PicoHarp 300

Picosecond Histogram Accumulating
Real–time Processor

PicoQuant GmbH
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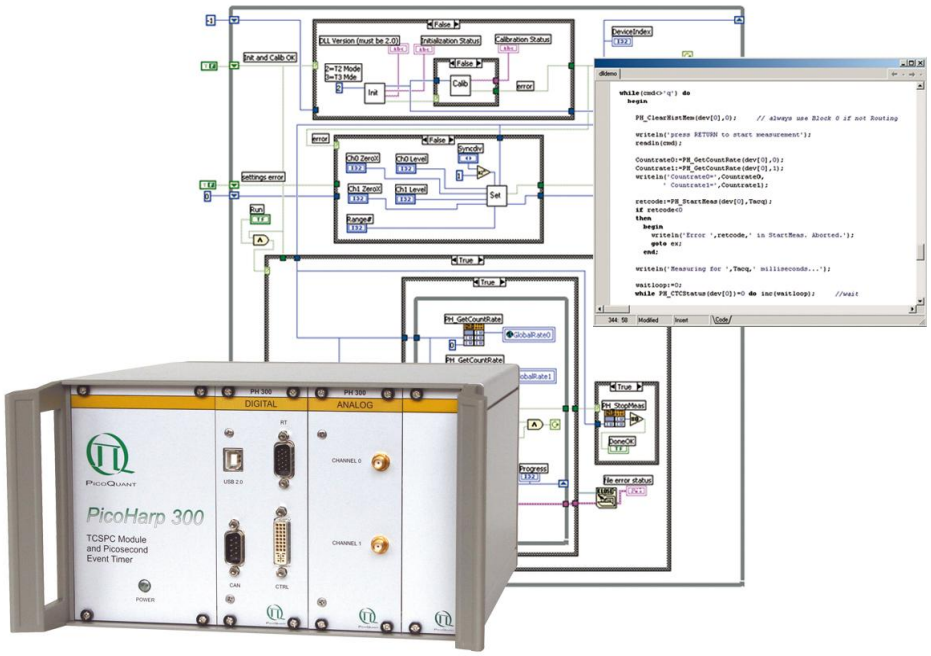
Forschung und Entwicklung

PHLib – Programming Library
for Custom Software Development



User's Manual

Version 3.0 – December 2013

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1. Introduction

The PicoHarp 300 is a compact easy–to–use TCSPC system with USB interface. It includes all components traditionally contained in bulky racks. Its integrated design keeps cost down, improves reliability and simplifies calibration. The circuit allows high measurement rates up to 10 Mcounts/s and provides a time resolution of 4 ps. The input channels are programmable for a wide range of input signals. They both have programmable Constant Fraction Discriminators (CFD). These specifications qualify the PicoHarp 300 for use with all common single photon detectors such as Single Photon Avalanche Photodiodes (SPAD), Photo Multiplier Tubes (PMT) and MCP–PMT modules (PMT and MCP–PMT via preamp). The time resolution is well matched to these detectors and the overall Instrument Response Function (IRF) will not be limited by the PicoHarp electronics. Similarly inexpensive and easy–to–use diode lasers such as the PDL 800–B with interchangeable laser heads can be used as an excitation source perfectly matched to the time resolution offered by the detector and the electronics. Overall IRF widths of 200 ps FWHM can be achieved with inexpensive PMTs and diode lasers. Down to 50 ps can be achieved with selected diode lasers and MCP–PMT detectors. 30 ps can be reached with femtosecond lasers. This permits lifetime measurements down to a few picoseconds with deconvolution e.g. via the FluoFit multi–exponential Fluorescence Decay Fit Software. For more information on the PicoHarp 300 hardware and software please consult the PicoHarp 300 manual. For details on the method of Time–Correlated Single Photon Counting, please refer to our TechNote on TCSPC.

The PicoHarp 300 standard software provides functions such as the setting of measurement parameters, display of results, loading and saving of measurement parameters and histogram curves. Important measurement characteristics such as count rate, count maximum and position, histogram width (FWHM) are displayed continuously. While these features will meet many of the routine demands, advanced users may want to include the PicoHarp's functionality in their own automated measurement systems with their own software. In particular where the measurement must be interlinked or synchronized with other processes or instruments this approach may be of interest. For this purpose a programming library is provided as a Dynamic Link Library (DLL) for Windows XP, Vista, 7 and 8. The library '`PHLib.dll`' supports custom programming in all major programming languages, notably C/C++, C#, Pascal (Delphi/Lazarus), MATLAB and LabVIEW. This manual describes the installation and use of the PicoHarp programming library `PHLib.dll` and explains the associated demo programs. Please read both this manual and the PicoHarp manual before beginning your own software development with the DLL. The PicoHarp 300 is a sophisticated real–time measurement system. In order to work with the system using the DLL, sound knowledge in your chosen programming language is required.

There is also a library version for Linux. Please refer to the separate manual for this version.

2. General Notes

This version of the PicoHarp 300 programming library is suitable for Windows XP, Vista, 7 and 8. The x64 editions of Windows are also supported.

The library has been tested with applications built under MinGW 4.5.0, MSVC++ 6.0, MSVC++ 2010, Borland C++ 5.5, Visual C# 2010 , Mono 2.10.8 as well as Delphi XE5, Lazarus 1.1 (Freepascal 2.7.1), LabView 8.0, and MATLAB 7.3.

This manual assumes that you have read the PicoHarp 300 manual and that you have experience with the chosen programming language. References to the PicoHarp manual will be made where necessary.

This version of the library supports histogramming mode and both TTTR modes.

Users who purchased a license for any older version of the library will receive free updates when they are available. For this purpose, please register by sending email to *info@picoquant.com*. with your name, your PicoHarp 300 serial number and the email address you wish to have the update information sent to.

Users upgrading from earlier versions of the PicoHarp 300 DLL need to adapt their programs. Some changes are usually necessary to accommodate new measurement modes and improvements. However, the required changes are usually minimal and will be explained in the manual (especially check section 6.1 and the notes marked in red in section 9.2).

Note that despite of our efforts to keep changes minimal, data structures, program flow and function calls may still change in future versions without advance notice. Users must maintain appropriate version checking in order to avoid incompatibilities. There is a function call tat you can use to retrieve the version number (see section 9.2). Note that this call returns only the major two digits of the version (e.g. 3.0). The DLL actually has two further sub–version digits, so that the complete version number has four digits (e.g. 3.0.0.0). They are shown only in the Windows file properties. These sub–digits help to identify intermediate versions that may have been released for minor updates or bug fixes. The interface of releases with identical major version will remain the same.

2.1. Warranty and Legal Terms

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3. Firmware Update

Note: You can skip this section if you bought your PicoHarp with the DLL option readily installed.

The PicoHarp 300 programming library requires a firmware update of your PicoHarp 300, unless you already bought it with the DLL option installed. The update is performed by `PHupdate.exe`. This file is provided to you (typically by download link) only if you purchased an upgrade for the DLL option. It is compiled specifically for the serial number of your PicoHarp and cannot be used on others. The firmware update only needs to be done once. If necessary, perform the following steps to install the update:

(see your PicoHarp manual for steps 1..3 listed below)

1. Make sure your PicoHarp 300 is powered and connected correctly through USB 2.0.
2. Check that the standard PicoHarp 300 software runs correctly.
3. Make sure to exit the PicoHarp 300 software.
4. Unpack `PHupdate.exe` to a temporary disk location.
5. Start the program `PHupdate.exe` from the temporary disk location.
6. Follow the instructions. Do not interrupt the actual update progress, it may take a minute or so. The program will report successful completion.

