

Picosecond Histogram Accumulating Real-time Processor



The image displays a Fluke 325 Precision multimeter and its LabVIEW control interface. The multimeter is a grey, rack-mountable unit with four channels (CH1-CH4) and various ports (USB 2.0, GND, CTRL). The LabVIEW diagram illustrates the control logic, including initialization, measurement loops, and error handling. It features several sub-blocks like 'Set Mode', 'Set Range', and 'Set Units', along with a 'while' loop for continuous data acquisition. A code window on the right shows the underlying LabVIEW script.

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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 new solid state 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 multiexponential 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 ME, 2000, XP and Vista. The library 'PHLib.dll' supports custom programming in all major 32 bit programming languages, notably C/C++, Delphi/Lazarus, Visual Basic, 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™ ME, 2000, XP and Vista.

The library has been tested with 32 bit Windows applications under MinGW 2.0 (free compiler for Windows, 32 bit), MSVC++ 6.0, Borland C++™ 5.5, Borland C++ Builder™ 3.0 as well as with Delphi™ 6.0, Lazarus 0.9.22, LabView™ 7.1/8.0, MATLAB 7.3 and Visual Basic™ 6.0.

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 and the notes marked in red in section 10).

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 that you can use to retrieve the version number (see section 10). Note that this call returns only the major two digits of the version (e.g. 2.2). The DLL actually has two further sub-version digits, so that the complete version number has four digits (e.g. 2.2.0.0). 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.

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With this product you have purchased a license to use the PicoHarp 300 programming library on a single PC. You have not purchased any other rights to the software itself. The software is protected by copyright and intellectual property laws. You may not distribute the software to third parties or reverse engineer, decompile or disassemble the software or part thereof. You may use and modify demo code to create your own software. Original or modified demo code may be re-distributed, provided that the original disclaimer and copyright notes are not removed from it.

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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 DLLUPD.EXE. This file is provided to you (typically by email) 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. Start the program DLLUPD.EXE from a temporary disk location.
5. 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. See the sections below for hints how to install and use it.

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').

You also need to install the PicoHarp 300 if you have not done so before (see your PicoHarp manual). The programming library will access the PicoHarp 300 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 a subfolder *driver*. Please direct the driver installation wizard to this folder.

Note that up to PHLib version 1.2 only one PicoHarp device was supported. 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 2.2 of the library package provides driver support for the x64 versions of Windows Vista. Note, however, that at this time the library itself remains designed for 32-bit programs. On the x64 versions of Windows such programs will run on top of the WOW64 layer. Apart from this, version 2.2 of PHLIB is fixing some bugs. These were notably issues with crosstalk when using routing devices.

Note that from PHLIB version 2.0 multiple PicoHarp devices can be controlled through the library. Up to PHLIB version 1.2 only one PicoHarp device was supported. This change required the introduction of new functions for open/close and a device index for every library call. Users upgrading from 1.x versions of PHLIB therefore need to adapt their programs. It is important to note here one more time that you must maintain appropriate version checking in order to avoid crashes due to such changes. There is a function call that you can use to retrieve the version number (see section 10). The changes from 1.2 to 2.x are also marked red in section 10.

6. The Demo Applications - 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++, Delphi/Lazarus, LabVIEW, MATLAB and Visual Basic. 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.

7. The Demo Applications by Programming Language

As outlined above, there are demos for C/C++, Delphi/Lazarus, LabVIEW, MATLAB and Visual Basic. 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 2000 and XP 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. 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 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.

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 for MSVC 5.0 or higher, 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 4096 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 Delphi/Lazarus Demos

Delphi or Lazarus users 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). Lazarus users can use the *.LPI files that refer to the same *.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 with MSVC 6.0, 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 also 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 Visual Basic Demos

The Visual Basic demos are in the 'VB' directory. VB users should start their work in standard mode from DLLDEMO.BAS. The code should be fairly self explanatory. If you update to a new DLL version please check the function parameters of your existing code against phlib.h in the demo directory. Note that where pointers to C-arrays are passed as function arguments you must pass the first element of the corresponding VB array by reference. In the VB function declaration you must declare the argument as the element type, not as an array.

