 step motor controller can drive two step motors. Both motors can be activated or deactivated by the 'Active' buttons. Start position, step width and stop position can be set independently for both motors.

A calibration of the drive position is achieved by an entry of the 'current position' before the fist measurement is started. If a measurement is started and one of the used drives is not calibrated a warning appears. Therefore, switch off motors which are not used by the 'active' button or set all device actions to 'No Action' (see below).

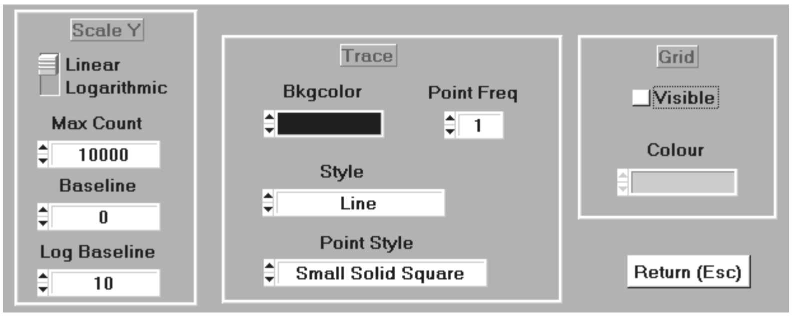
The button 'Define Device Action' opens a new window which is used to define the place of a step motor action within the measurement program loop. The 'Device Action' window is shown in the figure below.



Step motor actions can be defined at the start of the measurement, when the recording and accumulation of a curve is finished (‘after each curve’), after a number of repetitions of the measurement (‘after each cycle’) and at the end of the measurement. In the figure above device 1 runs to the start position at the beginning of the measurement, makes one step up after each curve and runs back to the start position after a cycle of several curves. Device 2 runs to the start position at the beginning of the measurement, makes one step after a cycle of several curves and runs back at the end of the measurement.

Display Parameters

The display parameter menu is shown in the figure below.



Scale Y

Under 'Scale Y' you can switch between a linear or logarithmic display of the curves. Furthermore, the curve window can be set to any fraction of the available count range.

Linear / Logarithmic:	Linear or logarithmic Y-scale
Max Count:	Upper limit of the display range for linear and logarithmic scale
Baseline:	Lower limit of the display range for linear scale
Log Baseline:	Lower limit of the display range for logarithmic scale

All limit values are given in 'counts'.

Trace

Bkgcolor:	Background colour of the curve window.
Style:	Display style of the curves. The styles 'Line', 'Points Only' and 'Connected Points' are available.
Point Style:	Style of the curve points for ‘Points Only’ and ‘Connected Points’
Point Freq:	At values >1 each n-th point is displayed only. 'Point Freq' has no influence if 'Line' is selected.

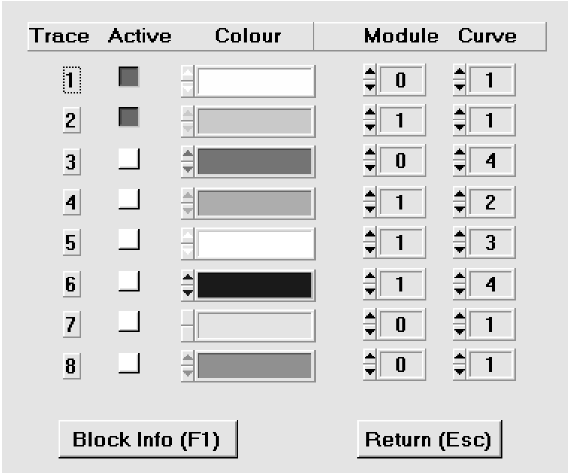
Grid

Visible:	Toggles the grid on and off.
Color:	Sets the grid colour.

Trace Parameters

Up to eight individual curves can be displayed in the curve window. The curves on the screen are referred to as 'traces'. In the trace parameter menu you can define which information the traces should contain and in which colour the are displayed. These curves can be measured curves from up to four MSA modules or data which have been loaded from an .sdt file.

The Trace Parameters menu is shown in the figure below.



With 'active' a particular trace can be switched on or off. We recommend to switch off traces that are not needed. This will increase the speed of the display.

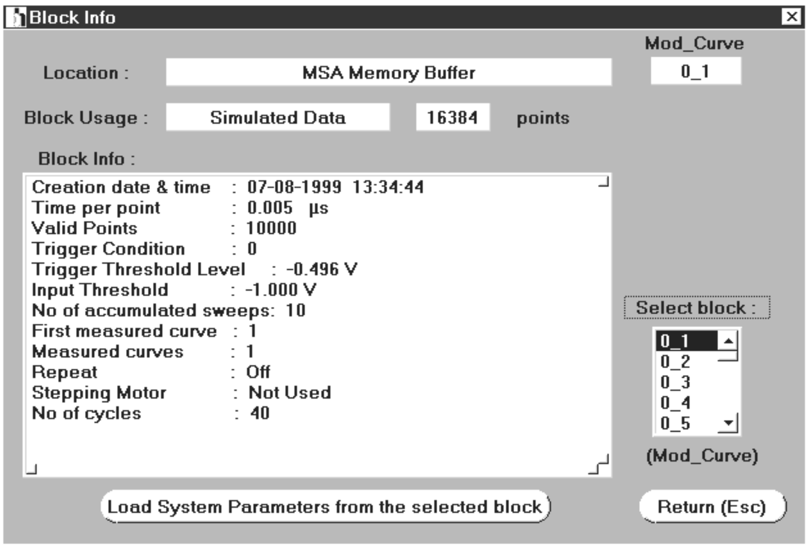
'Color' sets the colour of the trace.