After successful completion of the upgrade your PicoHarp is ready to use the DLL. At this point you may still need to install the DLL package on your PC. See the sections below for hints how to install and use the library.

4. Installation of the PHLib Software Package

PHLib and its demos will not be installed by the standard PicoHarp 300 software setup. The standard "interactive" PicoHarp 300 data acquisition software does not require the DLL, which is provided for custom application programming only. Vice versa, your custom program will only require the DLL and driver, but not the standard PicoHarp 300 data acquisition software. Installing both the standard PicoHarp software and DLL–based custom programs on the same computer is possible, but only one program at a time can use the PicoHarp 300.

To install PHLib, please back up your work, then disconnect the PicoHarp device(s) and uninstall any previous versions of PHLib. Then run the setup program SETUP.EXE in the PHLib folder on the installation CD. If you received the setup files as a ZIP archive, please unpack them to a temporary directory on your hard disk and run `SETUP.EXE` from there. On recent versions of Windows you may need administrator rights to perform the setup. If the setup is performed by an administrator but used from other accounts without full access permission to all disk locations, these restricted accounts may not be able to run the demos in the default locations they have been installed to. In such cases it is recommended that you copy the demo directory (or selected files from it) to a dedicated development directory, in which you have the necessary rights (e.g. in 'My Documents').

The programming library will access the PicoHarp 300 through a dedicated device driver. The driver is preinstalled (or updated) by both the standard PicoHarp software installer as well as the PHLib installer. It will then be detected and installed by standard Windows Plug&Play mechanisms. Dependent on the Windows version you use you may be prompted one more time for confirmation of the driver installation when the device is connected for the first time. Both the standard PicoHarp software distribution as well as the PHLib distribution media contain the driver and you can, if need be, install it manually from there.

You also need to install the PicoHarp 300 hardware and connect it with your signal sources, if you have not done so before (see your PicoHarp manual).

Starting from version 2.0 multiple devices can be controlled through PHLib. After connecting the device(s) you can use the Windows Device Manager to check if they have been detected (under the USB tree) and the driver is correctly installed. On some Windows versions you may need administrator rights to perform setup tasks. Refer to your PicoHarp 300 manual for other installation details.

It is recommended to start your work with the PicoHarp 300 by using the standard interactive PicoHarp data acquisition software. This should give you a better understanding of the system's operation before attempting your own programming efforts. It also ensures that your optical/electrical setup is working. If you are planning to use a router, try to get everything working without router first to avoid additional complications. See the subfolder DEMOS in your PHLib installation folder for sample code that can be used as a starting point for your own programs.

5. New in this Version

Version 3.0 of the library package constitutes a major overhaul with respect to the previous version 2.3. It provides new routines to change the time offset of the input channels, which eliminates the need for cable delay adjustments. There are also new routines to obtain information on hardware features and debug information. Furthermore, there is now a programmable holdoff time for marker signals in TTTR mode and the markers can be enabled/disabled individually. Multistop in histogramming and T3 mode can now be disabled if necessary. Finally, the policy of return values has been changed to carry only error/success information and never any other data. The latter are now always passed by reference. The new and changed routines are marked in red in section 9.2.

The demo set no longer contains source code for Visual Basic. If you still need to program in Visual Basic you may want to take the demos from the previous version 2.3 as a starting point and adapt them to the changes shown in section 9.2. If you do not have the old distribution you can request it by email.

6. The Demo Applications

6.1. Functional Overview

Please note that all demo code provided is correct to our best knowledge, however, we must disclaim all warranties as to fitness for a particular purpose of this code. It is provided 'as is' for no more than explanatory purposes and a starting point for your own work.

The demos are kept as simple as possible to maintain focus on the key issues of accessing the library. This is why most of the demos have a minimalistic user interface and / or run from a simple command box (console). For the same reason, the measurement parameters are mostly hard–coded and thereby fixed at compile time. It may therefore be necessary to change the source code and re–compile the demos in order to run them in a way that is matched to your individual measurement setup. Running them unmodified may result in useless data (or none at all) because of inappropriate sync divider, resolution, input level settings, etc.

For the same reason of simplicity, the demos will always only use the first PicoHarp device they find, although the library can support multiple devices. If you have multiple devices that you want to use simultaneously you need to change the code to match your configuration.

There are demos for C / C++, C#, Pascal / Delphi / Lazarus, LabVIEW and MATLAB. For each of these programming languages / systems there are different demo versions for various measurement modes:

Standard Mode Demos

These demos show how to use the standard measurement mode for on–board histogramming. These are the simplest demos and the best starting point for your own experiments. In case of LabVIEW the standard mode demo is already fairly sophisticated and allows interactive input of most parameters. The standard mode demos will not initialize or use a router that may be present. Please do not connect a router for these demos.

Routing Demos

Multi channel measurement (routing) is possible in standard histogramming mode and in TTTR mode. It requires that a PHR 40x or PHR 800 router and multiple detectors are connected. The routing demos show how to perform such measurements in histogramming mode and how to access the histogram data of the individual detector channels. The concept of routing in histogramming mode is quite simple and similar to standard histogramming. In T3 mode it is also very simple using the same library routines. Therefore, no dedicated demo is provided for routing in T3 mode. To get started see the section about routing in your PicoHarp 300 manual.

TTTR Mode Demos

These demos show how to use TTTR mode, i.e. recording individual photon events instead of forming histograms on board. This permits extremely sophisticated data analysis methods, such as single molecule burst detection, the combination of fluorescence lifetime measurement with FCS and picosecond coincidence correlation.

The PicoHarp 300 actually supports two different Time–Tagging modes, T2 and T3 mode. When referring to both modes together we use the general term TTTR here. For details on the two modes, please refer to your PicoHarp manual. TTTR mode always implicitly performs routing if a router and multiple detectors are used. It is also possible to record external TTL signal transitions as markers in the TTTR data stream (see the PicoHarp manual).

Note: TTTR mode is not part of the standard PicoHarp product. It must be purchased as a separate firmware option that gets burned into the ROM of the board. An upgrade is possible at any time. It always includes both T2 and T3 mode.

Because TTTR mode requires real–time processing and/or real–time storing of data, the TTTR demos are fairly demanding both in programming skills and computer performance. See the section about TTTR mode in your PicoHarp manual.

6.2. The Demo Applications by Programming Language

As outlined above, there are demos for C / C++, C#, Pascal / Delphi / Lazarus, LabVIEW, and MATLAB. For each of these programming languages/systems there are different demo versions for the measurement modes listed in the previous section. They are not 100% identical.

This manual explains the special aspects of using the PicoHarp programming library, it does NOT teach you how to program in the chosen programming language. We strongly recommend that you do not choose a development with the PicoHarp programming library as your first attempt at programming. You can find some general hints on how to call the library routines from the various programming languages in the individual language specific folders (See '`Calling.txt`' files). The ultimate reference for details about how to use the DLL is in any case the source code of the demos and the header files of PHLib (`phlib.h` and `phdefin.h`).

