Becker & Hickl GmbH
High-performance
Photon Counting

May 2004 Optimised for Printer HP 4000 TN PS

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PMS-300
PMS-400 and PMS-400A
800 MHz Gated Photon Counters / Multiscalers

- **2 Discriminator/Counter Channels**
- **800 MHz Count Rate**
- **1 ns min. Gate Pulse Width**
- **Down to 250 ns / Time Channel**
- **Up to 64 k Points / Curve**
- **Ultra-Fast Accumulation**
- **32 bit Counter Resolution**
- **Direct Interfacing to most Detectors**
- **Parallel Operation of up to four Modules supported**
- **Optional Step Motor Controller**
- **Steady State Measurements**
- **Optical Waveform Recording**
- **Sample Scanning, Recording of Spectra**
- **Event Recording Mode for Photon Burst Detection**
- **PC-Plug-in-Board**

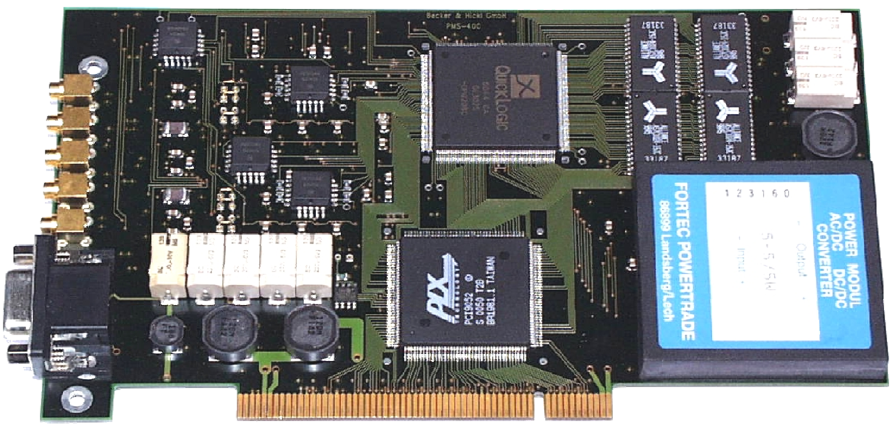


Table of Contents

Overview

The PMS-300, the PMS-400 and the PMS-400A are PC plug in boards with two fast gated photon counting and multiscaler channels. All devices contains ultra-fast discriminators for the counting and gating inputs, two fast 32 bit counters, a memory for storing the counter results, the timing and control logic and the PC bus interface. The PMS-300 has an ISA interface, the PMS-400 and the PMS-400A a PCI interface. Compared to the PMS-400, the PMS-400A has a considerably faster bus interface

The PMS counts all pulses with an amplitude greater than a selectable discriminator threshold and stores the results into subsequent locations of the memory. The inputs can be gated to count pulses either inside or outside an externally applied gating pulse.

The on-board timing and control logic controls the counting interval and the storing of the counting results. Up to four PMS modules , i.e. eight counter channels can be operated in one computer by the same control software.

Different operating modes allow for steady state measurements (luminescence spectra), waveform recording (luminescence decay curves) and event recording (e.g. for single molecule detection).

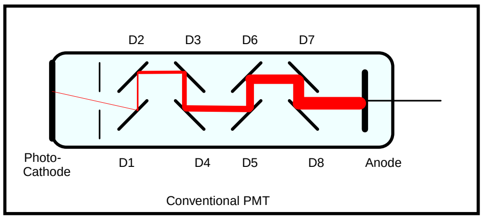
The PMS boards can be used for count rates of more than 800 MHz and can be gated by pulses down to 1 ns FWHM. Therefore the modules are applicable not only for photon counting, but also for other fast pulse counting applications.

All module functions are controlled by the ‘PMS Standard Software’. This software package runs under Windows 98, 2000, NT or XP and allows for parallel operation of up to four modules, i.e. 8 counting channels. The results are displayed either as bar graphs or as curves that represent the photon density as a function of the time or of any other externally variable parameter. In conjunction with a DCC-100 detector control board or a STP-340 step motor controller board a wide variety of experiment control functions can be performed directly from the PMS Standard Software.
Furthermore, the software allows setting of the device parameters, loading and saving of measurement data and system parameters, evaluation of measurement data and arithmetic operations between different curves.

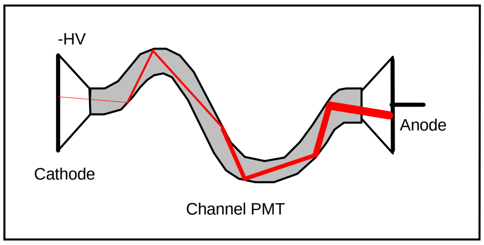
To facilitate programming of special user software DLL function libraries for Windows 98, 2000, NT, and XT, and for the Windows CVI system of National Instruments are available.

Introduction

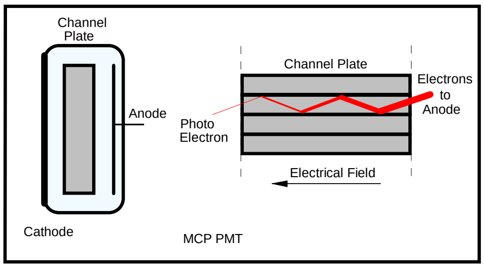
Detectors for Photon Counting



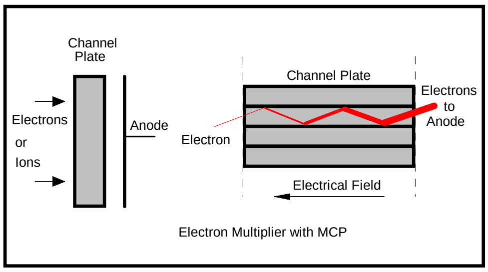
The most common detectors for low level detection of light are photomultiplier tubes. A conventional photomultiplier tube (PMT) is a vacuum device which contains a photocathode, a number of dynodes (amplifying stages) and an anode which delivers the output signal.



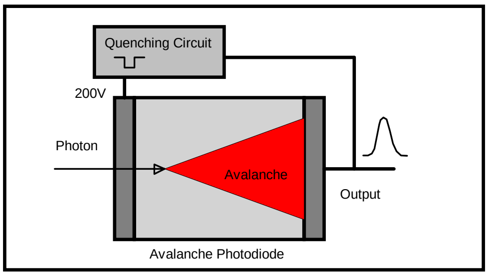
By the operating voltage an electrical field is built up that accelerates the electrons from the cathode to the first dynode D1, from D1 to D2 and to the next dynodes, and from D8 to the anode. When a photoelectron emitted by the photocathode hits D1 it releases several secondary electrons. The same 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.

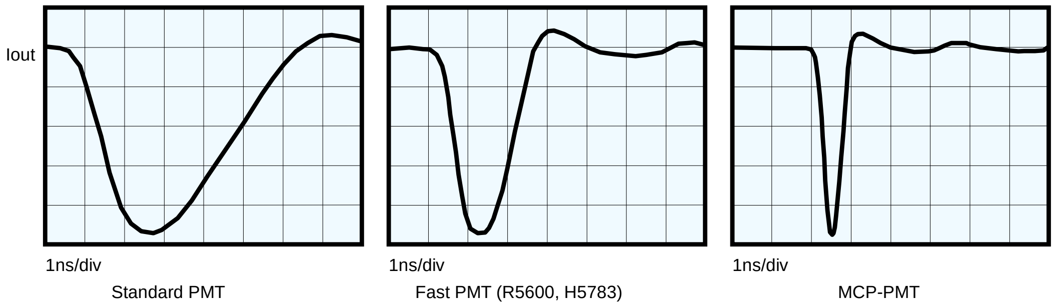
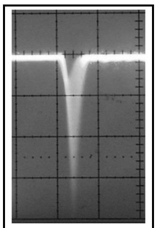


Fig. 3: Single Electron Response of Different PMTs



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.

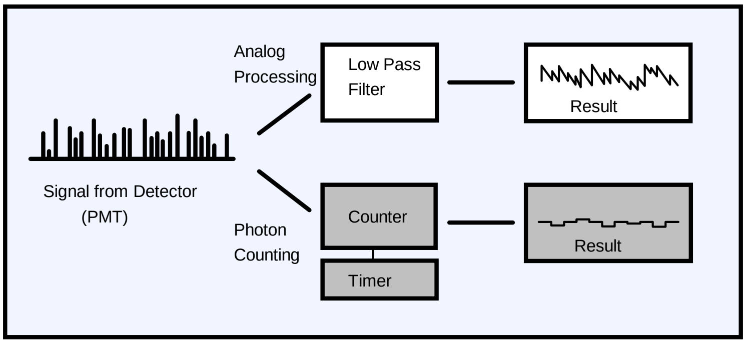
PMT	PMT Gain	FWHM	I_{SER}	V_{out} (50 Ω)	I_{max} (cont)
Standard	10^7	5 ns	0.32 mA	16 mV	100uA
Fast PMT	10^7	1.5 ns	1 mA	50 mV	100uA
MCP PMT	10^6	0.36 ns	0.5mA	25 mV	0.1uA

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.



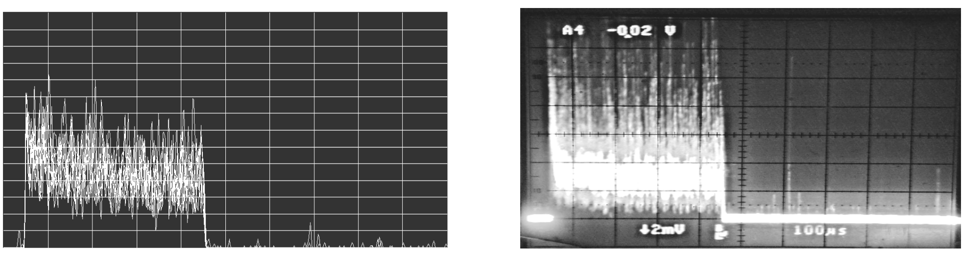
Analog acquisition of the PMT signal is done by smoothing the random pulse train from the PMT in a low pass filter. If the filter bandwidth is low enough the PMT signal is converted in a more or less continuous signal.

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:

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.

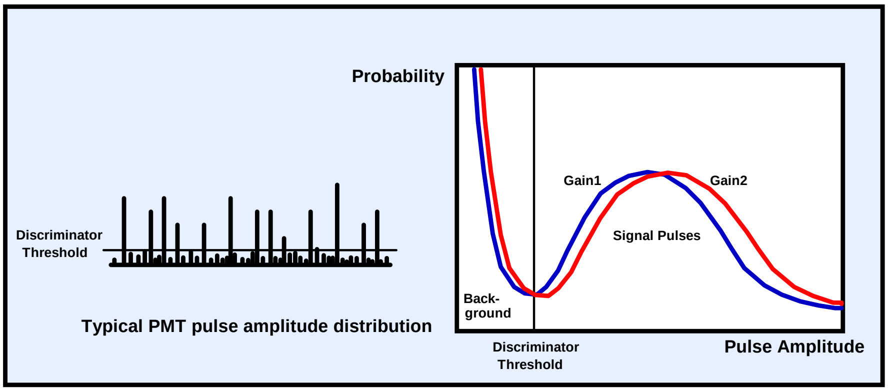
Photon Counting is insensitive to low frequency noise. There is also no baseline drift due to spurious currents in the PMT or in the PMT voltage divider. Analog Signal Acquisition is very sensitive to these effects.

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 extremely 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.

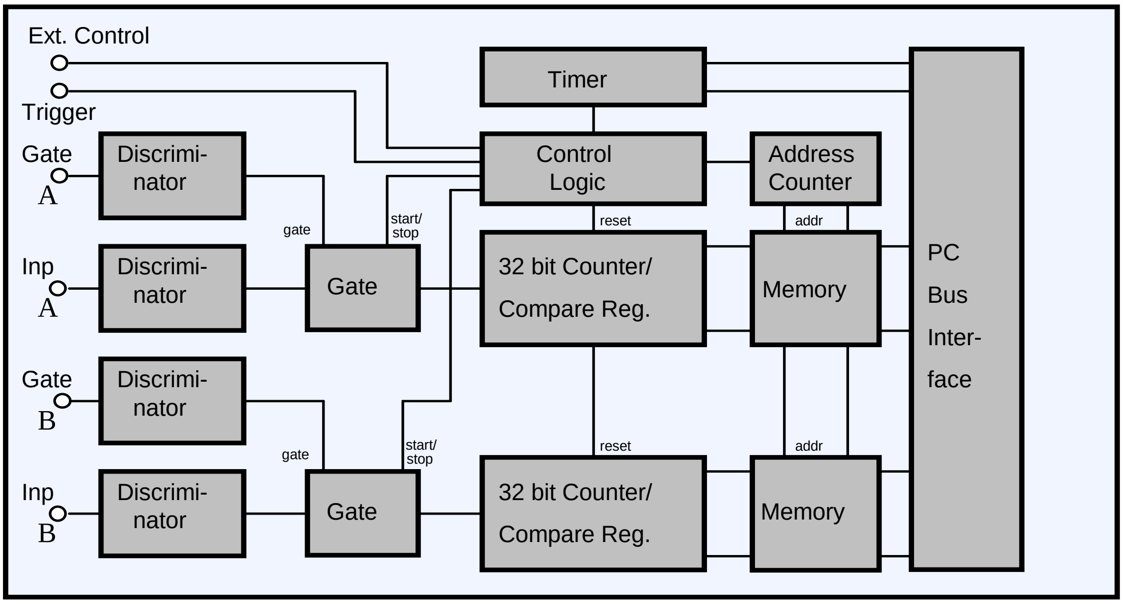
In conjunction with pulsed lasers the simple gating capability of a photon counting device is important. By suitably gating the measurement, background pulses of the detector and background light signals can be suppressed. Furthermore, a distinction between fluorescence, phosphorescence and Raman signals is possible.

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.

The PMS Module

Architecture of the PMS

A block diagram of the PMS is shown in the figure below.

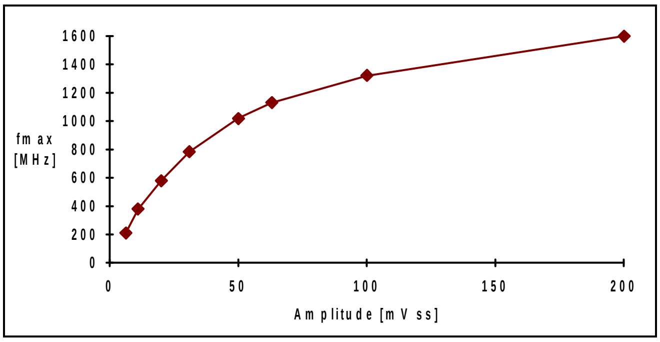


The counting inputs Inp A or Inp B receive the single photon pulses from the detectors. The input signals are fed to discriminators which respond when the input voltage exceeds a selected threshold. The input can be configured for positive or negative input pulses, the discriminator threshold can be set from -1V to +1V.

The discriminators at the Gate A and Gate B inputs receive the gate pulses. The gate threshold can be set in the range from -2 V to +2 V. Therefore analog gate signals (e.g. from a photodiode) can be used as well as digital signals (CMOS, TTL, ECL, NIM levels).

The pulses from the discriminators are fed to the gating circuits. These circuits deliver an output pulse if the leading edge of the discriminator output occurs within the gate pulse. Thus, the resolution of the gate function depends on the width of the gate pulse only - not on the width of the detector pulse. By carefully adjusting the gate input threshold a gate width down to 600 ps can be achieved. To use detector and gate pulses of any polarity, the circuit can be configured by jumpers for positive or negative detector pulses and for 'active low' and 'active high' gate pulses.

All discriminators have response times in the sub-ns range. The pulses from the gate circuits are counted by two fast 32 bit counters. Depending on the input pulse amplitude, correct counting can be achieved for frequencies up to 1 GHz and for a gate pulse width down to 1 ns. In the figure below the maximum count rate is shown as a function of the input amplitude for a sinusoidal input signal.



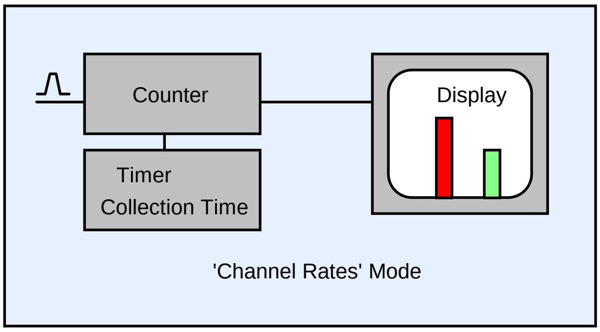
The measurement is controlled by the module control logic in conjunction with the timer. To set a defined collection time interval, the timer is loaded with the desired collection time value. When the measurement is started, the timer counts down with the reference clock frequency of the module. When the timer has expired the measurement is complete and the counter contents are - depending on the operation mode - either stored in the memory or read directly by the software.

Module control and data transfer is accomplished by I/O instructions. One module uses 24 subsequent I/O addresses which can be configured by a DIP switch. Furthermore, one independent 'SYNC' address is provided to enable parallel operation of several modules. This address is set by the software via the individual module address. It is used to start and to stop the measurement in several modules simultaneously by one I/O instruction.

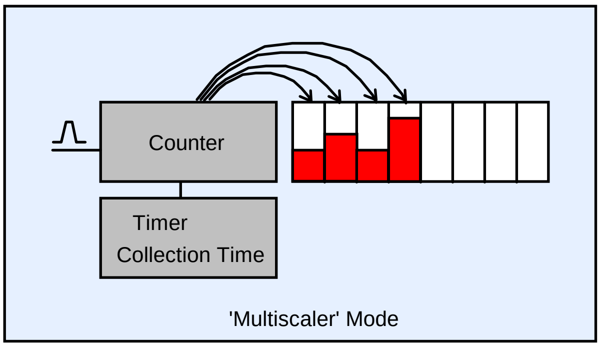
Operation Modes

Four different applications several operation modes are provided.

In the 'Channel Rates' Mode the counter results of the counter channels are displayed in an bar graph mode at the end of each collection time interval. Depending on the 'Trigger Condition' the recording can be started either immediately after finishing the last collection time interval (Trigger Condition 'none') or by the next rising or falling edge of the trigger pulse. The 'Channel Rates' mode is useful to test and to adjust the measurement setup before the final measurement is started.



In the ‘Multiscaler’ Mode the counter results of subsequent collections time intervals are stored in the memory. The results represent the input pulse density versus time or the waveform of the measured light signal. The time per curve point can be as short as 250 ns. The effective collection time per curve point is 50 ns shorter, because this time is required to read the counters and to store the results in the memory.