'Module' specifies the MSA module in which the data is recorded (up to four modules can be present).

‘Curve’ allows to select measurement results from different measurements or single curves from a multi-curve measurement (see ‘Configuring a measurement sequence’). The number of available curves depends an the parameter ‘Points / Curve’ and ranges from 1 (for 512 k points / curve) to 8192 (for 64 points / curve).

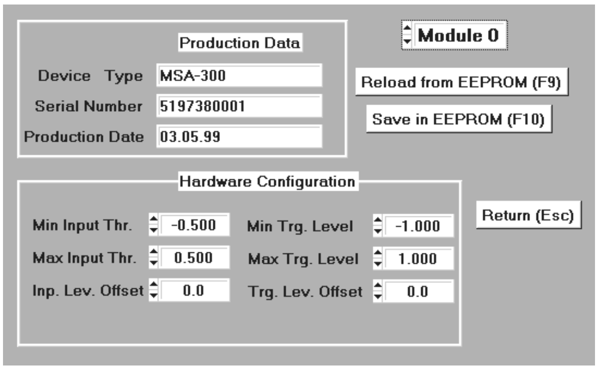
By changing 'Module' and 'Curve' the trace definition allows to display curves from different modules and different measurements at the same time.

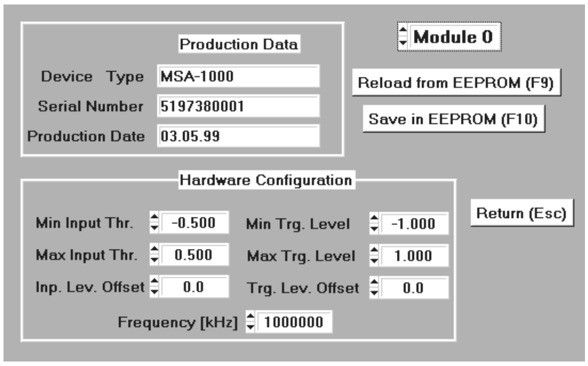
‘Block Info’ opens a new window which gives information about the data selected by ‘Module’ and ‘Curve’. An example of the block information window is given below.



Adjust Parameters

Adjust values and production information are stored in an EEPROM on the MSA module. The adjust values are accessible via the adjust parameters menu. To change the adjust parameters a certain knowledge about the MSA hardware is required. Wrong inputs may seriously deadjust the module. Therefore you can change the adjust parameters, but not save them to the EEPROM. The changed adjust values are used by the device, but they will be replaced by the original values after reloading from the EEPROM or after restarting the MSA software.





Production Data

This area contains manufacturing information about the particular module. The information is used by the software to recognise different module versions. Please do not change these parameters.

Hardware Configuration

Depending on user requirements, the Trigger and counter inputs of the MSA can be hardware-configured for different input voltage ranges. The parameters under 'Hardware Configuration' inform the software about the actual input threshold ranges.

Frequency (MSA-1000 only)

This parameter is the clock frequency of the MSA-1000 module.

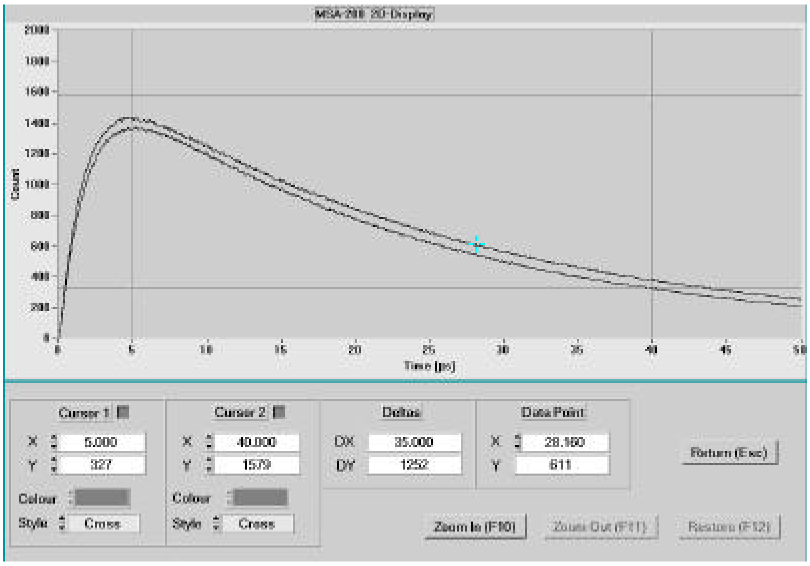
Display

'Curve Display' incorporates functions for inspection and evaluation of the measured data. Under 'Curve Display' the traces defined in the 'Trace Parameters' are displayed. The curve display window is shown in the figure below.

Two cursor lines are available to select curve points and to display the data values numerically. The scale can be changed in both axis by zooming the area inside the cursor lines. The cursor settings and the zoom state is stored when leaving the display routine. Thus the display will come up with the same settings when it is entered again.

The display style (linear/logarithmic, window limits, curve style, background and grid colours) is set in the display parameters.

When the 'Curve Display' is active, data operations can be accomplished via the 'Display' menu and selection of 'Data Processing'. Furthermore, the 'Display Parameters', the 'Trace Parameters' and the 'Print' function can be accessed directly.