Be warned that wrong parameters and / or variables, invalid pointers and buffer sizes, inappropriate calling sequences etc. may crash your application and / or your complete computer. This may even be the case for relatively safe operating systems such as Windows XP and later, because you are accessing a kernel mode driver through `PHLib.dll`. This driver has high privileges at kernel level, that provide all power to do damage if used inappropriately. We tried hard to protect against all thinkable mistakes but cannot foresee all possible sorts of inappropriate use. Make sure to backup your data and / or perform your development work on a dedicated machine that does not contain valuable data. Note that the DLL is not generally re-entrant. This means, it cannot be accessed from multiple, concurrent processes or threads at the same time. All calls must be made sequentially in the order shown in the demos, at least when accessing the same hardware device. This is not a matter of poor design. It follows from the fact that the hardware is in itself a state machine that must be programmed in an orderly fashion.

The C / C++ Demos

The demos are provided in the '`\C`' subfolder. The code is actually plain C to provide the smallest common denominator for C and C++. Consult `phlib.h, phdefin.h` and this manual for reference on the library calls. The library functions must be declared as `extern "C"` when used from C++. This is achieved most elegantly by wrapping the entire include statements for the library headers:

```
extern "C"
{
#include "phdefin.h"
#include "phlib.h"
}
```

In order to make the exports of `PHLib.dll` known to the rest of your application you may use `PHLib.exp` or link directly with the import library `PHLib.lib`. `PHLib.lib` was created with symbols decorated in Microsoft style. MSVC++ users who have version 5.0 or higher can use the supplied project files (`*.dsw`) where linking with `PHLib.lib` is already set up. The DLL also (additionally) exports all symbols undecorated, so that other compilers should be able to use them conveniently, provided they understand the Microsoft LIB format or they can create their own import library. The MinGW compiler understands the Microsoft format. With Borland C++ 5.x and C++Builder you can use the Borland Utility IMPLIB to create your own import library very easily:

```
implib PHLib_bc.lib PHLib.dll
```

It is normal if this gives you warnings about duplicate symbols. Then you link your project with `PHLib_bc.lib`. Failing to work with an import library you may still load the DLL dynamically and call the functions explicitly.

To test any of the demos, consult the PicoHarp manual for setting up your PicoHarp 300 and establish a measurement setup that runs correctly and generates useable test data. Compare the settings (notably sync divider, range and CFD levels) with those used in the demo and use the values that work in your setup when building and testing the demos.

The C demos are designed to run in a console ("DOS box"). They need no command line input parameters. They create their output files in their current working directory (*.out). The output files will be ASCII in case of the standard histogramming demos. The ASCII files will contain single or multiple columns of integer numbers representing the counts from the 4,096 histogram channels. You can use any editor or a data visualization program to inspect the ASCII histograms. For the TTTR modes the output is stored in binary format for performance reasons. The binary files must be read by dedicated programs according to the format they were written in. The file read demos provided for the PicoHarp TTTR data files can be used as a starting point. They cannot be used directly on the demo output because they expect a file header the demos do not generate. This is intentional in order to keep the PHLib demos focused on the key issues of using the library.

By default, the TTTR mode demo is configured for T2 mode. You need to change the mode input variable going into PH_Initialize to a value of 3 if you want T3 mode. Note that you probably also need to adjust the sync divider and the resolution in this case.

The C# Demos

The C# demos are provided in the 'Csharp' subfolder. They have been tested with MS Visual Studio 2010 as well as with Mono under Windows and Linux. The only difference is the library name, which in principle could also be unified.

Calling a native DLL (unmanaged code) from C# requires the `DllImport` attribute and correct type specification of the parameters. Not all types are easily portable. Especially C strings require special handling. See Calling.txt.

With the C# demos you also need to check wether the hardcoded settings are suitable for your actual instrument setup. The demos are designed to run in a console ("DOS box"). They need no command line input parameters. They create their output files in their current working directory (*.out). The output files will be ASCII in case of the standard and routing demos. For continuous and TTTR mode the output is stored in binary format for performance reasons. The ASCII files will contain single or multiple columns of integer numbers representing the counts from the 4096 histogram channels. You can use any editor or a data visualization program to inspect the ASCII histograms. The binary files must be read by dedicated programs according to the format they were written in.

The Delphi / Lazarus Demos

Pascal users (Delphi or Lazarus) please refer to the 'DELPHI' directory. The source code for Delphi and Lazarus is the same. Everything for the respective Delphi demo is in the project file for that demo (`*.DPR`). With most recent Delphi versions (XE5) please use the `*.DPROJ` project files. Lazarus users can use the `*.LPI` files that internally refer to the `*.DPR` files.

In order to make the exports of `PHLib.dll` known to your application you have to declare each function in your Pascal code as 'external'. This is already prepared in the demo source code. `PHLib.dll` was created in C with symbols decorated in Microsoft style. It additionally exports all symbols undecorated, so that you can call them from Delphi with the plain function name. Please check the function parameters of your code against phlib.h in the demo directory whenever you update to a new DLL version. For general reference on calling DLLs from Delphi see `calling.txt`.

The Delphi / Lazarus demos are designed to run in a console ("DOS box"). They need no command line input parameters. They create output files in their current working directory. The output files will be ASCII in case of the standard histogramming demo. In TTTR mode the output is stored in binary format for performance reasons. You can use any data visualization program to inspect the ASCII histograms. The binary files must be read by dedicated programs according to the format they were written in. The file read demos provided for the PicoHarp TTTR data files can be used as a starting point. They cannot be used directly on the demo output because they expect a file header the demos do not generate. This is intentional in order to keep the PHLib demos focused on the key issues of using the library.

By default, the TTTR mode demo is configured for T2 mode. This will not allow you to work with high sync rates. You need to change the mode input variable going into PH_Initialize to a value of 3 if you want T3 mode. At the same time you need to modify your program for an appropriate sync divider and a suitable range (resolution).

The LabVIEW Demos

The LabVIEW demo VIs are provided in the 'LABVIEW' directory. They are contained in LabVIEW libraries (`*.llb`). The top–level VI is always 'PicoHarp.vi'. Note that the sub–VIs in the various demos are not always identical, even though their names may be the same. You need to use at least LabVIEW 8.0.

The LabVIEW demos are the most sophisticated demos here. The standard mode demo resembles the standard PicoHarp software with input fields for all settable parameters. Run the top–level VI PicoHarp.vi. It will first initialize and calibrate the hardware. The status of initialization and calibration will be shown in the top left display area. Make sure you have a running TCSPC setup with sync and detector correctly connected. You can then adjust the sync level until you see the expected sync rate in the meter below. Then you can click the Run button below the histogram display area. The demo implements a simple Oscilloscope mode of the PicoHarp. Make sure to set an acquisition time of not much more than e.g. a second, otherwise you will see nothing for a long time. If the input discriminator settings are correct you should see a histogram. You can stop the measurement with the same (Run) button.

The TTTR mode demo for LabVIEW is a little simpler. It provides the same panel elements for setting parameters etc. but there is no graphic display of results. Instead, all data is stored directly to disk. By default, the TTTR mode demo is configured for T2 mode. This will not allow you to work with high sync rates. You need to change the mode input variable going into to the Initialization VI to a value of 3 if you want T3 mode. You also need to use an appropriate sync divider and a suitable range (resolution).

