Piezo · Nano · Positioning

MP 36E User Manual

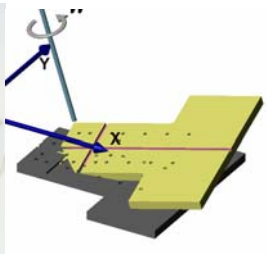
F-206 MicroMotion
Hexapod Positioning System

Release: 3.5.0 Date: 2008-07-16

This document describes the following product(s):

- F-206.S0
  MicroMotion Hexapod Positioning System
- F-206.SD
  MicroMotion Hexapod Positioning System with Built-in Front-Panel Display and Keyboard

Custom models differ in some respect; see included Technical Notes, if any.



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Declaration of Conformity

according to ISO / IEC Guide 22 and EN 45014

Manufacturer:	**Physik Instrumente (PI) GmbH & Co. KG**
Manufacturer´s Address:	Auf der Römerstrasse 1 D-76228 Karlsruhe, Germany

CE

The manufacturer hereby declares that the product

Product Name: **Six-Axis Precision Alignment System**

Model Numbers: **F-206**

Product Options: **all**

complies with the following European directives:

2006/95/EC, Low voltage directive (LVD)

2004/108/EC, EMC Directive

98/37/EC, Machinery Directive

The applied standards certifying the conformity are listed below.

Electromagnetic Emission:	EN 61000-6-3, EN 55011
Electromagnetic Immunity:	EN 61000-6-1
Safety (Low Voltage Directive) :	EN 61010-1
Safety of Machinery:	EN 12100

July 8, 2008
Karlsruhe, Germany

Dr. Karl Spanner
President

About This Document

Users of This Manual

This manual is designed to help the reader to install and operate the F-206 MicroMotion Hexapod Positioning System . It assumes that the reader has a fundamental understanding of basic servo systems, as well as motion control concepts and applicable safety procedures.
The manual describes the physical specifications and dimensions of the F-206 MicroMotion Hexapod Positioning System as well as the software and hardware installation procedures which are required to put the associated motion system into operation.
Updated releases are available for download from www.pi.ws or email: contact your Physik Instrumente Sales Engineer or write info@pi.ws.

Conventions

The notes and symbols used in this manual have the following meanings:

DANGER

Indicates the presence of high voltage (> 50 V). Calls attention to a procedure, practice or condition which, if not correctly performed or adhered to, could result in injury or death.

CAUTION

Calls attention to a procedure, practice, or condition which, if not correctly performed or adhered to, could result in damage to equipment.

!

NOTE

Provides additional information or application hints.

Related Documents

The software tools which might be delivered with F-206 MicroMotion Hexapod Positioning System are described in their own manuals. Updated releases are available from the download area of www.pi.ws or via email: contact your Physik Instrumente Sales Engineer or write info@pi.ws.

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1 Introduction

The F-206 hexapod six-axis positioning system consists of the positioner and a controller. A keyboard and monitor on the controller (either built-in or connected as peripherals) can be used to control the system directly, or, more commonly, the controller can be controlled from a host PC connected to it over an RS-232, TCP/IP or, optionally, a GPIB (IEEE 488) link.

The mechanics uses a parallel-kinematics positioning system. The mechanics contains six linear actuators with leadscrew drives and optical encoders. The system provides six degrees of freedom and a minimal incremental motion of 0.1 µm. The workspace limits are not parallel to the axes but they cannot exceed a rectangular solid that is given by the X,Y and Z travel ranges.

The controller is equipped with firmware that allows definition of a pivot point anywhere inside or outside the F-206 workspace. Rotation about that pivot point can be commanded for any combination of the three rotation axes.

The digital controller also handles complex positioning and motion tasks, including scan and align routines using optical or analog feedback signals from up to 2 power meters. Additionally, two separate PI stages and a 3D piezo system (NanoCube®) can be driven, and complex macro sequences in the BasMac language can be recorded and executed on the controller (see the BasMac User Manual).

The F-206 mechanics can be mounted in any orientation, but different load limitations apply.

1.1 Model Survey

The following models are available:

- F-206.S0 MicroMotion Hexapod Positioning System
- F-206.SD MicroMotion Hexapod Positioning System with Controller with Built-in Display and Keyboard

If you have a custom version, some portions of this manual may not apply, or may be superceded by a Technical Note.

The following accessories are available for use with the F-206

- GPIB card for faster communications between controller and host PC (order number F-206.I3E)
- Optical/Analog Input Board (infrared: order number F-206.iiU; visual: F-206.VVU)
- External, configurable, high-precision and highly stable optical power meter (F-361)
- Interface card for attaching 1 or 2 optical power meters (F361B0001)
- Manual Control Pad (F-206.MC6) and interface board (C-855.60)
- Firmware upgrade to control two additional, separate motor-driven axes (software upgrade, order number F-206.AC8)
- Driver card (E-760) for controlling a three-axis piezo nanopositioner (NanoCube®, P-611)

If you have a custom design, some portions of this manual may not apply, or may be superseded by a Technical Note.

1.2 Contents of Delivery

The exact contents are given in the packing list. A standard system should include the following:

- F-206 mechanics
- F-206 controller
- Mechanics-controller connecting cables (DC power and motor control)
- Controller line-power cord
- RS-232 null-modem cable
- Ethernet (TCP/IP) straight-through & crossover RJ45 cables
- US keyboard
- CD-ROM with PIMikroMove™ Software, LabVIEW drivers, DLL, additional software, sample programs and documentation files (latest releases are available for download from www.pi.ws)

- User Manual, MP36E, this document in printed form
- Torx driver, #8
- Allen wrench

1.3 Software Overview

With the F-206 Controller, all motion of the connected mechanics is programmed or controlled by software. To offer maximum flexibility, software interfaces at a number of different levels are provided and documented. Most of the individual programs and driver libraries are described in separate manuals. The included software and documentation is on the product CD, but not all of it will be copied to host during the installation procedure. Updated releases are available on www.pi.ws or via email: contact your PI Sales Engineer or write info@pi.ws.

- PITerminal is a Windows program which can be used as a simple terminal with almost all PI controllers.
- PIMikroMove™ (application for Microsoft Windows platforms) is operating software for this and many other PI controllers. With PIMikroMove™ you can start your motion system—host PC, controller and mechanics—immediately without writing customized software. PIMikroMove™ offers motion control displays and features that in many cases make it unnecessary to deal with ASCII command formats. It also has a complete command input facility, which lets you experiment with various commands easily. PIMikroMove™ uses the GCS DLL described below to command the controller.
- GCS LabVIEW drivers to communicate with the system from the National Instruments' LabVIEW environment (not included) using the GCS-DLL (see GCS LabVIEW Manual, MS93E).
- GCS DLL (Windows DLL Library): The GCS DLL is an intermediate layer providing easy access to the controller from Windows programs. The use of the DLL and the functions it contains is described in a separate manual (MS181E). Most of the DLL functions correspond directly with the commands of the PI General Command Set.
- OPM Test: Windows program for testing the optional F-361 optical power meter directly on the host PC
- F-206 Simulation: Software collection making it possible to simulate a controller and mechanics, and, if desired, to run the simulation in an emulated PC running in a Windows window in the same PC as the host software.

- F206_force_Direction.exe: Program for calculating approximate loads on the individual struts as a function of the load on the platform.

Historical Software

Certain programs predating the PI General Command Set (GCS) are also included for historical and compatibility reasons. They include a set of LabVIEW drivers and a DLL, and may not support many new features.

1.4 Documentation Overview

This manual contains the product description as well as a listing of the commands which are used with the F-206 Controller. A detailed description of the software that runs on your host PC can be found in separate manuals which are included on the F-206 software CD (the latest releases are available for download from www.pi.ws).

Your system may include accessories like the F-361 optical power meter, which are described in detail in separate manuals.

In addition to the manuals, there may be Technical Notes included describing certain parts of the system. The information in Technical Notes may augment or supersede that in the manuals.

1.5 Safety Precautions

CAUTION

Scan and MOV! command runout may damage attached application

The trajectory specified by the [X] [Y] [Z] [U] [V] and [W] parameters to the fast scan commands is not followed as exactly as motion initiated with a MOV command, but rather with a certain amount of wobble. For this reason large scanning ranges are not recommended: for example a scan of 2 mm may result in an additional deviation of up to 11 µm from the desired trajectory, which, if unexpected, could damage the attached setup.

For additional runout information see the individual fast scan command descriptions.

CAUTION

!

Warning: Fragile Mechanics

The F-206 mechanics can be permanently damaged by applying excessive force to the mobile platform. To maintain a safety factor, the maximum compressive force on this platform should never exceed 10N.

The maximum shock acceleration on the system without the platform installed should never exceed 25g.

For transportation and shipment, the special safety shipping box supplied by PI must be used.

Protect the intermediate plate from damage by mechanical forces by using the transport cover.

Take special care when connecting products from other manufacturers. Follow the General Accident Prevention Rules!

The program *F206_force_Direction.exe* on the product CD can be used to calculate the allowable stresses in different directions and with the unit in different orientations.

Do not lift the F-206 by the top platform.

DANGER

Warning: Electric Shock Hazard

Systems with the E-760 Piezo Axis (NanoCube®) Controller

Piezo stages are driven by amplifiers generating high voltages. The output power on the (optional) E-760 card and connected stage may cause serious injuries.

All work done with and on the modules described here requires adequate knowledge and training in handling high voltages.

CAUTION

During fast scan motion, the STOP, #24 and #27 commands may not take effect immediately.

CAUTION

Electrostatic Hazard: Add-In Cards Subject to Damage

Electronic components are sensitive to electrostatic electricity. Take appropriate electrostatic protection measures when installing or removing boards or opening the controller for any other reason.

CAUTION

Enter only valid commands. Commands with Incorrect syntax can have unexpected results. The fact that error codes exist for syntax errors does not guarantee that all syntax errors will be recognized. Unrecognized syntax errors can lead to execution of the command with altered parameters.

1.6 Prescribed Use

Based on their design and realization, PI F-206 controllers are intended to drive PI F-206 positioners and, optionally, separate piezo- or motor-driven axes. F-206 systems must not be used for applications not in conformance with this manual.

Observe the safety precautions given in this User Manual.

F-206 systems conform to Measurement Category I (CAT I) and may not be used for Measurement Categories II, III or IV. Other use of the device (i.e. operation other than instructed in this Manual) may affect the safeguards provided.

Standard F-206 systems are designed to operate under normal ambient conditions at least as listed here. More stringent conditions given in the Specifications tables are, of course, also met.

- Indoor use

- Altitude up to 2000 m
- Temperature range 5°C to 40°C
- Max. relative humidity 80% for temperatures up to 31°C, decreasing linearly to 50% relative humidity at 40°C
- Line voltage fluctuations not greater than ±10% of the line voltage
- Transient overvoltages as typical for public power supply
  Note: The nominal level of the transient overvoltage is the standing surge voltage according to the overvoltage category II (IEC 60364-4-443).
- Degree of pollution: 2

2 Quick Start

2.1 Unpacking

!

CAUTION: Fragile Mechanics

The F-206 mechanics can be permanently damaged by applying excessive force to the mobile platform. To maintain a safety factor, the maximum compressive force on this platform should never exceed 10N.

The maximum shock acceleration on the system without the platform installed should never exceed 25*g*.

a)

F-206 systems are usually shipped attached to a wooden baseplate and with with the top platform replaced by a shipping cover. These are a protective measures to avoid mechanical damage.

Remove the unit carefully. Preserve all packing materials in case the F-206 ever needs to be shipped again.

b)

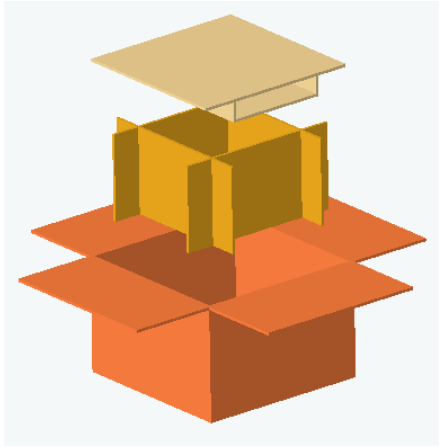


Fig. 1: F-206 packaging includes shipping case with foam inserts (a), cardboard box, cage and top (b)

The size and elasticity of the packaging has been calculated to prevent damage to the equipment during shipping.

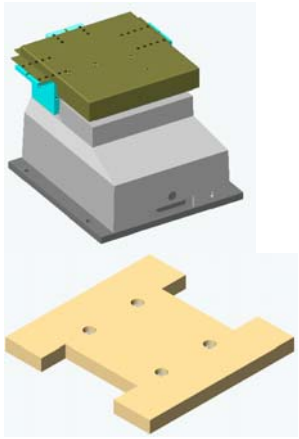


Fig. 2: F-206 itself comes mounted on a wooden baseplate for shipping

Be sure not to get the baseplate upside down when reshipping. The protruding rings (not shown) should face downwards. Wrap the F-206 and baseplate in foil wrapping before placing in cardboard box.

Prior to use, the transport cover must be removed and the platform mounted. Mount the moving platform on the intermediate (low-weight) platform as shown in Fig. 3. All 12 screws should be used to provide a secure and stiff connection.

CAUTION

Avoid Damage

Do not lift the F-206 by the top platform.

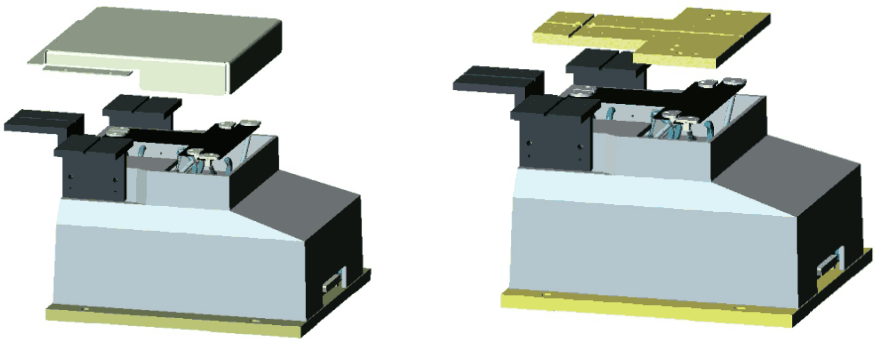


Fig. 3: Remove shipping protection cover and install the platform before use

2.2 Mounting

The F-206 may be mounted in any orientation, but different load limits apply to loads not on the Z-axis, and to loads applied when the unit is switched off (see Technical Data table, p. 116). Be sure not to exceed the load limits while installing your application. The strut-force calculation program (*F206_force_Direction.exe*) included on the product CD can be used as an aid. Simply enter the force and torque components, click on an orientation (normally "Z-up") and it calculates the forces on the struts. These must not exceed the values given on the screen.