Cursors

The two cursors are used to select and measure curve points and to set the range for zooming the displayed data.

With 'Style' you can select whether a cursor is a horizontal line, a vertical line or a cross of a vertical and a horizontal line. For each cursor the X-Position (vertical cursor), the Y-Position (horizontal cursor) or both (crossed line cursor) are displayed. Under 'Deltas' the differences between the cursor values are displayed. The colours of the cursors are set by 'Colors'.

The cursors can be moved with the mouse or with the keyboard. If the keyboard is used, the cursor is selected with 'page up' and 'page down' and shifted with the cursor keys. By pressing the cursor keys together with the 'shift' key a fine stepping is achieved.

Data Point

In addition to the cursors, the 'Data Point' may be used to measure data values. The data point is a small cross that can be shifted across the screen by the mouse. When the mouse key is released, the data point drops to the next true data location of the next trace. At the same time X and Y values are displayed.

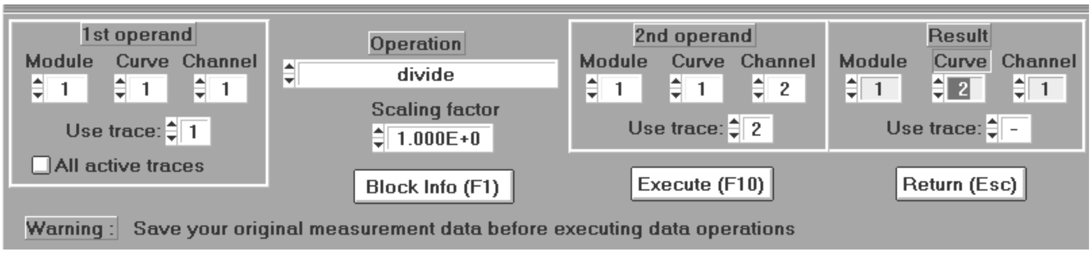
Zoom Function

'Zoom in' magnifies the area between the two cursors to the whole screen width. If the cursors are vertical lines the magnification occurs in X-direction. If the cursors are horizontal the scale is magnified in Y-direction. For crossed line cursors zooming is done in both directions stretching the rectangle between the cursor to the full screen.

'Zoom Out' restores the state before the last zooming action. This includes the zoom state as well as the other display parameters as 'linear' or 'logarithmic'. 'Restore' will restore the state as it had been when entering the 'Zoom' function.

2D Data Processing

When the 'Curve Display' is active, the 2D Data operations can be accessed via the 'Display' menu and selection of 'Data Processing'. In this case the lower part of the screen is replaced by the data processing window. In this window the source of the operands, the operation and the destination of the result can be selected. All operations refer to the range inside the cursors.



1st operand

In this place the curve number of the first operand has to be specified. This can be done either by ‘Module’, ‘Curve’ and ‘Channel’ or by selecting one of the active traces via 'use trace'. If an active trace is selected, ‘Module’, ‘Curve’ and ‘Channel’ are set according to the values in the trace parameters. ‘Module’, ‘Curve’ and ‘Channel’ are displayed in the colour of the selected trace. With 'all active traces' the selected operation is applied to all active traces at once.

Operation

'Operation' selects the operation to be applied to the operands. To keep the result inside the data range of the measurement memory the result is multiplied by the 'Scaling Factor'. This factor can be set to any floating point number.

2nd operand

In this place the curve number of the second operand has to be specified. This can be done either by ‘Module’, ‘Curve’ and ‘Channel’ or by selecting one of the active traces via 'use trace'. If an active trace is selected, ‘Module’, ‘Curve’ and ‘Channel’ are set according to the values in the trace parameters. ‘Module’, ‘Curve’ and ‘Channel’ are displayed in the colour of the selected trace.

Result

In this place the curve number of the result has to be specified. This can be done either by ‘Module’, ‘Curve’ and ‘Channel’ or by selecting one of the active traces via 'use trace'. If an active trace is selected, ‘Module’, ‘Curve’ and ‘Channel’ are set according to the values in the trace parameters. ‘Module’, ‘Curve’ and ‘Channel’ are displayed in the colour of the selected trace.

Block Info

‘Block Info’ opens a new window which gives information about the data in a selected (Module, Curve, Channel) data block. An example for the block information window is given in the section ‘Trace Parameters’.

Start

'Start' starts the measurement. If there are several MSA modules in the system the measurement is started in all modules simultaneously. However, if trigger conditions different from 'none' are selected each module starts the recording with its own trigger pulse. Triggering is indicated for all active modules by the trigger indicator 'lamps'.

The measurement continues until the specified number of points, number of accumulations, number of repetitions etc. has been reached. The measurement can be aborted by the operator by pressing the 'Stop' button.

Stop

'Stop' aborts a current measurement. Although the measurement data may be incomplete after a 'Stop' command, the current results are available as in case of correct termination.

Exit

The MSA software is left by 'Exit'. When the program is terminated, the system parameters are saved in a file 'auto.set'. This file is loaded automatically at the next program start. Thus the system will come up in the same state as in the moment of the exit.

If you do not want to save the current settings you can reject the saving by switching off the 'save data on exit' button.

Data File Structure

The data files consist of
- a file header which contains structural data used to find the other parts of the file
- the file information which was typed in when the file was saved
- the system setup data for hardware and software
- one or more measurement description blocks which contain the system parameters corresponding to the particular data blocks
- data blocks containing one curve each, along with information to which measurement description block they correspond.