To run the TTTR mode demo you start PicoHarp.vi. First set up the Sync and CFD levels. You can watch the sync rate in a graphic rate meter. Then you can select a measurement time and a file name. When you click the Run button a measurement will be performed, with the data going directly to disk. There is a status indicator showing the current number of counts recorded. There is also a status LED indicating any FIFO overrun.

Internally the TTTR mode demo also deserves a special note: each TTTR record as returned in the buffer of PH_TTReadData actually is a DWORD (32bit). However, LabVIEW stores DWORD data (U32) always in big endian format. On the x86 platform (little endian) this results in reversed bytes compared to C programs. For consistency with the demo programs for reading TTTR data this byte reversing of the data going to disk is avoided in the demo by declaring the buffer for PH_TTReadData as a byte array (hence 4 times longer than the DWORD array). You may instead want to work with a U32 array if your goal is not storing data to disk but doing some on–line analysis of the TTTR records. In this case you must initialize the array with 65,536 x U32 and change the type of buffer in the library calls of PH_TTReadData to U32.

The LabVIEW demos access the DLL routines via the 'Call Library Function' of LabVIEW. For details refer to the LabVIEW application note 088 'How to Call Win32 Dynamic Link Libraries (DLLs) from LabVIEW' from National Instruments. Consult `phlib.h` or the manual section further down for the parameter types etc. Make sure to specify the correct calling convention (stdcall).

Strictly observe that the PH_xxxx library calls are not re–entrant when they address the same device. They must be made sequentially and in the right order. They cannot be called in parallel as is the default in LabVIEW if you place them side by side in a diagram. Although you can configure each library call to avoid parallel execution, this still gives no precise control over the order of execution. For some of the calls this order is very important. Sequential execution must therefore be enforced by sequence structures or data dependency. In the demos this is e.g. done by chained and/or nested case structures. This applies to all VI hierarchy levels, so sub–VIs containing library calls must also be executed in correct sequence.

The MATLAB Demos

The MATLAB demos are provided in the 'MATLAB' directory. They are contained in m–files. You need to have a MATLAB version that supports the 'calllib' function. We have tested with MATLAB 7.3 but any version from 6.5 should work. Be very careful about the header file name specified in 'loadlibrary'. This name is case sensitive and a wrong spelling will lead to an apparently successful load but later no library calls will work.

The MATLAB demos are designed to run inside the MATLAB console. They need no command line input parameters. They create output files in their current working directory. The output files will be ASCII in case of the standard histogramming demo and in case of the routing demo. In TTTR mode the output is stored in binary format for performance reasons. You can use any data visualization program to inspect the ASCII histograms. The binary files must be read by dedicated programs according to the format they were written in. The file read demos provided for the PicoHarp TTTR data files can be used as a starting point. They cannot

be used directly on the demo output because they expect a file header the demos do not generate. This is intentional in order to keep the PHLib demos focused on the key issues of using the library.

By default, the TTTR mode demo is configured for T2 mode. This will not allow you to work with high sync rates. You need to change the mode input variable going into PH_Initialize to a value of 3 if you want T3 mode. At the same time you need to modify your program for an appropriate sync divider and a suitable range (resolution).

7. Advanced Techniques

7.1. Using Multiple Devices

Starting from version 2.0 the library is designed to work with multiple PicoHarp devices (up to 8). The demos always use the first device found. If you have more than one PicoHarp and you want to use them together you need to modify the code accordingly. At the API level of PHLib the devices are distinguished by a device index (0 .. 7). The device order corresponds to the order Windows enumerates the devices. If the devices were plugged in or switched on sequentially when Windows was already up and running, the order is given by that sequence. Otherwise it can be somewhat unpredictable. It may therefore be difficult to know which physical device corresponds to the given device index. In order to solve this problem, the library routine PH_OpenDevice provides a second argument through which you can retrieve the serial number of the physical device at the given device index. Similarly you can use PH_GetSerialNumber any time later on a device you have successfully opened. The serial number of a physical PicoHarp device can be found at the back of the housing. It is a 8 digit number starting with 0100. The leading zero will not be shown in the serial number strings retrieved through PH_OpenDevice or PH_GetSerialNumber.

It is important to note that the list of devices may have gaps. If you have e.g. two PicoHarps you cannot assume to always find device 0 and 1. They may as well appear e.g. at device index 2 and 4 or any other index. Such gaps can be due to other PicoQuant devices (e.g. Sepia II) occupying some of the indices, as well as due to repeated unplugging / replugging of devices. The only thing you can rely on is that a device you hold open remains at the same index until you close or unplug it.

As outlined above, if you have more than one PicoHarp and you want to use them together you need to modify the demo code accordingly. This requires briefly the following steps: Take a look at the demo code where the loop for opening the device(s) is. In most of the demos all the available devices are opened. You may want to extend this so that you

1. filter out devices with a specific serial number and
2. do not hold open devices you don't actually need.

The latter is recommended because a device you hold open cannot be used by other programs such as the regular PicoHarp software.

By means of the device indices you picked out you can then extend the rest of the program so that every action taken on the single device is also done on all devices of interest, i.e. initialization, setting of parameters, starting a measurement etc. At the end the demos close all devices. It is recommended to keep this approach. It does no harm if you close a device that you haven't opened.

7.2. Efficient Data Transfer

The TTTR modes are designed for fast real–time data acquisition. TTTR mode is most efficient in collecting data with a maximum of information. It is therefore most likely to be used in sophisticated on–line data processing scenarios, where it may be worth optimizing data throughput.

In order to achieve the highest throughput, the PicoHarp 300 uses USB 2.0 bulk transfers. This is supported by the PC hardware that can transfer data to the host memory without much help of the CPU. For the PicoHarp this permits data throughput as high as 5 Mcps and leaves time for the host to perform other useful things, such as on–line data analysis or storing data to disk.

In TTTR mode the data transfer process is exposed to the DLL user in a single function PH_TTReadData that accepts a buffer address where the data is to be placed, and a transfer block size. This block size is critical for efficient transfers. The larger the block size, the better the transfer efficiency. This is because setting up a transfer costs some fixed amount of time, independent of the block size. The maximum transfer block size is 131,072 (128k event records). However, it may not under all circumstances be ideal to use the maximum size. The demos use a medium size of 32,768 records.

As noted above, the transfer is implemented efficiently without using the CPU excessively. Nevertheless, assuming large block sizes, the transfer takes some time. Windows therefore gives the unused CPU time to other processes or threads i.e. it waits for completion of the transfer without burning CPU time. This wait time is what can also be used for doing ‘useful things’ in terms of any desired data processing or storing

within your own application. The best way of doing this is to use multi-threading. In this case you design your program with two threads, one for collecting the data (i.e. working with PH_TTReadData) and another for processing or storing the data. Multiprocessor systems can benefit from this technique even more. Of course you need to provide an appropriate data queue between the two threads and the means of thread synchronization. Thread priorities are another issue to be considered. Finally, if your program has a graphical user interface you may need a third thread to respond to user actions reasonably fast. Again, this an advanced technique and it cannot be demonstrated in detail here. Greatest care must be taken not to access the PHLib DLL from different threads without strict control of mutual exclusion and maintaining the right sequence of function calls. However, the technique also allows throughput improvements of 50% .. 100% and advanced programmers may want to use it. It might be interesting to note that this is how TTTR mode is implemented in the regular PicoHarp software, where sustained count rates over 5 millions of counts/sec (to disk) can be achieved on modern PCs.