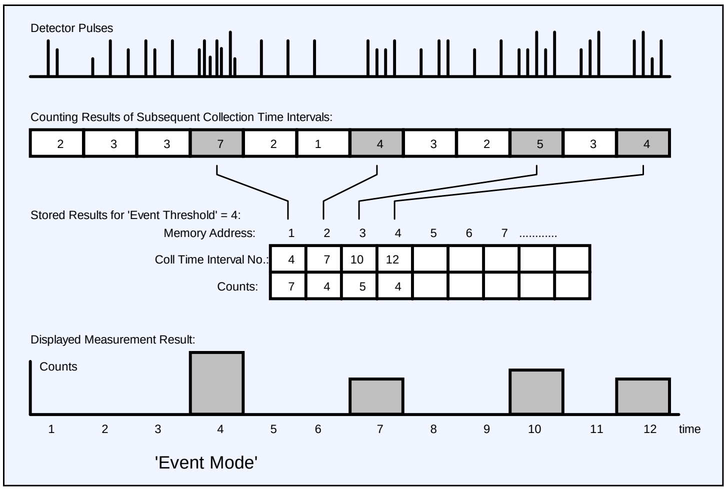


Depending on the 'Trigger Condition' the recording can be started either by the software start command (Trigger Condition 'none') or by the rising or falling edge of the trigger pulse.

In the Multiscaler Mode several signal periods can be accumulated. In this case the recording is restarted with the next trigger pulse after the end of the previous recording and the obtained counter results are added to the current memory contents. The accumulation is accomplished solely in the module hardware. This avoids time-consuming software actions between the signal periods and results in an exceptionally high accumulation efficiency at high signal repetition rates.

The whole measurement sequence is repeated if the 'repeat' button is pressed. In this case a 'Repetition Time' can be specified. If 'Repetition time' is longer than the overall recording time the subsequent measurements start in intervals of 'Repetition Time'. Otherwise the next measurement is started immediately after the previous one is finished.

The PMS software is able to control two step motors via the optional step motor controller card STP-240 (please see individual data sheet or http://www.becker-hickl.com). Step motor actions can be defined in several places of the measurement sequence. Therefore a lot of modifications of the measurement sequence are possible. If a step motor action is defined after each curve point, instead of a waveform the spatial dependence of the intensity or a spectrum is recorded. With a step motor action after each curve the dependence of the waveform of the light signal of a spatial parameter or the wavelength is obtained.



'Event Mode'

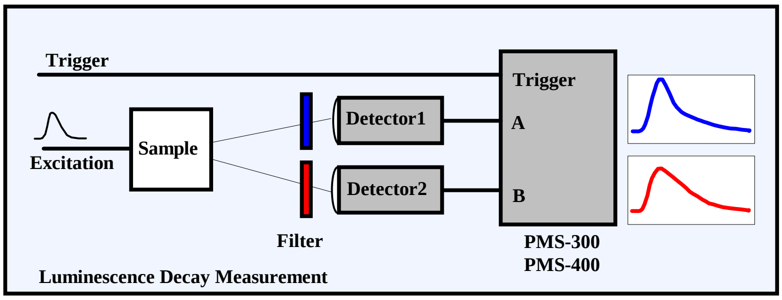
The ‘Event Mode’ is used for single molecule detection in continuous flow arrangements or similar applications. In this mode the incoming detector pulses are counted for the selected collection time intervals. When the current collection time interval is over the counter results are compared to a user defined 'Event Threshold' value. If the result is greater than the event threshold it is stored together with the time since the start of the measurement.

In all measurement modes the gating capability can be used. Gating is used in conjunction with pulsed excitation sources. The gate inputs can be used to reject background pulses between the excitations, to gate off straylight pulses during the excitation or to reduce fluorescence signals.

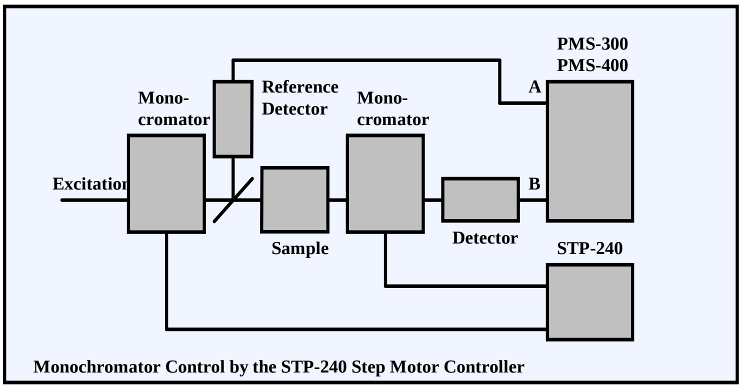
Applications

Some typical applications are shown in the figures below.

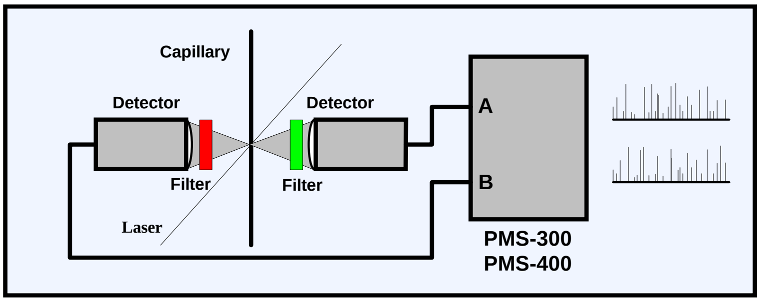
In the first figure luminescence decay curves are recorded. The sample is excited by the light pulses from a laser or a flash lamp. The light emitted by the sample is fed to the detectors through filters which select the desired wavelength range. The arrangement is very effective to record phosphorescence and delayed fluorescence decay curves or luminescence decay curves of inorganic samples. (For fluorescence decay measurements we recommend our time correlated single photon counting instruments with ps resolution.)



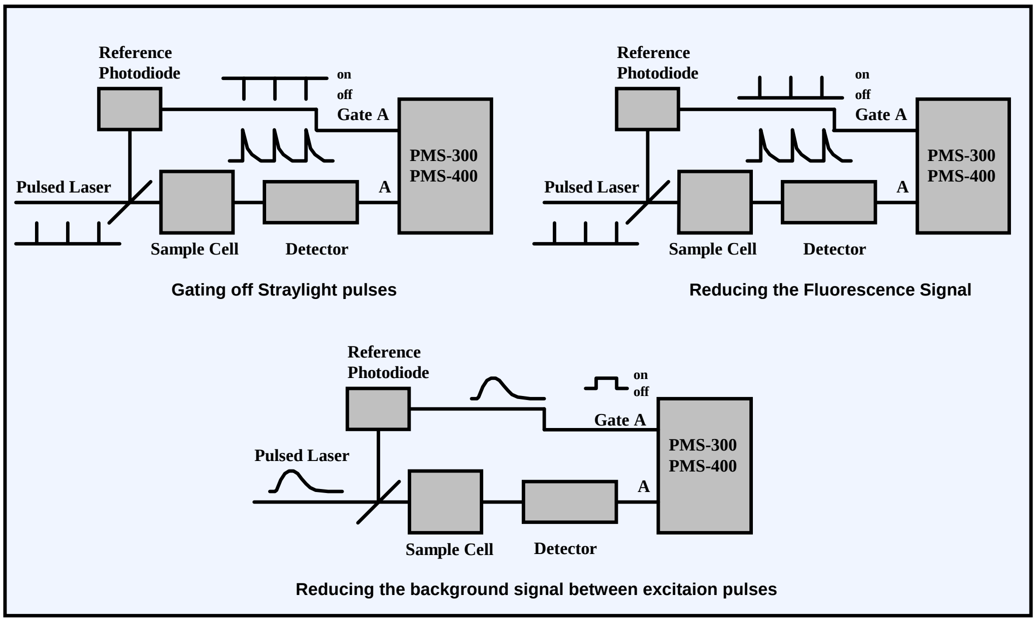
To control any external parameter during the measurement (e.g. monochromator setting), the optional step motor controller STP-240 is used (please see individual data sheets or http://www.becker-hickl.com). In the figure below the system is upgraded by two monochromators driven by step motors and the step motor controller STP-240. Depending on the step motor action defined in the PMS software the arrangement records luminescence spectra, excitation spectra, or luminescence decay curves at different excitation or emission wavelengths.



The figure below shows an application of the 'Event Mode' of the PMS for DNA sequencing or other single molecule detection problems. The molecules are running through a capillary. If a molecule travels through the laser focus it can perform some 10 000 absorption/emission cycles. If the counting result of the current collection time interval exceeds the specified 'Event Threshold', the counting result is stored along with the time since the start of the experiment.



In all operation modes the gate inputs can be used to reject background pulses between the excitation pulses, to gate off straylight pulses during the excitation or to reduce fluorescence signals. Some examples are shown in the figure below.



Installation

General Requirements

The computer must be a Pentium PC with a graphics card of 1024 by 628 resolution or more. The operating system can be Windows 98, 2000, NT, or XP. For one PMS modules the computer should have at least 128 Mb memory, for operation of several PMS modules 256 Mb are recommended. Although the PMS Software requires only a few Mb hard disk space, much more space should be available to save the measurement data files. Although not absolutely required, we recommend to use a computer with a speed of at least 1 GHz for convenient working with the PMS. For a single PMS-400 module one PCI slot is required. The older PMS-300 module needs an ISA slot. Up to four PMS modules can be operated in parallel. Please make sure that you have enough slots available.

Software Installation

With the introduction of the PMS-400A module in May 2004 the installation procedure was changed. The software comes on a CD that contains all software components commonly used for PMS systems.

PMS Application

The PMS-400 and PMS-400A modules come with a software package that contains all components to operate up to four PMS modules. The software works also for the older PMS-300 modules. The PMS software is described under ‘Software’ in this manual. The PMS software is free. The complete installation and updates are available from www.becker-hickl.com.

DCC Application

This application controls the DCC-100 detector controller card that is often used in conjunction with bh photon counters. For details, please see individual DCC manual or section ‘The DCC-100 detector controller’ in this manual. If you do not have a DCC-100 in your system you need not install the DCC application. The DCC software is free.

DLL Libraries

To facilitate the development of user-specific software DLL libraries for the PMS modules, the DCC-100, and the STP-340 step motor controller are available on extra order. Installing the DLLs requires a licence keyword.

Important note: Before you start into the laborious work of developing your own programs please check whether the problem can be solved by the functions of the PMS software or by the hardware control features of the PMS module. Please do not hesitate to discuss the control problem with bh.

Manuals

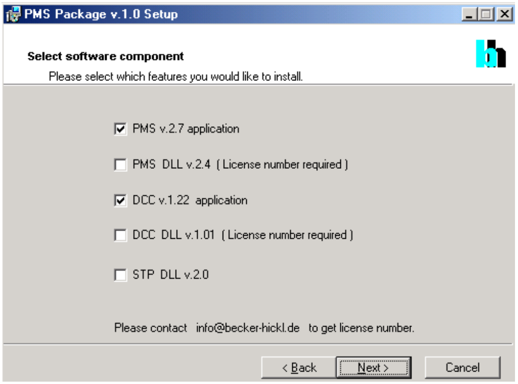
The pdf files of the PMS and DCC manuals and the manuals of the DLL libraries are in a ‘manuals’ folder on the CD. The latest versions of the manuals are also available from www.becker-hickl.com.

First Installation

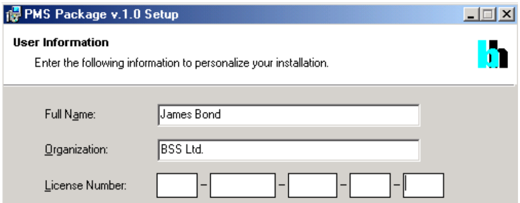
When you put the installation disk into the CD drive the installation procedure starts automatically. If you want to start the procedure on command for whatever reason, start PMS_setup_cd.exe from the CD. If the installation is run the first time it comes up with the window shown right.

The installation wizard bores you with the usual copyright warnings. We explicitly note that you are allowed

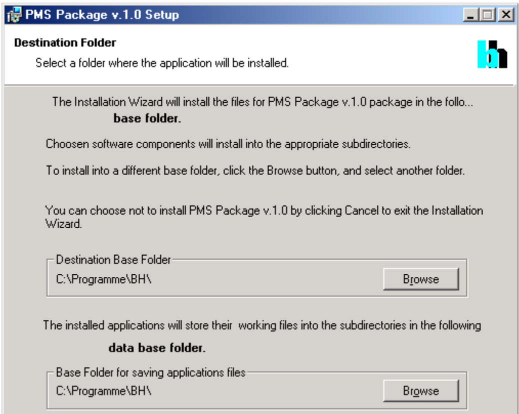
- to install all software features that are not licence-number protected on any computer and in any place you like to.
- to install the key-protected features on several computers within your workgroup for use with all PMS modules you purchased.



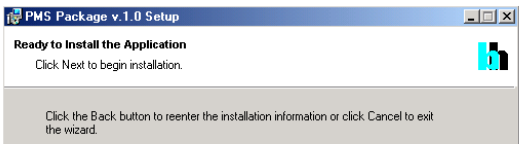
The next window allows to select the software components you want to install. If you have no other modules than the PMS module installing the PMS application is sufficient.



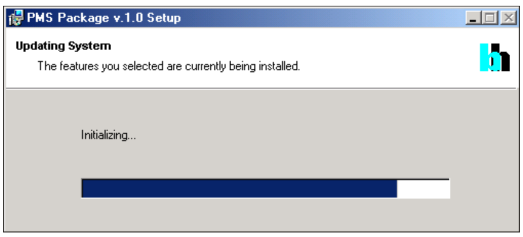
If you select features protected by a licence number the next widow asks you for the licence number. Type in your licence number, or, if you cannot find it, please call bh under +49 30 787 56 32 or email to info@becker-hickl.com. If possible keep the purchase number handy - this simplifies reproducing your licence number.



In the next window you can - but need not - change the directory ('base folder') in which the selected software features will be installed. The installation procedure will create individual sub-directories for the selected software components in the selected folder. Moreover, you can define a 'data base folder'. This folder is used as a working directory, and as a default directory for loading and saving data and setup files.



After you confirmed the base directory the installation wizard is ready to install the selected components. You have a last chance to cancel the installation or to go back to the previous step. After clicking on 'Next' the installation goes ahead.



Copying the files will take some seconds for each selected feature. It is not required to re-boot the computer after installation. At the end you get the message 'PMS package has been successfully installed'.

If you are using the PMS and DCC software frequently we recommend to create a shortcut on the desk top.

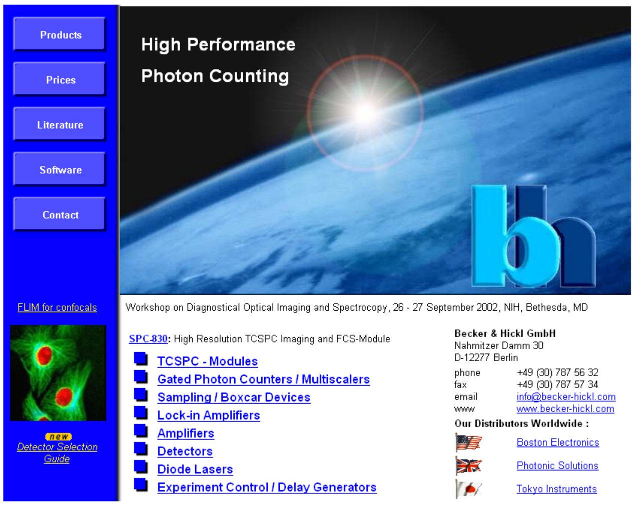
Note: If software components of the PMS package are already installed the next installation of the same version of the package comes up with a different start window. To install additional components or repair a damaged installation please see ‘Installing New Features’ or ‘Software Repair’.

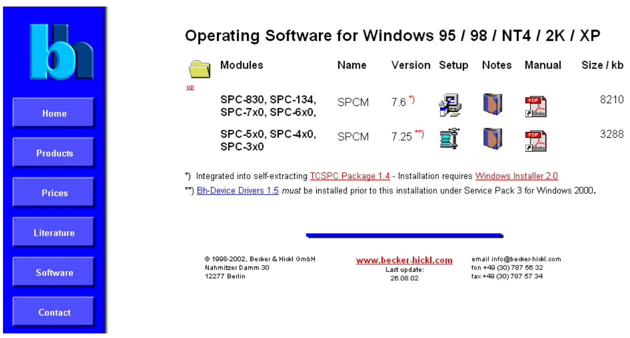
When you have installed the PMS software, please send us an email with your name, address and telephone number. This will help us to provide you with information about new software releases and about new features of your module which may become available in future. We won’t use your address to spam you with advertising.

Software Update

If you install a newer PMS software version over an older one the installation runs as described under ‘First Installation’. Only files are replaced which have a later date on the CD. This, to a certain extend, avoids overwriting setup files like auto.set (the last system settings) or hardware configuration files. 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 for all bh modules are available from the Becker & Hickl web site. To install the PMS software from the web, please open www.becker-hickl.com, and click on the ‘Software’ button.

On the ‘Software’ page, click on ‘PMS Modules’, ‘Operating Software for Windows 98 / NT4 / 2k /XP.

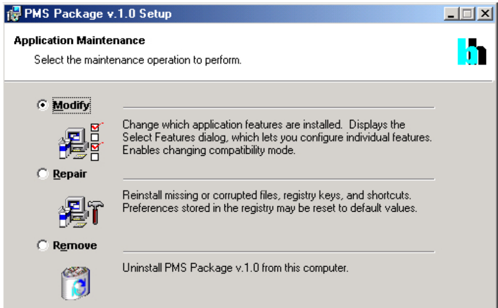
Then click on ‘Setup’ for PMS. Download PMS_setup_web.exe and execute it. It works in the same way as the installation from the CD.

It can - but need not - be required that you have to download the ‘Windows Installer’ from Microsoft. If the setup procedure complains that it is missing, please click on ‘Windows Installer 2.0’.

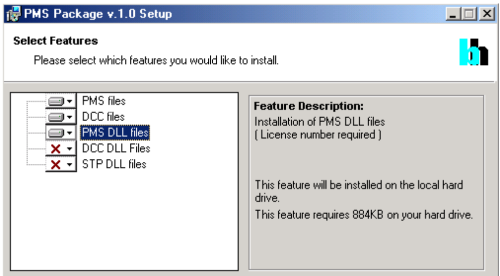
After installing a new software version we recommend also to download the corresponding manual. Click on ‘Manual’ and download the PDF file. Please see also under ‘Applications’ to find notes about new applications of the bh photon counting modules.