2.3 Load Calculation

Using the F206_force_Direction.exe program on the product CD (in the Simulation\F206_force_Direction\ directory) the load on individual struts can be approximately calculated as a function of the type and position of loads on the platform.

NOTE

F206_force_direction.exe is for F-206 Hexapods with standard geometry only.

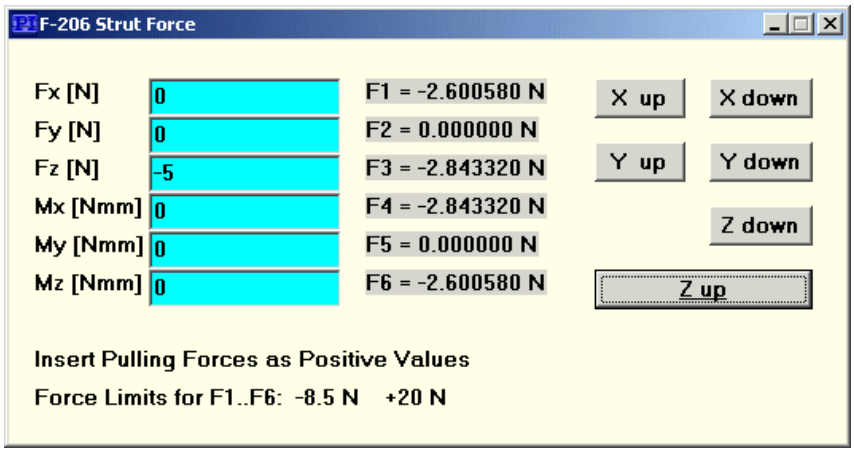


Fig. 4: F206_force_Direction.exe calculates strut stress with the unit in different orientations

Platform force and moment components can be entered in the fields on the left. The values labeled F1 through F6 are the resulting loads on struts 1 to 6, respectively. The values are recalculated whenever one of the orientation buttons is clicked (because of the weights of internal components, the strut loads will differ depending on how the unit is oriented); Z up corresponds to normal, horizontal mounting.

2.4 Connection and Startup

1 Connect the F-206 mechanics and the controller using the cables supplied. DC power for the F-206 mechanics is also drawn from the controller (for standard F-206s, 24 V). Note that some controller sockets are for special versions or options and are otherwise unused.

2 If you ordered control of the optional separate motorized axes with the system (order number F-206.AC8), it will be delivered with these axes preconfigured. Otherwise, use the software upgrade diskette in the controller to configure the interface for the stages in question (see p. 107 for details).

3 If you have ordered the optional E-760 piezo axis controller, it will be delivered preinstalled and precalibrated with the mechanics. See the E-760 and Nanocube® documentation for more information. Note that information there on commanding the controller card is not of importance, as this task is handled by the F-206 controller in response to the commands it receives.

4 Verify that the mechanics is not at the end of a travel range or in contact with any object that might hinder movement.

5 Connect controller to host PC using the appropriate cable for the interface you will be using (e.g. the included null-modem cable for the RS-232 interface). If using TCP/IP, connect the PC directly to the controller with a cross-over network cable, or connect both controller and host to network connection points with straight-through cables (see Section 4.2).

NOTE: Use Correct RS-232 Sockets

With an RS-232 link, on the F-206 controller side you will be using RS-232 port COM1, labeled “RS-232”. On the host PC side, any available COM port can be used.

If the system was ordered with the optional F-361 Optical Power Meter (OPM), an additional RS-232 board is installed in the controller with two sockets labeled OPM1 and OPM2. These sockets are only for connecting F-361 OPMs.

6 Power up host PC and F-206 hexapod controller. See “Troubleshooting” p. 102 if you suspect that the controller is not booting properly.

7 Install the host software on the host PC:
The software package supports a common installation

procedure. A setup program guides you through all installation steps using interactive dialogs. This program, setup,exe,  , is located in the root directory of the F-206 hexapod software CD that comes with the system. After running the setup program, the host software is ready to use.

8 If you are planning to use TCP/IP to communicate with the controller, make the correct settings as described in Section 4.2.

9 Start the PIMikroMove host software on the host PC. In the *Start up controller* window select *Hexapod* as controller type, and select the communications link used in step 5. If using RS-232, make sure the baud rate setting is the same at the controller and the host PC (the controller firmware defaults to 57600 baud). Click *Connect* to continue.

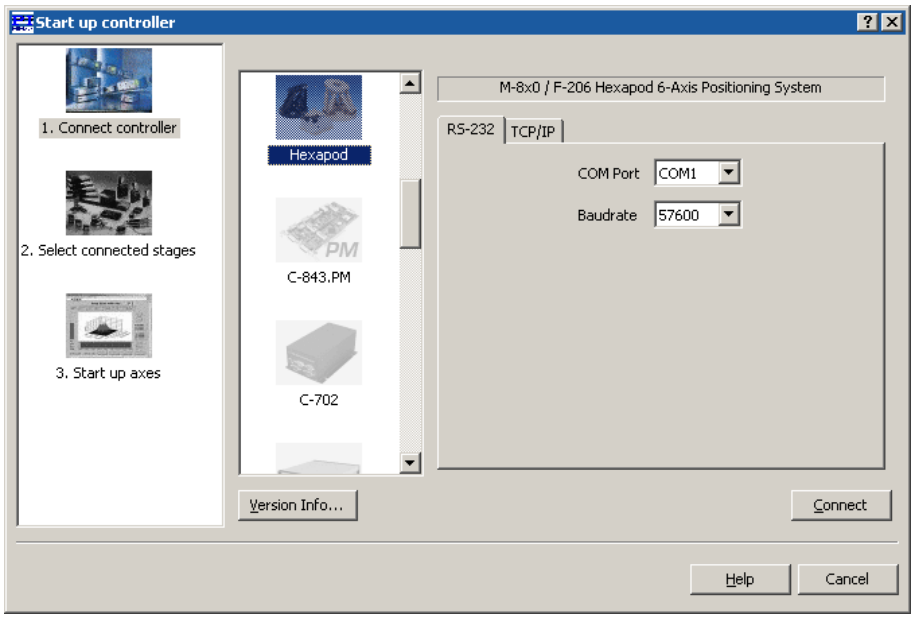


Fig. 5: PIMikroMove Start up Controller screen at Connect Controller step

10 In the screen that follows, *Configure Hexapod* check the optional features you wish to use. The separate axes and analog (optical) inputs checked must be installed properly and configured on the controller. Click *OK* to continue.

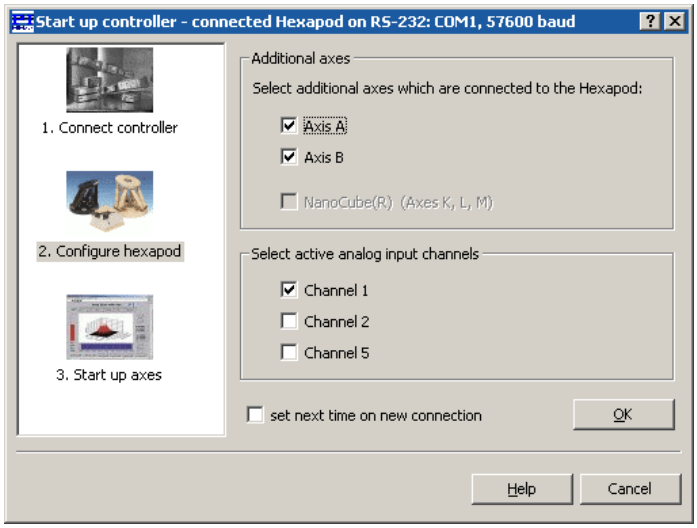


Fig. 6: PIMikroMove Start up Controller screen at Configure Hexapod step

11 In Step 3, *Start up Axes*, you can reference the axes (runs INI command). Make sure that nothing will be damaged when the axes move. If any Hexapod axes are selected, all F-206 axes will be referenced and all will move. Axes A and B are referenced separately. Click *Automatic* to reference the selected axes.

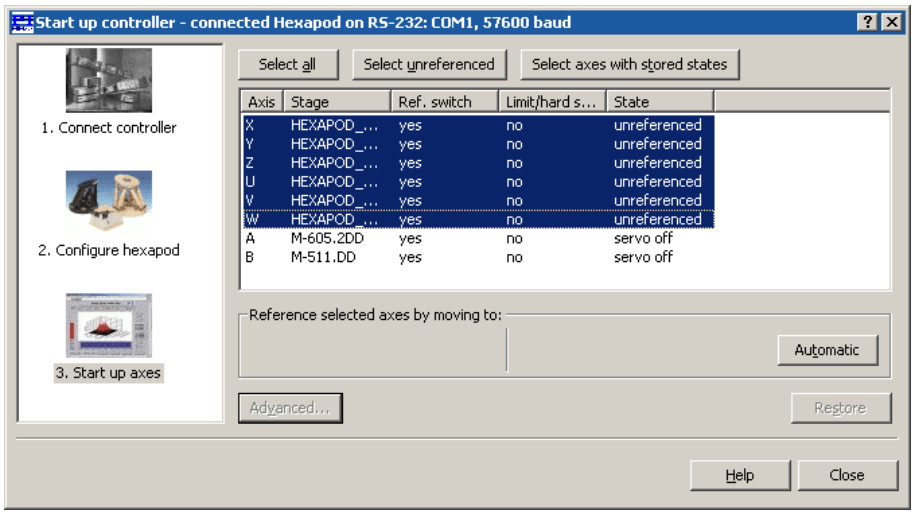


Fig. 7: PIMikroMove Start up Controller screen at Start up Axes step

12 If there are any problems with communication, please read the Troubleshooting section, p. 102.

13 After referencing make a few test moves to make sure that the system is operating properly.

3 System Description

F-206 systems consist of the F-206 mechanics—the movable platform supported by six linear actuators—the control electronics and two connecting cables.

Motion in all six degrees of freedom is performed using DC-motor-driven linear actuators.

Fig. 8: Controller included with F-206.SD has built-in display and keypad

The mechanics is controlled by a PC-based, multi-axis DC-motor controller with an installed motor-control board which can control the 6-DOF F-206 and, optionally, two separate DC-motor or voice-coil axes... An optional add-on board, the E-760, for control of 3 piezo axes is also available. The controller's internal firmware accepts motion commands via an RS-232, TCP/IP or, optionally, GPIB communication link from a host PC (not included) for the F-206 and any additional axes which are configured.

All commands for positioning the F-206 platform are given in orthogonal coordinates and transformed by the controller to the F-206 actuator-specific positions and velocities before execution.

With the F-206.AC8 firmware upgrade option, the controller can be configured to control additional axes A and B. Any stages compatible with PI's DC motor controllers, including voice coil stages, can be used (see p. 107).

With the F-206.NCU add-on card and included firmware upgrade, the F-206 can control additional axes K, L and M. Piezo positioners compatible with the E-760 controller, like the P-611 NanoCube® XYZ nanopositioner can be used (see p. 112).

3.1 F-206 Hexapod Mechanics

3.1.1 Design

The F-206 is based on a parallel-kinematics, parallel-metrology design with stationary, vertically acting linear actuators. Constant-length struts are mounted on top of the actuators to transfer the motion to the platform which they alone support. The advantages of this design are low weight, high stiffness, six-DOF motion, high resolution and no moving cables to cause drag or friction.

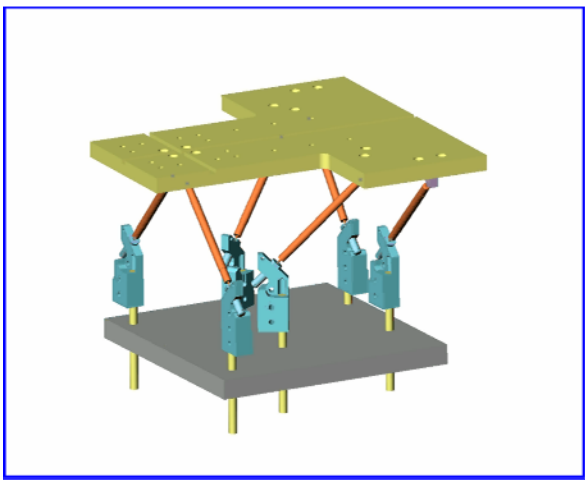


Fig. 9: F-206 internal linkage with parallel linear actuators and constant-length connecting struts

It is not possible to cause excessive mechanical stress to a standard F-206 by driving the struts to some random position. This may not be true of your attached application, however (see the SSL and other soft limits command descriptions).

3.1.2 Referencing

Upon power-up, an initialization routine must be first be run (INI command); during initialization each linear actuator is commanded to the absolute center of its travel range. All positioning commands are referenced to this center position.

3.1.3 Six-Axis Motion Synchronization

Even when the electronics drives the platform along orthogonal axes or around a fixed pivot point, all six actuators have to be moved in harmony based on complicated interpolations to guide the platform along the expected trajectory.

All motion commands refer to a platform position defined by three linear and three rotational coordinate values. The axes about which rotations are defined (U, V, W) are initially coincident with XYZ of the F-206 coordinate system. Their intersection, the pivot point, can, however, be shifted with a user command by any amount desired, and can lie inside or outside the system workspace. Moves which specify new X, Y or Z (translation) parameters also shift the pivot point (i.e. the pivot point “moves with” the platform). Similarly, a non-zero rotation around X (U-move), rotates the V and W rotation axes, and a non-zero rotation around Y (V parameter) rotates the W axis. This means, for example, that a W-move always rotates the platform about a line perpendicular to its plane.

To execute a move command, the system first evaluates the target position specification, then calculates how to get there from the current position in a smooth continuous vector motion, then performs that motion. See F-206 Coordinate System, p. 36, for examples and illustrations.

3.2 Electronics

Most of the system electronics is in the PC-based controller. The controller can be located up to about 10 m away from the mechanics. The controller contains an 8-axis DC-motor controller and the software needed to transform the user-commands into hardware-specific commands for the six F-206 Hexapod motors, and, optionally, for any additional axes installed.

Software is provided to send ASCII commands to the controller from a host PC (not included). In addition, the controller’s ASCII command interface is fully described, so as enable creation and use of custom software, if desired.

The F-206 controller is connected to the mechanics with a special shielded control cable and a PWM amplifier power cable.

Data transfer between the Hexapod controller and the host PC is based on a TCP/IP, RS-232 or, optionally, a GPIB link. This technique allows data transmission over large distances or remote locations, if required.

4 Communication with the Controller

The controller is itself a PC-based system. A directly connected keyboard and monitor can be used to change certain operating parameters and enter commands directly (see p. 33), but this is not necessary in normal operation. Some models have a built-in display and keyboard and all models have connections for external VGA monitor and keyboard. After starting the system, almost all activity direct or via the host, will be displayed on the monitor connected to the controller (if present).

