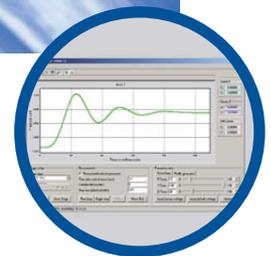
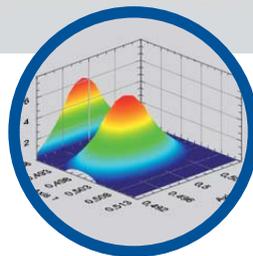
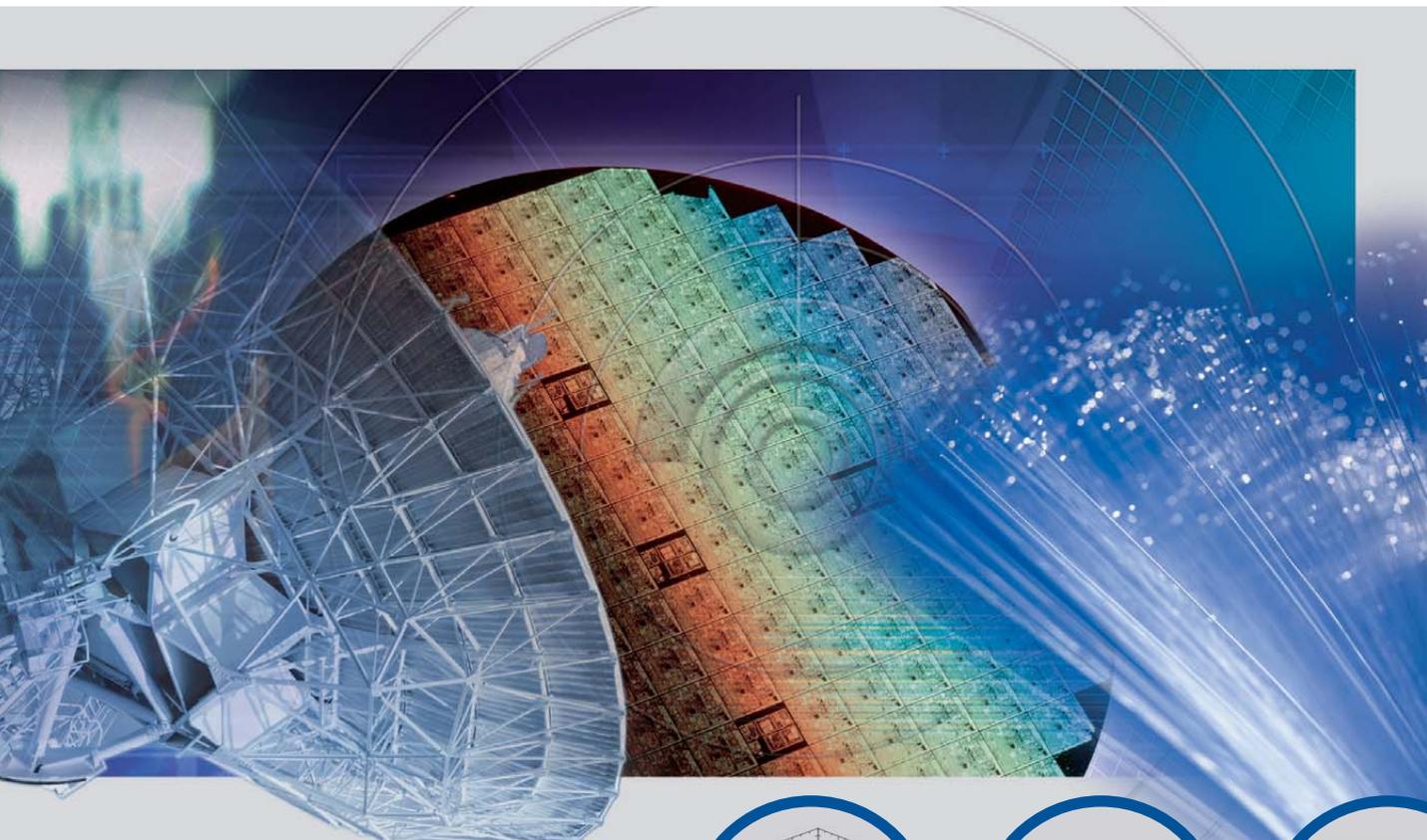
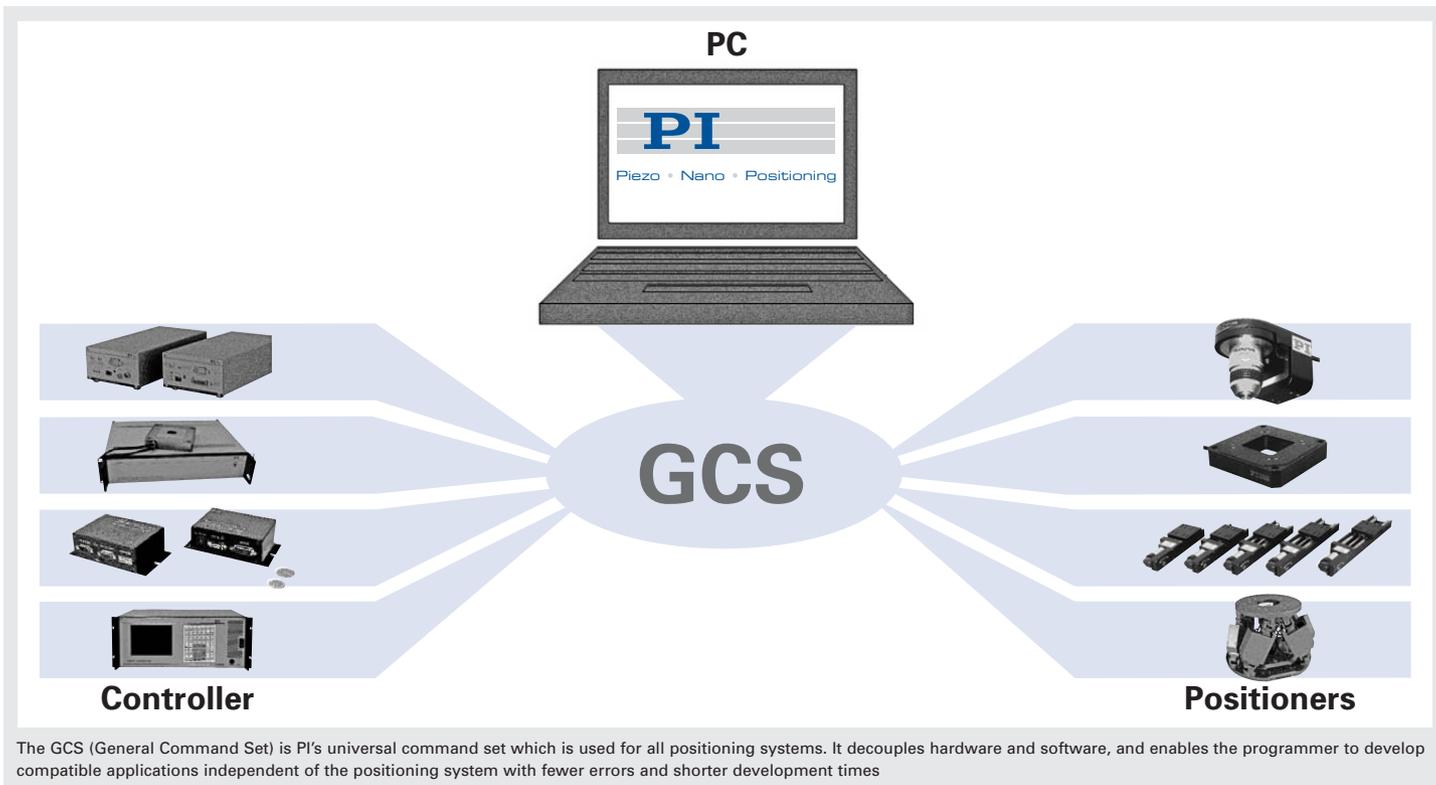