Installing New Features

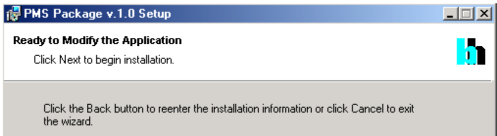
It may happen that you want to add new software components from the CD to an existent installation. In this case the installation procedure recognises the installed components and starts as shown in the figure right.



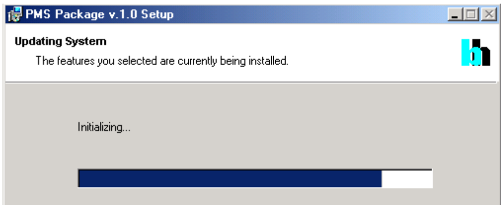
Chose 'Modify' and click on 'Next'. The next window shows which of the components are installed. To install a new component, click on the field with the '**X**', and chose 'Will be installed on local hard drive'. You can also chose 'Entire feature will be installed on local hard drive' to install the feature with all available sub-features. If you click on 'Entire feature will be installed when required' the feature will be copied from the CD when it is called the first time.



The rest of the installation works as described under 'First Installation'.



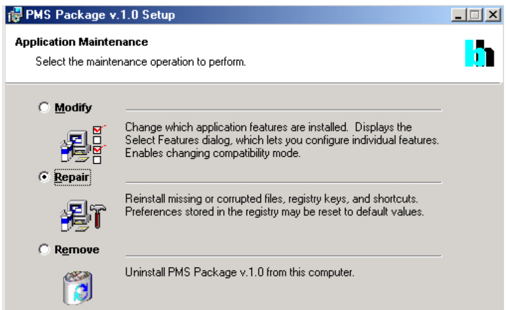
If you selected a key-protected feature you will be asked for your licence number. You get the licence number when you purchase the selected component(s). If you have already purchased the components but cannot find the licence number, please call bh under +49 30 787 5632 or mail to info@becker-hickl.com. If possible keep the purchase number handy - this helps reproducing your licence number.



Software Repair

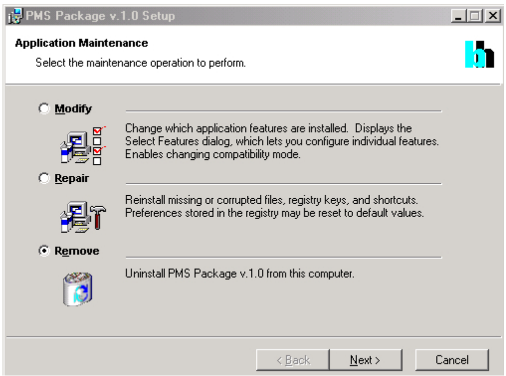
If the PMS package has been damaged, e.g. if a file has got lost or corrupted, please start the installation procedure as described above and chose 'Repair'.

The procedure will check your files and, if something is wrong or missing, copy the correct files to the hard disk.



Deleting the PMS Package

To delete the PMS package from a computer, start the installation CD and chose 'Remove'. The 'remove' procedure removes all software components of the package, but not the data and setup files of the previous measurements.



Installation of the PMS Module

To install the PMS module, switch off the computer and insert the 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 PMS as far as possible apart from loose cables or other computer modules to avoid noise pick-up.

PMS-400 and PMS-400A

The PMS-400 and -440A modules have PCI interfaces. Windows has a list of hardware components, and on the start of the operating system, it automatically assigns the required hardware resources to the components of this list. If you have several PMS-400 or -400A modules in the computer each PMS gets its own address range.

Windows has a list of PCI hardware components, and on the start of the operating system, it automatically assigns the required hardware resources to the components of this list. If you have several PMS modules in the computer each module automatically gets its own address range.

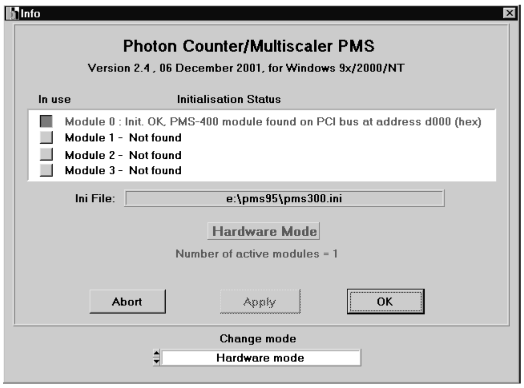
When the computer is started the first time with the PMS-400 Windows detects the PMS module and attempts to update the list of hardware components. Therefore it may ask for driver information from a disk. Please select the driver information file from the driver disk delivered with the module.

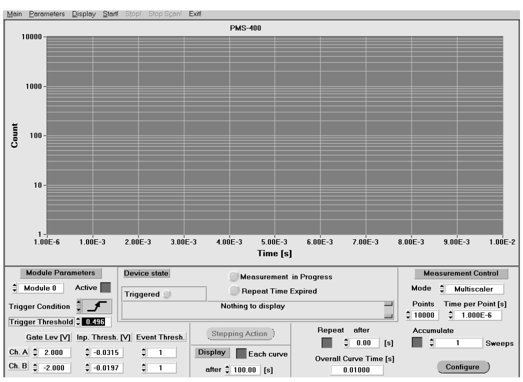
If you don't have the driver disk, please download the driver file from www.becker-hickl.com or www.becker-hickl.com, 'Software', 'Windows 98/NT/2000', 'Device drivers for bh modules'.

PMS-300

The PMS-300 has an ISA interface. It has a DIP switch to set the I/O address of the module. Changes of the module address for a single PMS-300 (see section below) are not normally required. However, for the operation of several PMS-300 modules in one computer the module addresses must be different, and the address values must be declared in the PMS300.INI file (see 'Changing the Module Address of the PMS-300'). If you purchase several PMS-300 modules for operation in one PC we can deliver the modules and the PMS300.INI file in a ready-to-use configuration.

Module Test





When the module is inserted, switch on, start Windows and start the PMS software. The initialisation panel shown right should appear. The installed modules are marked as 'In use'. PCI modules are shown with their serial number, PCI address and slot number.

The software runs a simple hardware test when it initialises the modules. If an error is found, a message 'Hardware Errors Found' is given and the corresponding module is marked red. In case of non-fatal hardware errors you can start the main panel by selecting 'Hardware Mode' in the 'Change Mode' panel. Please note that this feature is intended for trouble shooting and repair rather than for normal use.

When the startup window appears, click on 'OK' to open the main panel of the PMS software. Select 'Main' and start the 'Counter Test' function. If no error is returned, you can expect that the module works correctly. Note: For running the 'counter test' no input signals must be connected to the module. During the test, the modules apply test pulses to their own inputs to test the discriminator and counter reaction. If there are additional external input pulses the self test will show errors.

Installation Problems

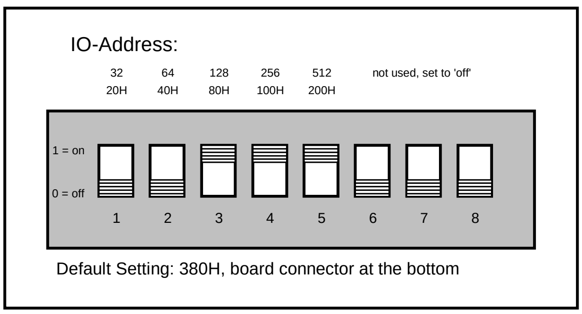
If there should be any malfunction after installing the PMS it may have one of the following reasons:

- Computer does not start: Module not correctly inserted or connector dirty. Clean connector with ethanol, propanol or acetone, insert module carefully. In terms of mechanical dimensions, computers are not even precision devices. Sometimes there is some side play in the connector, and mechanical stress can cause contact problems.
- PMS-300, Module not found: Address set on the module does not correspond to address in PMS300.INI file. Change setting of DIP switch or address in file (see below).
- PMS-300, Module not found: Another module in the PC has the same I/O address as the PMS-300. 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 PMS modules) should be free.
- PMS-300, 'Hardware Error detected': Another module in the PC has the same I/O address as the PMS-300. In this case change the module address as described under 'Module Address'.
- PMS-400, Module not found: Driver not correctly installed.
- PMS-400, Module not found: CMOS setting of the computer is wrong. New PCI devices are not accepted. Set 'Plug&Play' 'off'. Try with another computer.
- PMS-400, Module not found: Module not correctly inserted or connector dirty. Clean connector with ethanol, propanol or acetone, insert module carefully. In terms of mechanical dimensions, computers are not even precision devices. Sometimes there is some side play in the connector, and mechanical stress can cause contact problems.

Module Address, Installing Several PMS-300 Modules

If there is more than one PMS-300 module inserted in the computer or if the computer contains other measurement devices which occupy the PMS default address, the PMS module addresses must be changed.

Each module is controlled by a block of 32 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 PMS-300 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 PMS300.INI. Therefore, the DIP switch setting and the addresses in PMS300.INI must be the same. The PMS300.INI file can be edited with any ASCII editor (e.g. Norton Commander).