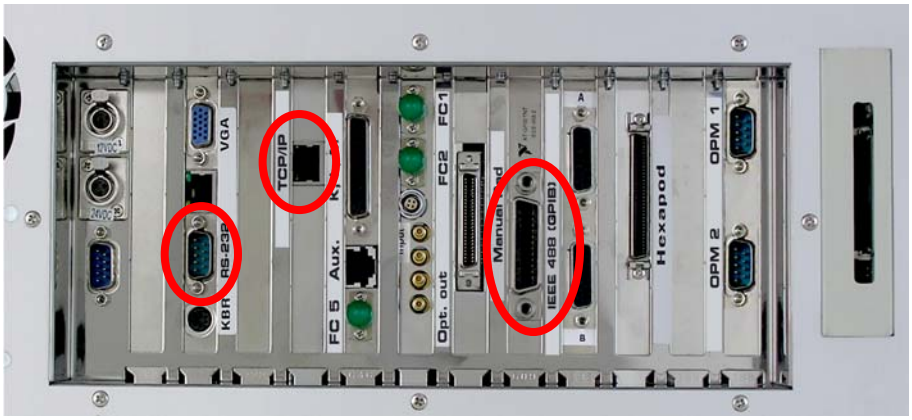


Fig. 10: F-206 Hexapod controller with RS-232, TCP/IP and GPIB (optional) connections circled

All operating commands to be performed by the controller can be sent via the communications interface. Some configuration changes (e.g. firmware update) must be made at the controller itself, either with a keyboard and monitor or via removable storage media.

The standard controller comes equipped for RS-232 and TCP/IP communication. RS-232 at 56 kbaud is activated as factory default. A GPIB (IEEE 488) communications card can be included in addition, or added later as an upgrade (PI part number F-206.I3E, if ordered with the controller, will be installed before shipping. Otherwise see p. 113 and p. 107).

4.1 RS-232 Connection

This section explains the settings required for using the RS-232 interface for sending ASCII commands to the controller from a host PC via a null-modem cable like the one included. All the included

software supports this connection type without installation of any additional drivers.

4.1.1 Controller-Side Parameters

To command the device over RS-232 (sub-D9m connector), RS-232 must be enabled as the ASCII command interface. This is the factory default setting, with the COM port set at 57600 baud. These settings must be made in the controller file system as described in Section 4.4 below. The procedure requires using a directly connected monitor and keyboard, because there are no ASCII commands for making these settings. The other RS-232 settings are 8 data bits, 1 stop bit, no parity and cannot be changed.

4.1.2 Host-Side Parameters

The baud rate should be set to match that of the controller, whose factory default is 57600; the other settings are always 8 data bits, 1 stop bit and no parity. The COM port to choose is the one the null-modem cable is plugged into on the host PC.

4.2 TCP/IP Connection

This section describes establishing a connection between the controller and the host PC using TCP/IP. The controller is shipped with a fixed IP address of 192.168.1.28. Depending on how you wish to access the system, you may need to change this setting (see “Controller-Side IP Parameters,” p. 26).

To command the hexapod over TCP/IP it is necessary to enable TCP/IP as the ASCII command interface (see “Enabling/Configuring ASCII Interface,” p. 31 for details), establish a connection to the device’s IP address (see below) and send ASCII commands to port 50000 (e.g. with PIMikroMove™ or PITerminal). To configure the TCP/IP interface itself, you need to connect via TCP/IP to port 80 with a browser (see p. 26), because no ASCII commands are available for that purpose.

TCP/IP access differs depending on the network availability, which can be as follows:

- Local Area Network (LAN)—use a suitable cable (some older LAN connection points only support straight-through cables), see Section 4.2.1 for details

- Direct connection to Ethernet card in host PC—use cross-over cable, see Section 4.2.2 for details

NOTE

In order to change the TCP/IP settings on the controller side, it is necessary to establish a TCP/IP connection with the controller. The controller has a fixed IP address of 192.168.1.28 as factory default.

4.2.1 Via Local Area Network

If a local area network is available, a straight-through cable can be used to connect the controller to a network access point. Some newer network access points also support use of a cross-over cable.

If the factory default IP settings are not compatible with the network, then they may have to be changed using the direct connection described in Section 4.2.2. Once connected over TCP/IP, the controller can be assigned a different fixed address or configured to obtain its IP address automatically from a server (e.g. DHCP).

The IP address can be confirmed over the connection with the *Search for Controllers* feature of PIMikroMove™ or PITerminal (if IP: 0.0.0.0 appears, select the line with a single click and the actual address will appear in the Address field in the upper right).

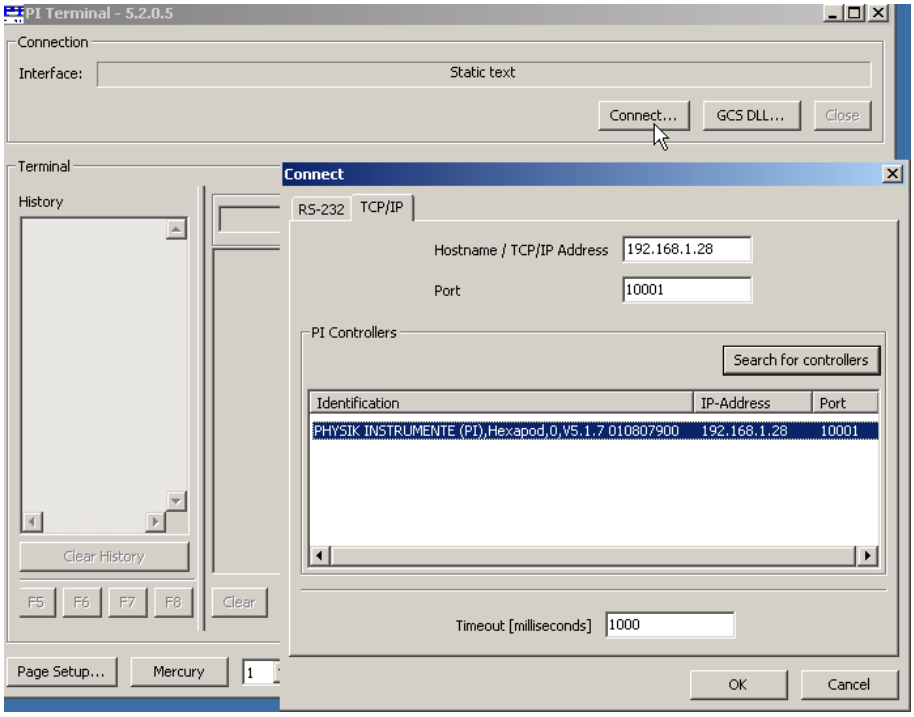


Fig. 11: The Connect dialog in PIMikroMove™or PITerminal can be used to determine IP addresses of connected controllers

When the controller is detected, attempt to establish a connection, either with PITerminal or with a browser.

If the controller is not found, or no connection can be established, then it will be necessary to change network or controller settings. To change controller settings in this situation, connect it directly to a PC as described in the next section.

4.2.2 Direct Connection to PC

When no network is available, or the network connection could not be established for some reason, you can try connecting the controller directly to an Ethernet socket in the host PC using a cross-over cable. This may be necessary as a temporary measure, just to change the controller's IP settings to make it compatible with the network.

For the direct connection, you may need to change the network settings of the PC. The PC and controller must be configured to be on the same subnet—i.e. the PC and controller IP addresses must be identical in all positions where the subnet mask, expressed in binary, has 1's (note: 255 decimal is all 1's in binary).

To change the PC IP address and subnet mask, proceed as follows.

NOTE

Be sure the PC is not connected to a network before changing the settings, and note the previous settings if they have to be restored for later operation.

The following steps may vary in some details depending on the language and version of the operating system on the PC:

1. Follow the *Start → Settings → Control Panel → Network and Dial-up Connections → Local Area Connection* menu sequence.

2. In the *Local Area Network* (LAN) status window, click the *Properties* button.

3. In the Properties window of the LAN connection, make sure *Internet Protocol (TCP/IP)* is checked and open its *Properties* window.

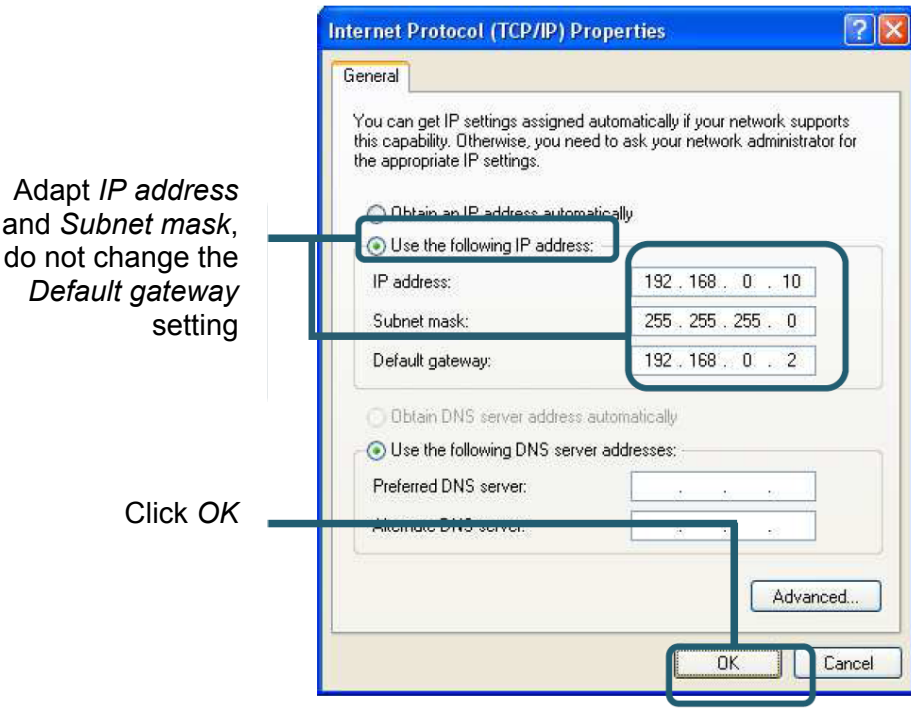


Fig. 12: Internet Protocol (TCP/IP) Properties window, the settings shown are only examples and may not match those you wish to use for your PC

4. In the *Internet Protocol (TCP/IP) Properties* window (Fig. 12), activate *Use the following IP address.* Make a note of the

current *IP address* and *Subnet mask* settings, if any, in case they need to be restored later.

5. Make at least the first portion of *IP address* identical to that of the IP address of the controller (factory default 192). For the other portions of the PC's IP address, choose values from 1 to 254 with at least one of them different from the controller's.

   Set *Subnet mask* to a valid value* with no binary 1's in any position where the controller and PC addresses differ (examples are 255.0.0.0, 255.255.0.0 and 255.255.255.0).

   To apply the changes confirm with *OK* in this window and then in the *Properties* window of the LAN connection

6. Use the *Search for Controllers* feature of PIMikroMove or PITerminal to establish the connection between PC and the controller.

   If no controller is found, then it may be helpful to return to Step 5 and try 10, 169, or 172 in the first portion of the PC IP address with a subnet mask of 255.0.0.0. Make sure such settings are not used on a machine connected to a network or the Internet!

4.2.3 Controller-Side IP Parameters

NOTE

The controller-side IP parameters can only be changed over the TCP/IP connection. If the controller is set to obtain its IP address automatically (not default), then the appropriate IP address service must be available to it, otherwise it may not be possible to establish a connection at all.

Use a browser on the PC to change the controller-side IP parameters over the TCP/IP connection (i.e. connect to port 80) as follows:

1. Input the current controller TCP/IP address, as determined with *Search for Controllers* in PIMikroMove™ or PITerminal, in the address line of the browser and press ENTER. If a password is requested, just press ENTER and continue.

* The binary representation of a valiid subnet mask consists of a string of 1's followed by a string of zeros.

2. If the controller is not found, try changing settings on the host or network side and try again.

3. When a connection is established with the browser, follow the instructions that appear. If a password is requested, just press ENTER and continue. Choose the network tab (on the left) and make your desired settings as shown below. The settings made become the new power-up defaults. Do not set the controller to obtain its IP address automatically unless you are sure a compatible service is available. Note the settings made in case communication is lost.

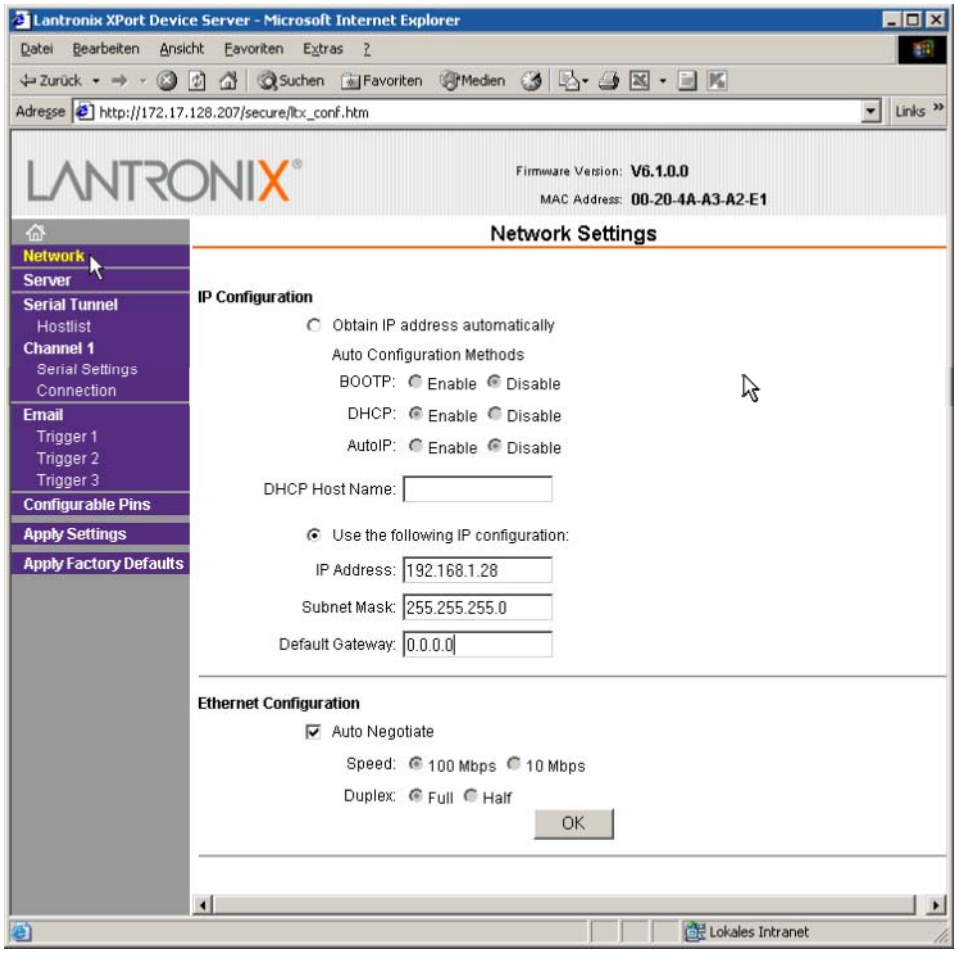


Fig. 13: Controller-side network settings as accessed over the TCP/IP interface with a browser

4. Confirm with OK, and on the next screen choose *Apply Settings*

5. A progress bar will appear. When it has completed, the unit will reboot with the new settings, dropping communication if the address has been changed.