# Software for Motion Control Systems Operating Ultra-Precision Positioning Systems with Ease



# PI Software

## Operating Positioning Systems Effectively & Conveniently



The GCS (General Command Set) is PI's universal command set which is used for all positioning systems. It decouples hardware and software, and enables the programmer to develop compatible applications independent of the positioning system with fewer errors and shorter development times

The high quality of positioning systems is made apparent in daily operation by PI software. Starting with simple commissioning, through convenient operation with a graphical interface, to quick and simple integration in customized programs, PI software covers all aspects important to an application.

### Software Independent of Controller and Mechanics

The same software can be used to control systems with piezo actuators, piezomotors, DC-motors, voice coils and hybrid drives together and uniformly. This makes operation generally independent of the number and type(s) of the connected stages, of the type(s) of controllers, and of the interface(s) used.

### Powerful Universal Command Set

Automated operation of PI positioning systems is eased

by the consistency of the GCS command set. This facilitates the development of custom macros, as well as integration with external programs like LabVIEW, MATLAB, Visual C++, etc.

### Software Updates Online

PI supports users with free updates, online help and well-structured manuals which ease initiation of the inexperienced but still answer the detailed questions of the professional.

### Simple Commissioning

The commissioning of PI positioning systems is quick and easy with the NanoCapture™ and PIMikroMove® host software (see pages 4 and 5). Controller and stages are selected and activated with a few clicks. Then the system can be used directly, usually without even rebooting.

Running the system from the NanoCapture™ or PIMikroMove®

host software graphical interface requires no programming knowledge, either for commissioning or direct operation. The powerful GCS concept—one command set for all controllers—accompanies the user with his or her application

through all phases: installation, getting familiar with the hardware features using the application software, and the compilation of custom software.

The screenshot shows the PI website's 'Downloads' page. At the top, there are navigation links: Home, Download, Upload, Contact, and Links. Below this, there are sections for 'Latest Downloads', 'User Login', and 'Who's online'. The main content area is titled 'Downloads' and features a 'Documents' table with columns for 'name', 'date', and 'file size'. The table lists several documents, including 'CD Mirror\_E 516\_V3.01' and 'E 516 Release News Archive'. Below the table, there are sections for 'Release news of all releases', 'E 516 Update\_2005\_10', and 'E 516 Version History'. At the bottom, there is a copyright notice: '© 1996-2005 PI (Physik Instrumente) GmbH & Co. KG. All rights reserved. Specifications subject to change without notice.'

All about software in the internet—a server offers download of manuals and software CD mirrors

## One Command Set for All Systems: Maximum System Compatibility

For uniform operation of nano- and micropositioning systems, the universal PI General Command Set (GCS) is used. This command set is supported by all new PI piezo and motor controllers including hexapod and hybrid-drive systems. With GCS, operation is independent of the hardware used, so that several positioning systems can be controlled together, or new systems can be introduced with a minimum of programming effort.

### Universal Command Set Saves Development Time

With GCS the development of custom application programs is simplified, because the commands for all supported devices are identical in syntax and function. The orientation phase normally required can be skipped completely. Through the use of the GCS command set with its convenient functions, the application development process is significantly accelerated. At the same time, the probability of error is greatly reduced.

The GCS commands are available at the controller terminal,

in macros and in the form of a universal driver set for LabVIEW (VIs), Windows dynamic link libraries (DLL) and COM objects (see page 6).

Controllers whose firmware is not based on GCS, are integrated with the help of an additional software layer. This is done in a completely transparent manner, so that these controllers also integrate smoothly into GCS software. Using the GCS DLLs and COM objects provided, or the GCS LabVIEW driver set, such controllers have been fully integrated into the PI graphical interface software and in customer-developed applications as well.

### Optimization of System Dynamics

For optimal system behavior, the servo-control parameters can be adjusted depending on the load and desired dynamics. The effects of adjustment of relevant parameters, such as P-I-D terms, notch filter frequencies and slew rate limit are displayed graphically in easy-to-understand diagrams.

In addition to manual optimization, the system behavior can

be tuned fully automatically with the Autotune option. With it, the system dynamics are analyzed and optimized with progressive approximation algorithms. This incomparably simple method provides excellent results in minimal time.

With InputShaping® and DDL, additional algorithms are available to improve the dynamic behavior of piezo positioning systems (see page 7).