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

```
[pms_base],
```

the module specific parts by the headlines

```
[pms_module0]
[pms_module1]
[pms_module2]
[pms_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.

In addition to the base address each module has a 'Sync Address' which is the same for all used modules. This address is used to start and to stop the modules simultaneously. It is not set by a switch on the module but programmed by software via the module base address block. The sync address must be dividable by four. The Sync Address is defined in the common part of the PMS300.INI file:

`sync_adr = 0x....` (hexadecimal)

or

`sync_adr = ....` (decimal)

For the 'Sync Address' space is provided within the base address block at base_adr + 18h (base_adr + 24). The default value is `sync_adr = 0x398`.

Using the PMS Software without PMS Hardware

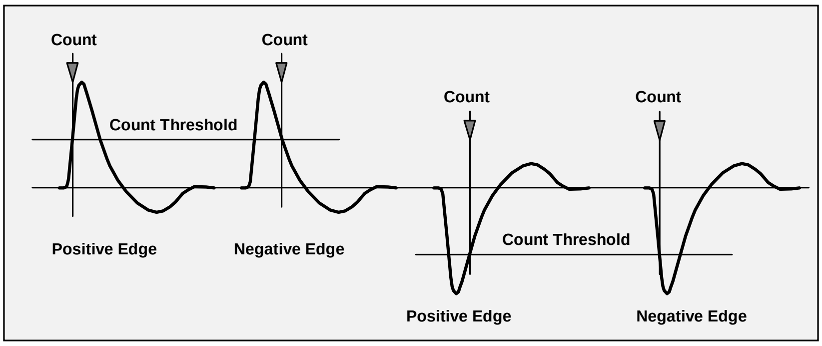
You can use the PMS software also without the PMS hardware. The software will display a warning that the module is not present. If you accept this warning the software will start in a special mode with the measurement being simulated. You can load, display, process and store data and do everything except a real measurement.

When a PMS module is present, the software can be forced into the simulation mode by selecting 'Hardware Mode' in the 'Change Mode' window of the initialisation panel .

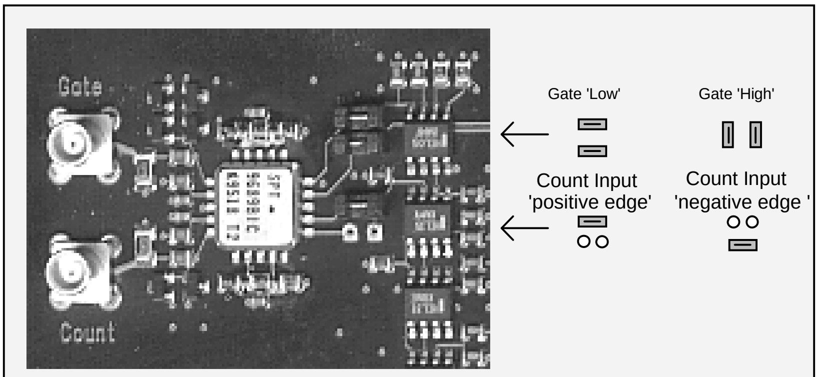
Building up Experiments with the PMS

Count Inputs

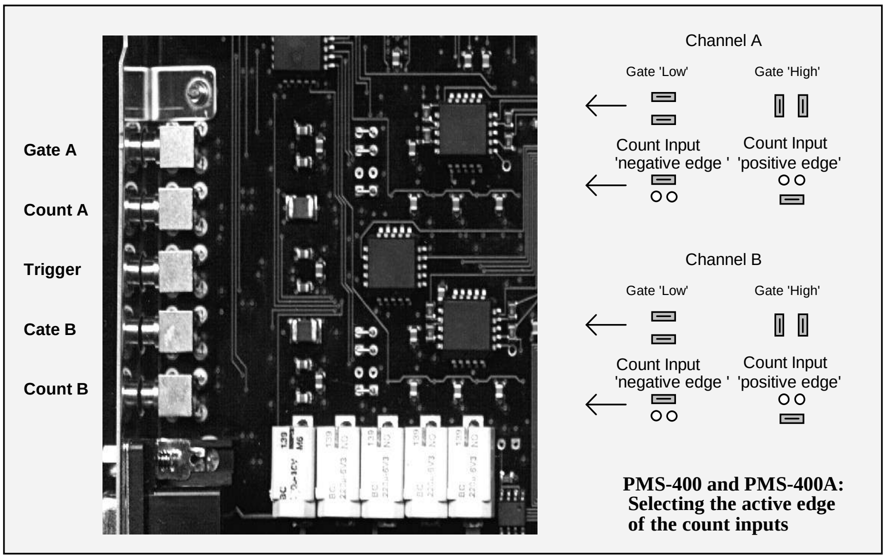
The detector pulses are fed to the COUNT inputs of the PMS-300 or PMS-400. The inputs can be configured to count either at the positive or on the negative pulse edge. A count is initiated when the input signal crosses the trigger threshold in the selected direction, see figure below.



The active edge is selected by jumpers on the PMM board. The default setting is 'negative edge' as required for photomultipliers. The location of the jumpers on the board is shown in the figure below. Both channels can be set independently.



PMS-300: Selecting the active edge of the count inputs



PMS-400 and PMS-400A: Selecting the active edge of the count inputs

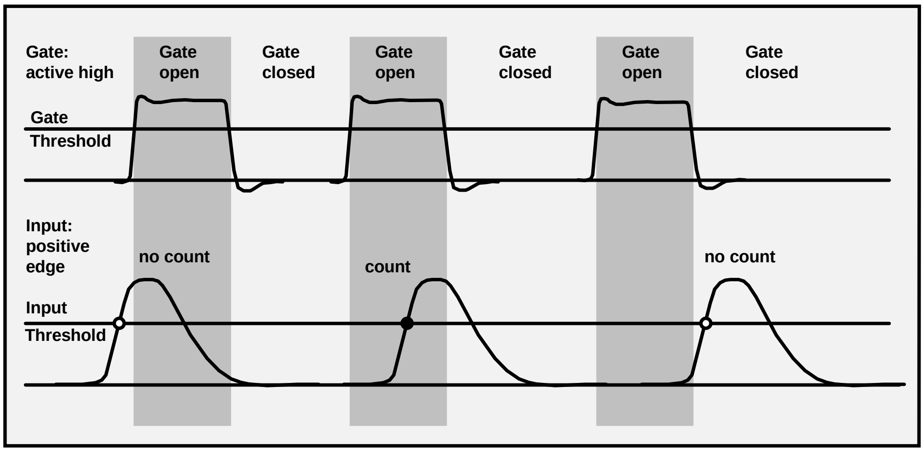
The input amplitude should be in the range between 20 mV and 1 V. Amplitudes above 1.5 V are clipped by safety diodes at the module input. Pulses up to 30 V (max. 1 us) and DC voltages up to 5 V will not damage the module. However, input amplitudes above 2.5 V should be avoided, since they can cause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

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 PMS module (please see individual data sheets or http://www.becker-hickl.com).

GATE Inputs

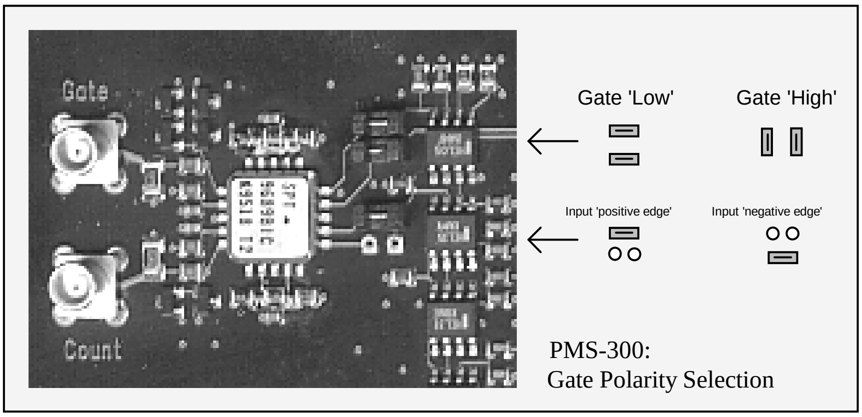
Fast gating of the counter operation is accomplished by using the GATE inputs. The pulse edges at the COUNT input are counted only as long as an appropriate level at the GATE input is present. Configurable by jumpers on the board, the counters can either be enabled by a 'high' input state (gate input voltage > gate threshold) or by a 'low' input state (gate input voltage < gate threshold).

The figure below shows the gate function for the ‘active high’ gate and the ‘positive edge’ count input configuration. An input pulse is counted when its active edge is within the gate pulse.

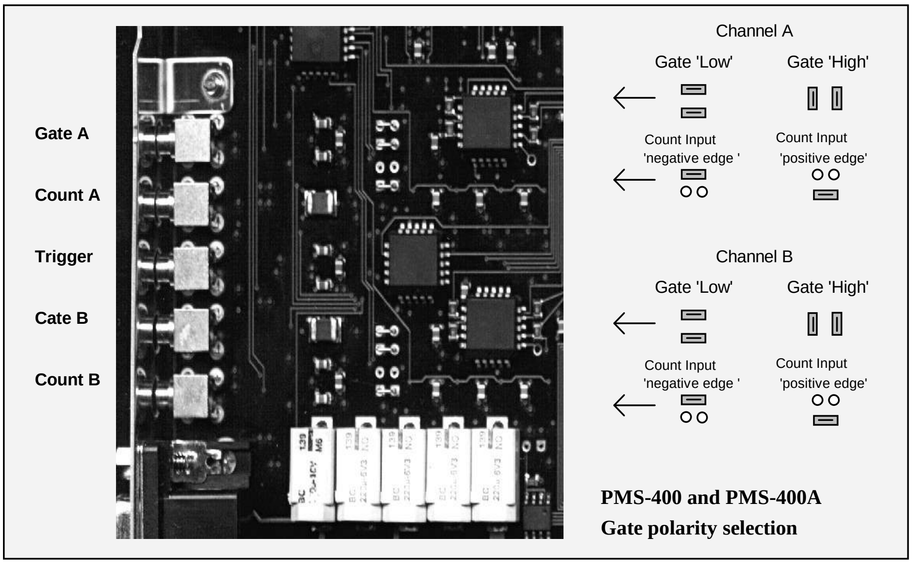


Because the gate of the PMS is edge controlled the gating resolution does not depend on the detector pulse width. The effective gate duration depends only on the gate pulse width, even if the gate pulse is shorter than the detector pulse.

The location of the jumpers on the board is shown in the figure below. Both channels can be set independently. The default setting in new modules is 'active high'.



PMS-300:
Gate Polarity Selection



PMS-400 and PMS-400A
Gate polarity selection

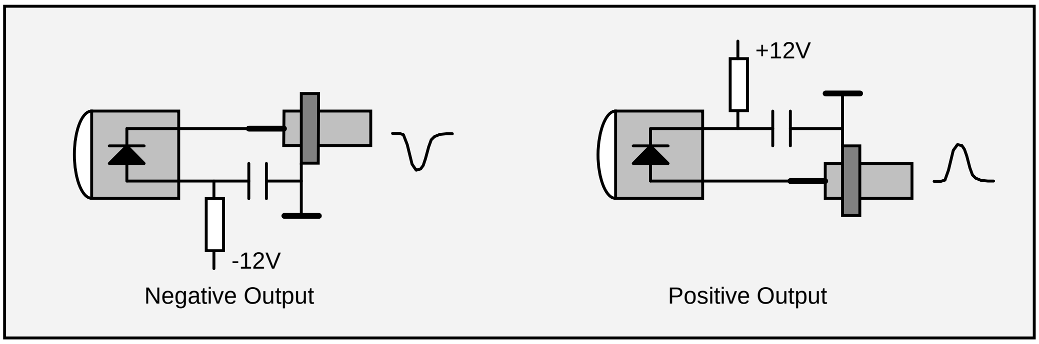
If the gate inputs are not used the gate must be set into the 'active' state by a gate threshold < 0 in the active high configuration or by a gate threshold > 0 in the active low configuration. If you do not know the setting of the jumpers on your module, run the 'Counter Test' function (under 'Main'), which returns the actual setting of the gate polarity jumpers.

The pulse amplitude at the gate inputs should be in the range from 20 mV to 2 V. Input voltages above 2.5 V are clipped by input protection diodes. Pulse amplitudes up to 30 V and DC levels up to 3.5 V will not damage the module. Input amplitudes > 2.5 V should, however, be avoided to reduce reflections and crosstalk between different inputs.

Generating a Gating Signal

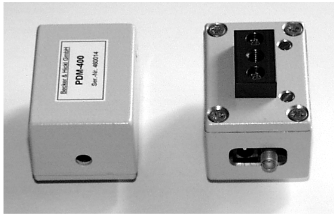
A gating signal is not required for standard multiscaler applications of the PMS. The PMS can, however, be used as a gated photon counter to gate off background pulses or to discriminate between luminescence and scattering. In many cases a simple photodiode can be used to generate a useful gating signal.

To derive a gating signal from a laser pulse sequence a fast PIN photodiode with >300 MHz bandwidth should be used. In the figure below two simple circuits for positive and negative output pulses are shown.



Complete photodiode modules are available from Becker & Hickl. These modules get their power from the PMS module so that no special power supply is required. For low repetition rates we recommend the PDM-400, for high repetition rates the PHD-400 which incorporates a current indicator for convenient adjusting. Please contact Becker & Hickl or see www.becker-hickl.com.





Fast Photodiode Modules from bh

Photomultipliers are not recommended for gating. The output signal of a PMT is a train of random single photon pulses (see ‘Introduction’). If such a signal is used to drive the gate input the gate is opened (or closed) by the individual photons rather than by the whole light pulse. If the use of a PMT for gating cannot be avoided (e.g. due to low intensity), the gain of the PMT should be reduced until a continuous output signal with an acceptable SNR is achieved.

Special Configurations of the GATE and COUNT Inputs

To meet special requirements the gate and count inputs can be configured with special discriminator level ranges. The modified values are stored in the on-board EEPROM and are used by the software to set and display the correct threshold values. Please contact Becker & Hickl if you have special requirements.

Trigger Input

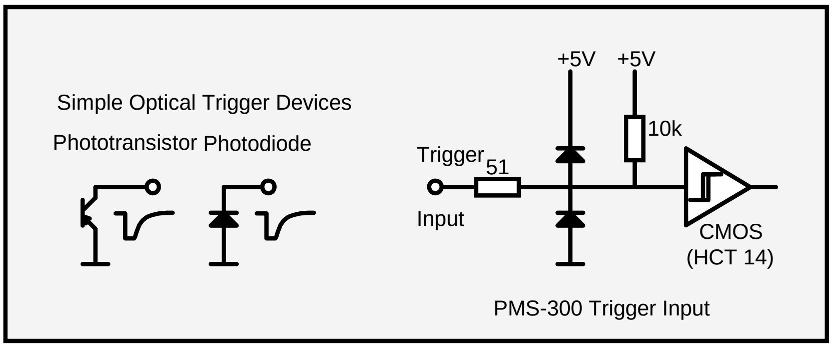
The trigger input is used to start a measurement by an external event (laser shot, spark discharge etc.). Although a measurement can be started by simply giving a software command, triggering is required for measurements at fast time scales and for accumulating a signal over several signal periods.

Depending on the 'Trigger Condition' the recording can be started either by the software 'Start' command (Trigger Condition 'none') or by the rising or falling edge of the trigger pulse. If the step motor controller is used and the trigger condition is different from 'none' the trigger action depends on the defined step motor actions. As long as no step motor action is defined 'After each Point' (see 'Stepping Device Configuration') the trigger starts the recording of a complete curve or a complete sweep (if 'Accumulate' is active). With a step motor action

'After each Point' each collection time interval is started by a trigger pulse. This allows the synchronisation of the stepping action with a pulsed light source.

PMS-300

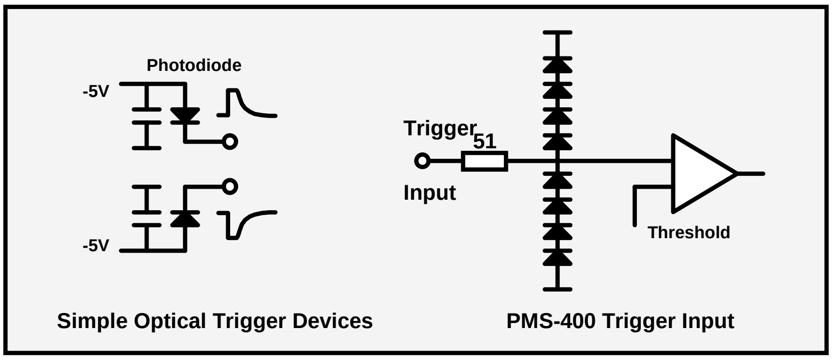
The trigger input of the PMS-300 uses TTL/CMOS levels and is connected to pin 4 of the sub-D connector. The internal configuration of the trigger input and some simple optical trigger devices are shown in the figure below.



The input is protected by two safety diodes and a 50 Ω resistor. The 10 kΩ resistor pulls the open trigger input up to the 'high' level. Therefore, a simple photodiode or phototransistor can be used to derive a trigger signal from an optical pulse. The minimum trigger pulse width is 5 ns.

PMS-400

The PMS-400 has a fast discriminator at the trigger input. The input connector is at the backplane together with the Count and Gate inputs. The trigger threshold can be selected from -2 V to +2 V. The internal configuration of the trigger input and some simple optical trigger devices are shown in the figure below.



Choosing and Connecting the Detector

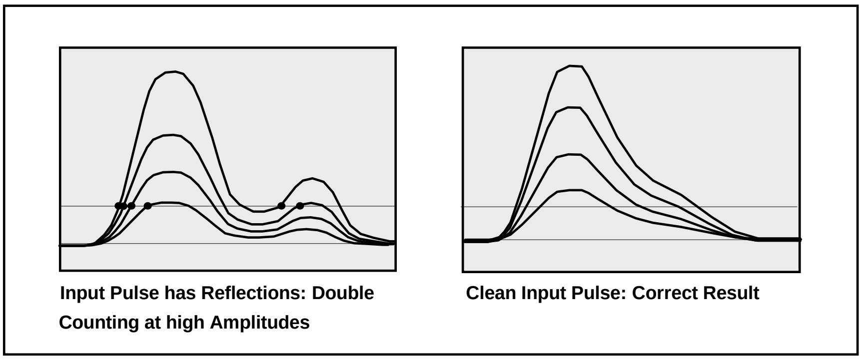
Conventional PMTs

A wide variety of PMTs is available for the PMS. Most PMTs can be connected to the PMS-300 or PMS-400 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 an detector overload indicator which responds when the maximum detector current is exceeded.

Since the time resolution of the PMT is usually not a concern for the PMS you can select the PMT by the desired spectral range, the cathode sensitivity, the dark count rate and the pulse height distribution. Simple side window PMTs (R928, R931 etc.) often give good results. However, these PMTs have a SER (Single Electron Response) rise time of some ns which can impair the gating resolution. Therefore, for gated measurements with gate pulses below 10ns faster PMTs or PMT modules should be used (e.g. PMH-100 or H5783).

Generally, the PMT should be operated at a gain as high as possible. This helps to suppress noise signals from lasers, from the computer or from radio transmitters.

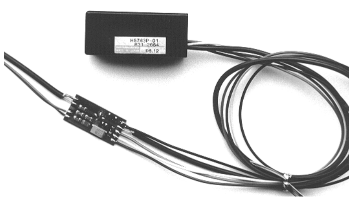
The output pulses of photomultipliers do not have a defined pulse height - the amplitude changes from pulse to pulse. Even good photomultipliers specified for photon counting have an amplitude spread of 1:2 and more. With standard PMTs the amplitude spread can easily reach 1:5 or 1:10. As the figure below shows, double counting can occur if the pulses have a broad amplitude distribution and a bad pulse shape. Therefore, 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. The PMS-400A has a selectable low-pass filter (‘Holdoff’ function) in the discriminators.



Hamamatsu R5600, R7400 and Derivatives

The R5600 and R7400 tubes made by Hamamatsu are small (15 x 15 mm) PMTs with a correspondingly fast response.

Based on these PMTs are the H5783P and H5773P Photosensor modules. The H5783P incorporates a R5600 or R7400 PMT and the HV power supply. 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.



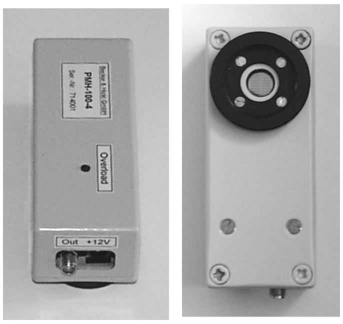
The Hamamatsu H5783 with a PMA-100 low cost amplifier

The H5783-P can be connected directly to the PMS-300 and PMS-400 modules. However, to get maximum counting efficiency and 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.

The H5785P and H5773P require a +12 V supply and a gain control signal. The +12 V is can be taken from the Sub-D connector of the PMS modules. The gain control voltage can be obtained from a simple voltage divider. A more comfortable solution is the DCC-100 detector controller of bh (see 'The DCC-100 Detector Controller'). This module allows software controlled gain setting, detector on/off switching and overload shutdown in conjunction with a bh HFAC-26 preamplifier.

PMH-100 and PMC-100

The PMH-100 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. Due to its compact design and the internal preamplifier the PMH-100 features excellent noise immunity.



PMH-100

The PMC-100 is a cooled version of the PMH-100. The PMC-100 requires the DCC-100 detector controller for proper operation. The DCC-100 delivers the current for the peltier cooler and provides an overload shutdown of the detector. Due to the cooling, the PMC-100 is available with NIR-sensitive cathodes and yet delivers low dark count rates. Especially the PMC-100-20 is an excellent detector for NIR diffuse optical tomography.

The PMH-100 and PMC-100 detectors feature exceptionally stable instrument response functions at high count rates. For count rates up to several MHz the walk of the first moment of the IRF in TCSPC applications is less than 2 ps.

PMC-100

Hamamatsu H7422 and H8632

The H7422 and the H8632 are high speed, high sensitivity PMT modules. The module feature excellent sensitivity in the red and near-infrared region. They contain a GaAs photomultiplier along with a thermoelectric cooler and a high voltage generator. The resolution in the TCSPC (time-correlated single photon counting) mode is typically 250 ps. The H7422 comes in different cathode versions for the wavelength range up to 900 nm. The H8632 is available for the wavelength range up to 1100nm.

The modules must be handled with care because the cathodes can easily be damaged by overload. Exposure to daylight is not allowed even when the devices are switched off. Therefore, the H7422 and the H8632 should be used with an HFAC-26-1 preamplifier. Gain control and cooling can be achieved by using the **bh** DCC-100 detector controller.

Hamamatsu H7421