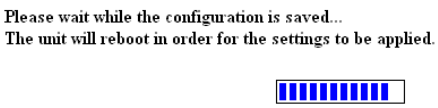


Fig. 14:Progress bar appears after Apply has been selected

If communication is lost and you wish to see the mask with the new settings again, reestablish it in the address line of the browser.

4.2.4 Host-Software Parameters

Once a TCP/IP connection has been established and enabled as the ASCII command interface, it is necessary to get the host software to use it. The current versions of some of the host software will do so directly, for example, PITerminal and PIMikroMove™.

Other programs may require installation of redirection drivers (not included) in order to make use of the TCP/IP connection. Read the driver documentation carefully. Typically, when the driver is installed, a new COM port will appear in the system. Data sent to that COM port will be sent out the TCP/IP link, addressed to the desired correspondent (here, the F-206 Hexapod controller on port 50000). When the driver has been installed, start the software, choose connection type RS-232 and choose that new COM port.

4.3 IEEE 488 (GPIB) Connection

4.3.1 Controller-Side Parameters

To command the device over a GPIB link, the controller must have the GPIB interface card and GPIB must be enabled as the ASCII command interface. This is the factory default setting for controllers ordered with the interface card. If the card was ordered separately, then this setting, and the setting of the GPIB address, must be made in the controller file system as described in Section 4.4 below. The procedure requires using a directly connected monitor and keyboard, because there are no ASCII commands for that purpose.

4.3.2 Host-Side Parameters

The host must have IEEE 488 (GPIB) communications capability. PI does not offer GPIB cards, but tests its devices with cards from National Instruments. Consult the manufacturer documentation for further information.

4.4 Controller Configuration File

Except for the controller-side TCPIP configuration discussed in Section 4.2.3, controller-side interface configuration changes must be made by editing a file on the controller file system.
The parameters include ASCII interface selection (TCP/IP, RS-232 or IEEE 488), RS-232 baud rate (default 57600) and IEEE address (default 4).

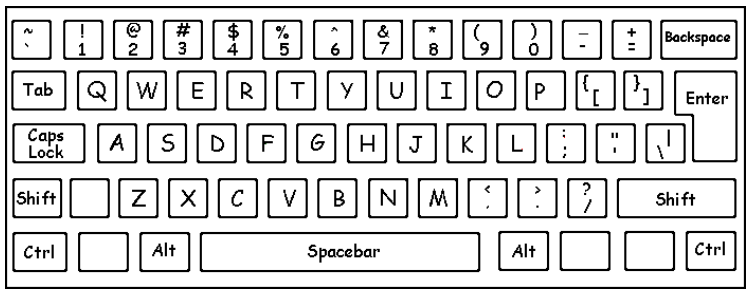


Fig. 15: Keyboard with US layout, included with the hexapod system

4.4.1 Editing HEXBRATE.DAT

To check or change settings, you must access the HEXBRATE.DAT file on the controller file system as follows:

1. If your controller has a built-in keyboard and display and you wish to use them, go on to the next step, Otherwise connect a standard PC keyboard (US-layout, Fig. 15) and VGA monitor to the appropriate connectors of the controller.

2. Power up the Hexapod controller, and after it boots, exit the Hexapod software with F10; you will now have a DOS prompt.

3. In the "\HEXAPOD" directory use the "EDIT" command (or, alternatively the DOS Commander, "DC" command), to access the HEXBRATE.DAT file.

```
C:\HEXAPOD>edit hexbrate.dat
```

Fig. 16: DOS prompt (above), HEXBRATE.DAT in editor (below)

4 HEXBRATE.DAT should have the structure shown in Fig. 16: Depending on which interface is enabled as ASCII command interface, there may be a 6th line in the file. There must be no blank lines

5 Edit the file as required for the desired configuration (see corresponding below)

6 Save the file, exit the editor and reboot the controller. If using EDIT, access the menu bar by pressing and releasing the ALT key. Save (Speichern) and Exit (Beenden) are under the leftmost item. Select yes (ja), if asked if the file may be overwritten.

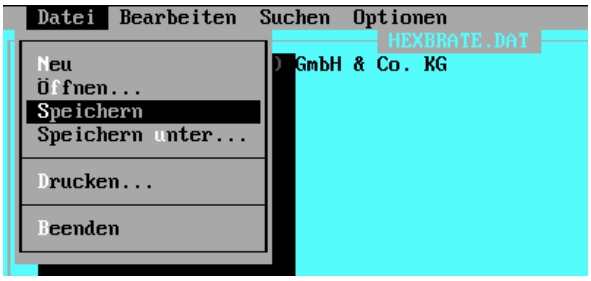


Fig. 17: DOS EDIT (German version shown): Press and release Alt to activate menu bar, then save with S.

4.4.2 Enabling/Configuring ASCII Interface

RS-232

For RS-232 communication to be enabled, there must be no 6th line in the HEXBRATE.DAT file (see Section 4.4). The baudrate to use when the RS-232 interface is enabled is alone on line 5. Do not use a thousands separator.

Other RS-232 parameters cannot be changed from 8 data bits, 1 stop bit, no parity. The required RS-232 null-modem cable comes with the system.

TCP/IP

The Ethernet TCP/IP interface on the controller is always activated, but by default it is not enabled as the ASCII command interface. Its default setting is to use a fixed IP address of 192.168.1.28.

To enable the TCP/IP interface as the ASCII command interface for the device, the HEXBRATE.DAT file on the controller must have “TCPIP” (Firmware 6.xx or newer) or “COM2” in line 6 (the line after the baudrate value, which must be present). See Section 4.4.1 for detailed instructions on accessing this file. No spaces are allowed in the entry, and no blank lines in the file, which looks as follows:

```
PHYSIK INSTRUMENTE (PI) GmbH
Auf der Römerstraße 1
D-76228 Karlsruhe
Baudrate
57600
TCPIP
```

Changing the TCP/IP parameters, including the IP address behavior, is not possible here. It is done by addressing the IP address with a browser (port 80) from the host PC over the Ethernet cable (see Section. 4.2.3). This is possible even when TCP/IP is not enabled as ASCII command interface.

GPIB (IEEE 488)

For GPIB the HEXBRATE.DAT file on the controller must have an entry like “GPIB4” in Line 6 (the line after the baudrate value, which must be present but is ignored). See Section 4.4.1 for detailed instructions on accessing this file.This setting enables GPIB communication with the (default) address 4. The general entry is “GPIBx” where x is the GPIB address of the system.

```
PHYSIK INSTRUMENTE (PI) GmbH
Auf der Römerstraße 1
D-76228 Karlsruhe
Baudrate
57600
GPIB4
```

4.5 Communication Checks

Install PITerminal or PIMikroMove™ on the host PC if you have not already done so.

Connect the controller and the host PC with the appropriate cable or network. Switch on the controller, start the terminal program or PIMikroMove™ on the host PC, select the communication mode and appropriate host-side parameters. PIMikroMove will lead you through initialization of the mechanics automatically.

With a terminal program, first send an innocuous command like:

HLP? LF

(the answer reports all commands that are currently available in the controller).
Next make sure that nothing will be damaged by motion of the platform to its central position and type in the initialize command to reference the axes:

INI LF

Watch the system: it will move to the “INI” position. Even if the system is close to the “INI” position, a small movement of all struts can be observed because they always approach their reference points from the same direction.

Next type in the simplest move command

MOV Z 1 LF

Watch the system. All struts will move as to move the platform by 1 mm. Similarly in PIMikroMove, command a few moves with the buttons in the Axis list window. See the PIMikroMove manual for more details.

4.6 Direct Control

The Hexapod system comes in versions with built-in keyboard and display. An external keyboard (included) and display can be connected to all versions.

4.6.1 Main Screen

The main screen shows a graphic display of the hexapod position, the current position, pivot point coordinates, maximum velocity setting, and key assignments.

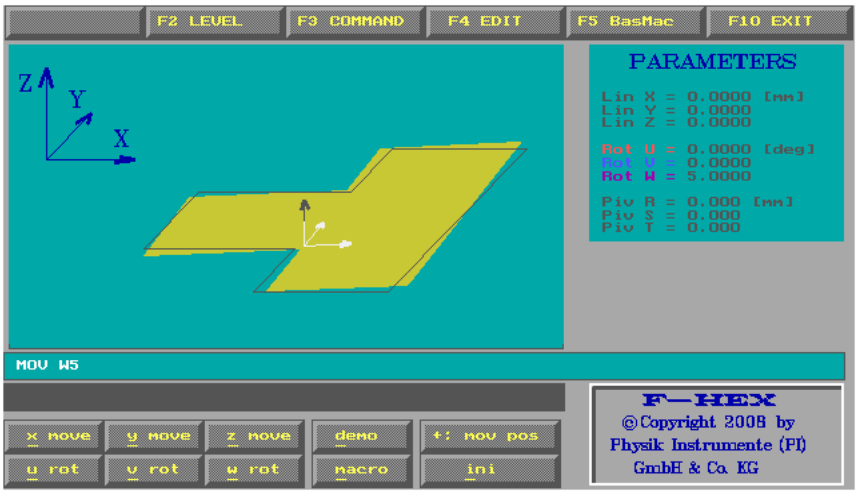


Fig. 18: Main screen on F-206 Hexapod controller with MOV W5 in last-command line

Key	Function
I	Initialize system (INI command)
X, Y, Z, U, V, W	Move one step in the specified direction using step size set with F4
D	Executes the commands starting in line 5 of DEMO.DAT
F10	Exit software
F3	Open a command entry pane (close it with ESC)
F2	Show/hide axis/channel A & B display
F4	Open field to set step sizes for X, Y & Z and U, W & W

4.6.2 Command Entry Pane

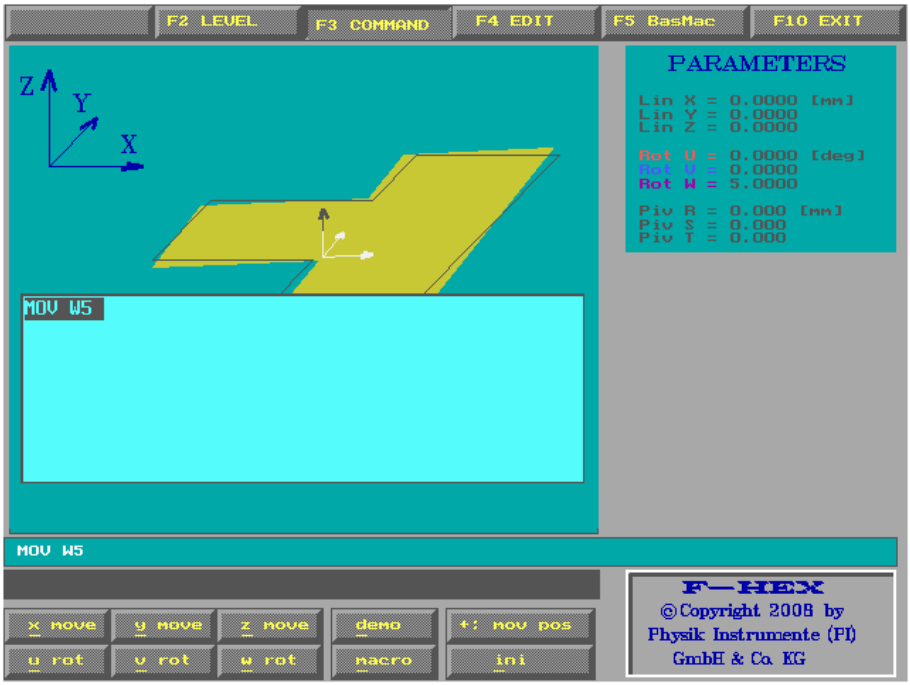


Fig. 19: Command entry, direct on F-206 Hexapod controller; exit with ESC *to activate other buttons*

The direct command interface and one remote interface can be active at the same time. Remote commands are shown below the command entry field as they arrive.

Useful keys are:

ENTER	Repeat the last-entered command
ESC	Close the Command Entry pane

While the Command Entry pane is open, the shortcut buttons visible around it (like *F10 EXIT*) on the screen are not available. Nor are multi-character representations of single-character commands accepted.

4.7 Firmware Update/Upgrade

It is not possible to send firmware changes over the ASCII or TCP/IP interface. Firmware updates and upgrades are applied using removable media. The update/upgrade will be accompanied by a Technical Note containing installation instructions. Follow the

instructions very carefully; in some cases, breaking off an installation or repeating steps can have adverse effects.

If the instructions require booting from a drive other than C: and the controller boots from C: even with the medium inserted, then the controller boot sequence must be changed (press DEL while booting to get to the BIOS Setup), where the boot sequence is under Advanced. There, the first boot device should be the removable media drive, the second the HDD, and *Boot Other Device* must be enabled).

5 F-206 Coordinate System

5.1 Translation and Rotation Axis Definitions

Translations (linear moves) are all measured relative to the position of the platform after an INI command. Angular moves are referenced around the "pivot point." If the pivot value is (0, 0, 0), it is located relative to the platform as shown in Fig. 20.

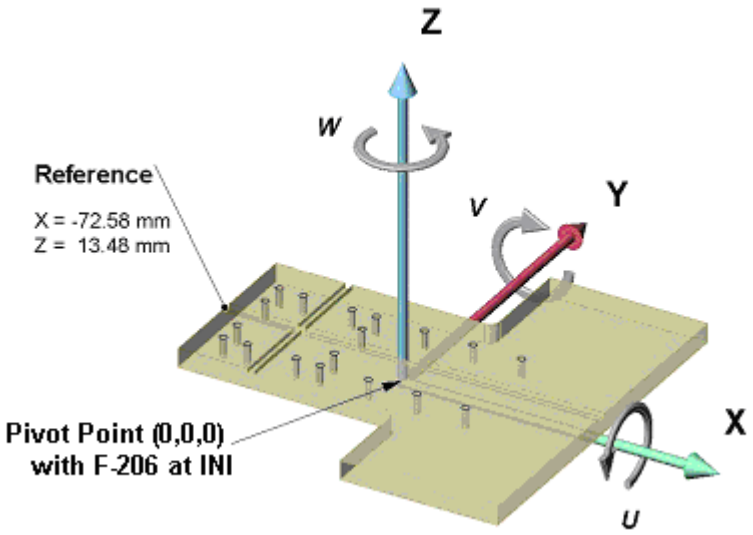


Fig. 20: Location of pivot point after start-up initialization

5.2 Translations

Translations (XYZ moves) are measured relative to the position of the platform after an INI command. All translations (XYZ moves) are performed on an interpolated straight-line path. That means all struts start and stop their moves at the same time and their velocities are calculated accordingly.