When working with multiple PicoHarp devices, the overall USB throughput is limited by the host controller or any hub the devices must share. You can increase overall throughput if you connect the individual devices to separate host controllers without using hubs. If you install additional USB controller cards you should prefer PCI-express models. Traditional PCI can become a bottleneck in itself. However, modern mainboards often have multiple USB host controllers, so you may not even need extra controller cards. In order to find out how many USB controllers you have and which one the individual USB sockets belong to, you can use Microsoft's tool “usbview.exe”. In case of using multiple devices it is also beneficial for overall throughput if you use multi-threading in order to fetch and store data from the individual devices in parallel. Again, re-entrance issues must be observed carefully in this case, at least for all calls accessing the same device.

7.3. Working with Very Low Count Rates

As noted above, the transfer block size is critical for efficient transfers. The larger the block size, the better the transfer efficiency. This is because setting up a transfer costs some fixed amount of time, independent of the block size. However, it may not under all circumstances be ideal to use the maximum size. A large block size takes longer to fill. If the count rates in your experiment are very low, it may be better to use a smaller block size. This ensures that the transfer function returns more promptly. It should be noted that the PicoHarp has a “watchdog” timer that terminates large transfer requests prematurely so that they do not wait forever if new data is coming very slowly. The timeout period is approximately 80 ms. This results in PH_TTReadData returning less than requested (possibly even zero). This helps to avoid complete stalls even if the maximum transfer size is used with low or zero count rates. However, for fine tuning of your application may still be of interest to use a smaller block size. The block size must be a multiple of 512. The smallest is therefore 512. The hardware rate meters used via GetCountrate employ a gate time of 100 ms. This gate time cannot be changed. The readings may therefore be inaccurate or fluctuating when the rates are low. If accurate rates are needed you must perform a full blown measurement and sum up the recorded events.

7.4. Working with Warnings

The library provides routines for obtaining and interpreting warnings about critical measurement conditions. The mechanism and warning criteria are the same as those used in the regular PicoHarp software. In order to obtain and use these warnings also in your custom software you may want to use the library routine PH_GetWarnings. This may help inexperienced users to notice possible mistakes before stating a measurement or even during the measurement.

It is important to note that the generation of warnings is dependent on the current count rates and the current measurement settings. It was decided that PH_GetWarnings does not obtain the count rates on its own, because the corresponding calls take some time and might waste too much processing time. It is therefore necessary that PH_GetCountrate has been called for all channels before PH_GetWarnings is called. Since most interactive measurement software periodically calls PH_GetCountrate anyhow, this is not a serious complication.

The routine PH_GetWarnings only delivers the cumulated warnings in the form of a bit field. In order to translate this into readable information you can use PH_GetWarningsText. Before passing the bit field into PH_GetWarningsText you can mask out individual warnings by means of the bit masks defined in phdefin.h. This may be useful if your experiment conditions are special and would permanently generate some warnings that you expect and do not care about.

8. Problems, Tips & Tricks

8.1. PC Performance Issues

Performance issues with the DLL are the same as with the standard PicoHarp software. The PicoHarp device and its software interface are a complex real–time measurement system demanding appropriate performance both from the host PC and the operating system. This is why a fairly modern CPU and sufficient memory are required. A modern PCI express graphics interface is strongly recommended. Screen resolution should be at least 800x600. At least a 1 GHz processor, 1024 MB of memory and a fast hard disk are recommended. However, as long as you do not use TTTR mode, these issues should not be of severe impact. If you do intend to use TTTR mode with real-time streaming to files you should consider a modern solid state disk.

8.2. USB Interface

In order to deliver the required throughput, the PicoHarp 300 uses USB 2.0 bulk transfers. This is why the PicoHarp must rely on having a working USB 2.0 host interface. USB 2.0 host controllers of modern PCs are usually integrated on the mainboard. For older PCs they may be upgraded as PCI cards. Throughput is usually limited by the host controller and the operating system, not the PicoHarp. Make sure that the host controller drivers are correctly installed, otherwise they may be running only in USB 1.0 mode. This may require using the mainboard manufacturer's driver disk rather than relying on Windows drivers alone. Do not run other bandwidth demanding devices on the same USB interface when working with the PicoHarp. USB cables must be rated for USB 2.0 high speed. Old cables often do not meet this requirement and can lead to errors and malfunction. The same happens when the USB 2.0 specification is violated in other ways, e.g. when the cable length exceeds 5 metres and/or obscure plugs for cable extension are used. Similarly, some PCs have poor internal USB cabling, so that USB sockets at the front of the PC are sometimes unreliable.

8.3. Troubleshooting

Troubleshooting should begin by testing your hardware and driver setup. This is best accomplished by the standard PicoHarp software for Windows (supplied by PicoQuant). Only if this software is working properly you should start work with the DLL. If there are problems even with the standard software, please consult the PicoHarp manual for detailed troubleshooting advice.

The DLL will access the PicoHarp device through a dedicated device driver. You need to make sure the device driver has been installed correctly. The driver is installed by standard Windows Plug&Play mechanisms. You will be prompted for driver installation when the device is connected for the first time. Both the standard PicoHarp software distribution as well as the PHLib distribution media contain the driver in the subfolder `\Driver`. Please direct the driver installation wizard to this folder. You can use the Windows Device Manager to check if the board has been detected and the driver is installed (under the USB tree). On some Windows versions you may need administrator rights to perform hardware setup tasks. Please consult the PicoHarp manual for hardware related problem solutions.

The next step, if hardware and driver are working, is to make sure you have the right DLL version installed. It comes with its own setup program that must be executed as administrator. In the Windows Explorer you can also right click `PHLib.DLL` (in `\Windows\System32`) and check the version number (under *Properties*). You should also make sure your board has the right firmware to use the DLL. The DLL option is not free, a license must be purchased. If you do not have it, you can order an upgrade at any time.

To get started, try the readily compiled demos supplied with the DLL. For first tests take the standard histogramming demos. If this is working, your own programs should work as well. Note that the hard coded settings may not be compatible with your experimental setup. Then the pre–compiled demo may not work as expected. Only the LabVIEW demo allows to enter the settings interactively.

8.4. Access permissions

On some Windows versions you may need administrator rights to perform the DLL setup. If the setup is performed by an administrator but used from other accounts without full access permission to all disk locations, these restricted accounts may no be able to run the demos in the default locations they have been installed to. In such cases it is recommended that you copy the demo directory or selected files from it to a dedicated development directory in which you have the necessary rights. Otherwise the administrator must give full access to the demo directory. On Windows XP and Vista it is possible to switch between user accounts without shutting down the running applications. It is not possible to start a PicoHarp program if any other program accessing the device is running in another user account that has been switched away. Doing so may cause crashes or loss of data.