File Header

All MSA data files start with a file header which contains information about the location and the length of the other parts of the file. The header file variables are shown in the table below.

short	revision	software revision number
long	info offset	offset of the info part which contains general information (Title, date, time, contents etc.)
short	info length	length of the info part
long	setup_offs	offset of the setup data (system parameters, display parameters, trace parameters etc.)
short	setup_length	length of the setup data
long	data_block_offset	offset of the first data block (one data block contains one curve)
short	no_of_data_blocks	number of data blocks
long	data_block_length	length of one data block
long	meas_desc_block_offset	offset to 1st. measurement description block (system parameters connected to data blocks)
short	no_of_meas_desc_blocks	number of measurement description blocks
short	meas_desc_block_length	length of the measurement description blocks
unsigned short	header_valid	valid: 0x5555, not valid: 0x1111
unsigned long	reserved1	
unsigned short	reserved2	length of the data block extension header (no of 4-byte words)
unsigned short	chksum	checksum of file header

Info

This part contains the general information which has been typed in when the data was saved. The info part is stored in ASCII. An example is given below.

```
*IDENTIFICATION
    ID              : _MSA Setup & Data File_
    Title           : startup
    Version         : 007
    Revision        : 1
    Date            : 10-10-1997
    Time            : 12:29:01
    Author          : Bond, James
    Company         : Unknown
    Contents        : Dye sample from Dr. No
*END
```

Setup

The setup block contains all the system parameters, display parameters, trace parameters etc. It is used to set the MSA system (hardware and software) into the same state as it was in the moment when the data file was stored. The values are stored together with an identifier of the particular parameter. This method allows to maintain compatibility between different MSA versions. If a parameter is missing in the setup part, a default value is used when the file is loaded. A typical setup part is shown below.

```
*SETUP
    SYS_PARA_BEGIN:
    #PR [PR_BASE_S,I,928]
    #PR [PR_PCOL,I,1]
    #PR [PR_PWHAT,I,0]
    #PR [PR_PF,B,0]
    #PR [PR_PFNAME,S,IMAGE.PRT]
    #PR [PR_PORIEN,I,0]
    #PR [PR_PEJECT,B,1]
    #PR [PR_PWIDTH,F,180]
    #PR [PR_PHEIGH,F,120]
    #PR [PR_PFULL,B,0]
    #PR [PR_PAUTO,B,0]
    #PR [PR_SAVE_T,I,0]
    #PR [PR_MODE,I,0]
    #PR [PR_COL_TIME,F,0.005]
    #PR [PR_POINTS,I,10000]
    #PR [PR_ACCUM,B,1]
    #PR [PR_SWEEPS,I,65535]
    #PR [PR_REP_TIME,F,0]
    #PR [PR_CURVES,I,1]
    #PR [PR_FCURVE,I,1]
    #PR [PR_ASAVE,I,0]
    #PR [PR_FNAME,S,file1.sdt]
    #PR [PR_REPEAT,B,0]
    #PR [PR_CYCLES,I,0]
    #PR [PR_DIS_TIME,F,14]
    #PR [PR_DAES,B,1]
    #PR [PR_USESTP,B,0]
    #PR [PR_STP_FN,S,STP.CFG]
    #PR [PR_DEV_STA1,F,300]
    #PR [PR_DEV_STA2,F,500]
    #PR [PR_DEV_STE1,F,128]
    #PR [PR_DEV_STE2,F,1]
    #PR [PR_DEV_ACTIVE,I,3]
    #PR [PR_START_ACT,U,983055]
    #PR [PR_CURVE_ACT,U,983055]
    #PR [PR_CYCLE_ACT,U,983055]
    #PR [PR_STOP_ACT,U,983055]
    #PR [PR_SLEEP,I,13]
    #DI [DI_SCALE,I,1]
    #DI [DI_MAXCNT,M,100000]
    #DI [DI_LBLINE,M,10]
    #DI [DI_BLINE,M,0]
    #DI [DI_GRID,B,0]
    #DI [DI_GCOL_F,I,8]
    #DI [DI_GCOL_B,I,0]
    #DI [DI_TRSTYL,I,0]
    #DI [DI_TRNO,I,1]
    #DI [DI_PSTYLE,I,9]
    #DI [DI_PFREQ,I,1]
    #DI [DI_2DC1,B,1]
    #DI [DI_2DC2,B,1]
    #DI [DI_2DC1C,I,9]
    #DI [DI_2DC2C,I,13]
    #DI [DI_2DC1S,I,0]
    #DI [DI_2DC2S,I,0]
    #DI [DI_SIZE,I,67109604]
    #MP0 [MP_BASE,I,896]
    #MP0 [MP_ACTIVE,B,1]
    #MP0 [MP_ENABLE_MEAS,B,1]
    #MP0 [MP_TRIGGER,I,1]
    #MP0 [MP_INP_THR,F,-0.09842519]
    #MP0 [MP_TRIG_THR,F,0.18110237] SYS_PARA_END:
    #MP0 [MP_INP_HF,F,4.6277928]
    #MP0 [MP_TRIG_HF,F,3.0049]
    #MP0 [MP_ST_DEL,F,0]
    #MP0 [MP_ACT_EDGE,I,0]
    TRACE_PARA_BEGIN:
    #TR #0 [1,14,0,1]
    #TR #1 [0,11,0,1]
    #TR #2 [0,13,0,2]
    #TR #3 [0,10,0,2]
    #TR #4 [0,15,0,3]
    #TR #5 [0,9,0,3]
    #TR #6 [0,7,0,1]
    #TR #7 [0,8,0,1]
    TRACE_PARA_END:
*END
```

Measurement Description Blocks

Each data block can (but need not) have its own system (hardware) parameter set which can differ from the setup parameters. In the block header of each data block a corresponding measurement description block is specified. Therefore the number of measurement description blocks can vary from one (if all stored data blocks are measured with the same hardware parameters) to the number of saved data blocks (if all blocks are measured with different hardware parameters). The number, the length and the location of the measurement description blocks is stored in the file header at the beginning of the file. Some measurement parameters are individual for each data block (e.g. channel's gate level, trigger condition) – these parameters are stored in a data block extension header.