For pure translations, the orientation of the platform stays unchanged.

5.3 Rotations

For rotations, the current pivot point is taken into consideration. It can be set with the linear coordinates R, S, T defined relative to the (0,0,0) point located along the centerline of the mechanics at an offset from the top platform surface which is given in Fig. 20 Note that R, S and T move with the platform (the pivot point translates with platform XYZ moves). Any rotations (U,V and W moves) are performed about

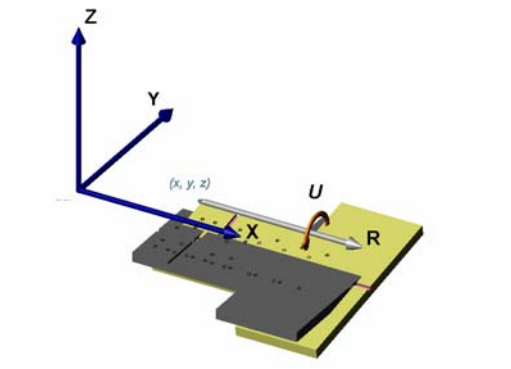
the current pivot point. The pivot point value cannot be changed unless the platform is parallel to the X-Y plane (U=V=W=0).

The final position after a move with rotation components is calculated by considering the UVW position components in the order U then V then W. This is done without regard to whether these values were explicitly given in the current command or the result of previous commands. Furthermore, the actual motion to the final position so calculated is smooth, with all motion components executing concurrently.

Note that the INI command does not reset the pivot point from its previous value. The pivot point start-up default coordinate values are set in lines 35-37 of the Hexdata.dat file on the controller file system. Factory default is (0,0,0).

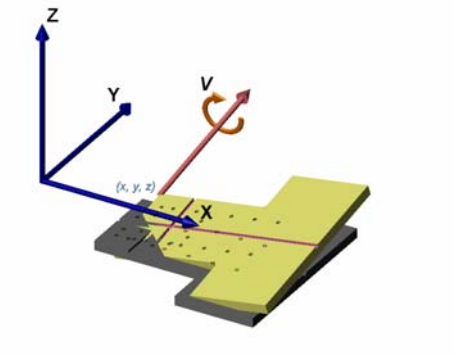
The evaluation of U, V and W position specifications is illustrated below.

The evaluation of U, V and W position specifications is illustrated below.



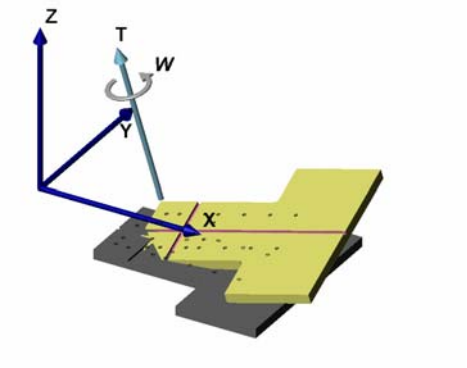
Platform at INI position

Platform at a position (x, y, z) and U=10; U axis is always parallel to X



Platform at INI position

Platform position of (x, y, z), U=10 and V=-10; note direction of the V axis, always parallel to plane of platform



Platform at INI position

Platform position of (x, y, z), U=10, V=-10 and W=10; note direction of the W axis, always normal to platform.

X, Y, Z axes are shown displaced to avoid clutter, pivot point set to "upper left" corner of platform.

In summary:

- *Axis around which a U-rotation is measured is always parallel to the X-axis*
- *V-rotation axis direction depends on the U position*
- *W-rotation axis direction depends on both the U and V positions*

Fig. 21: F-206 coordinate system interdependencies with pivot point set to "upper left" corner of platform

5.4 Workspace

The available XYZ workspace depends the values of the rotation coordinates U, V, and W, as shown in the examples that follow.

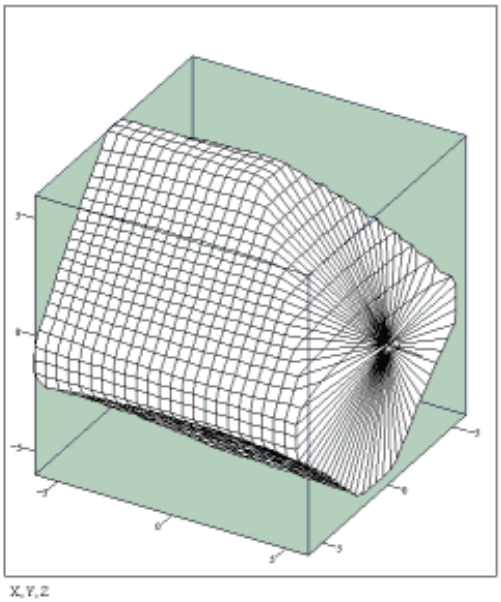


Fig. 22: U=V=W=0

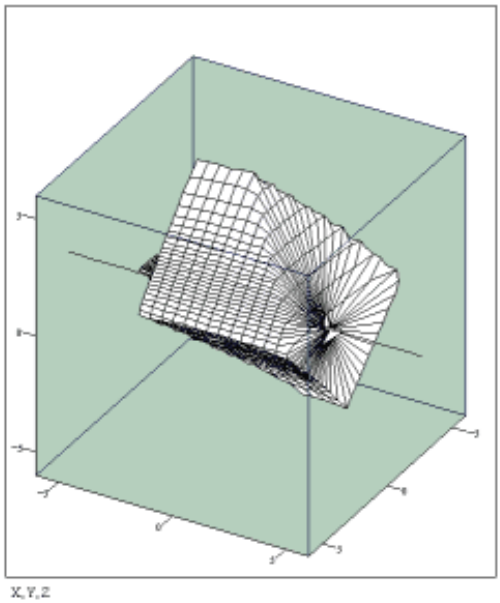


Fig. 23: U=4°, V=W=0

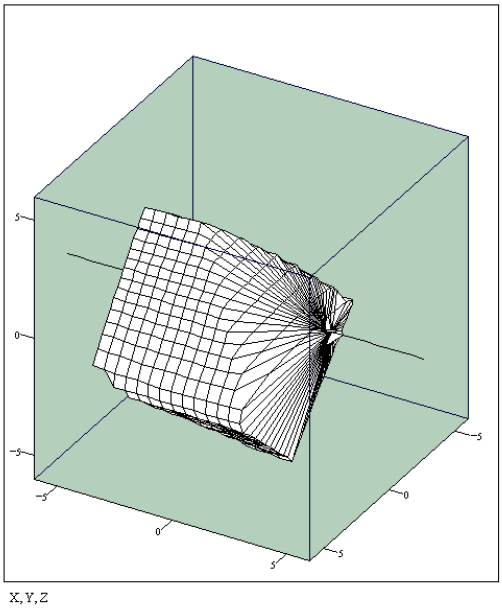


Fig. 24: U=-4°, V=W=0

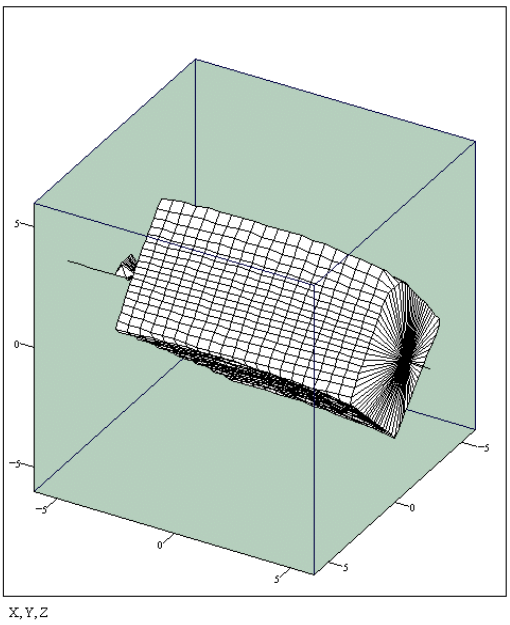


Fig. 25: U=0, V=4°, W=0

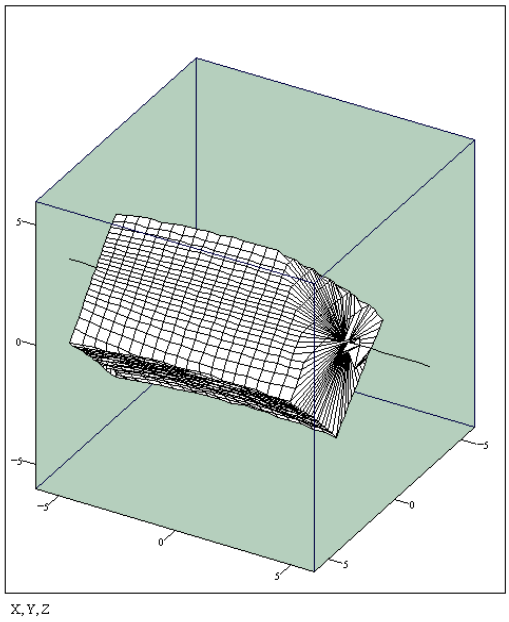


Fig. 26: U=0, V=-4°, W=0

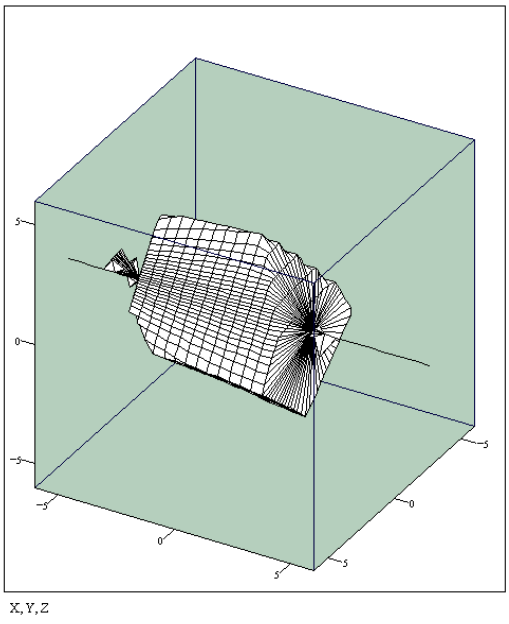


Fig. 27: U=V=0, W=4°

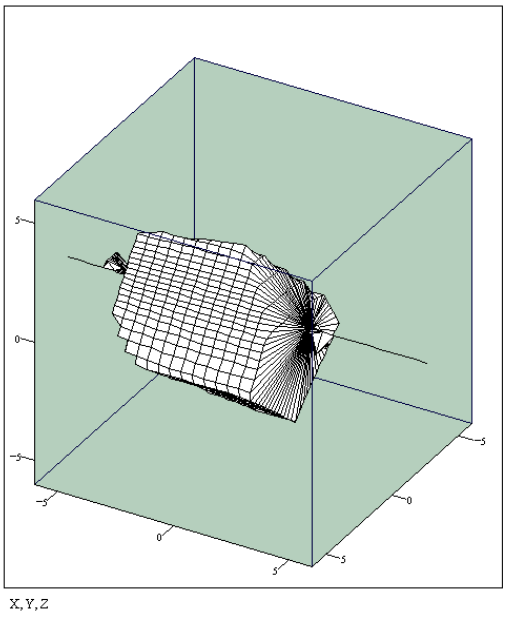


Fig. 28: U=V=0, W=-4°

6 Macro Storage on Controller

The F-206 supports controller macros in the BasMac language. Here, only a brief description of the features available will be given. The controller commands used to manage the BasMac macros are described in detail in the command reference section. For a description of BasMac statements and syntax, see the BasMac User Manual, SM145 provided with the installation.

BasMac is much more highly developed as a macro language than GCS. The macro management commands of the two models are the same, but the format of the statements in the macros is different.

6.1 BasMac Statements

BasMac has statements not only to command action from the controller (e.g. CMD (“MOV Z 3”) but also to enable branching, looping, storing controller responses in variables, parsing strings, and performing arithmetic and logical calculations.

NOTE

The syntax of the statements after the MAC BEG command on the F-206 differs from that of GCS macros. Examples in the “Quick Start” Section of the BasMac User manual provided with the installation, however, contain all the information necessary to make BasMac macros out of GCS macros

6.2 Macro Management Options

Controller macros can either be managed directly by the controller commands provided (see the MAC and MAC? command descriptions, p. 72), or the Controller Macro feature of PIMikroMove™ can be used. Note that PIMikroMove™ will not translate macros from GSC to BasMac format or vice versa, but it will formulate and issue the commands needed to store, execute, read, delete and otherwise manage the entire controller macro collection (not just those entered with PIMikroMove™).

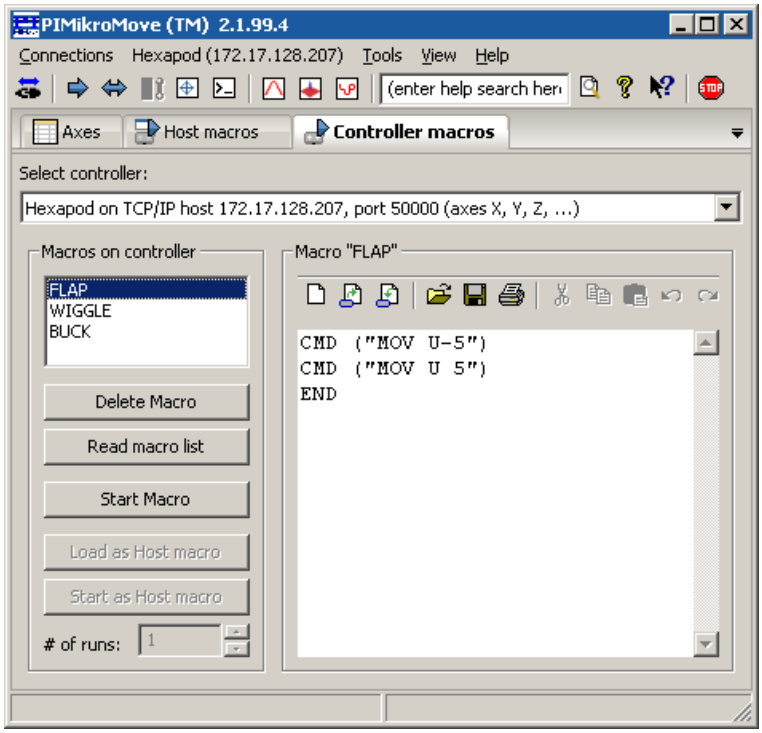


Fig. 29: Managing controller macros with PIMikroMove™, showing BasMac statements in a macro

7 System Commands

The native command set of the F-206 controller is very similar to PI's General Command Set, which is implemented for most PI motion controllers Non-compatible commands differ usually only in some minor way.

The system comes with control software for running on a host PC (see the appropriate software manuals for details regarding the use of this software). Alternatively, the system can be controlled with custom software, or manually with a keyboard and monitor connected directly to the controller (see p. 33).