The VB demo programs use a simple console for user I/O, which can be replaced by the usual visual components to build a GUI. For VB there are no pre-compiled EXEs of the demos since you need to have VB installed on your machine anyway, to get the VB runtime libraries. All measurement parameters are set directly in the VB code. However, you should run the standard PicoHarp software first, to see if your hardware setup is correct.

The VB demos create output files in their current working directory (*.out). The output file will be ASCII in case of the standard histogramming demo. The ASCII files will contain columns of integer numbers representing the counts from the histogram channels. You can use any data visualization program to inspect the histograms. In TTTR mode 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. 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 (LabView 7.1) 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 have LabVIEW 7.1 or 8.0. Even newer versions will probably work but have not been tested.

The LabVIEW demos are the most sophisticated demos here. The standard mode demo closely resembles the standard PicoHarp software with input fields for all settable parameters. Run the toplevel 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 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 65536 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. 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).

8. Advanced Techniques

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.

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 131072 (128k event records). However, it may not under all circumstances be ideal to use the maximum size. The demos use a medium size of 32768 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 way of doing this is to use multithreading. 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 graphic user interface you may need a third thread to respond to user actions reasonably fast. Again, this is 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 multithreading 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.

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.

9. Data Types

The PicoHarp programming library PHLib.DLL is written in C and its data types correspond to standard C/C++ data types on 32 bit platforms as follows:

char	8 bit, byte (or character in ASCII)
short int	16 bit, signed integer
unsigned short int	16 bit, unsigned integer
int	32 bit, signed integer
unsigned int	32 bit, unsigned integer
long int	32 bit, signed integer
unsigned long int	32 bit, unsigned integer
float	32 bit, floating point

These types are supported by all major programming languages. Unfortunately Visual Basic is somewhat limited, it does not have the 16-bit types. You need to use byte arrays and convert each pair of successive bytes to the equivalent 16 bit number in a 32 bit variable.

10. 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.

New, starting from v2.0: this is now a multi device library. Device specific functions now take a new device index argument. See section 5.

```
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 PH_Initialize. Use it to ensure compatibility of the library with your own application.

//all functions below are device specific and require a device index

```
int PH_OpenDevice(int devidx, char* serial); //new from v2.0
```

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); //new from v2.0
```

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

```
//all functions below can only be used after PH_Initialize
```

```
int PH_GetHardwareVersion(int devidx, char* model, char* vers);
```

```
arguments:    devidx = device index 0..7
              model = pointer to a buffer for at least 16 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);
```

```
arguments:    devidx = device index 0..7
```

```
return value: >0      base resolution in ps (corresponds to resolution in Range 0)
              <0      error
```

```
int PH_Calibrate(int devidx);
```

```
arguments:    devidx = device index 0..7
```

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

Note: Calibration is normally only required after warming up and after each PH_Initialize.

```
int PH_SetCFDLevel(int devidx, int channel, int value);
```

```
arguments:    devidx = device index 0..7
              channel =      number of the input channel (0 or 1)
              value =      CFD discriminator level in millivolts
                          minimum = DISCRMIN
                          maximum = DISCRMAX
```

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

Note: value is given as a positive number although the electrical signals are actually negative.

```
int PH_SetCFDZeroCross(int devidx, int channel, int value);
```

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

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

Note: value is given 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_SetStopOverflow(int devidx, int stop_ovfl, int stopcount);
```

arguments: devidx = device index 0..7
 stop_ovfl 0 = do not stop, or 1 = do stop on overflow
 stopcount count level at which should be stopped (max. 65535)

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_ovfl is 0 the measurement will continue
 but counts above 65535 in any bin will be clipped.

```
int PH_SetRange(int devidx, int range);
```

arguments: devidx = device index 0..7
 value = Measurement range code
 minimum = 0 (smallest, i.e. base resolution)
 maximum = RANGES-1 (largest)

return value: =0 success
 <0 error

Note: Range code 0 = base resolution, 1 = 2x base resolution, 2=4x, 3=8x and so on.