The information in the measurement description blocks is used for the 'Block Info' function in the Load, Save and Trace Parameter menus. If the button 'Use System Parameters from the Selected Block' is pressed, the system parameters are replaced by the data in the measurement description block.

The measurement description blocks are stored in a binary format. The structure is shown below.

char	time[9];	time of creation
char	date[11];	date of creation
unsigned long	points;	length of data
unsigned long	no_of_accum_curves;	
short	first_curve;	
short	curves;	
float	col_time;	collection time interval of 1 point
float	rep_time;	
short	repeat;	
u_short	cycles;	acquire cycles
short	use_motor;	
char	reserved1;	
short	reserved2;	

Data Blocks

Each data block contains the data of one curve. The number, the length and the location of the data blocks is contained in the file header at the beginning of the data file. Each data block starts with the block header, then follows the block header extension and finally the data set.

Each data block can (but need not) be measured with different hardware parameters. Therefore, for each block a data block header is provided, which specifies a corresponding measurement description block. Furthermore the header contains a block number, the offset of the data block from the beginning of the file, the offset to the next data block and an information about the data in the block (none, measured, loaded from file, calculated, simulated).

The structure of data block header is shown below.

short	block_no	number of the block in the file, from 0 to no_of_data_blocks-1
long	data_offs	offset of the data block from the beginning of the file
long	next_block_offs	offset to the data block header of the next data block
unsigned short	block_type	0: unused 1: measured 2: data from file 3: calculated data 4: simulated data
short	meas_desc_block_no	Number of the measurment description block corresponding to this data block
unsigned long	reseved1	
unsigned long	reserved2	

The block header extension contains specific block information. The length of the header extension is defined in the file header (field 'reserved2'). The structure of the block header extension is shown below.

char	mod_ser_no[16];	serial number of the module
short	trigger;	trigger condition
float	inp_threshold;	input threshold level
float	trig_threshold;	trigger threshold level
short	module_type;	
float	inp_holdoff;	input holdoff level[ns]
float	trig_holdoff;	trigger holdoff level[ns]
float	time_resolution;	time resolution[µs]
float	start_delay;	start delay[µs]
int	active_edge;	active edge of the input signal

The data of the block specified by the block header is stored as shown below. It follows directly after the data block header extension. The data is interpreted as 32-bit values of subsequent points of the curve.

unsigned long	curvepoint[0]
unsigned long	curvepoint[1]
.	.
unsigned long	curvepoint[data_block_length-1]

Trouble Shooting

Although we believe that our MSA modules work reliably tests can be recommended after an accident such as overvoltage, mechanical stress or another extreme situation. Furthermore, if a measurement setup does not work as expected a test of the MSA module can help to find out the reason. However, the best strategy **before a test is required** is: **Avoid damage to the module**!

How to Avoid Damage

The best way to avoid any trouble is to avoid conditions that can cause damage to the MSA module. The most dangerous situations are described below.

Electrostatic Discharge

Electrostatic discharge can damage the module when it is inserted or removed from a computer or when it is touched for other reasons. It happens when your body is electrically charged and you touch a sensitive part of the MSA module. To avoid damage due to electrostatic discharge we recommend to follow the rules given below:

Before inserting an MSA module into a computer, you should touch the computer at a metallic (grounded) part to drain a possible charge off your body.

When the module is taken from its packaging box it should be touched at first at the front panel.

Before bringing the module into contact with the computer touch both the module at the front panel and a metallic part of the computer.

When taking a module from a computer touch a metallic part of the computer before touching the MSA module.

There are extreme situations (especially in heated rooms in the winter) when sparks are crackling when touching anything. Such an environment should be avoided when handling any electronic parts. Or, if this is not possible, it is not ridiculous to take off shoes and socks when handling sensitive electronic devices.

Overvoltage at the signal inputs

Damaging the signal inputs is the most expensive accident, because the ultra-fast input comparators has to be replaced in this case. Therefore:

Never connect a photomultiplier to the MSA module when the high voltage is switched on! Never connect a photomultiplier to the MSA module if the high voltage was switched on before with the PMT output left open! Never use switchable attenuators between the PMT and the MSA! Never use cables and connectors with bad contacts! The same rules should be applied to photodiodes that are operated at supply voltages above 20V. The reason is as follows: If the PMT output is left open while the HV is switched on, the output cable is charged by the dark current to a voltage of some 100V. When connected to the MSA the cable is discharged into the MSA input. The energy stored in the cable is sufficient to destroy the input circuitry. Normally the limiter diodes at the input will prevent a destruction, but the action will stress the diodes enormously. Therefore, don't tempt fate!