### GCS-compatible Controllers

Micropositioning:  
C-663, C-843, C-843.PM, C-848,  
C-862, C-865, C-866, C-880, C-702

Nanopositioning:  
E-516, E-621, E-625, E-665, E-710,  
E-725, E-753, E-755, E-761, C-702

All Hexapod Controllers for:  
F-206, M-850, M-840, M-824

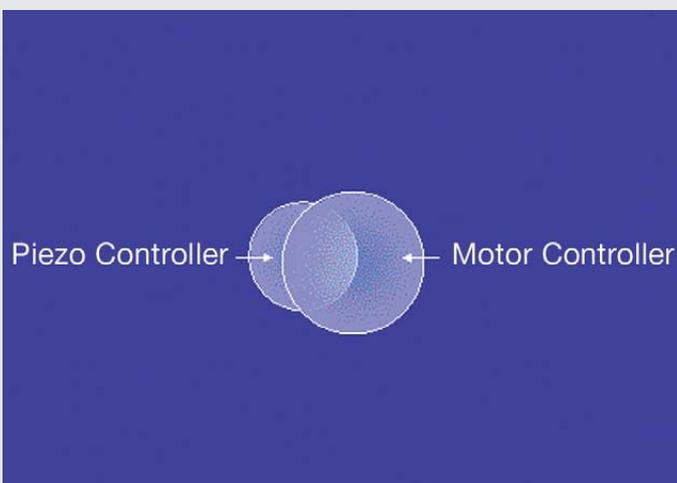
### Supported Operating Systems

Microsoft Windows XP

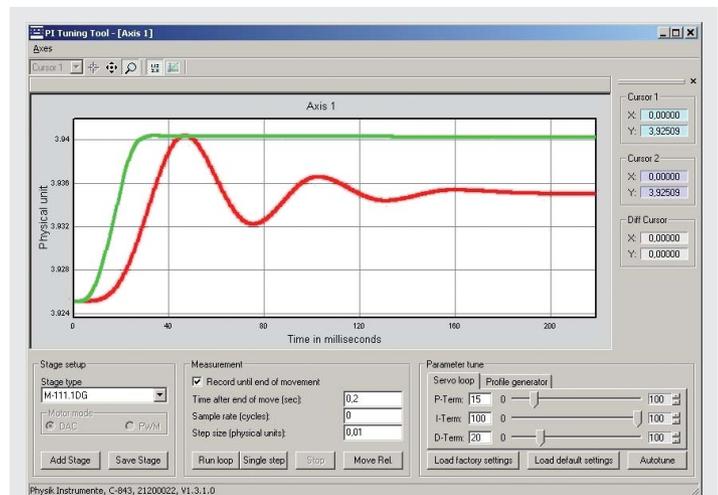
Microsoft Windows 2000

Microsoft Vista

Linux (on request)



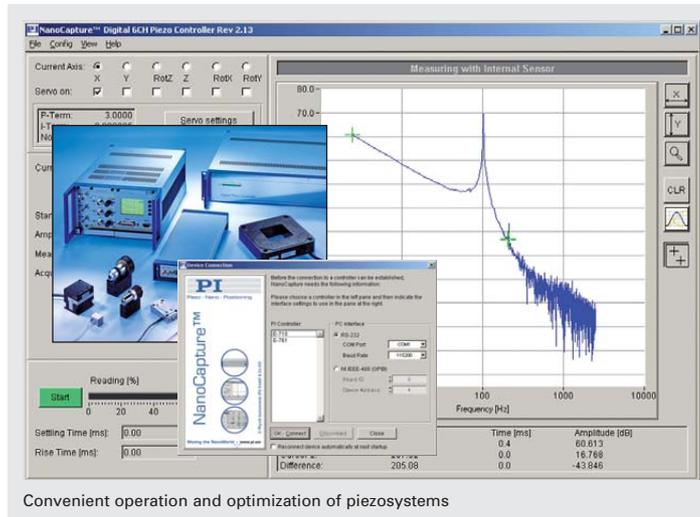
The intersection demonstrates the uniform implementation of identical functions in different PI controllers



Step response of a controlled micropositioning stage with optimized and non-optimized dynamic parameters

# Successfully Operating Piezo Systems

## Optimizing System Performance Using Digital Piezo Controllers with PI Software



- Operation of Digital & Analog Piezocontrollers
- NanoCapture™ Application Software Offers Simple Interface
- Enables Optimization of All Servo Parameters
- Displays Response Behavior & Resonant Frequency, Creates Bode Plots

NanoCapture™ provides basic and highly advanced functions for operating digital piezo servo-controllers. With its graphical interface, NanoCapture™ enables convenient system optimization and can display settling behavior, resonant frequency, Bode plots, etc. If the nanopositioning system is equipped with directly measuring position sensors, these features are available with no additional instrumentation.