The commands described in this section can be entered with the direct input facilities of the host software or on a keyboard connected directly to the controller.

Custom software must either send the commands as ASCII strings over the interface, or use the DLL or COM libraries described in their respective manuals.

7.1 Command Structure

F-206 controller native commands are almost all GCS compatible. Because there are a few differences, all the commands are described in detail in this manual as they function with the F-206 controller.

7.1.1 Mnemonics and Arguments

Command mnemonics and keyword arguments (such as axis designators) are not case-sensitive.

Most mnemonics are 3 letters in length. Query commands end with an additional question mark (?). Some special commands end with an additional exclamation point (!) and *IDN? has an initial asterisk.

One group of commands consists of a single ASCII character. The characters used are not alphanumeric, the commands take neither arguments nor terminator and evoke a response. Many single-character commands can be issued at times when other commands would not be executed and cause an error.

Arguments follow the mnemonic separated by a space SP. In general keyword arguments are used, with one- or two-character keywords,

though some commands like TAV have place-sensitive arguments. The most common keywords are the axis designators X, Y, Z, U, V and W. The keyword is usually followed by a numeric value, which may be separated by a space. The value must follow the keyword, but the order of the keyword-value units is usually not important.

Example:
FSC YZ0.2 S0.05 A2 L1
Performs a scan in the YZ plane over an area of 0.2 mm side length, with 0.05 mm distance between the scan lines until optical input A2 exceeds a value of 1.

7.1.2 Command Terminator

Commands transferred as strings over the interface must be terminated with a LF (linefeed, ASCII character decimal 10, hex 0A). It may be possible to use a carriage return CR in addition to or instead of a line feed. The command line terminators are not usually shown explicitly in this manual.

NOTE

The command line terminators are not usually shown explicitly in this manual.

Commands entered on a keyboard connected to the controller are executed when ↵ (enter key) is pressed; pressing ↵ on a blank line reececutes the previous command

7.1.3 Report Terminator

Report messages (responses) are terminated by line feeds LF . If a report consists of more than one line, all lines but the last have a single space SP (ASCII #32,#20h) preceding the line feed. This fact can be used to determine whether the controller has more data to send. Response terminators are shown in this manual for some multi-line responses only.

7.2 Command Reference (alphabetical)

CAUTION

Enter only valid commands. Commands with incorrect syntax can have unexpected results. The fact that error codes exist for syntax errors does not guarantee that all syntax errors will be recognized. Unrecognized syntax errors can lead to execution of the command with altered parameters.

*IDN? (Get Identity Number)

Description:	Reports the controller device ID
Format:	*IDN?
Arguments:	none
Response:	One-line response similar to: PHYSIK INSTRUMENTE (PI),F-206,0,V5.1.1-2510399LF

AAP (Fast Automated Alignment Procedure)

CAUTION

Scan command runout may cause damage to the attached application.

The trajectory specified by the [X] [Y] [Z] [U] [V] and [W] parameters is not followed as exactly as motion initiated with a MOV command, but rather with a certain amount of wobble. For large scanning ranges, for example 1 mm, this may result in an additional deviation of up to 2.6 µm from the desired trajectory, which, if unexpected, could cause errors or, in rare cases, even damage the attached setup.

CAUTION

During fast scan motion, the STOP, #24 and #27 commands may not take effect immediately.

!

Description: Fast Automated Alignment

Automated alignment part of the FSA command, but works for combinations of both linear and angular axes. #24 stops execution (e.g. if tracking mode was commanded)

Default: SA: 0.001 [mm]
N: 3
A: 1

Fig. 30:

Format: AAP [ax] [SA] [N] [A]

Arguments:

ax: axis pair specification, (can be XZ,YZ, XZ, UV or UW) followed by scan area size in mm or deg

SA: Step size; recommended: 0.0005 to 0.002 mm, default 0.001 mm

N: Number of repeated positions to stop procedure, default 3;
Use N = 0 for continuous tracking

[A] indicates which analog input or which optical power meter (F-361) to use. Can be 1, 2 or 5. If omitted, A1 is used.

NOTE

If there is an F-361 Optical Power Meter (OPM) configuration file in the F-206 controller firmware file system (C:\HEXAPOD\F-361.DAT), an OPM will addressed (max. 2, A1 and A2) and any other analog inputs present will not be accessible. If that file does not exist, A1 and A2 will address the corresponding optical board and A5 the optical input on the E-760 piezo axis controller, if installed.

Example:	AAP YZ0.1 SA0.001 N3 A2 Performs a scan in the YZ plane over an area of max. 0.1 mm side length, with 1 µm step size. Maximum intensity position should be reached 3 times before scan stops. Optical board 2 is read.
Response:	'1' if the auto align was successful (max. > threshold) within given max. area '0' if the auto align was not successful (max. ≤ threshold) in given max. area
Troubleshooting:	Parameter out of range

CST? (Get Stage name)

Description: Reports the names of the stages connected to the specified axes.

Format: CST? [X] [Y] [Z] [U] [V] [W] [K] [L] [M] [A] [B]

X, Y, Z, U, V, W: linear and rotary axes of the F-206

K, L, M: Piezo (Nanocube®) axes

A, B: separate motorized axes (support optional)

CST ? without any parameters is interpreted as CST? X Y Z U V W (if no separete axes are configured) or CST? X Y Z U V W A B (if separate axes are configured)

Examples: CST?

Response (with no separate axes configured):
X=F-206_AXIS_X[SP][LF]
Y=F-206_AXIS_Y[SP][LF]
Z=F-206_AXIS_Z[SP][LF]
U=F-206_AXIS_U[SP][LF]
V=F-206_AXIS_V[SP][LF]
W=F-206_AXIS_W[LF]

Response (if two separate axes are configured, both for M-505.6PD):
X=F-206_AXIS_X[SP][LF]
Y=F-206_AXIS_Y[SP][LF]
Z=F-206_AXIS_Z[SP][LF]
U=F-206_AXIS_U[SP][LF]
V=F-206_AXIS_V[SP][LF]
W=F-206_AXIS_W[SP][LF]
A=M-505.6PD[SP][LF]
B=M-505.6PD[LF]

CST? XA

Response (if no separate axes are configured):
X=F-206_AXIS_X[SP][LF]
A=NOSTAGE[LF]

Response (if axis A is configured for M-505.6PD):
X=F-206_AXIS_X[SP][LF]
A=M-505.6PD[LF]

([SP] space; [LF] line feed)

ECO? (Echo String)

Description:	A string will be echoed. The string must not contain non-printable characters.
Example	INI ECO? INI_FINISHED MOV X 10 ECO? MOV_FINISHED
Remarks:	Facilitates the handling of the FIFO command stack, especially in a test environment. The string to echo must not contain the string “STOP”.

ERR? (Get Error)

Description: Get Error code. Error codes almost always refer to the previously received command (some innocuous commands like VER? do not always set the code to 0). Note that the ERR? command itself never fails and always sets the error code to 0.

0	No error
1	Parameter syntax error
2	Unknown command
3	Command too long
5	INI or Servo ON required before move at this time
6	SGA parameter out of range
7	Motion range exceeded.
8	Velocity range exceeded.
9	Attempt to set pivot point while U, V or W not all equal to 0
10	Last command was STOP or DRV
11	SST parameter out of range
13	NAV parameter out of range
14	Invalid analog channel
15	Invalid axis identifier
17	Command parameter out of range
23	Invalid Axis
25	Invalid Real Number
26	Missing Parameter
27	Soft Limit out of Range
46	F-361 (Optical Power Meter) missing
47	F-361 cannot be initialized/is not initialized
48	F-361 communications error
53	MOV! command motion in progress
54	Unknown parameter
57	Data Record Table does not exist
63	INI is running
200	No stage connected
201	File with stage/axis parameters not found
202	Invalid Axis Parameter File
210	Illegal File Name
211	File not found
212	File write Error
213	DTR hinders Velocity Change
214	Position Unknown

217 Unexpected Strut Stop
218 Reported Position is based on Interpolation (MOV, MWG or MAR! is running)
219 Reported Position is based on Estimation (MOV! is running)
301 Buffer overflow
333 Hardware Error, motion deviation limit exceeded
555 Gereral error in using macros
1000 Too many nested macros
1001 Macro already defined
1002 No macro recording
1003 Invalid MAC parameter

Format: ERR?

Arguments: none

Response: Error number

Troubleshooting: Command awaiting execution in queue

FAA (Fast Angular Line Scan to Maximum)

CAUTION

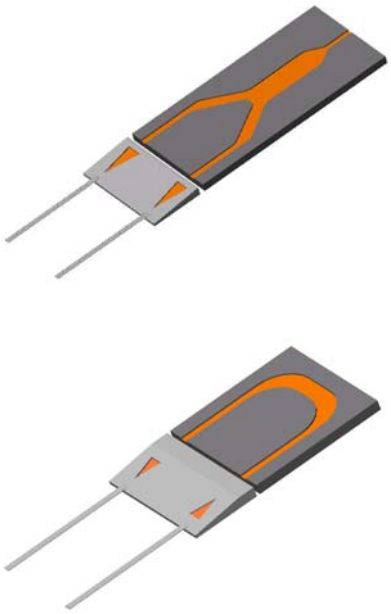
Scan command runout may cause damage to the attached application.

The trajectory specified by the [X] [Y] [Z] [U] [V] and [W] parameters is not followed as exactly as motion initiated with a MOV command, but rather with a certain amount of wobble. For large scanning ranges, for example 1 mm, this may result in an additional deviation of up to 2.6 µm from the desired trajectory, which, if unexpected, could cause errors or, in rare cases, even damage the attached setup.

CAUTION

During fast scan motion, the STOP, #24 and #27 commands may not take effect immediately.

Description:



Fast angular line scan to maximum. Executes an angular scan in the [ax] direction. [ax] can be the U, V or W. The voltage at the analog input specified by A is read > 500/sec during motion.

The scan starts at the current position and returns to this position if the programmed threshold level [L] is not exceeded. If the maximum intensity during the scan exceeds the threshold level, the stage is moved to that position after the scan.

Default: L: 0.1 [V]

A: 1

Fig. 31:

NOTE

Because of the out of plane motion during a large angular fast scan, this command should be used in two steps:

First perform a large angle scan with normal velocity and low threshold level,

then add a small angle scan with reduced velocity (e.g.. 0.2 mm/s) and higher threshold level.

Format: FAA [ax] [L] [A]

Arguments: ax: axis identifier (can be U, V or W) followed by scan area size in deg.

L: Threshold level at analog input

[A] indicates which analog input or which optical power meter (F-361) to use. Can be 1, 2 or 5. If omitted, A1 is used.

NOTE

If there is an F-361 Optical Power Meter (OPM) configuration file in the F-206 controller firmware file system (C:\HEXAPOD\F-361.DAT), an OPM will addressed (max. 2, A1 and A2) and any other analog inputs present will not be accessible. If that file does not exist, A1 and A2 will address the corresponding optical board and A5 the optical input on the E-760 piezo axis controller, if installed.

Example:	FAA V0.2 L1 A2 Performs a scan in V over a range of 0.2 deg. The maximum intensity in the scanning line should exceed 1 V for analog input 2.
Response:	'1' if there is a maximum which exceeds the threshold level '0' if the threshold was not reached or any other error occured.
Troubleshooting:	Parameter out of range

FAM (Fast Angular Scan to Maximum)

CAUTION

Scan command runout may cause damage to the attached application.

The trajectory specified by the [X] [Y] [Z] [U] [V] and [W] parameters is not followed as exactly as motion initiated with a MOV command, but rather with a certain amount of wobble. For large scanning ranges, for example 1 mm, this may result in an additional deviation of up to 2.6 µm from the desired trajectory, which, if unexpected, could cause errors or, in rare cases, even damage the attached setup.

CAUTION

During fast scan motion, the STOP, #24 and #27 commands may not take effect immediately.

Description:

Fast angular scan to maximum. Executes a 2-dimensional angular scan over the axis pair specified in [ax].. [ax] can be UW, VW or UV. The voltage at the analog input specified by A is read > 500/sec during motion.

The scan starts at the current position and returns to this position if the programmed threshold level [L] is not exceeded. The distance between the scan lines is defined by [S]. If the maximum intensity during the scan exceeds the threshold level, the stage is moved to that position after the scan. Especially for intensity distributions with secondary maxima the use of FAM instead of FAS is recommended.

Fig. 32:

Fig. 33:

Default:			
	L:	1	[V]
	S:	0.02	[deg]
	A:	1	

FAM [ax] [L] [S] [A]

Arguments:

ax: axis pair specification, (can be UW, VW or UV) followed by scan area size in deg.

L: Threshold level at analog input

S: Distance between scan lines

[A] indicates which analog input or which optical power meter (F-361) to use. Can be 1, 2 or 5. If omitted, A1 is used.

NOTE

If there is an F-361 Optical Power Meter (OPM) configuration file in the F-206 controller firmware file system (C:\HEXAPOD\F-361.DAT), an OPM will addressed (max. 2, A1 and A2) and any other analog inputs present will not be accessible. If that file does not exist, A1 and A2 will address the corresponding optical board and A5 the optical input on the E-760 piezo axis controller, if installed.

Example:	FAM VW0.1 L1 S0.001 A2 Performs a scan in VW over an area of 0.1 deg side length, with 1 mdeg distance between the scan lines. The maximum intensity in the scanning area should exceed 1 V for analog input 2.
Response:	'1' if there is a maximum which exceeds the threshold level '0' if no maximum was found or maximum was lower than the threshold
Troubleshooting:	Parameter out of range

FAS (Fast Angular Scan)

CAUTION

Scan command runout may cause damage to the attached application.

The trajectory specified by the [X] [Y] [Z] [U] [V] and [W] parameters is not followed as exactly as motion initiated with a MOV command, but rather with a certain amount of wobble. For large scanning ranges, for example 1 mm, this may result in an additional deviation of up to 2.6 µm from the desired trajectory, which, if unexpected, could cause errors or, in rare cases, even damage the attached setup.

CAUTION

During fast scan motion, the STOP, #24 and #27 commands may not take effect immediately.

!

Description: Fast angular scan. Executes a 2-dimensional angular scan in the axes specified in [ax] . [ax] can be the UW, VW or UV. The voltage at the analog input specified by A is read > 500/sec during motion. The scan starts at the current position and returns to this position if the programmed threshold level [L] is not exceeded. The distance between the scan lines is defined by [S]. If [L] is exceeded during the scan, the system stops at this position.

Fig. 34:

Default:

L:	1	[V]
S:	0.02	[deg]
A:	1	

Format: FAS [ax] [L] [S] [A]

Arguments: ax: axis pair specification, (can be UW, VW or UV) followed by scan area size in deg. L: Threshold level at analog input S: Distance between scan lines [A] indicates which analog input or which optical power meter (F361) to use. Can be 1, 2 or 5. If omitted, A1 is used.