The H7421 is a TTL output version of the H7422. The module feature excellent sensitivity in the red and near-infrared region and comes in different cathode versions for the wavelength range up to 900 nm. The H7421 can be connected to the PMS via a 10 dB to 20 dB attenuator. Because the H7421 has its own discriminator you cannot change the count threshold for the

SER pulses. Moreover, the discriminator is not as fast as the discriminators in the bh PMS, MSA or SPC modules. That means that the H7421 has less time resolution when used in TCSPC applications. Furthermore, the peak count rate when used with a **bh** PMS or MSA module is lower than for the H7422. As long as peak count rate is not a concern and the H7421 is for the PMS only it can be used as well as the H7422.

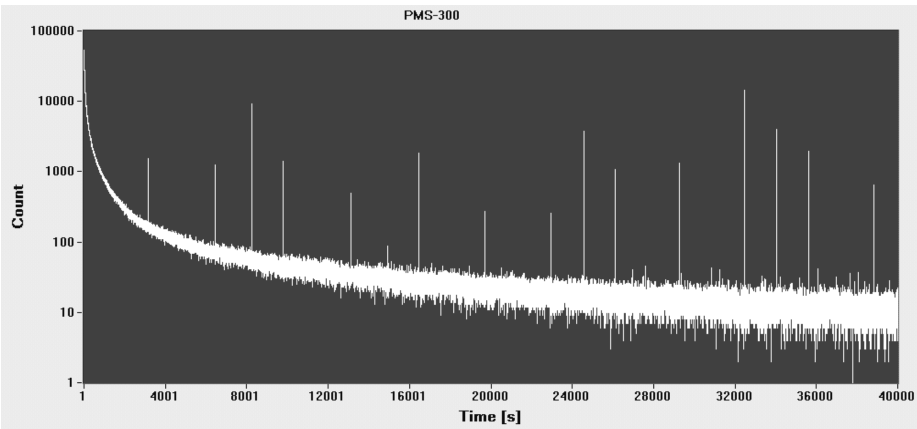
MCP PMTs

MCP-PMTs (e.g. the Hamamatsu R3809U) 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. There lifetime 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 the PMS there is no reason why you should use such an expensive detector. If an MCP is used with the PMS-300 or PMS-400 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.
- Avoid heating the detector by the voltage divider or by step motors, shutters, preamplifiers etc. Already a few degrees increase in temperature can double the dark count rate.
- 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 dramatically 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.

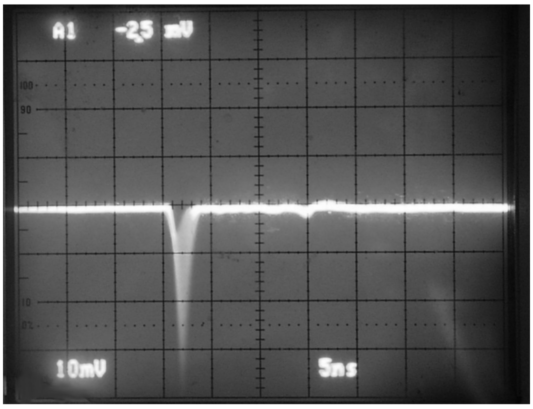


Decrease of dark count rate (counts per second) of a H5773P-01 after exposing the cathode to room light. The device was cooled to 5°C. The peaks are causes by scintillation effects.

- 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.
- Avoid the contact of the PMT with helium. Helium permeates through the glass and impairs the vacuum in the tube.
- An efficient way to reduce the effective dark count rate is to use gated detection in conjunction with pulsed excitation. Depending on the laser repetition rate and the gate width a background reduction of several orders of magnitude can be achieved, see 'Gated Detection'.

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 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 PMS 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 a PMS module when the high voltage is switched on! Never connect a photomultiplier to a PMS if the high voltage was switched on before with the

PMT output left open! Never use switchable attenuators between the PMT and the PMS! Never use cables and connectors with bad contacts! The same rules should be applied to photodiodes (at the gate 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 PMS the cable is discharged into the PMS 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. If a high count rate is desired 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.

The SPCM-AQR single photon avalanche diode modules from EG&G (Perkin Elmer) work with the PMS modules if connected directly to the 'Count' inputs. The SPCM-AQR modules deliver 5 V pulses with 20 to 50 ns duration. The high amplitude causes some reflection at the PMS input, which is, however, no problem as long as the connection cable is shorter than 2.5 m. However, if an APD module is connected to one PMS channel and a PMT to the other, we recommend to use an attenuator of 20 dB (10:1) to avoid crosstalk into the P and PMS-400MT channel.

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 PMS channel crosstalk can result if both detectors are optically coupled.

Preamplifiers

Most PMTs deliver pulses of 20 to 50 mV when operated at maximum gain. Although these pulses can easily be detected by the PMS-300 and PMS-400 input discriminators a preamplifier improves the noise immunity, the threshold accuracy and the safety against damaging the PMM input. Furthermore, it can extend the detector lifetime by reducing the required detector output current and avoiding overload conditions.

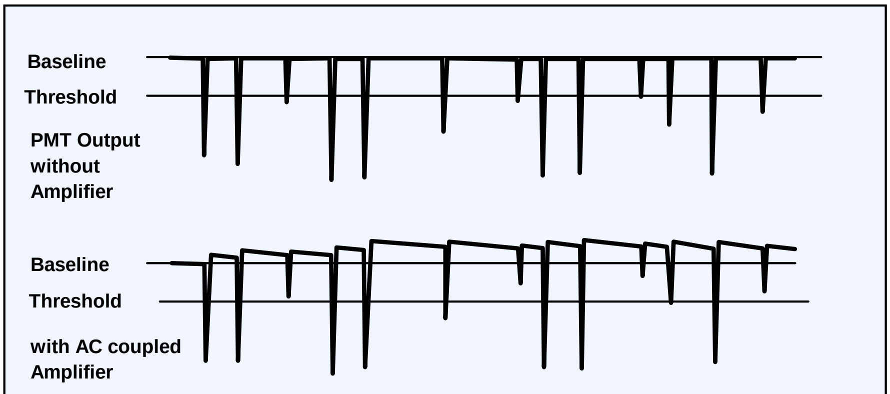
HFAC-26 Amplifier

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. 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 right.

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.



Effect of an AC coupled Amplifier

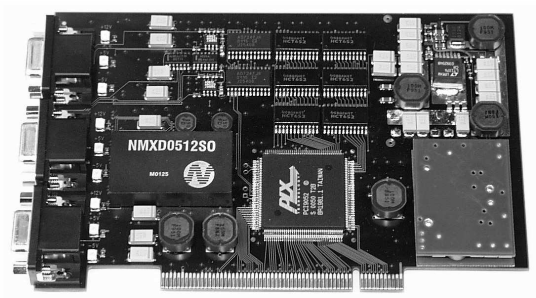
The effect increases with increasing width of the detector pulses. For fast PMTs (PMH-100, R5600, R7400) it is barely detectable and usually not distinguishable from the normal counting loss due to the limited pulse resolution of the detector. If the effect of AC coupling is a concern it can be minimised 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.

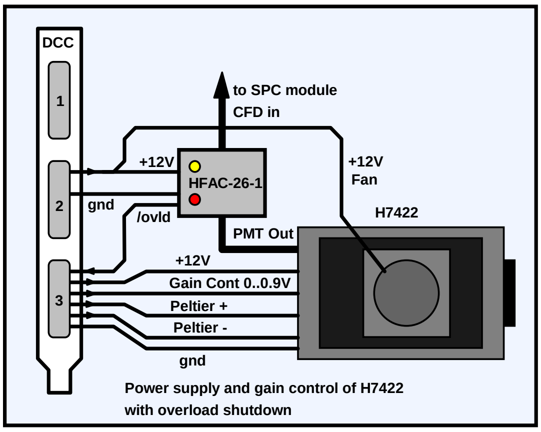
Distortions due to AC baseline shift are avoided with DC coupled amplifiers. DC coupled amplifiers are, however, slower and have a higher noise than the typical AC coupled HF amplifiers. Furthermore, the gain at low frequencies can cause problems due to line frequency pickup. For DC coupled amplifiers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

The DCC-100 detector controller

The DCC-100 module is used to control detectors in conjunction with **bh** photon counters. It can be used to control the gain of the Hamamatsu H7422, H5783, H6783 or similar photosensor modules by software. The gain of MCPs and PMTs can be controlled via the FuG HCN-14 High Voltage Power Supply. In conjunction with **bh** preamplifiers, overload shutdown of the detectors can be achieved. Furthermore, the DCC-100 delivers the current for thermoelectric coolers, e.g. for the Hamamatsu H7422. High current digital outputs are available for shutter or filter control. The DCC-100 is a PCI module for IBM compatible computers. It works under Windows 98, 2000, NT, and XP.

The figure right shows how a H7422 module is controlled via the DCC-100. For more information, please see DCC-100 data sheet and DCC-100 manual, www.becker-hickl.com.





Power supply and gain control of H7422 with overload shutdown

Dead Time Considerations

Although there is no perfect optical system and no perfect detector 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.

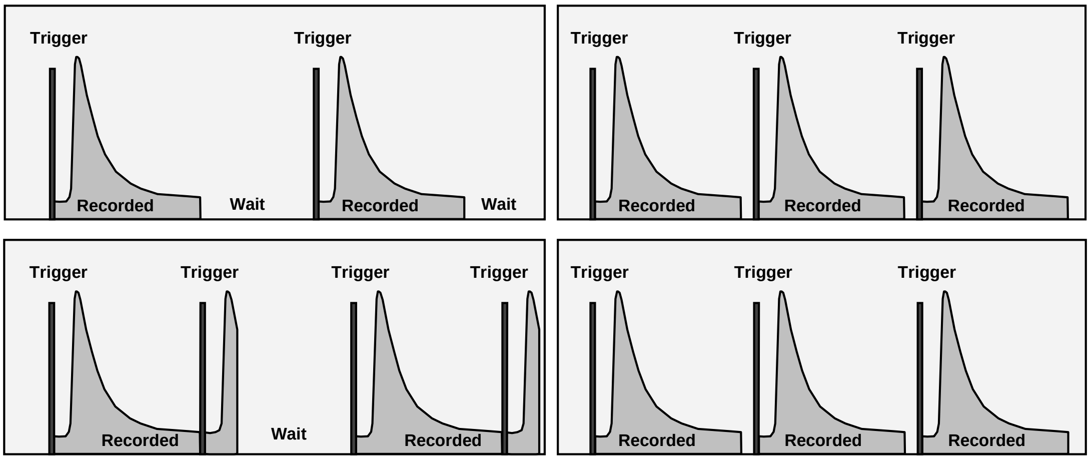
Dead Time between Sweeps

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 have to 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 PMS devices, the photons from subsequent sweeps are added directly in the high speed memory. 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 bit longer than the sweep duration.

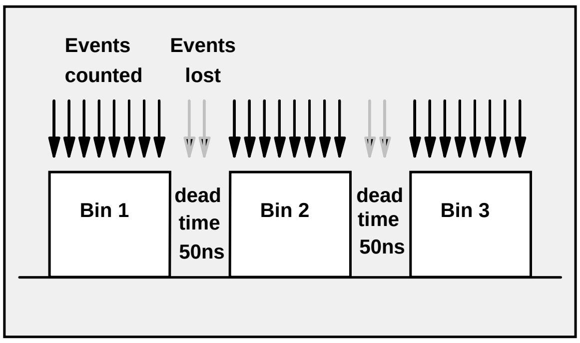
The situation is shown in the figure below. By optimising the signal repetition rate or the recording length long waiting for trigger or wasting of parts of signal periods can be avoided.



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

Dead Time between Bins

Dead time between subsequent bins - or points - of the multiscaler recording results in a counting efficiency smaller than one independently of the signal count rate. The PMS modules have a dead time of 50 ns between subsequent bins. The resulting counting loss is almost not noticeable at longer 'Time per Point' but becomes appreciable if 'Time per Point' is below 1 µs.



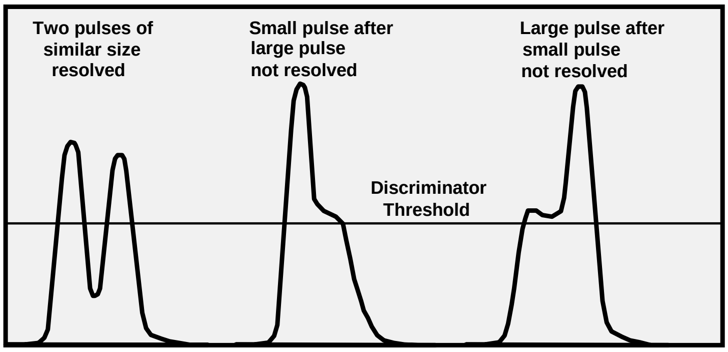
Counting loss due to dead time between subsequent bins

The dead time between bins is the tradeoff to achieve a high count rate and to minimise the dead time between counts, see below. The structure of the PMS is an ultra-fast counter that is read and reset periodically. This gives high count rate but reading and resetting the counter requires some time.

Dead Time between Counts

Dead time between counts is the most troublesome class of dead time because it makes the function of the number of counts versus intensity nonlinear. Furthermore, it causes counting loss not only in the multiscaler mode but also in steady state and gated photon counting applications.

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 similar 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.



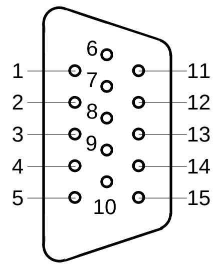
Effect of pulse height fluctuation on pulse resolution

The peak count rate is about 100 to 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 to 10 ns and 10 to 20 ns respectively. For an MCP-PMT the peak count rate can be higher, probably more than 500 MHz. However, the average count rate of an MCP should be kept below 100 kHz to avoid degradation due to sputtering effects.

The PMS is able to count pulses with rates up to 800 MHz, or with an edge-to edge distance of 1.25 ns. That means, the PMS records the photon pulses from all these detectors almost without additional dead time between counts.

External Control Signals and Supply Voltages

For the external control signals and for the power supply of external amplifiers a 15 pin sub-d connector is provided at the PMS-300 and PMS-400 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	
3	/DisableCollect
4	Trigger (Input, PMS-300 only)
5	GND
6	- 5 V, max. 100 mA via 1.0 Ω
7	
8	/Disable Collect (Input)
9	/DisableArm (Input)
10	+12V, max. 500 mA
11	Do not connect, -12V in other B&H devices
12	/Armed (Output)
13	/Measure (Output)
14	/Collect
15	GND

Input Signals

The TRIGGER signal is used to start the measurement by an external event (See also 'Trigger Input').

By /DisableArm = L the start of the recording in both channels of the module can be suppressed. However, if the recording has already been started, counting is not aborted by /DisableArm. The input has internal pull up resistors so that the open input is pulled to the inactive (H) state.

By /DisableCollect = L the start of the next collection time interval (for the next curve point) is suppressed. However, if the collection for the next point is already running it is not influenced by /DisableCollect. The input has internal pull up resistors so that the open input is pulled to the inactive (H) state.

Output Signals

The '/Armed' signal indicates that the corresponding channel has been started. It goes to 'Low' when the measurement has been started. However, if a trigger condition different from 'none' is used the measurement does not start until the specified trigger edge is detected.

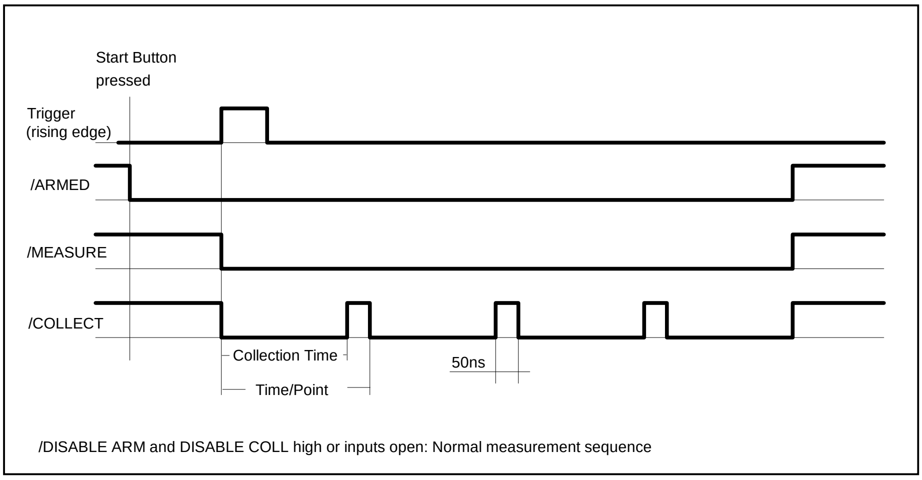
The '/Measure' signal indicates that the measurement is running. If no trigger condition is used ('none') the '/Measure' signal is the same as the '/Armed' signal. With a trigger condition different from 'none' the 'Measure' signal goes to 'Low' when a trigger edge was recognised.

The '/Collect' signal indicates that the counters are collecting photons. It is 'Low' when the counters are active. In the multiscaler mode, the '/Collect' signal goes to 'High' for the time when the counters are read and the results are stored in the memory. This is for 50 ns after the end of each collection time interval (or curve point).

To provide the power supply for external devices (detectors, amplifiers) +5V, -5V and +12V are available at the sub-D connector. The +5V and -5V signals are short circuit protected. The

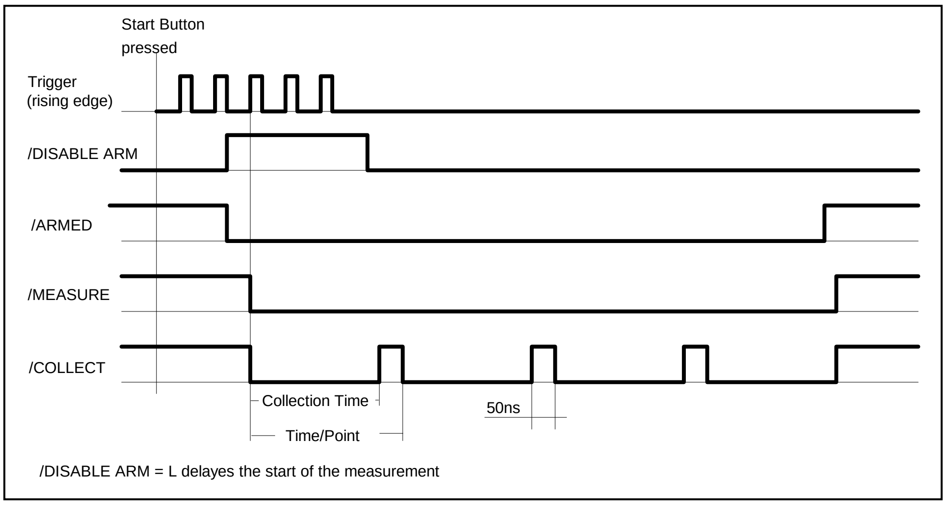
+12V output comes - via an RF filter - directly from the power supply of the computer. Thus the overload behaviour depends on the power supply of the computer. Under normal conditions, a current up to of 500 mA can be drawn from the +12V output.

The behaviour of the /Armed, /Measure and /Collect signals with inactive (unconnected) /DisableArm and /DisableCollect signals is shown in the figure below.



/Armed goes to L when the measurement is started by the software. If a trigger condition was specified (the low-to-high transition in the figure above) the measurement starts with the trigger and the /Measure signal goes to L. The /Collect signal is L when the counters are active. Therefore the /Collect signal consists of a number of pulses equal to the number of curve points with a repetition rate of 'Time / Point'. The pulse duration is 50 ns less than 'Time/Point'. This is because 50 ns are required to read the counters and to store the result in the current memory location.

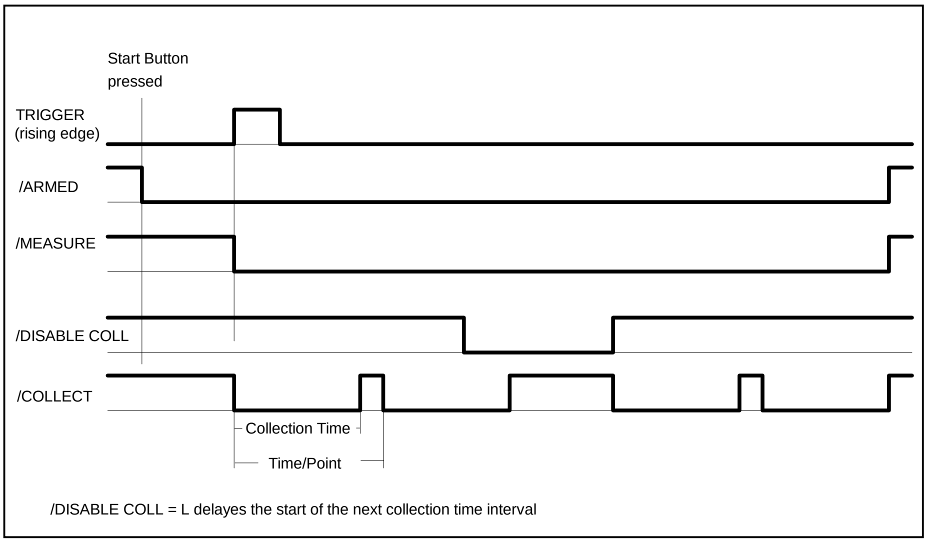
In the next figure the effect of the /DisableArm signal is shown.



If /DisableArm is L when the 'Start Measurement' button is pressed the start of the measurement is delayed until /DisableArm is H. If a trigger condition is specified (the rising edge in the example above) the measurement starts with the next trigger after

/DisableArm = H. If no trigger condition is given, the measurement starts immediately after /Disable ARM = H.

The figure below shows the effect of /DisableCollect.



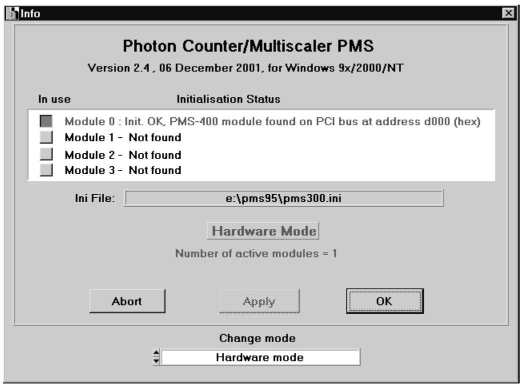
If /DisableColl is L at the start of a collection time interval the collection is not started. The measurement stops until /DisableColl = H is detected.

All digital outputs are TTL compatible. The digital inputs are TTL and CMOS compatible. Open inputs are seen as 'High'. Please be careful not to connect a device to the 15 pin connector which is not intended for that purpose. This can damage the PMS module or the connected device.