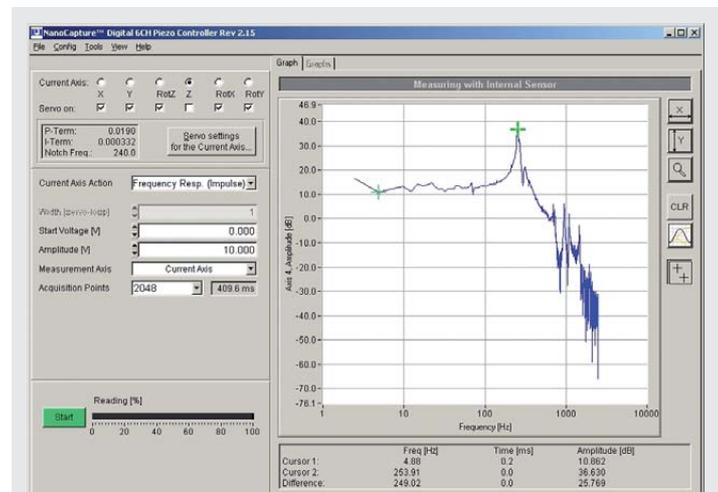
### Comprehensive System Optimization

The functions described above are especially useful when the mechanical properties of the system calibrated at the factory are changed, e.g. by applying a higher load.

In such a case, the adjustment of parameters like control-loop amplification (P-I parameters), notch filter frequency or the zero-point of the integrated sensors, can optimize response behavior and system stability.

In addition, NanoCapture™ supports numerous controller-specific properties.

Wave Generator: synchronized operation of multiple axes with mathematically defined curves, or with arbitrarily customized functions (see page 7).



The frequency response of an open-loop nanopositioning stage pictured in a Bode plot

### Software Support for Analog Piezo Controllers

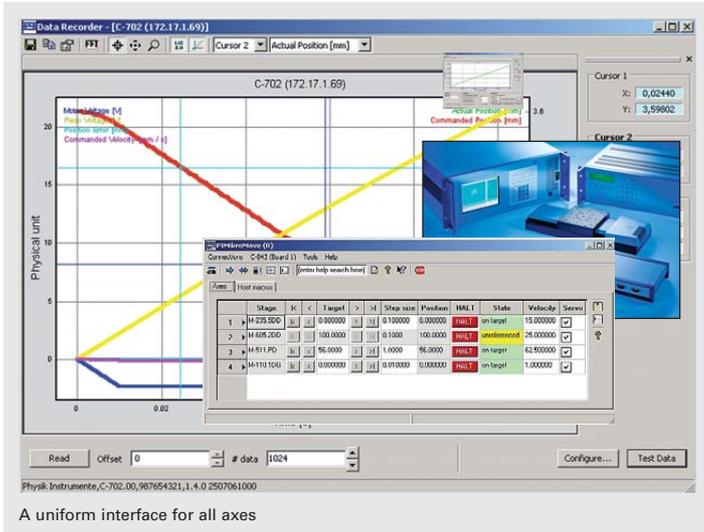
Analog piezo controllers without a digital interface are supported by PI software with a set of LabVIEW drivers in combination with a DAQ board (see page 6).

### Global Technical Support, Firmware Updates, Calibration

PI maintains nanometrology labs with state-of-the-art calibration equipment on three continents. Should a nanopositioning system require recalibration or user-specified custom tuning, an experienced PI service engineer will be able to support you. PI applications engineers can also help you with firmware and software updates or other system adaptations.

# PIMikroMove® Software

## Simple Operation of Positioning Systems



- Operation of PI Motor, Piezo, Piezomotor & Hybrid Controllers
- Optimizing all Servo Parameters
- Macros for Recurring Tasks

Positioning systems with most PI GCS motor, piezo, piezomotor and hybrid controllers can be controlled with PIMikroMove® in a clear and simple manner. All connected controllers and axes are accessed via the same graphical interface. PIMikroMove® supports quick commissioning of controllers and positioners, comprehensive system optimization as well as the programming of macros.