NOTE

If there is an F-361 Optical Power Meter (OPM) configuration file in the F-206 controller firmware file system (C:\HEXAPOD\F-361.DAT), an OPM will addressed (max. 2, A1 and A2) and any other analog inputs present will not be accessible. If that file does not exist, A1 and A2 will address the corresponding optical board and A5 the optical input on the E-760 piezo axis controller, if installed.

Example: FAS VW0.1 L1 S0.001 A2

	Performs a scan in VW over an area of 0.1 deg side length, with 1 mdeg distance between the scan lines. A threshold level of 1 V should be reached for analog input 2.
Response:	'1' if the threshold level was exceeded '0' if the threshold level was not exceeded
Troubleshooting:	Parameter out of range

FIO (Fast Input-Output Alignment Procedure)

CAUTION

Scan command runout may cause damage to the attached application.

The trajectory specified by the [X] [Y] [Z] [U] [V] and [W] parameters is not followed as exactly as motion initiated with a MOV command, but rather with a certain amount of wobble. For large scanning ranges, for example 1 mm, this may result in an additional deviation of up to 2.6 µm from the desired trajectory, which, if unexpected, could cause errors or, in rare cases, even damage the attached setup.

CAUTION

During fast scan motion, the STOP, #24 and #27 commands may not take effect immediately.

Description:

Fig. 35:

Scanning procedure for aligning waveguides or fiber arrays where light from one channel is transferred to another channel within one chip. For this application, the alignment of the input channel requires the simultaneous alignment of the output channel to get a signal. Therefore, the platform follows a linear spiral path and, at each point of that spiral an angular scan is performed around the pivot point (which needs to have been set to the location of the input or output channel).

Format: FIO [ax] [S] [AR] [L] [A]

Arguments:

ax: axis pair specification, (can be YZ, XZ or XY) followed by linear scan area size in mm

S: Stepsize of the linear spiral

AR: Size of angle scan, deg

L: Threshold level at analog input

[A] indicates which analog input or which optical power meter (F-361) to use. Can be 1, 2 or 5. If omitted, A1 is used.

NOTE

If there is an F-361 Optical Power Meter (OPM) configuration file in the F-206 controller firmware file system (C:\HEXAPOD\F-361.DAT), an OPM will addressed (max. 2, A1 and A2) and any other analog inputs present will not be accessible. If that file does not exist, A1 and A2 will address the corresponding optical board and A5 the optical input on the E-760 piezo axis controller, if installed.

Response:

‘1’ if the threshold level was exceeded

‘0’ if the threshold level was not exceeded

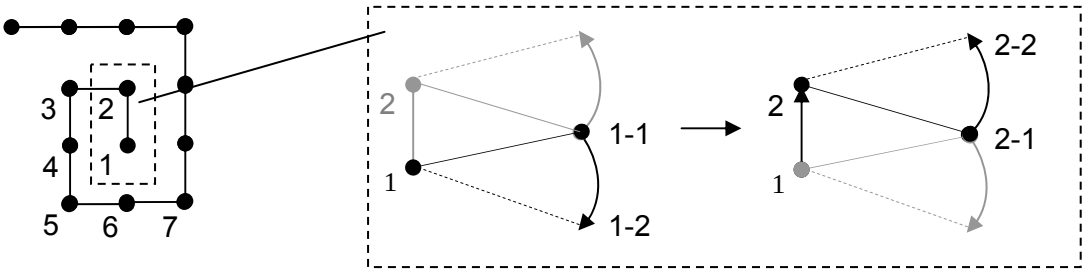


Fig. 44: Fast I-O scanning procedure performs linear spiral plus angular scan

Troubleshooting: Parameter out of range

Example: FIO YZ0.1 S0.01 AR0.1 L1 A2

Performs a linear spiral scan in YZ over an area of max. 0.1 mm side length, with 10 µm step size. The angular movement covers 0.1 deg for axis U. A threshold level of 1 V should be reached for analog input 2.

FSA (Fast Scan with Automated Alignment)

CAUTION

Scan command runout may cause damage to the attached application.

The trajectory specified by the [X] [Y] [Z] [U] [V] and [W] parameters is not followed as exactly as motion initiated with a MOV command, but rather with a certain amount of wobble. For large scanning ranges, for example 1 mm, this may result in an additional deviation of up to 2.6 µm from the desired trajectory, which, if unexpected, could cause errors or, in rare cases, even damage the attached setup.

CAUTION

During fast scan motion, the STOP, #24 and #27 commands may not take effect immediately.

Description: Fast Scan with Auto Align

This function is based on the FSC command.

On exceeding the Threshold level [L] during the scan, the auto align procedure (see AAP command) is automatically executed.

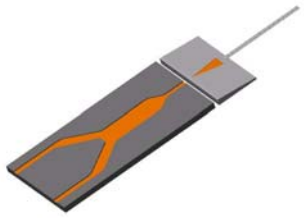


Fig. 45:

Default:			
	L:	1	[V]
	S:	0.01	[mm]
	SA:	0.001	[mm]
	A:	1	

Format: FSA [ax] [L] [S] [SA] [A]

Arguments:

ax: axis pair specification, (can be YZ or XZ) followed by scan area size in mm

L: Threshold level at analog input

S: Distance between scan lines

SA: Step size for auto align, recommended: 0.0005..0.002 mm

[A] indicates which analog input or which optical power meter (F-361) to use. Can be 1, 2 or 5. If omitted, A1 is used.

NOTE

If there is an F-361 Optical Power Meter (OPM) configuration file in the F-206 controller firmware file system (C:\HEXAPOD\F-361.DAT), an OPM will addressed (max. 2, A1 and A2) and any other analog inputs present will not be accessible. If that file does not exist, A1 and A2 will address the corresponding optical board and A5 the optical input on the E-760 piezo axis controller, if installed.

Example:	FSA YZ0.1 L1 S0.01 SA0.001 A2 Performs a scan in the YZ plane with 0.1 mm side length with 10 µm distance between the scan lines. If a threshold level of 1 V for analog input 2 is found during the scan, the system stops at this position and proceeds with an automated alignment using a step size of 1 µm.
Response:	'1' if the automated alignment was started '0' if the automated alignment was not started
Troubleshooting:	Parameter out of range

FSC (Fast Scan with Abort)

Description:

Executes a scan in the [ax] plane. [ax] can be the YZ, XZ or XY plane. The voltage at the analog input specified by A is read > 500/sec during motion.

The scan starts at the current position and returns to this position if the programmed threshold level [L] is not exceeded. If [L] is exceeded during the scan, the system stops at this position. Distance between scan lines is defined by [S].

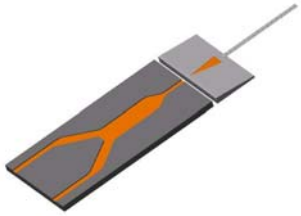


Fig. 46:

Defaults	L:	1	[V]
	S:	0.01	[mm]
	A:	1	

The controller automatically reports '1' on exceeding the specified threshold level [L], and motion stops. If the threshold is not exceeded, '0' is reported at the end of the scan.

CAUTION

The scanning path is trajectory-controlled only for YZ and XZ scans. Using FSC for XY will result in a wobbly motion with runout. Large XY scanning areas (> approx. 1.0 mm), are not recommended because they may result in out-of-plane motion of > 2 µm. Make sure the attached setup will not be damaged!

CAUTION

During fast scan motion, the STOP, #24 and #27 commands may not take effect immediately.

Format:	FSC [ax] [L] [S] [A]
Arguments:	ax: axis pair specification, (can be YZ or XZ) followed by scan area size in mm L: Threshold level at analog input S: Distance between scan lines [A] indicates which analog input or which optical power meter (F-361) to use. Can be 1, 2 or 5. If omitted, A1 is used.

NOTE

If there is an F-361 Optical Power Meter (OPM) configuration file in the F-206 controller firmware file system (C:\HEXAPOD\F-361.DAT), an OPM will addressed (max. 2, A1 and A2) and any other analog inputs present will not be accessible. If that file does not exist, A1 and A2 will address the corresponding optical board and A5 the optical input on the E-760 piezo axis controller, if installed.

Response:	'1' if the threshold level was exceeded '0' the threshold level was not exceeded
Troubleshooting:	Axis identifier is incorrect Parameter out of range

Example:

FSC YZ0.2 L1 S0.05 A2

Performs a scan in the YZ plane over an area of 0.2 mm side length, with 50 µm distance between the scan lines.

A threshold level of 1 V should be reached for opt. board 2.

The scan starts at the current position and returns to this position if the programmed threshold level [L] is not exceeded. If [L] is exceeded during the scan, the system stops at this position. Distance between scan lines is defined by [S].

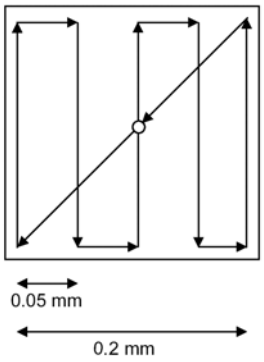


Fig. 47: Schematic scanning algorithm for FSC YZ0.2 L1 S0.05 (L not exceeded)

Default	L:	1	[V]
	S:	0.01	[mm]
	A:	1	

The controller automatically reports '1' on exceeding the programmed threshold level [L], and motion stops. If the threshold is not exceeded, '0' is reported at the end of the scan.

FSM (Fast Scan to Maximum)

CAUTION

Scan command runout may cause damage to the attached application.

The trajectory specified by the [X] [Y] [Z] [U] [V] and [W] parameters is not followed as exactly as motion initiated with a MOV command, but rather with a certain amount of wobble. For large scanning ranges, for example 1 mm, this may result in an

additional deviation of up to 2.6 µm from the desired trajectory, which, if unexpected, could cause errors or, in rare cases, even damage the attached setup.

CAUTION

During fast scan motion, the STOP, #24 and #27 commands may not take effect immediately.

!

Description:

Fast Scan to Maximum. This function is similiar to the FSC command. In contrast with the FSC command, this function does not stop when the threshold level is reached, but performs a complete scan of the scan area. If the maximum intensity exceeds the threshold level, the stage is moved to that position after the scan. Especially for intensity distributions with side maxima the use of FSM instead of FSC or FSA is recommended.

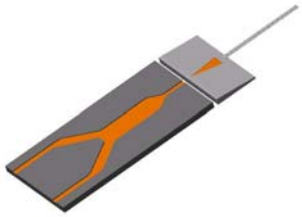


Fig. 48:

Fig. 49:

Default:

L:	1	[V]
S:	0.01	[mm]
A:	1	

Format: FSM [ax] [L] [S] [A]

Arguments:

ax: axis pair specification, (can be YZ or XZ) followed by scan area size in mm

L: Threshold level at analog input

S: Distance between scan lines

[A] indicates which analog input or which optical power meter (F-361) to use. Can be 1, 2 or 5. If omitted, A1 is used.

NOTE

If there is an F-361 Optical Power Meter (OPM) configuration file in the F-206 controller firmware file system (C:\HEXAPOD\F-361.DAT), an OPM will addressed (max. 2, A1 and A2) and any other analog inputs present will not be accessible. If that file does not exist, A1 and A2 will address the corresponding optical board and A5 the optical input on the E-760 piezo axis controller, if installed.

Example:	FSM YZ0.1 L1 S0.001 A2 Performs a scan in the YZ plane over an area of 0.1 mm side length with 1 µm distance between the scan lines. A threshold level of 1 V should be reached for analog input 2.
Response:	'1' if there is a maximum which exceeds the threshold level '0' if no maximum was found or maximum was lower than the threshold
Troubleshooting:	Parameter out of range

FSN (Fast Scan)

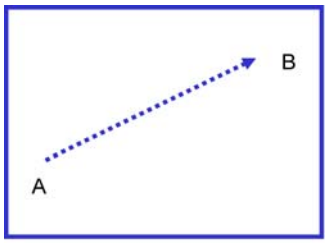
CAUTION

WARNING! Scan command runout may cause damage to the attached application.

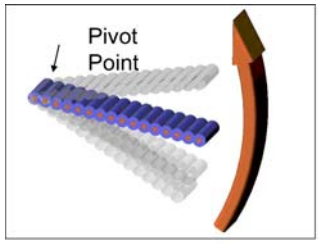
The trajectory specified by the [X] [Y] [Z] [U] [V] and [W] parameters is not followed as exactly as motion initiated with a MOV command, but rather with a certain amount of wobble. Large scanning ranges are not recommended, partly because, for example, a 2 mm scan may incur a deviation of up to 11.4 µm from the desired trajectory, which, if unexpected, could damage the attached setup.

Description: Fast scan. Executes a fast scan following a trajectory described by the various parameters. The voltage at the analog input specified by the *value* in A<*value*> is read more than 500 times per

second during motion.



FSN Y2.6 D0 C0 R0 L0.5 A2



FSN V0.6 D0 C0 R0 L0.5 A2

Fig. 50: Fast scan examples

CAUTION

During fast scan motion, the STOP, #24 and #27 commands may not take effect immediately.

!

Defaults: A: 1 (analog input 1)
L: 1 (threshold in volts, or in unit specified in TAV)
D: 1 (do not invert direction)
R: 0 (do not return to start)
C:0 (do not center around starting point)

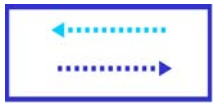
Format: FSN [X] [Y] [Z] [U] [V] [W] [L] [D] [R] [C] [A]

Arguments: [A]indicates which optical board channel or which Optical Power Meter (F-361) analog input to use. Can be A1 or A2. If omitted, A1 is used.

If there is an F-361 Optical Power Meter (OPM) configuration file (C:\HEXAPOD\F-361.DAT in the controller file system), the OPM will be addressed and any optical board present will not be accessible, otherwise the specified optical board channel will be addressed.

[L] Threshold Level. Level of analog input, in volts for an optical board analog input, or in the unit specified in the TAV command for an OPM.

[D] If D0 is specified, the scan direction will be inverted.



[R] If R1 is specified, the position after finishing the command will be the same as the position before. If R0 is specified, the Hexapod remains at its last scan position.
[C] Describes whether the area scanned is centered around the current position or not: C1=centered, C0 start at current position.

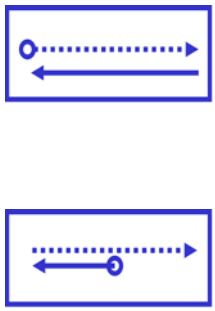


Fig. 51: FSN parameters

Examples:

FSN Y0.1	Let X_S, Y_S, Z_S, U_S, V_S and W_S be the position when FSN is invoked. The trajectory begins at X_S, Y_S, Z_S, U_S, V_S, W_S and stops at X_S, Y_S+0.1, Z_S, U_S, V_S, W_S.
FSN X0.1 D0 R1	Since D0 (invert) is specified, this command is interpreted as the command FSN X-0.1 R1. Here, the resulting trajectory begins at X_S, Y_S, Z_S, U_S, V_S, W_S and stops at X_S-0.1, Y_S, Z_S, U_S, V_S, W_S. Having finished scanning, a move to the start position of X_S, Y_S, Z_S, U_S, V_S, W_S will be executed.
FSN V0.1 C1	Preparing to scan, the Hexapod moves to the scan start position at X_S, Y_S, Z_S, U_S, V_S-0.05, W_S. The scan stops at X_S, Y_S, Z_S, U_S, V_S+0.05, W_S. The Hexapod remains at this position. See figure below.