To provide maximum safety against damage we recommend to connect a resistor of about 10 kOhm from the PMT anode to ground inside the PMT case and as close to the PMT anode as possible. This will prevent cable charging and provide protection against damage due to bad contacts in connectors and cables.

Furthermore, please pay attention to safety rules when handling the high voltage of the PMT. Make sure that there is a reliable ground connection between the HV supply unit and the PMT. Broken cables, lose connectors and other bad contacts should be repaired immediately.

Please be careful when working with low repetition rate lasers. Most of these lasers deliver so high pulse energies, that a photodiode can switch into a breakthrough state and deliver an extremely high current for hundreds of ns. Even PMTs can deliver pulses of several 100 mA when they are hit by the laser pulse.

Software Testing Facilities

Interface, Registers and DACs

When the MSA standard software starts it automatically tests the interface functions, the internal control registers and the DACs for the count and trigger threshold. Therefore, if the software starts without any error message you can expect that these parts of the module work correctly.

Memory Test

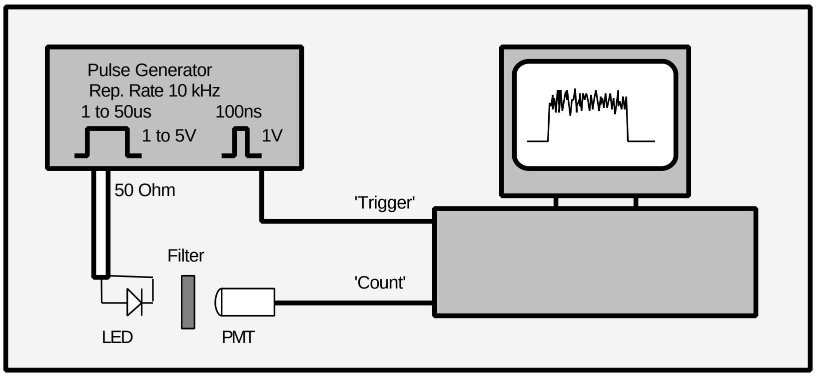
If you suspect any problems with memory of the MSA, run the 'MSA Test' program delivered with the MSA Standard Software. The main panel of this program is shown below.

Switch on 'Repeat' and 'Break on Error' and start the test. If the program performs several test loops (indicated by 'Test Count') without indicating an error you may be sure that the memory of the module works correctly. Depending on the speed of the computer, it can take some 10 s to run one test loop.

If an error should be displayed, check that the module is inserted correctly and that there is no address conflict.

Test with a PMT

A simple setup for testing the combination of the MSA and the detector is shown in the figure below.

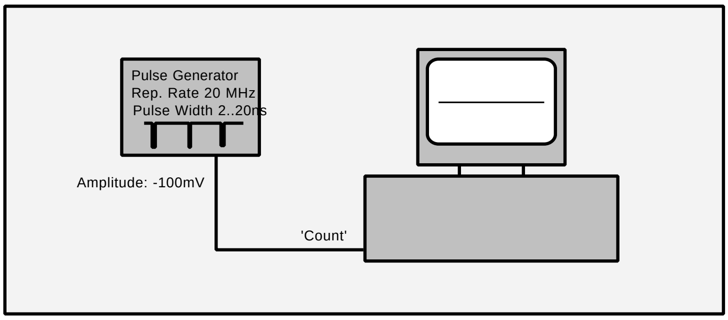


The recommended MSA settings are:

Module Parameters and Measurement Control
Time per Point = 5ns, 1ns for MSA-1000
Points = 10,000
Repeat = ON
Accumulate ON, 100 Sweeps
Display 'Each Curve'
Repeat after 0 s
Trigger Condition = Rising Edge
Trigger Threshold = +0.1V
Inp. Thresh. = -0.05 V (depends on detector)
Display Parameters
Scale Y = Logarithmic
Max Count = 1000
Log Baseline = 1
Trace Parameters
Trace 1: Active, Module 0, Curve 1, Colour different from background
Configure Menu
Record 1 Curve starting from Curve 1
Repeat sequence after 0s

Tests with a Pulse Generator

A test setup for correct counting is shown in the figure below.

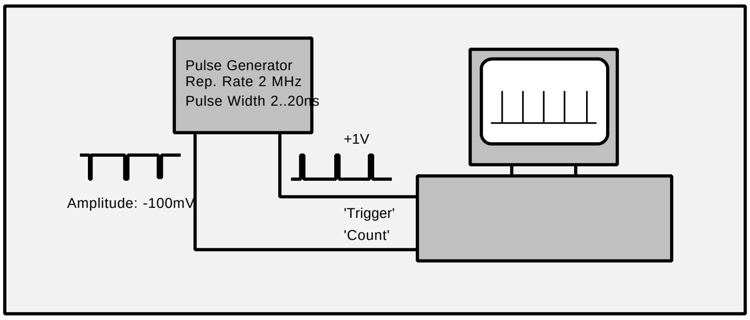


Use the following settings for the test:

Module Parameters and Measurement Control
Time per Point = 5ns, 1ns for MSA-1000
Points = 1000
Repeat = ON
Accumulate ON, 1000 Sweeps
Display 'Each Curve'
Repeat after 0 s
Trigger Condition = none
Trigger Threshold = +0.4V
Inp. Thresh. = -0.05 V
Display Parameters
Scale Y = Logarithmic
Max Count = 10 000
Log Baseline = 1
Trace Parameters
Trace 1: Active, Module 0, Curve 1, Colour different from background
Configure Menu
Record 1 Curve starting from Curve 1
Repeat sequence after 0s

With the recommended settings the result should be a horizontal line at a level of approximately 100 counts for the MSA-200/300 and 20counts for the MSA-1000. Some fluctuations are possible due to interference between the pulse generators and the MSA clock.