8.5. Version tracking

While PicoQuant will always try to maintain a maximum of continuity in further hardware and software development, changes for the benefit of technical progress cannot always be avoided. It may therefore happen, that data structures, calling conventions or program flow will change. In order to design programs that will recognize such changes with a minimum of trouble we strongly recommend that you make use of the functions provided for version retrieval of hardware and DLL. In any case your software should issue a warning if it detects versions other than those it was tested with.

8.6. Software Updates

We constantly improve and update the software for our instruments. This includes updates of the configurable hardware (FPGA). Such updates are important as they may affect reliability and interoperability with other products. The software updates are free of charge, unless major new functionality is added. It is strongly recommended that you register for eMail notification on software updates. If you wish to receive such notification, please eMail your name and the serial number of your PicoQuant product(s) to *info@picoquant.com*. You will then receive update information with links for download of any new software release.

8.7. Bug Reports and Support

The PicoHarp 300 TCSPC system has gone through several iterations of hardware and software improvement as well as extensive testing. Nevertheless, it is a fairly challenging development and some glitches may still occur under the myriads of possible PC configurations and application circumstances. We therefore would like to offer you our support in any case of problems with the system. Do not hesitate to contact PicoQuant in case of difficulties with your PicoHarp or the programming library.

If you should observe errors or bugs caused by the PicoHarp system please try to find a reproducible error situation. Then send a detailed description of the problem and all relevant circumstances, especially other hardware installed in your PC, to *info@picoquant.com*. Please run `msinfo32` to obtain a listing of your PC configuration and attach the summary file to your error report. Your feedback will help us to improve the product and documentation.

Of course we also appreciate good news: If you have obtained exciting results with one of our systems, please let us know, and where appropriate, please mention the instrument in your publications. At our Web–site we maintain a large bibliography of publications related to our instruments. It may serve as a reference for you and other potential users. See http://www.picoquant.com/scientific/references. Please submit your publications for addition to this list.

9. Appendix

9.1. Data Types

The PicoHarp programming library `PHLib.DLL` is written in C and its data types correspond to standard C/C++ data types as follows:

`char`	8 bit, byte (or characters in ASCII)
`short int`	16 bit signed integer
`unsigned short int`	16 bit unsigned integer
`int` `long int`	32 bit signed integer
`unsigned int` `unsigned long int`	32 bit unsigned integer
`float`	32 bit floating point number
`double`	64 bit floating point number

Note that the format for the decimal point may depend on your Windows settings at run–time of the PicoHarp software (usually national language dependent).

Note also that on platforms other than x86 machines byte swapping may occur when the PicoHarp data files are read there for further processing. We recommend using the native x86 environment consistently.

9.2. Functions Exported by `PHLib.DLL`

See **`phdefin.h`** for predefined constants given in capital letters here. Return values `< 0` usually denote errors. See **`errcodes.h`** for the error codes. All functions must be called with `_stdcall` convention.

9.2.1. General Functions

These functions work independent from any device.

`int PH_GetErrorString (char* errstring, int errcode);`

```
arguments:          errstring:      pointer to a buffer for at least 40 characters
                    errcode:        error code returned from a PH_xxx function call

return value:       =0              success
                    <0              error

Note:               This function is provided to obtain readable error strings that explain the
                    cause of the error better than the numerical error code. Use these in error
                    handling message boxes etc.
```

`int PH_GetLibraryVersion (char* vers);`

```
arguments:          vers:           pointer to a buffer for at least 8 characters

return value:       =0              success
                    <0              error
```

Note: This is the only function you may call before opening and initializing a device. Use it to ensure compatibility of the library with your own application. Take this seriously if you do not want to end up in a mess when new versions come out.

9.2.2. Open/Close/Initialize Functions

All functions below are device related and require a device index.

int PH_OpenDevice (int devidx, char* serial);

arguments:	devidx:	device index 0..7
	serial:	pointer to a buffer for at least 8 characters
return value:	=0	success
	<0	error

int PH_CloseDevice (int devidx);

arguments:	devidx:	device index 0..7
return value:	=0	success
	<0	error

Note: Closes and releases the device for use by other programs.

int PH_Initialize (int devidx, int mode);

arguments:	devidx:	device index 0..7
	mode:	0 = histogramming, 2 = T2_Mode 3 = T3_Mode
return value:	=0	success
	<0	error

9.2.3. Functions for Initialized Devices

All functions below can only be used after PH_Initialize was successfully called.

int PH_GetHardwareInfo (int devidx, char* model, char* partnum, char* vers); **changed in v.3.0**

arguments:	devidx:	device index 0..7
	model:	pointer to a buffer for at least 16 characters
	partnum:	pointer to a buffer for at least 8 characters
	vers:	pointer to a buffer for at least 8 characters
return value:	=0	success
	<0	error

int PH_GetSerialNumber (int devidx, char* serial);

arguments:	devidx:	device index 0..7
	vers:	pointer to a buffer for at least 8 characters
return value:	=0	success
	<0	error

int PH_GetBaseResolution (int devidx, double* resolution); **changed in v.3.0**

arguments:	devidx:	device index 0..7
	resolution:	base resolution of the device (passed by reference)

```
return value:       =0              success
                    <0              error
```

int PH_GetFeatures (int devidx, int* features); **new in v.3.0**

```
arguments:          devidx:         device index 0..7
                    features:       features of this device (a bit pattern, passed by reference)
return value:       =0              success
                    <0              error
```

Note: Use the predefined bit mask values in phdefin.h to probe for a specific feature

int PH_Calibrate (int devidx);

```
arguments:          devidx:         device index 0..7
return value:       =0              success
                    <0              error
```

int PH_SetInputCFD (int devidx, int channel, int level, int zerocross); **changed in v.3.0**

```
arguments:          devidx:         device index 0..7
                    channel:        number of the input channel (0 or 1)
                    level:          CFD discriminator level in millivolts
                                       minimum = DISCRMIN
                                       maximum = DISCRMAX
                    level:          CFD zero cross in millivolts
                                       minimum = ZCMIN
                                       maximum = ZCMAX
return value:       =0              success
                    <0              error
```

Note: Values are passed as a positive number although the electrical signals are actually negative.

int PH_SetSyncDiv (int devidx, int div);

```
arguments:          devidx:         device index 0..7
                    div:            input rate divider applied at channel 0
                                    (1, 2, 4, or 8)
return value:       =0              success
                    <0              error
```

Note: The sync divider must be used to keep the effective sync rate at values <= 10 MHz. It should only be used with sync sources of stable period. The readings obtained with PH_GetCountRate are corrected for the divider setting and deliver the external (undivided) rate.

int PH_SetSyncOffset (int devidx, int offset); **new in v.3.0**

```
arguments:          devidx:         device index 0..7
                    offset:         offset (time shift) in ps for that channel
                                       minimum = SYNCOFFSMIN
                                       maximum = SYNCOFFSMAX
return value:       =0              success
                    <0              error
```

Note: This function can replace an adjustable cable delay. A positive offset corresponds to inserting a cable in the sync input. See also `PH_SetRoutingChannelOffset`.

int PH_SetStopOverflow (int devidx, int stop_ovfl, int stopcount);

```
arguments:          devidx:          device index 0..7
                    stop_ofl:        0 = do not stop,
                                     1 = do stop on overflow
                    stopcount:       count level at which should be stopped
                                     (max. 65,535)
return value:       =0               success
                    <0               error
```

Note: This setting determines if a measurement run will stop if any channel reaches the maximum set by stopcount. If stop_ofl is 0 the measurement will continue but counts above 65,535 in any bin will be clipped.

int PH_SetBinning (int devidx, int binning); **changed in v.3.0**

```
arguments:          devidx:          device index 0..7
                    binning:         binning code
                                        minimum = 0    (smallest, i.e. base resolution)
                                        maximum = (MAXBINSTEPS–1)            (largest)
return value:       =0               success
                    <0               error
```

Note: The binning code corresponds to a power of 2, i.e.