### All Axes in One View

With PIMikroMove® all axes connected to the host PC can be controlled from one program instance. This, independent of which PI controller is connected to which axis. For example, it is possible to have two axes in an XY application connected to two different controllers, but still command them with PIMikroMove® from the same window.

### Optimal System Behavior

PIMikroMove® also allows the user to optimize the system

behavior through convenient servo tuning.

This possibility is especially helpful if the mechanical properties of a system are changed, for example by applying a different load. The system response and stability can then be optimized with the convenient parameter tuning tool.

For recurring tasks, different sets of optimized parameters can be saved as stage profiles and then activated as needed in custom-programmed applications.

### Macros Ease Recurring Tasks

PIMikroMove® considerably simplifies the creation of macros for recurring tasks.

Execution of a macro, consisting of a previously stored list of GCS commands, can be commanded over the interface or, if supported by the controller, run automatically on power-up, with or without a host PC connected.

Controllers without their own macro facility, like the C-843, can be commanded by host macros which PIMikroMove® edits and stores in the host PC. Host macro execution can be triggered with digital I/O lines and support multiple axes connected to different controllers.

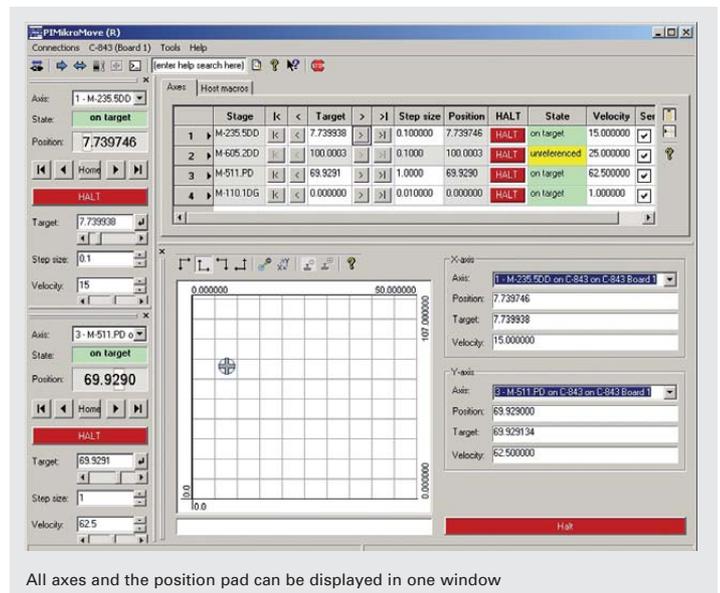
With the position pad, two or more independent axes can be moved by a mouse or joystick as an XY stage, also in vector moves.

### FFT, Profile Generator, Data Recorder

PIMikroMove® also supports controller-specific features.

Data recorder: record various motion and system parameters, run FFT (fast Fourier transformation) on the data as well as export it to programs like Microsoft Excel (CSV format).

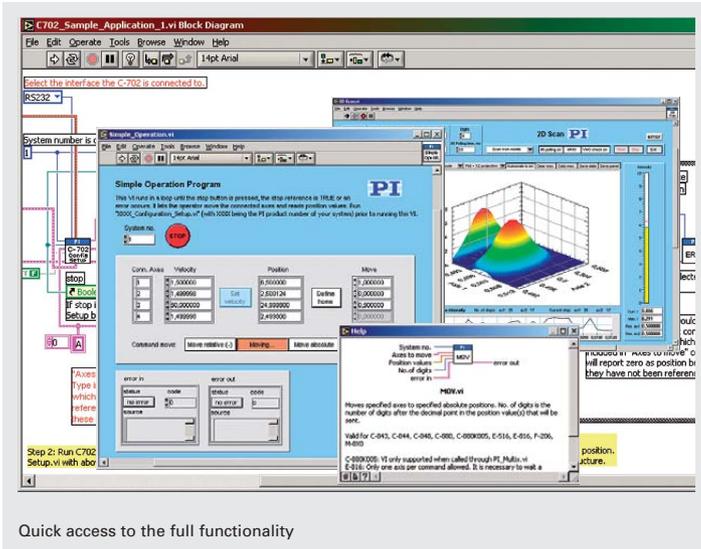
Profile Generator: synchronize motion of several axes along multi-order, mathematically defined curves or customized arbitrary functions (see page 7).