The trigger function and the accuracy of the time base are tested in the setup shown below.



Use the same MSA settings as for the previous test except for ‘Trigger Condition’, which is set to ‘rising edge’.

When the measurement is started the ‘Triggered’ indicator should turn on. The result shows narrow peaks with a distance of the generator cycle time, i.e. 500 ns.

Frequently Encountered Problems

The module is not found by the MSA software

MSA-200: Check the address in the MSA.INI file and the setting of the DIP switch on the MSA module (See ‘Changing the Module Address’). Try another address to be sure that the problem is not caused by an address conflict with another module.

MSA-300, MSA-1000: Check whether the Windows drivers are installed correctly. Windows must have an entry in its device driver list. Even if no bh driver is installed there should be at least an unknown PCI device in the list.

All MSAs: Check that the module is correctly inserted. Especially when moving the computer the module can work loose. Make sure that the bus connector is clean. If necessary, clean with ethanol, isopropanol or acetone.

All MSAs: Check that the clock configuration jumpers are set correctly. If the clock jumpers are set to ‘external’ there **must** be a clock signal at the clock input. If you work with external clock, make sure that the clock signal is present and that its frequency is between 160 MHz and 200 MHz.

If you work with Windows NT: Is the correct software version installed? Was the software installed under Windows NT? Installing the software under Windows 95 and working under Windows NT is not possible.

No curves on the screen after starting the measurement

Check the ‘Count Threshold’.

Check the ‘Time per Point’ and the ‘Points’ settings. These values determine the overall curve time (shown in the lower part of main window).

Check ‘Accumulate / Sweeps’. For a long overall curve time and a high number of accumulations it can take a long time until the measurement is completed. If this time is long, switch on ‘Display each Curve’ or set ‘Display after ...’ to some seconds to display intermediate results.

Do you display the correct curves? Is the selected colour different from the background colour? Check the Trace Parameters and the settings in the ‘Configure’ menu.

Check the Display Parameters. Check ‘Maxcount’ to be sure that the expected result is within the display range.

Does the MSA trigger? The trigger indicator must turn on. If it doesn't, check the Trigger Threshold and the trigger signal.

Check the signal at the Count Input. Have the detector pulses the expected signal amplitude? (Please see also 'Checking the SER of PMTs')

Measurement does not finnish

Does the MSA trigger? The trigger indicator must turn on. If it doesn't, check the Trigger Threshold and the trigger signal. In a multi MSA system all active modules must trigger to finish the measurement.

Check 'Accumulate / Sweeps'. For a long overall curve time and a high number of accumulations it can take a long time until the measurement is completed. If this time is long, switch on 'Display each Curve' or set 'Display after ...' to some seconds to display intermediate results.

Curve(s) on the screen do not change when measured

You display another curve than you are measuring. Check the Trace Parameters and the settings in the 'Configure' menu.

Ripple or waves in the curves

Check your Trigger signal. It should not exceed the range from -2.5 V to +2.5 V.

Keep the trigger cable and the cable to the count input well separated.

Try with a slightly higher 'Input Threshold'. If the threshold is too close to zero the input discriminators can respond to spurious signals. This can impair the timing accuracy. Please take also into account that there can be an offset of some 10mV due discriminator offset and DC current on the input line.

Make sure that there is no electrical noise from your light source. Especially diode lasers often are radio transmitters rather than light sources.

Chaotic Results in the Multiscaler Mode

Check whether the MSA is triggered correctly. Check Trigger signal and trigger condition. If the measurement is not triggered accurately subsequent sweeps cannot be averaged correctly.

Check also for loose cables and ground loops or for input threshold too close to zero.

Measurement shows steady state light instead of expected pulses

Check whether the MSA is triggered correctly. Check Trigger signal and trigger condition. If the measurement is not triggered accurately subsequent sweeps cannot be averaged correctly.

Please check also whether the trigger pulse has the correct temporal position referred to the light signal.

High or unstable count rate although the detector is off or doesn't get light

Noise from the environment. Check your setup for ground loops. All components (computer and its peripherals, light source, monochromator etc.) should be operated from the same power socket.

Isolate the detector from the laboratory table. This can interrupt a possible ground loop.

Check the input thresholds. For values close to zero the noise from radio transmitters can be detected. Please take into account that there can be an appreciable offset on the count input signals due to DC currents flowing through the signal cables.

Disconnect network cables from the computer that contains the MSA. These cables often work as antennas and introduce strong noise signals into the system.

Check for damaged cables and loose connectors.

Dark Count Rate too high

Check the input threshold. If the threshold is too low spurious signals from the detector power supply, small dark pulses of the detector and noise from computers or radio transmitters can be detected. Furthermore, multiple counting can occur due to ringing and reflection in cables.

Keep the detector as cool as possible.

Make sure that the detector does not detect daylight.

Insufficient Sensitivity

Check the Input Threshold. Check the SER of the Detector (Please see 'Checking the SER of PMTs').

Is the MSA triggered for each light pulse to be accumulated?