0 = 1x base resolution,
1 = 2x base resolution,
2 = 4x base resolution,
3 = 8x base resolution, and so on.

int PH_SetMultistopEnable (int devidx, int enable); **new in v.3.0**

```
arguments:          devidx:          device index 0..7
                    enable:          0 = disable
                                     1 = enable (default)
return value:       =0               success
                    <0               error
```

Note: This is only for special applications where the multistop feature of the PicoHarp is causing complications in statistical analysis. Ususally it is not required to call this funktion. By default, multistop is enabled after PH_Initialize.

int PH_SetOffset (int devidx, int offset);

```
arguments:          devidx:          device index 0..7
                    offset:          offset in picoseconds (histogramming and T3 mode only)
                                        minimum = OFFSETMIN
                                        maximum = OFFSETMAX
return value:       =0               success
                    <0               error
```

Note: The true offset is an approximation of the desired offset by the nearest multiple of the base resolution. This offset only acts on the difference between ch1 and ch0 in histogramming and T3 mode. Do not confuse it with the input offsets.

int PH_ClearHistMem (int devidx, int block);

```
arguments:          devidx:          device index 0..7
                    block:           block number to clear
return value:       =0               success
                    <0               error
```

int PH_StartMeas (int devidx, int tacq);

arguments:	devidx:	device index 0..7
	tacq:	acquisition time in milliseconds minimum = ACQTMIN maximum = ACQTMAX
return value:	=0	success
	<0	error

int PH_StopMeas (int devidx);

arguments:	devidx:	device index 0..7
return value:	=0	success
	<0	error

Note: Can also be used before the CTC expires but for internal housekeeping it MUST be called any time you finish a measurement, even if data collection was stopped internally, e.g. by expiration of the CTC or an overflow.

int PH_CTCStatus (int devidx, int* ctcstatus); **changed in v.3.0**

arguments:	devidx:	device index 0..7
	ctcstatus:	=0 acquisition time still running >0 acquisition time has ended
return value:	=0	success
	<0	error

int PH_GetHistogram (int devidx, unsigned int* chcount, int block); **changed in v.3.0**

arguments:	devidx:	device index 0..7
	chcount:	pointer to an array of at least HISTCHAN double words (32bit) where the histogram data can be stored
	block:	block number to fetch (block > 0 meaningful only with routing)
return value:	=0	success
	<0	error

Note: The current version counts only up to 65,535 (16 bits). This may change in the future.

int PH_GetResolution (int devidx, double* resolution); **changed in v.3.0**

arguments:	devidx:	device index 0..7
	resolution:	resolution at current binning (passed by reference)
return value:	=0	success
	<0	error

int PH_GetCountRate (int devidx, int channel, int* rate); **changed in v.3.0**

arguments:	devidx:	device index 0..7
	channel:	number of the input channel (0 or 1)
	rate:	current pulse rate at this channel (passed by reference)
return value:	=0	success
	<0	error

Note: The hardware rate meters employ a gate time of 100 ms. You must allow at least 100 ms after PH_Initialize or PH_SetDyncDivider to get a valid rate meter reading. Similarly, wait at least 100 ms to get a new reading. The readings are corrected for the sync divider setting and deliver the external (undivided) rate. The gate time cannot be changed. The readings may therefore be inaccurate or fluctuating when the rates are very low. If accurate rates are needed you must perform a full blown measurement and sum up the recorded events.

int PH_GetFlags (int devidx, int* flags); **changed in v.3.0**

arguments:	devidx:	device index 0..7
	flags:	current status flags (a bit pattern, passed by reference)
return value:	=0	success
	<0	error

Note: Use the predefined bit mask values in phdefin.h (e.g. FLAG_OVERFLOW) to extract individual bits through a bitwise AND. It is also recommended to check for FLAG_SYSERROR to detect possible hardware failures. In that case you may want to call PH_GetHardwareDebugInfo and submit the results for support.

int PH_GetElapsedMeasTime (int devidx, double* elapsed); **changed in v.3.0**

arguments:	devidx:	device index 0..7
	elapsed:	elapsed measurement time in ms (passed by reference)
return value:	=0	success
	<0	error

int PH_GetWarnings (int devidx, int* warnings); **changed in v.3.0**

arguments:	devidx:	device index 0..7
	warnings:	warnings, (passed by reference) bitwise encoded (see phdefin.h)
return value:	=0	success
	<0	error

Note: Must call PH_GetCoutRates for all channels prior to this call.

int PH_GetWarningsText (int devidx, int warnings, char* text);

arguments:	devidx:	device index 0..7
	warnings:	integer bitfield obtained from PH_GetWarnings
	text:	pointer to a buffer for at least 16384 characters
return value:	=0	success
	<0	error

int PH_GetHardwareDebugInfo (int devidx, char* debuginfo); **new in v.3.0**

arguments:	devidx:	device index 0..7
	debuginfo:	pointer to a buffer for at least 16384 characters
return value:	=0	success
	<0	error

Note: It is recommended to use PH_GetFlags and check for FLAG_SYSERROR to detect possible hardware failures. In that case you may want to call PH_GetHardwareDebugInfo and submit the results for support.

9.2.4. Special Functions for TTTR Mode

To use these functions, you must have purchased the TTTR mode option. You can use `PH_GetFeatures` to probe for it.

`int PH_ReadFiFo (int devidx, unsigned int* buffer, int count, int* nactual);` **changed in v.3.0**

arguments:	devidx:	device index 0..7
	buffer:	pointer to an array of count dwords (32bit) where the TTTR data can be stored
	count:	number of TTTR records to be fetched (max TTREADMAX)
	nactual:	number of dwords actually read (passed by reference)
return value:	=0	success
	<0	error

Note: Must not be called with count larger than buffer size permits. CPU time during wait for completion will be yielded to other processes/threads. Function will return after a timeout period of ~80 ms, even if not all data could be fetched. Return value indicates how many records were fetched. Buffer must not be accessed until the function returns.

`int PH_SetMarkerEdges (int devidx, int me0, int me1, int me2, int me3);`

arguments:	devidx:	device index 0..7
	me<n>:	active edge of marker signal <n>, 0 = falling, 1 = rising
return value:	=0	success
	<0	error

Note: PicoHarp devices prior to hardware version 2.0 support only the first three markers. Default after Initialize is “all rising”.

`int PH_SetMarkerEnable (int devidx, int en0, int en1, int en2, int en3);` **new in v.3.0**

arguments:	devidx:	device index 0..7
	me<n>:	enabling of marker signal <n>, 0 = disabled, 1 = enabled
return value:	=0	success
	<0	error

Note: PicoHarp devices prior to hardware version 2.0 support only the first three markers. Default after Initialize is “all enabled”.