Software

The PMS Standard Software is able to control up to four PMS-300 or four PMS-400 modules. It runs under Windows 98, 2000, NT or XP. At least 32 Mb of memory should be available. If a PMS-300 should ever be used in old 386 or 486-SX systems (which is not recommended) a mathematical coprocessor is required. The VGA resolution must be 1024 by 628 or more.

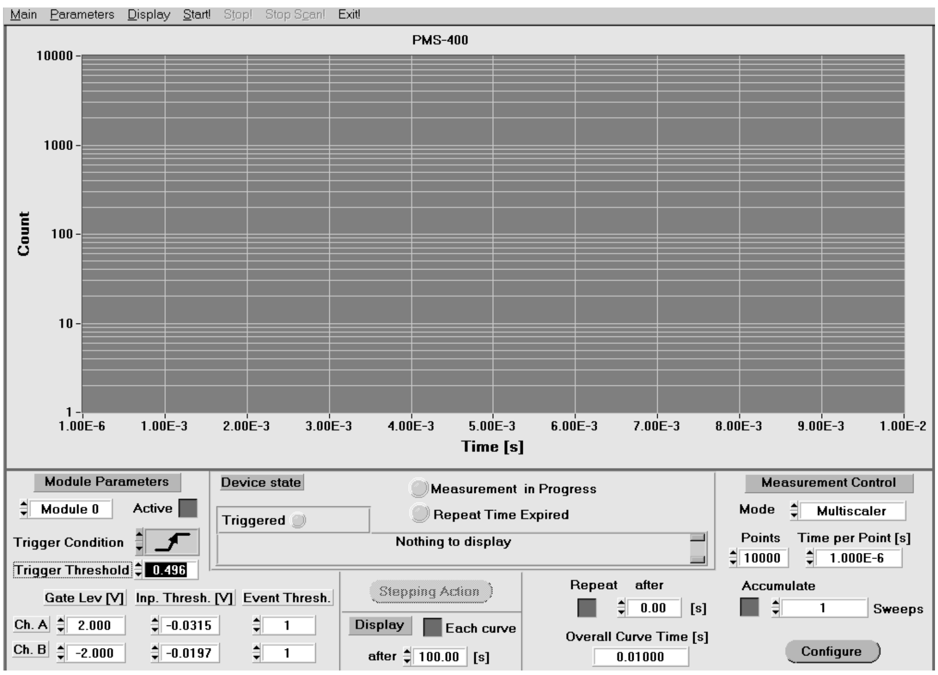
The PMS Standard Software includes the setting of the measurement parameters, the control of the measurement, the loading and saving of measurement data and parameters, the display of the results as curves or bars and the application of mathematical operations to the result curves. Furthermore, the software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



When the PMS software is started the initialisation panel shown right should appears. The installed modules are marked as ‘In use’. PCI modules are shown with their serial number, PCI address and slot number.

The software runs a simple hardware test when it initialises the modules. If an error is found, a message ‘Hardware Errors Found’ is given and the corresponding module is marked red. In case of non-fatal hardware errors you can start the main panel by selecting ‘Hardware Mode’ in the ‘Change Mode’ panel. Please note that this feature is intended for trouble shooting and repair rather than for normal use.

When the initialisation panel appears, click on ‘OK’ to open the main panel of the PMS software. The main panel 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 below.



Menu Bar

The menu bar incorporates the following items:

Main Parameters Display Start Stop StopScan Exit

Under these items the following functions are available:

Main:	Load, Save, Convert, Print, Counter Test
Parameters:	Step Device Configuration, Display Parameters, Trace Parameters, EEPROM Parameters
Display:	Curve display with cursor and zoom functions, mathematical operations
Start:	Start of the measurement
Stop:	Stop of a measurement
StopScan:	Stop of the x position during the measurement of a curve
Exit:	Exit from the PMS 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. The display mode depends on the operation mode, the parameter 'points' and on the current setting of the 'Trace Parameters' and the 'Display Parameters'. In the 'Channel Rates' mode the count rates of the counter channels are displayed as bars. In the 'Multiscaler' mode curves are displayed with the specified 'Number of Points'. Normally these are the waveforms of the measured signals. However, if the step motor controller is used and configured for stepping after each curve point spectra or a spatial dependencies of the signals are obtained.

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 the repeat time has expired before the last measurement had been finished.

The 'Triggered' indicators turn on when a module was triggered. Up to four trigger indicators are displayed depending on the number of PMS 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 / 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 PMS300.INI file. The modules can be switched on and off by the 'active' button.

Trigger Condition

'Trigger Condition' defines the condition for the start of the measurement. With 'None' the recording starts immediately after pressing the 'Start' button of the menu bar. If 'Rising Edge' or 'Falling Edge' is selected, the measurement is initiated with the 'Start' button, but the recording does not start until the specified transition at the trigger input is recognised.

A reasonable accumulation of several sweeps in the Multiscaler mode is possible only if the PMS 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 PMS modules are present the trigger condition can be set independently for different modules. Each module starts its measurement by its own trigger pulse. However, 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.

Gate Level

'Gate Level' is the discriminator threshold for the gate signal. Values from -2V to +2V can be set. If no gate signal is used, a 'Gate Level' <0 for the 'Active High' configuration and a 'Gate Level' >0 for the 'Active Low' configuration has to be set to enable counting. (See section 'Gate Inputs')

Trigger Threshold (PMS-400)

'Trigger Threshold' is the discriminator threshold for the trigger input of the PMS-400. Values from -2V to +2V can be set. A trigger threshold setting exists for the PMS-400 only. The PMS-300 has a TTL/CMOS trigger with a fixed threshold.

Input Threshold

'Input Threshold' is the discriminator threshold of the counting input. Values from -1V to +1V can be set. The counting 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.

Event Threshold

This parameter is used in the 'Event Mode' of the PMS only. In this mode the counter results within the specified collection time interval are compared to the specified 'Event Threshold'. If the result of one channel exceeds the specified 'Event Threshold' the results of both module channels are stored together with the time from the start of the measurement. The measurement continues until a number of events equal to the parameter 'Points' have been recorded.

Measurement Control

Mode

Channel rates

The results of the counters within the specified collection time are displayed as bars. If 'Repeat' is set the measurement is repeated in intervals of 'Repeat Time' and the current results are continuously displayed on the screen. Depending on the 'Trigger Condition' the recording can be started either immediately after finishing the last collection time interval (Trigger Condition 'none') or by the next rising or falling edge of the trigger pulse. The 'Channel Rates' mode is useful to test and to adjust the measurement setup before the final measurement is started.

Multiscaler

In the multiscaler mode the counter results of subsequent collections time intervals are stored in subsequent memory locations. The results represent the input pulse density versus time, i.e. the waveform of the measured light signal. The time per curve point can be as short as 250 ns. The effective collection time per curve point is 50 ns shorter, because 50 ns are required to read the counters and to store the results in the memory.

Depending on the 'Trigger Condition' the recording can be started either by the software 'Start' command (Trigger Condition 'none') or by the rising or falling edge of the trigger pulse. If the step motor controller is used and the trigger condition is different from 'none' the trigger action depends on the defined step motor actions. As long as no step motor action is defined 'After each Point' (see 'Stepping Device Configuration') the trigger starts the recording of a complete curve or a complete sweep (if 'Accumulate' is active). With a step motor action 'After each Point' each collection time interval is started by a trigger pulse. This allows the synchronisation of the stepping action with a pulsed light source.

If 'Accumulate' is set several signal periods are accumulated. In this case the recording is restarted with the next trigger pulse after the end of the previous recording and the obtained counter results are added to the current memory contents.

The whole measurement sequence is repeated if the 'repeat' button is pressed. In this case a repetition time ('repeat after ...') can be specified. If the repetition time is longer than the overall recording time the subsequent measurements start in intervals of the repetition time. Otherwise the next measurement is started immediately after the previous one is finished.

Under 'System Parameters' / 'Stepping Device Configuration' / 'Action' step motor actions can be defined in several places of the measurement sequence. Therefore, with the optional step motor controller STP-240 a lot of modifications of the measurement sequence are possible. With a step motor action after each curve the dependence of the waveform of the light signal on a spatial parameter or the wavelength is obtained. If a step motor action is defined after each curve point, instead of a waveform a spatial dependence of the intensity or a spectrum is recorded.

Event Mode

In the event mode the incoming detector pulses are counted for the selected time intervals. When the current collection time interval is over the counter results are compared to the 'Event Threshold' value. If the result is greater than the event threshold value it is stored together with the time since the start of the measurement.

The actual collection time is 50 ns shorter than the parameter ‘Collection Time’ because some time is deeded to compare and store the result. The measurement stops when a number of events specified by ‘Points per Curve’ was recorded.

Repeat

If 'Repeat' is set, the measurement is repeated when the specified repeat time ('Repeat after..') has expired and all active channels have finished their current measurement. 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, 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

In the multiscaler mode the parameter 'Points per Curve' determines the number of points or subsequent collection time intervals for one complete curve.

In the event mode 'Points per Curve' is the maximum number of events that can be recorded. Values from 2 to 65536 are available for 'Points per Curve'.

Time per Point

In the multiscaler mode the parameter 'Time per Point' determines the time scale of the recording. The time per curve point can be as short as 250 ns. The effective collection time per curve point is 50 ns shorter than 'Time per Point, because 50 ns are required to read the counters and to store the results in the memory.

If a stepping device action is specified after each curve point (see 'Parameters', 'Stepping Device Configuration', 'Action') the time scale of the X axis is replaced by another scale defined in the 'Stepping Device Configuration' via the STP.CFG file. In this case 'Time per Point' determines the collection time for each point which, again, is 50 ns shorter than 'Time per Point'.

In the event mode the incoming detector pulses are counted for the selected time intervals. When the current collection time interval is over the counter results are compared to the 'Event Threshold' value. If the result is greater than the event threshold value it is stored together with the time since the start of the measurement. The parameter 'Time per Point' refers to the collection time plus the time required for comparing and storing the result. Again, the effective collection time is 50 ns shorter than the 'Time per Point'.

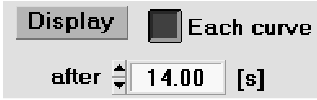
Accumulate

If 'Accumulate' is set a number of signal periods (specified by 'Sweeps') are accumulated. In this case the recording is restarted with the next trigger pulse after the end of the previous recording and the obtained counter results are added to the current memory contents. 'Accumulate' is available in the multiscaler mode only.

Overall Time

'Overall Time' is the length of the recording in the multiscaler mode. It is the product of 'Time per Point' and 'Points per Curve'. The 'Overall Time' is displayed for information only, an entry is not possible.

Display Control



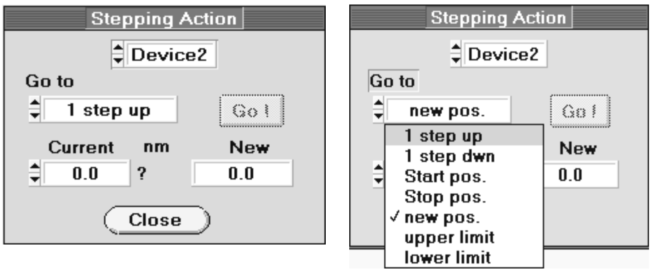
Depending on 'Time per Point', 'Points per Curve' and 'Accumulations' the measurement time can vary in a wide range. Therefore, the display rate can be configured by 'Display after' and the 'Display after each Curve' button.

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 time.

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).

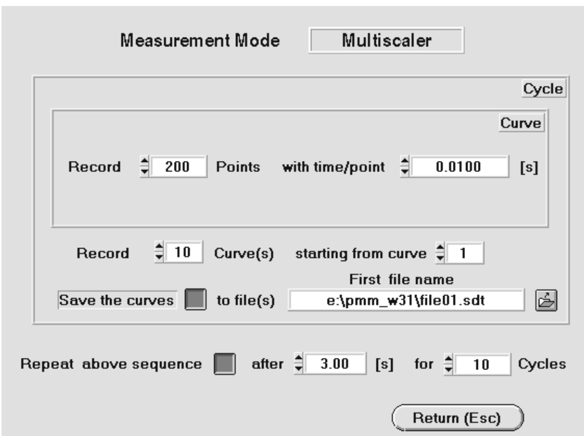


With 'Device 1' or 'Device 2' one of the two motors driven by the STP-240 can be selected. Several actions are available, as shown in the figure above (right). The action is initiated by the 'Go' button.

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

Configuring a measurement sequence

The PMS 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 main panel . The measurement sequence can (but need not) consist of three program loops:

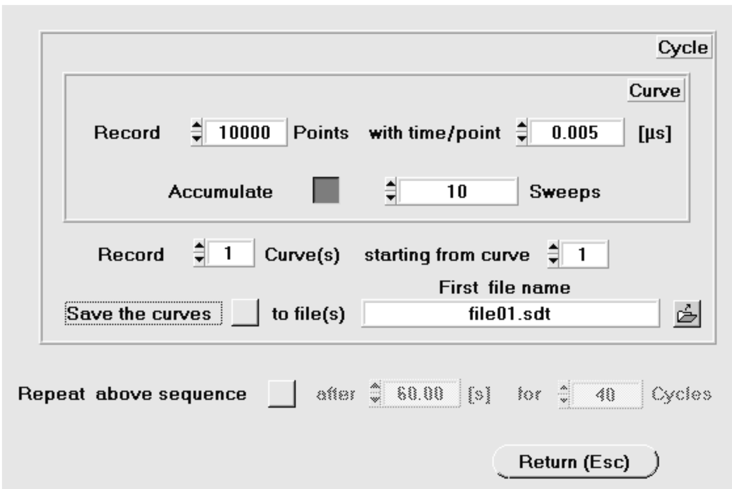
- The inner loop is the recording of a 'curve' with the specified number of sweeps accumulated for each of the activated measurement channels. This is the normal 'multiscaler' recording sequence which is controlled by the parameters 'points' and 'time / point'.
- The curve recording can be repeated for a number of 'cycles' specified by 'Record ... Curve(s)'. The number of available curves depends an the parameter ‘Points / Curve’ and ranges from 1 (for 32768 points / curve) to 32 (for 1024 points / curve or less). 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 point, 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.



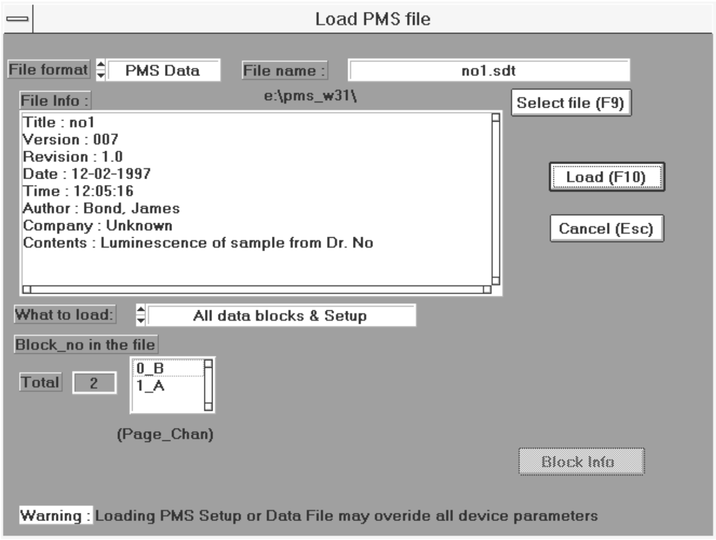
Functions in the Menu Bar

Main: Load, Save, Print, Counter Test