Is there a light pulse for each trigger pulse the MSA detects? If there are reflections on the trigger pulse the MSA can trigger also on the second edge of the trigger pulse. If this edge is outside the recorded time interval the MSA starts a sweep, but does not record the correct part of the signal.

Preamplifier / Detector does not work when powered from the MSA-200/300

If the preamplifier or the detector is powered from the sub-D connector of the MSA: Check the +12V output (pin 10). If the +12V supply is missing in an MSA-200 you have most likely shorted the +12V at the sub-D connector and burned the connection on the MSA module.

Assistance through bh

We are pleased to assist you in case of problems associated with your MSA module. To fix the problem we ask you to send us a data file (.sdt) of the questionable measurement or (if a measurement is not possible) a setup file (.set) with your system settings.

Furthermore, please add the following information:

Description of the Problem
MSA Serial Number
Software Version
Detector type, Operating voltage of the detector, PMT Cathode type
Preamplifier type, Gain, Bandwidth etc.
Laser System: Type, Repetition Rate, Wavelength, Power
Trigger Signal Generation: Photodiode, Amplitude, Rise Time
Optical System: Basic Setup, Sample, Monochromator
System Connections: Cable Lengths, Ground Connections. Add a drawing if possible.
Environment: Possible Noise Sources
Your personal data: E-mail, Telephone Number, Postal Address

The fastest way is to send us an email with the data file(s) attached. We will check your system settings and – if necessary – reproduce your problem in our lab. Usually we will send you an answer within one or two days.

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Specification MSA-200 and MSA-300

Count Input

Input Pulse Polarity	positive or negative (configurable)
Input Pulse Amplitude	±20 mV ... ±1 V (Preamplifiers available)
Min.Count Input Pulse Width	800 ps
Input Impedance	50 Ω
Count Input Threshold	-0.5V ... +0.5V, Resolution 9 bit

Trigger Input

Input Polarity	positive or negative (selectable via software)
Trigger Slope	rising or falling slope
Input Impedance	50 Ω
Input Amplitude	±20 mV to ±1 V (Preamplifiers available)
Min. Trigger Pulse Width	800 ps
Trigger Input Threshold	-1V to +1 V, 9 bit resolution

Data Recording

Time per Channel	min. 5 ns
Count Rate	up to 100 MHz
No of Points / Curve	up to 512 k
Accumulation (up to 255 counts/point)	Hardware, no dead time between recording cycles
Accumulation (> 255 counts/point)	Software, readout when one channel reaches 256 counts

Data Readout

Data Readout	subsequent data points are read by subsequent input instructions
Typical readout rate	1us/point (for Pentium 200 MHz, C^{++}, read 1 point and store into a data array)

PC Interface

Module Access	via I/O only
Parallel Operation of several Modules	up to four modules
Bus Interface, MSA-200	ISA 16 bit
Bus Interface, MSA-300	PCI
Power Consumption	approx. 8 W at +5 V
Dimensions	200 x 110 mm

Maximum Ratings (exceeding these values can cause permanent damage to the device)

Input Voltage at Count Inputs	±5V (DC), ±30V (1µs)
Input Voltage at Gate Inputs	±5V (DC), ±30V (1µs)
Load at Sub-D connector, +12V out	600 mA
Power Supply Voltage	-0.2V to 5.5 V
Ambient Temperature	60 °C

Options (see individual data sheets)

Wideband Preamplifier ACA-xx, up to 32 dB, 2 GHz
Wideband Preamplifier with Current Monitoring, 26 dB, 1.6 GHz
DC stable Wideband Amplifier DCA-xx, up to 20 dB, 500 MHz
Step Motor Controller STP-240, for unipolar Motors up to 1 A phase current
Photomultipliers and Photomultiplier Modules
High Speed PIN and Avalanche Photodiode Modules

Specification MSA-1000

Count Input

Input Connector	SMA, 50 Ω
Input Pulse Polarity	positive or negative (selectable via software)
Input Pulse Amplitude	±20 mV ... ±1 V (Preamplifiers available)
Min.Count Input Pulse Width	800 ps
Input Impedance	50 Ω
Count Input Threshold	-0.5V ... +0.5V, Resolution 9 bit

Trigger Input

Input Connector	SMA, 50 Ω
Input Polarity	positive or negative (selectable via software)
Trigger Slope	rising or falling slope
Input Impedance	50 Ω
Input Amplitude	±20 mV to ±1 V (Preamplifiers available)
Min. Trigger Pulse Width	800 ps
Trigger Input Threshold	-1V to +1 V, 9 bit resolution

Data Recording

Time per Channel	min. 1 ns
Count Rate	up to 1000 MHz
No of Points / Curve	up to 128 k
Accumulation (up to 255 counts/point)	Hardware, no dead time between recording cycles
Accumulation (> 255 counts/point)	Software, readout when one channel reaches 256 counts

Data Readout

Data Readout	subsequent data points are read by subsequent input instructions
Typical readout rate	1us/point (for Pentium 200 MHz, C^{++}, read 1 point and store into a data array)

PC Interface

Module Access	via I/O
Parallel Operation of several Modules	up to four modules
Bus Interface	PCI
Power Consumption	approx. 8 W at +5 V
Dimensions	95 x 120 mm

Maximum Ratings (exceeding these values can cause permanent damage to the device)

Input Voltage at Count Inputs	±5V (DC), ±30V (1µs)
Input Voltage at Gate Inputs	±5V (DC), ±30V (1µs)
Power Supply Voltage	-0.2V to 5.5 V
Ambient Temperature	60 °C

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