All axes and the position pad can be displayed in one window

# Programming

## Quick Integration in LabVIEW



ages and positions, velocity, etc.) can be used in conjunction with a National Instruments DAQ (data acquisition) board to operate positioning systems based on analog PI controllers.

### Using Powerful GUI Programs Directly

Beside the command VIs, high-level VIs can be included directly. A comprehensive selection of GUI programs is provided, such as a terminal application, interface selection routine, wave generator samples, 1D and 2D scan and align functions, joystick control, etc.

Furthermore, the patented Hyperbit™ technology is available under LabVIEW for these systems. HyperBit™ allows attaining position resolution many times better than the resolution of the DAQ board used.

### Quick and Easy System Setup

For commissioning a positioning system, the special Configuration Setup VI is executed once. This VI gathers all necessary system information for LabVIEW, including:

- Communication parameters
- Connected controller(s)
- Types & configurations of the connected stages/axes

### Integrate & Customize Configuration Setup VIs

With its connectors, the Configuration Setup VI can be customized completely to meet the application requirements; it is included as initialization VI directly in the LabVIEW application. After it has been run, all command VIs and high-level routines of the system can be used.

- Full Functionality of All PI GCS Controllers Available under LabVIEW
- High-Level & Low-Level VIs, Including GUI Programs
- Special VIs for Quick System Configuration
- Identical Control for Analog & Digital Controllers
- Open-Source Code of VIs Enables Customization
- Preprogrammed Routines Accelerate Frequently Used Tasks
- Comprehensive Help: Manual, Online Help, Sample Programs

The integration and control of PI positioning systems under LabVIEW is greatly simplified by the provision of comprehensive LabVIEW libraries. The LabVIEW drivers support all GCS-capable controllers from PI, independent of the type of connected stage. Thus it is possible to operate piezo, DC-motor, piezomotor, hybrid and hexapod controllers with one driver together in one application.

controllers are absolutely uniform in the VIs.

This strongly reduces the effort required in case of controller upgrade or replacement. In addition, existing programs for different PI GCS controllers can be reused with greater ease. Very often adaptation consists simply of replacing the controller-specific Configuration Setup VI.

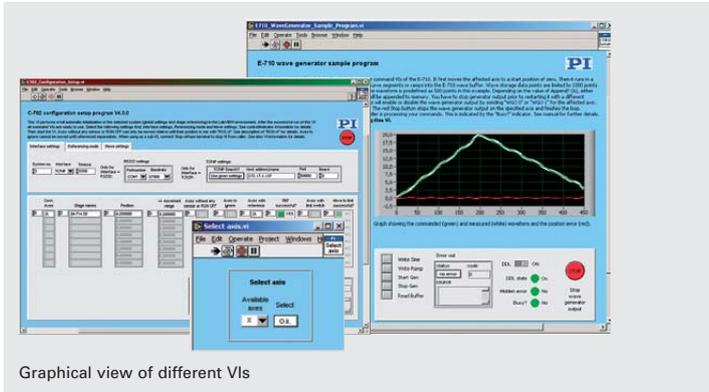
### One LabVIEW Driver for Different Controllers

One big advantage of the combination of the GCS command set and the VIs from PI is the identity in functionality of different positioning systems. Identical functions in different

Any controller-specific functionality is, however, also fully available under LabVIEW.

### Full Support for NI DAQ Boards

The same LabVIEW VIs that are available for PI digital controllers (e.g. set and read volt-



Graphical view of different VIs

## Flexible Integration in Text-Based Programming Languages

The operation of PI positioning systems from external programs running under Microsoft Windows is eased with Dynamic Link Libraries (DLLs) and COM objects.

### Maximum flexibility

The drivers which are provided support all current programming languages (see inset) and all positioning systems from PI. Since the drivers are based on the uniform PI GCS command set (see page 3), GCS functionality can be included directly in external programs. The advantages of the GCS command set are available whether accessed from the DLL or the COM object.