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 'PMS Data' and 'PMS Setup'. The selection refers to different file types.

With 'PMS 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 'PMS 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 'PMS Data' have the extension '.sdt', files for 'PMS 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.

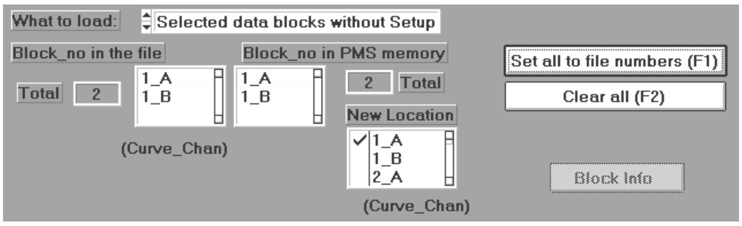
Load, Cancel

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 PMS 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.



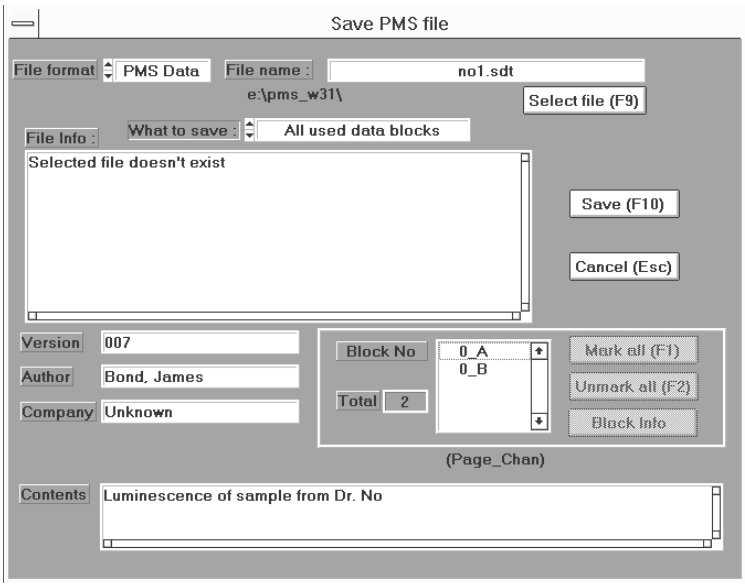
The list 'Block no in the file' shows the curves available in the file. Under 'Block no in the memory' the destination of the data blocks (curves) in the memory is shown. With 'Set all to file numbers' the destination in the memory can be set to the same block numbers as in the file. To set the destination 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 'Operation Mode' and 'Number of Points' 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 'PMS Data' and 'PMS Setup'. The selection refers to different file types. With 'PMS 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 'PMS 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 'PMS Data' have the extension '.sdt', files created by 'PMS 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 may edit the existing file information. When you load the file later on, this text is displayed. This helps to identify the correct file before loading.

Save / Cancel

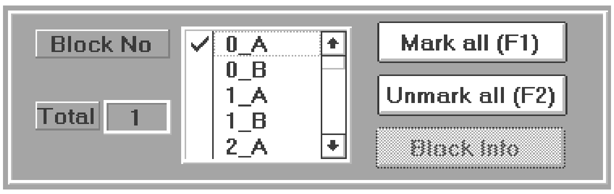
Saving of the selected file is started by 'Save' or F10. 'Cancel' rejects the saving and closes the 'Save' menu.

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

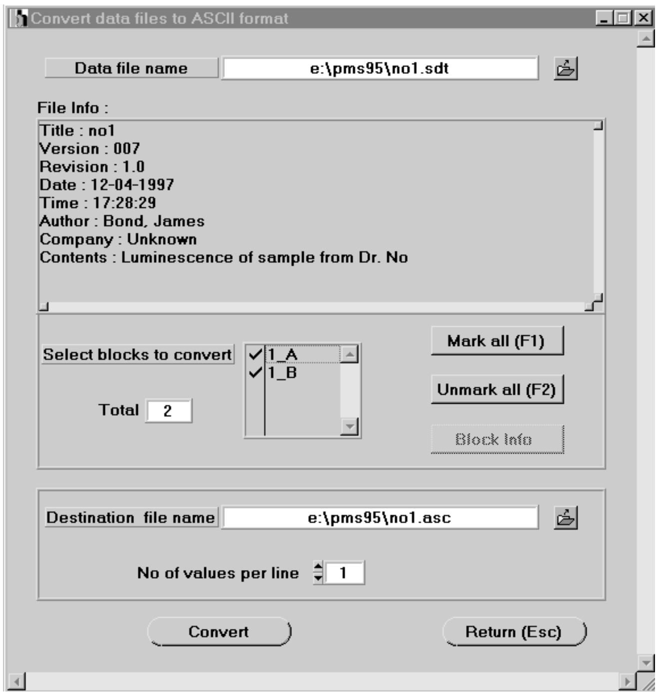
The ‘Convert’ functions are used to convert the .sdt files of the PMS Standard Software into ASCII data files. The ‘Convert’ menu is shown in the figure below.

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.

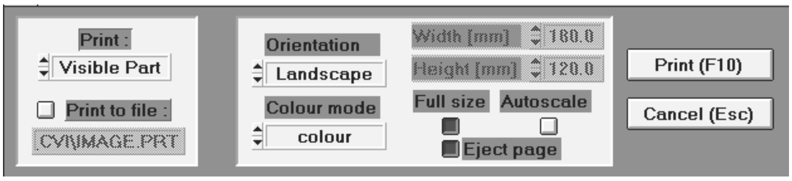
The style of the generated ASCII can be changed by setting ‘Number of values per line’ to the desired value.



For ‘Multiscaler’ measurements the subsequent ASCII values resemble the subsequent counter values. For ‘Event Mode’ measurements pairs of values are generated which resemble the counter values and the times for the subsequent events.

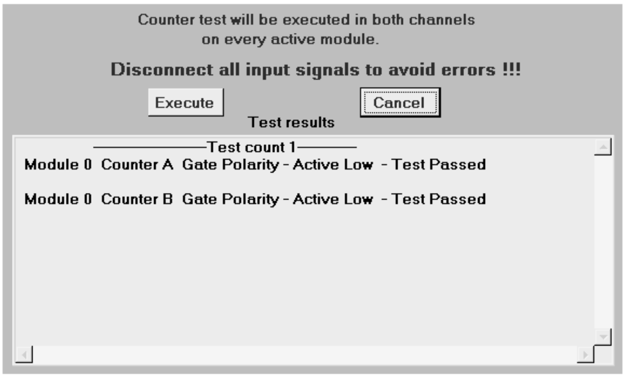
Print

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 clipboard from where it (usually) can be loaded into any other program.

Counter Test



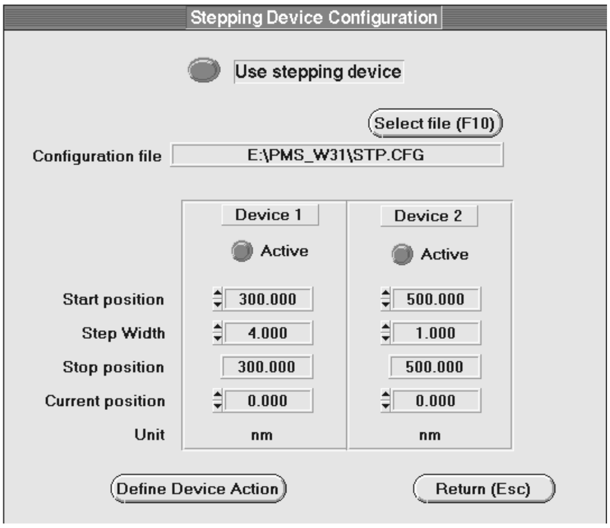
'Counter Test' is used to test the hardware functions of the present PMS modules. During the test all input signals must be switched off (we recommend to disconnect the cables). The test includes most of the PMS-300 and PMS-400 hardware functions. Moreover, it determines the configuration of the gate inputs (active low or active high, see section 'Gate Inputs').

Should the Counter Test return an error for a PMS-300, we recommend to check for possible address conflicts between different modules in the PC. If there are other modules with unknown I/O addresses, try with different PMS base and SYNC addresses before you send us the module for repair.

Parameters

Stepping Device Configuration

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

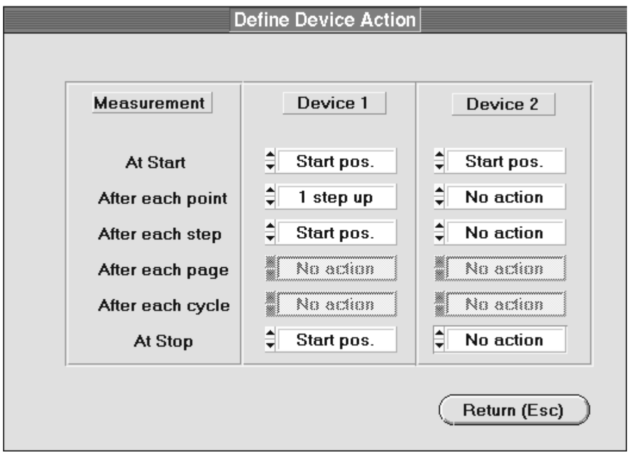


The basic electrical and mechanical parameters of the step motor drive are configured by a configuration file. This file contains the stepping frequency, start and stop ramps, duration of overvoltage pulses, end positions, the unit of the driven axis (e.g. nm for a wavelength drive) and the number of 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).

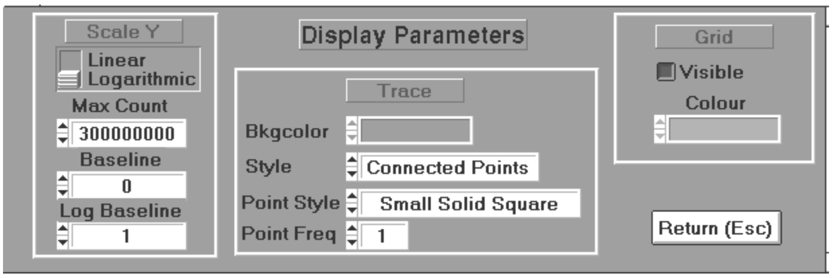
The button 'Define Device Action' opens a new window which is used to define the place of a step motor action within the measurement program loop. The 'Device Action' window is shown in the figure below.



Step motor actions can be defined at the start of the measurement, after each curve point, when the recording reaches the last curve point, when the accumulation for one measurement is finished and after a number of repetitions 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 point and runs back to the start position at the end of the recording of the curve. If 'Accumulate' is set this sequence is repeated for the specified number of accumulations, and the results are accumulated in the memory. If 'Device 1' drives a monochromator the result is a spectrum of the investigated light signal.

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.

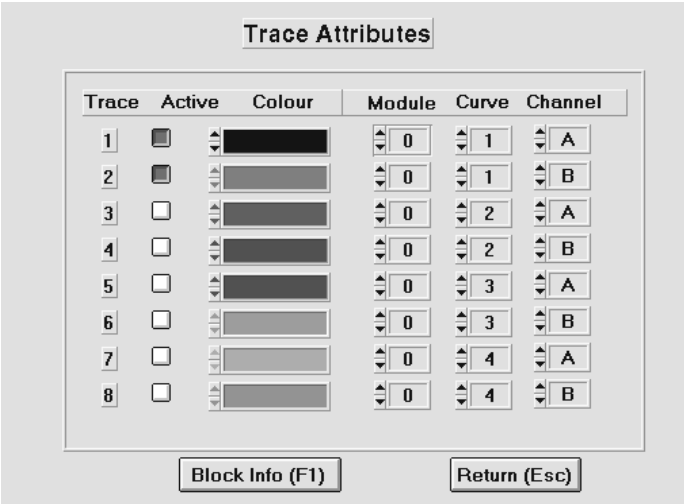
Grid

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 PMS 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.

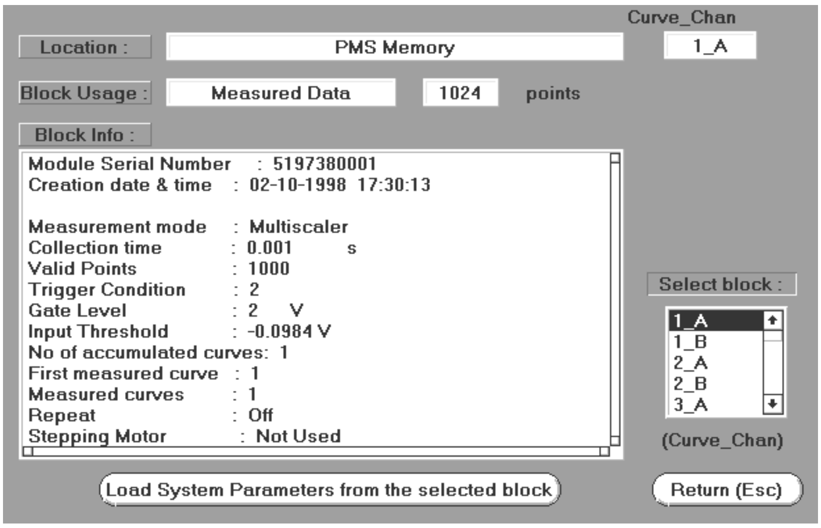
'Module' specifies the PMS module in which the data is recorded (up to four modules can be present).

‘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 65536 points / curve) to 64 (for 1024 points / curve or less).

'Channel' is the counter channel (A or B) of the specified 'Module'.

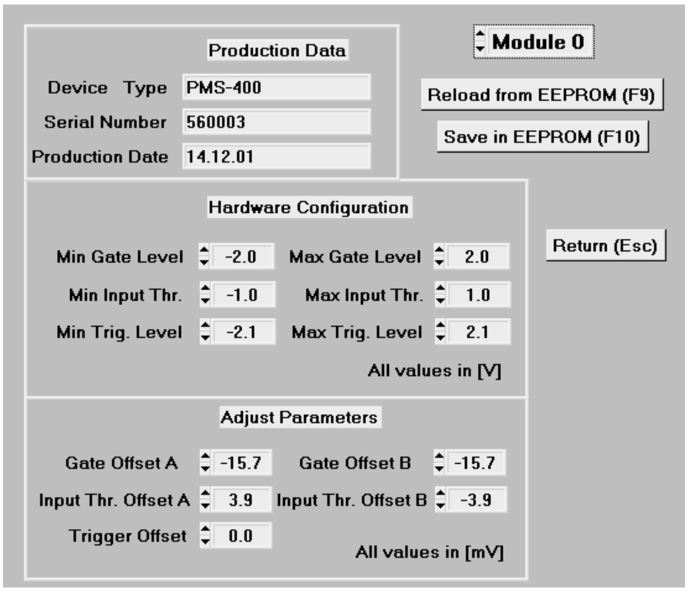
By changing 'Module', 'Curve' and 'Channel' the trace definition allows to display curves from different modules and different measurements at the same time.

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



Adjust Parameters

Adjust values and production information is stored in an EEPROM on the PMS module. The adjust values are accessible via the adjust parameters menu. To change the adjust parameters a certain knowledge about the PMS 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 PMS 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 gate and counter inputs of the PMS can be configured for different input voltage ranges. The parameters under 'Hardware Configuration' inform the software about the actual input threshold ranges.

Adjust Parameters

These parameters compensate the offset of the gate, count and trigger inputs.

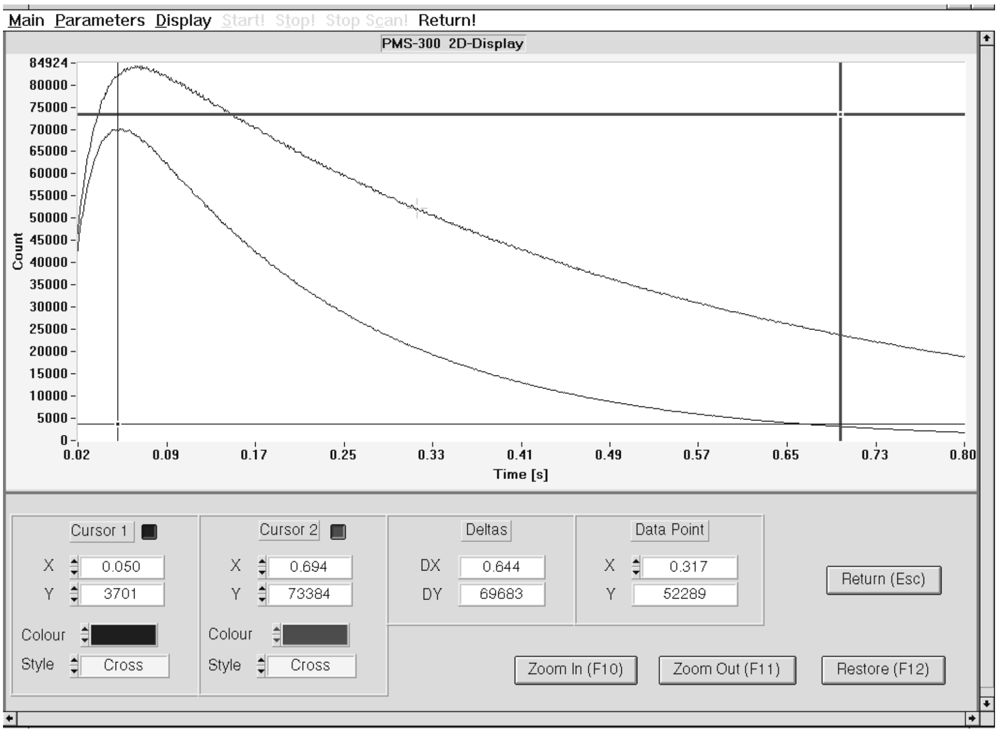
Display

'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.

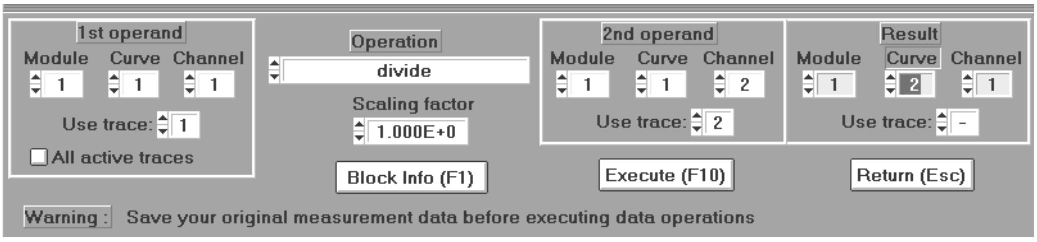
Zoom Function

'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 PMS 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 after a correct termination.

Stop Scan

Stop scan is used to stop the recording of spectra or other measurements with a step motor action after each curve point. In the ‘Stop Scan’ state the button changes into ‘Start Scan’. The measurement is continued when 'Start Scan' is pressed.

Exit

The PMS 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.

The PMS Data File Format

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 PMS 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 each data block
long	meas_desc_block_offset	offset to 1st. measurement description block (sytem 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
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          : _PMS 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 PMS system (up to four modules 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. If a parameter is missing in the setup part, a default value is used when the file is loaded. A typical setup section 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,STP.CFG]
 #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,1]
 #PR [PR_COL_TIME,F,0.0001]
 #PR [PR_POINTS,I,65536]
 #PR [PR_ACCUM,B,0]
 #PR [PR_STEPS,I,100]
 #PR [PR_REP_TIME,F,0]
 #PR [PR_CURVES,I,1]
 #PR [PR_FCURVE,I,1]
 #PR [PR_REPEAT,B,0]
 #PR [PR_ALL_TIME,F,10]
 #PR [PR_ASAVE,I,0]
 #PR [PR_FNAME,S,file1.sdt]
 #PR [PR_CYCLES,I,0]
 #PR [PR_DIS_TIME,F,10]
 #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,1]
 #PR [PR_DEV_STE2,F,1]
 #PR [PR_DEV_ACTIVE,I,0]
 #PR [PR_START_ACT,U,983055]
 #PR [PR_POINT_ACT,U,983055]
 #PR [PR_STEP_ACT,U,983055]
 #PR [PR_CURVE_ACT,U,983055]
 #PR [PR_CYCLE_ACT,U,983055]
 #PR [PR_STOP_ACT,U,131074]
 #DI [DI_SCALE,I,0]
 #DI [DI_MAXCNT,M,10000]
 #DI [DI_LBLINE,M,1]
 #DI [DI_BLINE,M,0]
 #DI [DI_GCOL_B,I,1]
 #DI [DI_GRID,B,0]
 #DI [DI_GCOL_F,I,8]
 #DI [DI_TRSTYL,I,0]
 #DI [DI_TRNO,I,2]
 #DI [DI_PSTYLE,I,0]
 #DI [DI_PFREQ,I,1]
 #DI [DI_2DC1,B,1]
 #DI [DI_2DC2,B,1]
 #DI [DI_2DC1C,I,13]
 #DI [DI_2DC2C,I,14]
 #DI [DI_2DC1S,I,0]
 #DI [DI_2DC2S,I,0]
 #MP0 [MP_BASE,I,896]
 #MP0 [MP_ACTIVE,B,1]
 #MP0 [MP_MODE,I,0]
 #MP0 [MP_ENABLE_MEAS,B,1]
 #MP0 [MP_TRIGGER,I,0]
#MP0 [MP_GATE_A,F,2]
#MP0 [MP_GATE_B,F,2]
#MP0 [MP_INP_THR_A,F,0.13779527]
#MP0 [MP_INP_THR_B,F,-0.21653543]
#MP0 [MP_EVENT_THR_A,G,1]
#MP0 [MP_EVENT_THR_B,G,1]
#MP0 [MP_COL_TIME,F,0.0001]
#MP0 [MP_ALL_TIME,F,10]
SYS_PARA_END:
TRACE_PARA_BEGIN:
#TR #0 [1,15,0,0,1]
#TR #1 [1,14,0,1,1]
#TR #2 [0,15,0,0,1]
#TR #3 [0,5,0,1,1]
#TR #4 [0,5,0,0,1]
#TR #5 [0,6,0,1,1]
#TR #6 [0,7,0,0,1]
#TR #7 [0,8,0,1,1]
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
short       meas_mode;
U_SHORT     points;               length of data
U_SHORT     no_of_accum_curves;
short       first_curve;
short       curves;
float       col_time;             collection time interval
float       rep_time;
short       repeat;
U_SHORT     cycles;               acquire cycles
float       all_time;
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	gate_level;	gate discriminator level
float	inp_threshold;	input threshold level
U_SHORT	event_threshold;	
int	events_no;	
float	reserved2;	

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 interpretation of the data depends on the measurement mode in which the block was measured (‘meas_mode’ field in the proper measurement description block).

For the multiscaler mode 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]

For the ‘Event Mode’ the first half of the data block contains the 32-bit counter values of the subsequent events up to the number of events defined in the block header extension (field ‘events_no’). The second half of the data block contains the ‘Macro Time’ (in seconds) of the subsequent events stored as float values (4 bytes).

unsigned long	counter_value_of_event[0]
unsigned long	counter_value_of_event [1]
.	.
.	counter_value_of_event [events_no-1]
unsigned long	not_valid_point[events_no] *)
.	.
unsigned long	not_valid_point[data_block_length/8 -1] *)
float	time_value_of_event [0]
float	time_value_of_event [1]
.	time_value_of_event [events_no-1]

*) If events_no is less than data_block_length/8, there will be no valid bytes after the last event counter value up to the half of the data where events time information begins.

Trouble Shooting

Although we believe that our PMS 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 PMS 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 PMS 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. This happens when your body is electrically charged and you touch a sensitive part of the PMS module. To avoid damage due to electrostatic discharge we recommend to follow the rules given below:

Before inserting a PMS module into a computer, you should touch the computer at a metallic (grounded) part to drain a possible charge of 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 PMS module.

There are extreme situations (especially in heated rooms in the winter) where 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 PMS module when the high voltage is switched on! Never connect a photomultiplier to the PMS module if the high voltage was switched on before with the PMT output left open! Never use switchable attenuators between the PMT and the PMS! 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 PMS the cable is discharged into the PMS 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.

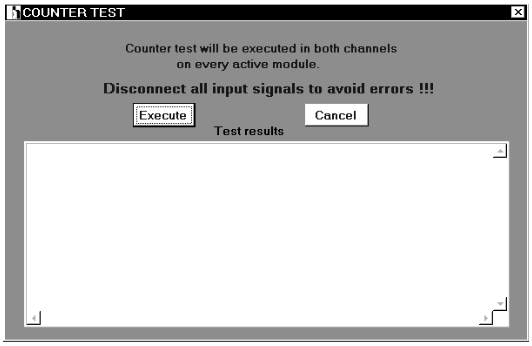
Please be careful when working with low repetition rate lasers. Most of these lasers deliver so high pulse energies, that a photodiode can switch into a breakthrough state and deliver an extremely high current for hundreds of ns. Even PMTs can deliver pulses of several 100 mA when they are hit by the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

Software Testing Facilities

Interface, Registers and DACs

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

Counter Test

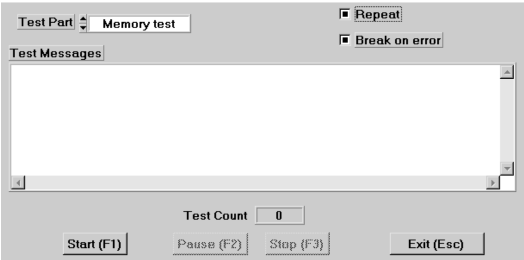


To test the input comparators, gates and counters the ‘Counter Test’ function is implemented (‘Software’, ‘Functions in the Menu Bar’). The counter test internally applies pulses to the gate and count inputs for different threshold settings and checks the corresponding counter results. To run the Counter Test, all external signals must be disconnected.

If the Counter Test does not return errors it is very unlikely that the module is damaged. The only parts that remains untested are the input protection resistors and diodes. However, these parts can be destroyed only by extreme overload, and it is unlikely that the overload protection is destroyed while the comparators are still working.

Memory Test

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



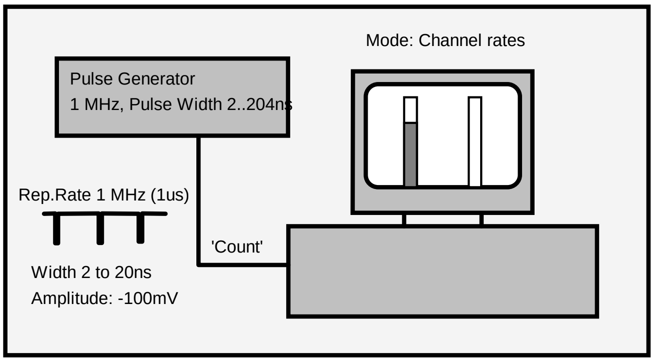