`int PH_SetMarkerHoldofftime (int devidx, int holdofftime);` **new in v.3.0**

arguments:	devidx:	device index 0..7
	holdofftime:	holdofftime in nanoseconds
return value:	=0	success
	<0	error

Note: This setting can be used to clean up glitches on the marker signals. When set to X ns then after detecting a first marker edge the next marker will not be accepted before X ns. Observe that the internal granularity of this time is only about 50 ns. The holdoff time is set equally for all marker inputs but the holdoff logic acts on each marker independently.

9.2.5. Special Functions for Routing

These functions require a PHR 402 / 403 / 800.

int PH_GetRoutingChannels (int devidx, int* rtchannels);

```
arguments:          devidx:          device index 0..7
                    rtchannels:      number of routing channels (passed by reference)
return value:       =0               success
                    <0               error
```

int PH_EnableRouting (int devidx, int enable);

```
arguments:          devidx:          device index 0..7
                    enable:          routing state control code
                                        1 = enable routing
                                        0 = disable routing
return value:       =0               success
                    <0               error
```

Note: This function can also be used to detect the presence of a router.

int PH_GetRouterVersion (int devidx, char* model, char* vers);

```
arguments:          devidx:          device index 0..7
                    model:           pointer to a buffer for at least 8 characters
                    vers:            pointer to a buffer for at least 8 characters
return value:       =0               success
                    <0               error
```

int PH_SetRoutingChannelOffset (int devidx, int offset);

```
arguments:          devidx:          device index 0..7
                    offset:          offset (time shift) in ps for that channel
                                        minimum = CHANOFFSMIN
                                        maximum = CHANOFFSMAX
return value:       =0               success
                    <0               error
```

Note: This function can be used to compensate small timing delays between the individual routing channels. It is similar to PH_SetSyncOffset and can replace cumbersome cable length adjustments but compared to PH_SetSyncOffset the adjustment range is relatively small. A positive number corresponds to inserting cable in that channel.

int PH_SetPHR800Input (int devidx, int channel, int level, int edge);

```
arguments:          devidx:          device index 0..7
                    channel:         router channel to be programmed (0 .. 3)
                    level:           trigger voltage level in mV (–1600 .. 2400)
                    edge:            trigger edge
                                        0 = falling edge,
                                        1 = rising edge
return value:       =0               success
                    <0               error
```

Note 1: Not all channels may be present.

Note 2: Invalid combinations of level and edge may lock up all channels!

int PH_SetPHR800CFD (int devidx, int channel, int dscrlevel, int zerocross);

arguments:	devidx:	device index 0..7
	channel:	router CFD channel to be programmed (0 .. 3)
	dscrlevel:	discriminator level in mV (0 .. 800)
	zerocross:	zero crossing level in mV (0 .. 20)
return value:	=0	success
	<0	error

9.3. Warnings

The following is related to the warnings (possibly) generated by the library routine PH_GetWarnings. The mechanism and warning criteria are the same as those used in the regular PicoHarp software and depend on the current count rates and the current measurement settings.

Note that the software can detect only a subset of all possible error conditions. It is therefore not safe to assume “all is right” just by obtaining no warning. It is also necessary that PH_GetCoutrate has been called for all channels before PH_GetWarnings is called.

The warnings are to some extent dependent on the current measurement mode. Not all warnings will occur in all measurement modes. Also, count rate limits for a specific warning may be different in different modes. The following table lists the possible warnings in the three measurement modes and gives some explanation as to their possible cause and consequences.

Warning	Histo Mode	T2 Mode	T3 Mode
WARNING_INP0_RATE_ZERO No counts are detected at input channel 0. In histogramming and T3 mode this is the sync channel and the measurement will not work without that signal.	√		√
WARNING_INP0_RATE_TOO_LOW The count rate at input channel 0 is below 1 kHz and the sync divider is >1. In histogramming and T3 mode this is the sync channel and the measurement will not work without a signal <1 kHz if the sync divider is >1. If your sync rate is really so low then you do not need a sync divider >1.	√		√
WARNING_INP0_RATE_TOO_HIGH You have selected T2 mode and the count rate at input channel 0 is higher than 5 MHz. The measurement will inevitably lead to a FiFo overrun. There are rare measurement scenarios where this condition is expected and the warning can be disabled. Examples are very short measurements where the FiFo can absorb all data.		√	
WARNING_INP1_RATE_ZERO No counts are detected at input channel 1. In histogramming and T3 mode this is the photon event channel and the measurement will yield nothing without this signal. You may sporadically see this warning if your detector has a very low dark counts. In that case you may want to disable this warning.	√		√
WARNING_INP1_RATE_TOO_HIGH If you have selected T2 mode then this warning means the count rate at input channel 1 is higher than 5 MHz. The measurement will inevitably lead to a FiFo overrun. There are rare measurement scenarios where this condition is expected and the warning can be disabled. Examples are very short measurements where the FiFo can absorb all data. In histogramming and T3 mode this warning is issued when the input rate is >10 MHz. This will probably lead to deadtime artefacts. There are rare measurement scenarios where this condition is expected and the warning can be disabled.	√	√	√

Warning	Histo Mode	T2 Mode	T3 Mode
WARNING_INP_RATE_RATIO This warning is issued in histogramming and T3 mode when the rate at input 1 is over 5% of the rate at input 0. This is the classical pile-up criterion. It will lead to noticeable dead-time artefacts. There are rare measurement scenarios where this condition is expected and the warning can be disabled. Examples are antibunching measurements.	√		√
WARNING_DIVIDER_GREATER_ONE You have selected T2 mode and the sync divider is set larger than 1. This is probably not intended. The sync divider is designed primarily for high sync rates from lasers and requires a fixed pulse rate at channel 0. In that case you should use T3 mode. If the signal at channel 0 is from a photon detector (coincidence correlation etc.) a divider >1 will lead to unexpected results. There are rare measurement scenarios where this condition is intentional and the warning can be disabled.		√	
WARNING_TIME_SPAN_TOO_SMALL This warning is issued in histogramming and T3 mode when the sync period (1/Rate[ch0]) is longer that the start to stop time span that can be covered by the histogram or by the T3 mode records. You can calculate this time span as follows: Histogramming mode: Span = Resolution * 65536 T3 mode: Span = Resolution * 4096 Events outside this span will not be recorded. There are some measurement scenarios where this condition is intentional and the warning can be disabled.	√		√
WARNING_OFFSET_UNNECESSARY This warning is issued in histogramming and T3 mode when an offset >0 is set even though the sync period (1/Rate0) can be covered by the measurement time span without using an offset. The offset may lead to events getting discarded. There are some measurement scenarios where this condition is intentional and the warning can be disabled.	√		√

If any of the warnings you receive indicate wrong count rates, the cause may be inappropriate input settings, wrong pulse polarities, poor pulse shapes or bad connections. If in doubt, check all signals with a scope.

Note that all count rate dependent warnings relate to the PicoHarp's native input channels. If you are using a router, remember that all routing channels share the PicoHarp's input channel 1 and hence create a cumulated common rate at that channel.

Warnings are a feature to support beginners and to add convenience to the software. They are not strictly required and the related functions need not be called if you have no need for them.

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