```
int PH_SetOffset(int devidx, int offset);
```

arguments: devidx = device index 0..7
 value = Offset in picoseconds
 minimum = OFFSETMIN
 maximum = OFFSETMAX

return value: ≥ 0 new offset
 <0 error

Note: The true offset is an approximation of the desired offset by the nearest multiple of
 the base resolution.

```
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.

```
int PH_CTCStatus(int devidx);
```

```
arguments:   devidx = device index 0..7
```

```
return value: 0      acquisition time still running
              >0      acquisition time has ended
```

```
int PH_GetBlock(int devidx, unsigned int *chcount, int block);
```

```
arguments:   devidx = device index 0..7
              *chcount = pointer to an array of double words (32bit) of HISTCHAN
                        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 65535 (16 bits).
This may change in the future.

```
int PH_GetResolution(int devidx);
```

```
arguments:   devidx = device index 0..7
```

```
return value: >0      resolution (histogram bin width) in ps, at the current range
              <0      error
```

```
int PH_GetCountRate(int devidx, int channel);
```

```
arguments:   devidx = device index 0..7
              channel = number of the input channel (0 or 1)
```

```
return value: >=0     current count rate at this channel
              <0      error
```

Note: Allow at least 100 ms after PH_Initialize or PH_SetDyncDivider to get a stable 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.

int PH_GetFlags(int devidx);

arguments: devidx = device index 0..7

return value: current status flags (a bit pattern)

Note: Use the predefined bit mask values in phdefin.h (e.g. FLAG_OVERFLOW)
 to extract individual bits through a bitwise AND.

int PH_GetElapsedMeasTime(int devidx);

arguments: devidx = device index 0..7

return value: elapsed measurement time in ms

SPECIAL FUNCTIONS FOR TTTR MODE (Must have purchased the TTTR mode option)**int PH_TTReadData(int devidx, unsigned int* buffer, unsigned int count);**

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)

return value: >=0 number of records actually returned in buffer
 <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_TTSetMarkerEdges(int devidx, int me0, int me1, int me2, int me3);

arguments: devidx = device index 0..7

meX = active edge of marker signal X, 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.

SPECIAL FUNCTIONS FOR ROUTING (Must have PHR 402/403/800)

```
int PH_GetRoutingChannels(int devidx);
```

arguments: devidx = device index 0..7

return value: >0 available number of routing channels
 <0 error

```
int PH_EnableRouting(int devidx, int enable);
```

arguments: devidx = device index 0..7
 enable = 1 -> enable routing
 enable = 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); // new from version 2.0
```

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 available number of routing channels
 <0 error

```
int PH_SetPHR800Input(int devidx, int channel, int level, int edge); // new fom version 2.0
```

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, 1=rising)

return value: >0 available number of routing channels
 <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); // new from v. 2.0
```

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 available number of routing channels
 <0 error

Note 1: CFDs may not be present on all devices

Note 2: Dscrlevel and zerocross are given as positive numbers although the electrical signals are actually negative.

11. Problems, Tips & Tricks

PC Performance Issues

Performance issues with the DLL are the same as with the standard PicoHarp software. The PicoHarp and its software interface are a complex real-time measurement system demanding considerable performance both from the host PC and the operating system. This is why a reasonably modern CPU (1 GHz min.) and at least 512 MB of memory are recommended. The USB 2.0 interface must be configured correctly and use only high speed rated components. A modern AGP or PCI express graphics interface is also strongly 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 streaming to disk you should also have a fast modern hard disk.

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 a 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/System or 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.

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 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. 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.

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.

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.

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 offer you our support in any case of trouble with the system and ask your help to identify any such problems. Do not hesitate to contact PicoQuant in case of difficulties with your PicoHarp or the programming library. Should you observe errors or unexpected behaviour related to the PicoHarp system, please try to find a precise and reproducible error situation. E-mail a detailed description of the problem and relevant circumstances to info@picoquant.com. Please include all PC system details, ideally obtained through *msinfo32*. Your feedback will help us to improve the product and documentation.



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