In addition to direct GCS commands, the driver sets also make more complex function-

alities—with their own graphical interfaces—available to external programs. It is thus possible, for example, to use a DLL function call to include the Wave Editor or Profile Generator, complete with operator dialogs, in an external program.

### Languages Supported by PI

- MATLAB
- Visual Basic, Delphi
- C, C++, Python
- LabVIEW (see page 6)

```
int main(int argc, char* argv[])
{
    ID = ES16_ConnectRS232(1, 115200);
    if (ID!=0)
    {
        ES16_qIDW(ID, idn_string, 100);
        printf(idn_string);
        ES16_MOV(ID, axis, target_position);
        ES16_qPOS(ID, axis, current_position);
    }
}
```

Integration of GCS commands like MOV and POS? in DLL

Integration of GCS MOV command in COM object

## Support of Controller-Specific Features

### Improved Piezo Control: Dynamic Digital Linearization (DDL)

Conventional piezo controllers cannot completely avoid phase-shift and tracking errors in applications with rapid, periodic motion. This is due in part to the non-linear nature of the piezoelectric material, the finite control bandwidth and the inherent limitations of P-I (proportional-integral) servo-control, which only reacts when a position error is detected.

The DDL option, available with recent digital piezo controllers, solves this problem. This technology, developed by PI, reduces the error between current and desired position to imperceptible values. The dynamic linearity and effectively usable bandwidth are thus improved by up to three orders of magnitude. DDL is of benefit to single- and multi-axis applications where motion follows a

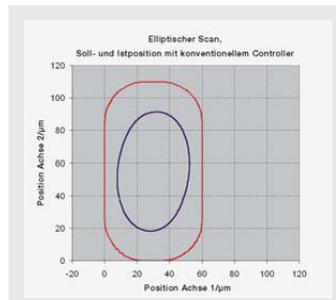
given trajectory repeatedly (see measurement curves).

### Trajectory Profiles

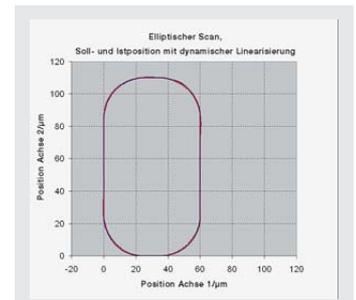
Trajectory profiles of arbitrary, user-defined mathematical functions enable complex 2-axis motion. With the Wave Editor and Profile Generator graphical interfaces, standard functions (sine wave, square wave, ramps, scans, etc.) are selected and customized. Depending on the controller used, either time- and-position data value pairs can be saved (Wave Editor) or complete trajectory profiles with velocity, acceleration and jerk (rate of change of acceleration) can be specified (Profile Generator).

The functionality includes:

- Programming complex functions
- Quick access to common functions (e.g. sine, triangle and square waves ...)



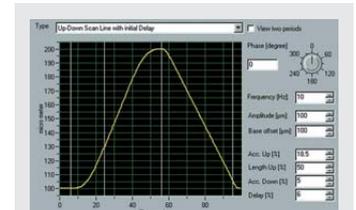
Elliptical scan with a XY piezo scanner and standard controller. The outer curve shows the desired position, the inner curve shows the actual motion



The same scan as before but with a DDL controller. The tracking error is reduced to a few nanometers, desired and actual position cannot be distinguished in the graph

- Coordination of two axes, e.g. for applications requiring circular motion
- Saving of defined functions in the controller

The Wave Editor and Profile Generator are also available as DLL function calls, which enables their simple integration in external programs.



With the Wave Editor, not only are configurable functions like triangle, square, sine wave, etc. available, but also complex scans are defined

## Request the hardbound PI Catalog



Call or go to: <http://www.pi.ws>

### Program Overview

- Piezoelectric Actuators
- Piezo Nanopositioning Systems and Scanners
- Active Optics / Tip-Tilt Platforms
- Capacitive Sensors
- Piezo Electronics: Amplifiers and Controllers
- Hexapods
- Micropositioners
- Positioning Systems for Fiber Optics, Photonics and Telecommunications
- Motor Controllers
- PLine® High-Speed Ceramic Linear Motors

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