Switch on ‘All Parts’, ‘Repeat’ and ‘Break on Error’ and start the test. If the program performs several test loops (indicated by ‘Test Count’) without indicating an error you may be sure that the memory of the module works correctly. Depending on the speed of the computer, it can take some 10 s to run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

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

Tests with a Pulse Generator

Test for General Function

These test requires a pulse generators with a pulse width of 2 to 20 ns and a repetition rate of 16 MHz and 1 MHz respectively. A simple test setup is shown below.



The pulses from the pulse generator are applied to one Count input of the PMS. The Gate input is left open. The PMS is operated in the 'Channel Rates' mode with

Module Parameters and Measurement Control
Time per Point = 1s
Accumulate = OFF
Repeat = ON
Repeat after 0 s
Trigger Condition = NONE
Inp. Thresh. = -0.05 V
Gate Threshold = -2V for 'Active High Configuration'
Gate Threshold = +2V for 'Active Low Configuration'

Display Parameters
Scale Y = Logarithmic
Max Count = 10^7
Log Baseline = 1

Trace Parameters
Trace 1: Active, Module 0, Curve 1, Channel A, Colour different from background
Trace 2: Active, Module 0, Curve 1, Channel B, Colour different from background

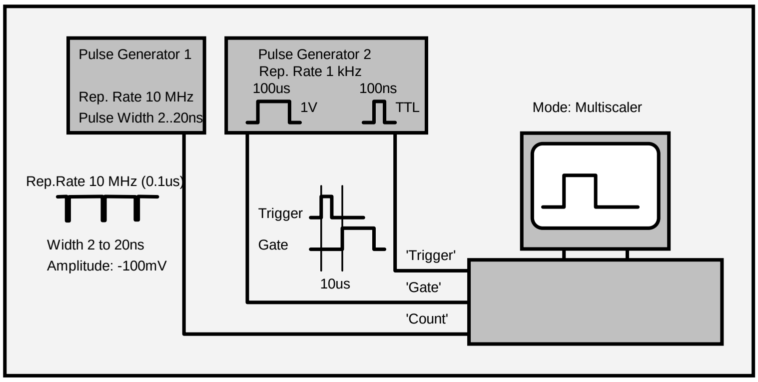
Configure Menu
Record 1 Curve starting from Curve 1
Repeat sequence after 0s

After starting the measurement the count rate bar of the used channel should indicate about 10^6 counts. Now change the pulse repetition rate - the result should follow the rate of the generator.

To test the gates reverse the polarity of the Gate Threshold. This closes the gate so that the counting result should drop to zero.

Test for Gating and Triggering

A complete test for counting, gating and triggering can be done in the setup shown below. This test requires two pulse generators. One of them must have two channels or an additional trigger output. Due to the complexity of the setup this test is recommended only under very special circumstances.



Use the following settings for the test:

Module Parameters and Measurement Control
Time per Point = 250ns
Points = 1000
Repeat = ON
Accumulate ON, 100 Sweeps
Display 'Each Curve'
Repeat after 0 s
Trigger Condition = Rising Edge
Inp. Thresh. = -0.05 V
Gate Threshold = +200mV, 'Active High Configuration'

Display Parameters
Scale Y = Logarithmic
Max Count = 1000
Log Baseline = 1

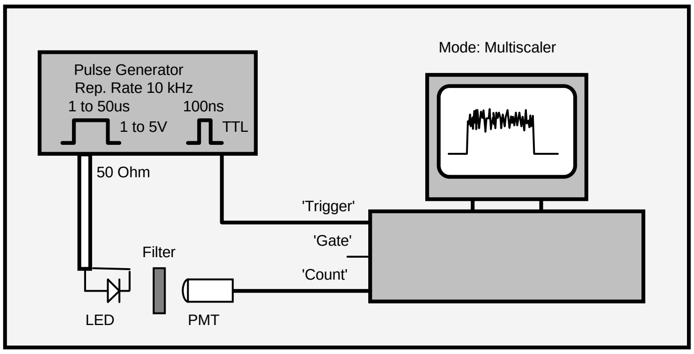
Trace Parameters
Trace 1: Active, Module 0, Curve 1, Channel A, Colour different from background
Trace 2: Active, Module 0, Curve 1, Channel B, Colour different from background

Configure Menu
Record 1 Curve starting from Curve 1
Repeat sequence after 0s

When the measurement is started the 'Triggered' indicator should turn on. The PMS should count the pulses from Generator 1 inside the gate pulse from Generator 2. With the recommended settings the result should be a rectangular pulse with the width of the gate pulse and with an upper level of approximately 200 counts. Some fluctuations are possible due to interference between the pulse generators.

Test with a PMT

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



The recommended PMS settings are:

Module Parameters and Measurement Control
Time per Point = 250ns
Points = 1000
Repeat = ON
Accumulate ON, 100 Sweeps
Display 'Each Curve'
Repeat after 0 s
Trigger Condition = Rising Edge
Inp. Thresh. = -0.05 V (depends on detector)
Gate Threshold =+100mV, 'Active High Configuration'

Display Parameters
Scale Y = Logarithmic
Max Count = 1000
Log Baseline = 1

Trace Parameters
Trace 1: Active, Module 0, Curve 1, Channel A, Colour different from background
Trace 2: Active, Module 0, Curve 1, Channel B, Colour different from background

Configure Menu
Record 1 Curve starting from Curve 1
Repeat sequence after 0s

Frequently Encountered Problems

The module is not found by the PMS software

Check the address in the PMS.INI file and the setting of the DIP switch on the PMS 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.

Check that the module is correctly inserted. Especially when moving the computer the module can work loose. Furthermore, the connectors can have some longitudinal play which can cause problems for PCI connectors. Make sure that the bus connector is clean. If necessary, clean with ethanol, isopropanol or acetone.

If you work with Windows NT: Is the correct software version installed? Was the software installed under Windows NT? Installing the software under Windows 98 and working under Windows NT is not possible.

No counts in the Channel Rates Mode

Run the 'Counter Test' (you find it under 'Main'). For the test, the input signals must be disconnected. If the counter test does not show errors, the module is most likely not the reason of the problem.

Check the Input Thresholds. To make sure that you are using appropriate values, check the SER of your PMT. (see 'Checking the SER of PMTs).

Switch on 'Repeat', check the 'Time per Point' setting.

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.

Gate is not used: Check the gate polarity (by 'Counter Test') and the Gate Threshold. For Gate Polarity 'Active Low' the Gate Threshold must be positive, for Gate Polarity 'Active High' the Gate Threshold must be negative.

Gate is used: Check the gate polarity (by 'Counter Test') and the Gate Threshold.

Check the gate signal by an oscilloscope. (Don’t forget to switch the input impedance to 50 Ω)

Trigger is not used: Check that ‘Trigger Condition’ is ‘none’

Trigger is used: Does the PMS trigger? The trigger indicator must turn on. If it doesn’t, check your trigger signal.

No curves on the screen in the Multiscaler Mode

Does the PMS display results in the Channel Rates mode? If not, refer to the previous section.

Check the Input Thresholds.

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

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.

Gate is not used: Check the gate polarity (by ‘Counter Test’) and the Gate Threshold. For Gate Polarity ‘Active Low’ the Gate Threshold must be positive, for Gate Polarity ‘Active High’ the Gate Threshold must be negative.

Gate is used: Check the gate polarity (by ‘Counter Test’) and the Gate Threshold.

Check the gate signal by an oscilloscope. Don’t forget to switch the input impedance to 50 Ω.

In the Multiscaler mode usually the trigger is used. Does the PMS trigger? The trigger indicator must turn on. If it doesn’t, check your trigger signal.

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

You display another curve than you are measuring. Check the trace parameters as described above.

Ripple or waves in the curves

Check your Trigger signal. It should not exceed the range from 0V to +5V.

Keep the trigger cable and the cables to the count inputs 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 to 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 PMS is triggered correctly. Check the trigger signal and the 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 PMS 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 dark

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 often 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 PMS. These cables often act as antennas and introduce strong noise signals into the system.

Check for faulty 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 reflections in cables.

Keep the detector as cool as possible.

Make sure that the detector does not detect daylight.

Crosstalk between Channels

Input threshold too close to zero. Please note that there can be an offset of some 10mV due to DC currents flowing in ground loops.

Check the system for ground loops. Check for faulty cables.

Insufficient Sensitivity

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

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

Preamplifier / Detector does not work when powered from the PMS

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

Assistance through bh

We are pleased to assist you in case of problems associated with your PMS 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
PMS 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
Gate Signal Generation: Photodiode, Amplitude, Rise Time
Optical System: Basic Setup, Sample, Monochromator
System Connections: Cable Lengths, Ground Connections. Add a drawing if necessary.
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 PMS-300

Counting Inputs	
Number of Channels	2
Input Pulse Polarity	positive or negative (configurable)
Input Pulse Amplitude	10 mV ... 1 V (Preamplifiers available)
Input Connector / Impedance	SMA / 50 Ω
Input Threshold	-1V ... +1V, Resolution 9 bit
Gate Signals	
Configuration	separate inputs for both channels
Input Pulse Polarity	positive or negative (configurable)
Gate Pulse Amplitude	20 mV ... 2 V (Preamplifiers available)
Input Connector / Impedance	SMA / 50 Ω
Input Threshold	-2 V ... +2 V, Resolution 9 bit
Gate Pulse Width	min. 1 ns at 200 mV p-p
Counters	
Number of Channels	2
Count Rate	>800 MHz at 50 mV p-p input amplitude
Counter Resolution	32 bit
Memory	
Memory Size	256 k bytes for each channel
No. of Time Channels (Multiscaler)	64 k
No. of Events (Event Mode, Memory)	32 k
Measurement Control	
Internal Timer	Common Timer for both channels
Collection Time	0.2 µs ... 100 000 s
Time/Channel (Multiscaler)	250 ns ... 100 000 s
Time Resolution in Event Mode	min. 250 ns
Trigger	TTL/CMOS, pos. or neg. Edge
Trigger Pulse Width (Pulse Amplitude > 3 V)	min. 5 ns
Optional External Control Signals	/Disable Arm (Input, TTL/CMOS) /Disable Collect (Input, TTL/CMOS) Armed (Output, TTL/CMOS) Collect (Output, TTL/CMOS)
PC Interface	
Module Access	via I/O only
Parallel Operation of several Modules	up to four modules, via common programmable SYNC Address
Bus Connection	ISA 16 bit
Power Consumption	approx. 8 W at +5 V
Dimensions	200 x 110 mm
Maximum Ratings	
Input Voltage at Count Inputs	5V (DC), 30V (1µs)
Input Voltage at Gate Inputs	5V (DC), 30V (1µs)
Input Voltage at external Control Inputs	DC: -2V ... +7V, 1 us: -10V ... +20V
Load at Power Supply Outputs	+5 V, -5V: 100 mA +12 V: 500 mA
Power Supply Voltage	5.5 V
Ambient Temperature	60 °C

Specification PMS-400 and PMS-400A

Counting Inputs	
Number of Channels	2
Input Pulse Polarity	positive or negative (configurable)
Input Pulse Amplitude	10 mV ... 1 V (Preamplifiers available)
Input Connector / Impedance	MCX / 50 Ω
Input Threshold	-1V ... +1V, Resolution 9 bit
Gate Inputs	
Configuration	separate inputs for both channels
Input Pulse Polarity	positive or negative (configurable)
Gate Pulse Amplitude	20 mV ... 2 V (Preamplifiers available)
Input Connector / Impedance	MCX / 50 Ω
Input Threshold	-2 V ... +2 V, Resolution 9 bit
Gate Pulse Width	min. 1 ns at 200 mV p-p
Trigger Input	
Input Pulse Polarity	positive or negative
Trigger Pulse Amplitude	20 mV ... 2 V (Preamplifiers available)
Input Connector / Impedance	MCX / 50 Ω
Input Threshold	-2 V ... +2 V, Resolution 9 bit
Trigger Pulse Width	min. 1 ns at 200 mV p-p
Counters	
Number of Channels	2
Count Rate	>800 MHz at 50 mV p-p input amplitude
Counter Resolution	32 bit
Memory	
Memory Size	256 k bytes for each channel
No. of Time Channels (Multiscaler)	64 k
No. of Events (Event Mode, Memory)	32 k
Measurement Control	
Internal Timer	Common Timer for both channels
Collection Time	0.2 µs ... 100 000 s
Time/Channel (Multiscaler)	250 ns ... 100 000 s
Time Resolution in Event Mode	min. 250 ns
Trigger	TTL/CMOS, pos. or neg. Edge
Trigger Pulse Width (Pulse Amplitude > 3 V)	min. 5 ns
Optional External Control Signals	/Disable Arm (Input, TTL/CMOS) /Disable Collect (Input, TTL/CMOS) Armed (Output, TTL/CMOS) Collect (Output, TTL/CMOS)
PC Interface	
Module Access	via I/O only
Parallel Operation of several Modules	up to four modules
Bus Interface	PCI
Power Consumption	approx. 8 W at +5 V
Dimensions	200 x 110 mm
Maximum Ratings	
Input Voltage at Count Inputs	5V (DC), 30V (1µs)
Input Voltage at Gate Inputs	5V (DC), 30V (1µs)
Input Voltage at Trigger Input	5V (DC), 30V (1µs)
Input Voltage at external Control Inputs	DC: -2V ... +7V, 1 us: -10V ... +20V
Load at Power Supply Outputs	+5 V, -5V: 100 mA +12 V: 500 mA
Power Supply Voltage	5.5 V
Ambient Temperature	60 °C

Options

The options listed below are available and work with the PMS-300 and PMS-400. Please see individual data sheets or http://www.becker-hickl.de

PMH-100 High Speed PMT Head

PMC-100 High Speed Cooled PMT Head

Hamamatsu H7422P photosensor modules

DCC-100 Detector Control Module

ACA-xx Wideband Preamplifiers, up to 32 dB, 2 GHz

HFAC-26 Wideband Preamplifier for PMTs, with Current Monitoring, 26 dB, 1.6 GHz

DC stable Wideband Amplifier DCA-xx, up to 20 dB, 500 MHz

Step Motor Controller STP-340, for unipolar Motors up to 1 A phase current

PHD-400 and PDM-400 High Speed PIN photodiode modules (for gating)

APM-400 Avalanche Photodiode Modules (for gating)

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