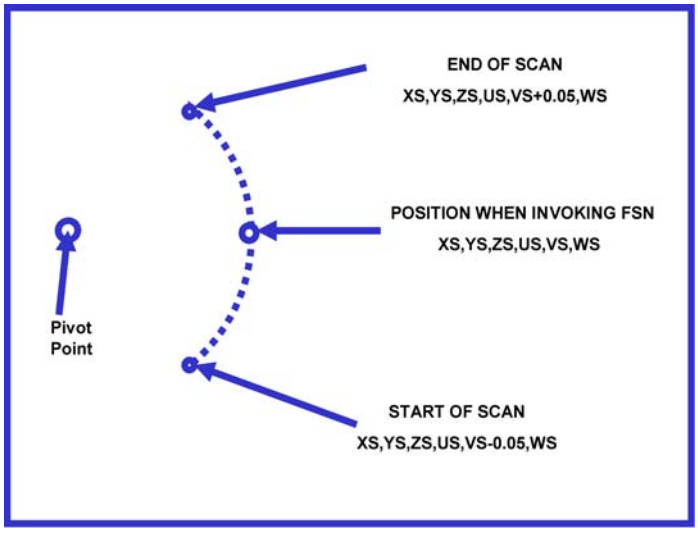


Fig. 52: Before and after FSN V0.1 C1

Response: '1' The maximum voltage reached the threshold level.
'0' The maximum voltage did not reach the threshold level, or an error occurred. Since errors will also cause this response, the ERR? command should be issued to see what happenned.

Troubleshooting: Parameter out of range.

Parameter Charts:

Start of Scan Position Table

Position before evoking FSN	Para-meters of FSN	D0 C0	D0 C1	D1 C0	D1 C1
X_S	X	X_S	X_S+X/2	X_S	X_S –X/2
Y_S	Y	Y_S	Y_S+Y/2	Y_S	Y_S-Y/2
Z_S	Z	Z_S	Z_S+Z/2	Z_S	Z_S-Z/2
U_S	U	U_S	U_S+U/2	U_S	U_S-U/2
V_S	V	V_S	V_S+V/2	V_S	V_S-V/2
W_S	W	W_S	W_S+W/2	W_S	W_S-W/2

End of Scan Position Table

Position before evoking FSN	Para-meters of FSN	D0 C0	D0 C1	D1 C0	D1 C1
X_S	X	X_S-X	X_S-X/2	X_S +X	X_S +X/2
Y_S	Y	Y_S-Y	Y_S-Y/2	Y_S+Y	Y_S+Y/2

Z_S	Z	Z_S-Z	Z_S-Z/2	Z_S+Z	Z_S+Z/2
U_S	U	U_S-U	U_S-U/2	U_S+U	U_S+U/2
V_S	V	V_S-V	V_S-V/2	V_S+V	V_S+V/2
W_S	W	W_S-W	W_S-W/2	W_S+W	W_S+W/2

FSN Finished Position Table

Position before evoking FSN	R0	R1
X_S	End-of-Scan Position	X_S
Y_S	End-of-Scan Position	Y_S
Z_S	End-of-Scan Position	Z_S
U_S	End-of-Scan Position	U_S
V_S	End-of-Scan Position	V_S
W_S	End-of-Scan Position	W_S

FSN? (Get Fast Scan Result)

Description:	Get result of the FSN command. The system reports the position of the highest analog input and its value.
Format:	FSN?
Arguments:	none
Response:	X=0.1001SP LF Y=1.002SP LF Z=-0.01SP LF U=0.0SP LF V=1.1SP LF W=0.1SP LF LW=3.99LF

SP = space
LF = line feed

LW shows the analog signal level at its maximum. For an optical board, the unit is volts; for an OPM the response will contain unit, as set with the TAV command.

The position is given in absolute coordinates, not relative to the start position of the scan trajectory or the position when evoking FSN.

HELP

Description: Same as HLP?

HELP

Description:	Lists available commands
Format:	HLP?
Arguments:	none
Response:	List of commands with short descriptions
Troubleshooting:	RS-232 communication breakdown Command awaiting execution in queue

INI (Initialize)

Format:	INI [A][B]
Arguments:	none for F-206, A for separate axis A, B for separate axis B
Response:	none
Troubleshooting:	DC power failure Command awaiting execution in queue

In case INI is invoked without any arguments, the F-206 goes to its reference point at a safe speed. The initialization is carried out in a number of steps:

7 All actuators start toward their reference positions (midpoint reference switches) at the same time and at the same velocity. Note that the platform trajectory in X, Y, Z, U, V, W coordinates can be quite complicated.

8 The platform is then moved slightly so that the reference switches can all be re-approached from the same side.

9 The actuators are then adjusted one by one to their reference points.

10 All motion parameters except the pivot point, velocity and manual pad step-size are reset.

NOTE

To stop motion during an INI command, send an ASCII #24 to the controller (with *HexControl* on the host computer, this can be done by pressing the ESC key). Alternatively, Ctrl-X can be pressed on the controller keyboard, if present.

INI with A or B parameters will move separate motorized axes to their reference positions.

MAC (Manage Macros)

Description: Permits recording, deleting and running BasMac macros on the controller (see Macro Storage on Controller, p. 41 and BasMac manual for details).

Format:
MAC BEG *macroname*
MAC DEL *macroname*
MAC END
MAC ERR?
MAC START *macroname*

Arguments: <keyword> determines which macro function is performed :

MAC BEG *macroname*
Start recording a BasMac macro on the controller to be named *macroname*, (A-Z and 0-9 only); GCS macros not accepted. If a macro with name *macroname* already exists, or if *macroname* is unsuitable, macro recording mode will not be entered, an error code will be set and controller will beep.
MAC END
End macro recording ; ERR? after this command will show certain recording errors
MAC DEL *macroname*
Deletes specified macro
MAC START *macroname*
Starts execution of specified macro. Responses to commands for the controller in the macro are not sent to the host directly (see “PRINT” statement in BasMac User Manual). A controller running a macro will respond directly to single-character commands;
MAC ERR?
Show error messages from BasMac, usually about a macro just run

Response: none

Troubleshooting: Macro recording is active (keywords BEG, DEL, ERR?) or inactive (END)
Macro recording did not begin because *macroname* unsuitable

Example:

```
MAC BEG TWIST
 CMD("MOV W 5")
 END
MAC END
```

For more examples see BasMac User Manual

MAC? (List Macros)

Description:	List macro names or contents of a given macro.
Format:	MAC? [<macroname>]
Arguments:	<macroname>: name of the macro whose contents shall be listed; if omitted, the names of all stored macros are listed
Response:	<string> if <macroname> is given, <string> is the contents of this macro (BasMac statements) if <macroname> is omitted, <string> is a list with the names of all macros stored on the controller, one per line
Troubleshooting:	No macro named *macroname* on controller

MAR! (Move and Respond)

Identical to the MOV command (see below), except that two separate one-line responses are given, one when the motion of the platform actually begins and one when the motion of the platform completes. (Some versions of the Control software may not recognize these responses as valid and instead display an error message even though the command executes properly).

The MAR! command sends “1”, when the platform move actually begins, and “0” at its end.

Separate stages should not be commanded with the MAR! command since strut movements will be ignored completely when the on-line responses are generated.
The use of singe char polling commands should be avoided while using this command to prevent problems in the data flow protocol.

MOV (Move Absolute)

Description:	Move F206, and/or separate motorized or piezo axes. Units: X,Y,Z (F-206 linear axes) in mm

K,L,M: mm, (with P-611 NanoCube®, piezo axes K, L, M correspond in order *and direction* to X, Y, Z marked on stage. Handedness of P-611 differs from that of F-206.)

U,V,W: deg (the direction of the axis around which a V move is calculated depends on the U position; the W axis direction depends on both U and V positions. See page 36 for details).

Units for A, B depend on connected stage.

The values are interpreted as floating point format.

Internal accuracy for all transformations is 18 digits.

The controller checks whether the specified target position can be reached directly before it starts motion. If it cannot, or if any separate axis is out of range, motion will not be started.

Axes not explicitly mentioned in the command retain their current positions, so it is sufficient to set new positions only for the axes to be moved.

Format: MOV[X][Y][Z][U][V][W][K][L][M][A][B]

X, Y, Z, U, V, W linear and rotary axis designators of the F-206; K,L,M separate piezo axes; A, B separate motorized axes. Follow each axis keyword by numeric target in [mm] or [deg]

Example: After initialization the system position is:

X=0; Y=0; Z=0; U=0; V=0; W=0.

The new command is: MOV Y3.245678 X1.23 V4.56789 The new target position is:

X= 1.23mm Y= 3.2457mm Z= 0mm;

U= 0deg V= 4.5679deg W= 0deg.

After a new command MOV Z1.2 the new target position is:

X= 1.23mm; Y= 3.2457mm; Z= 1.2mm;

U= 0deg; V= 4.5679deg; W= 0deg.

The pivot point is set by the SPI command.. See the discussion on page 36 for a description of the rotation axis definitions.

Response: none

Troubleshooting: Specified target position out of limits

MOV?(Motion Complete)

Description:	Motion complete? The system reports ‘1’ when the F-206 platform motion is complete. This command is run after all previous commands complete and no '1' is sent until the system has come to a standstill.
Format:	MOV?
Arguments:	none
Response:	‘1’, when motion complete
Troubleshooting:	Command awaiting execution in queue

MOV! (Move To Absolute Position)

!

CAUTION

The move is executed along a trajectory described by the initial and target linear and angular positions The motion does not follow the ideal trajectory exactly. There is a wobbly motion occuring instead. For large scanning trajectories, for example 1 mm, this may result in a deviation of > 2.5 µm from the desired trajectory which, could cause errors or, in rare cases, even damage the attached setup.

Identical to the MOV command (see above), except that:

- During MOV! motion, a new target position can be set by a new MOV! command. When this is done, the new target will be programmed immediately. Motion will change in a smooth manner according to the acceleration limitation settings in the C842data.dat configuration file entry.

  By sending MOV! commands at periodic intervals, it is possible to avoid pauses in motion between moves. Furthermore, the MOV! command adjusts the velocity so as to reach the target at the end of the interval, which is set using the SCT command.

The MOV! command will not refresh the current real position that is displayed on the controller monitor. No progress bar or any other feedback will be seen on the controller´s monitor.

- MOV! can move the F-206 platform but not the separate axes.
- During MOV! motion all commands except MOV, MAR!, FSN, MWG, MVC,, FSN, MOV? and INI will be performed immediately. These commands will be queued until the MOV! target position is reached before executing.
- During MOV! motion, it is the strut velocities that are limited by the velocity value set with the VEL command, rather than the platform velocity. As a consequence of this, F-206 velocity will depend on its position and orientation and may be slightly higher than expected.

MWG (Move Without Graphics)

Description: This command is identical to the MOV command but is slightly faster because no graphics will be displayed or position information updated on the controller's monitor. Cannot be used for separate axes.

NAV (Set Number of Values for TAV?)

NOTE

To use this command, at least one analog input (optical board, E-760 piezo controller or external power meter) must be installed.

If there is an F-361 Optical Power Meter (OPM) configuration file in the F-206 controller firmware file system (C:\HEXAPOD\F-361.DAT), an OPM will addressed (max. 2, A1 and A2) and any other analog inputs present will not be accessible. If that file does not exist, A1 and A2 will address the corresponding optical board

and A5 the optical input on the E-760 piezo axis controller, if installed. See p. 109 for details.

Description: Set number of readings of the analog signal to average in order to determine its level. Subsequent TAV? commands will reply with the average of the specified number of readings.

Range: 1 to 10000.

Default: N = 1, A1

Format: NAV N [A]

Arguments: N: Number of readings
[A] indicates which analog input or which optical power meter (F-361) to use. Can be 1, 2 or 5. If omitted, A1 is used.

Example: NAV 10 A2

The next TAV? A2 command will reply with the average of 10 readings of the analog input 2.

NAV? (Get Number of Values Used by TAV?)

NOTE

To use this command, at least one analog input (optical board, E-760 piezo cotroller or external power meter) must be installed. See p. 109 for details.

If there is an F-361 Optical Power Meter (OPM) configuration file in the F-206 controller firmware file system (C:\HEXAPOD\F-361.DAT), an OPM will addressed (max. 2, A1 and A2) and any other analog inputs present will not be accessible. If that file does not exist, A1 and A2 will address the corresponding optical board and A5 the optical input on the E-760 piezo axis controller, if installed. See p. 109 for details.

Description: Reports the programmed number of readings of the analog signal to be averaged when a value is required.

Format:	NAV? [A]
Arguments:	[A] indicates which analog input or which optical power meter (F-361) to use. Can be 1, 2 or 5. If omitted, A1 is used.
Response:	N= 1 to 10000
Troubleshooting:	Command awaiting execution in queue

NLM (Set Negative Soft Limit)

NOTE

Soft limits are only respected if soft limits are activated by SSL

Description:	Sets the negative soft limit for the specified Hexapod axis. All limit values must be negative, so that the zero point cannot be excluded from the working space. The platform can be moved only if the target position lies inside the soft limits. If the platform is outside the soft limits, the platform may move to positions that are inside the soft limits. All soft limits are initialized with values stored in the configuration files; factory defaults are same as travel range limits.
Format:	NLM [X] [Y] [Z] [U] [V] [W] X, Y, Z, U, V, W (linear and rotary axis designators of the Hexapod)
Examples:	NLM X-1 NLM Y-2 Z-2 W-2
Response:	none
Troubleshooting:	Parameter out of limits

NLM? (Get Negative Soft Limit)

Description:	Gets the negative soft limit for the specified Hexapod axis.
Format:	NLM? [X] [Y] [Z] [U] [V] [W] X, Y, Z, U, V, W (linear and rotary axes of the Hexapod)

NLM ? without any arguments is interpreted as
NLM? X Y Z U V W

Examples:
NLM?
Response :
X=vvvvvSP LF
Y=vvvvvSP LF
Z=vvvvvSP LF
U=vvvvvSP LF
V=vvvvvSP LF
W=vvvvv LF

NLM? X W
Response :
X=vvvvvSP LF
W=vvvvvLF

(SP space; LF line feed)

PLM (Set Positive Soft Limit)

NOTE

Soft limits are only respected if soft limits are activated by SSL

Description: Sets the positive soft limit for the specified Hexapod axis.
All limit values must be positive, so that the zero point cannot be excluded from the working space.
The platform can be moved only if the target position lies inside the soft limits.
If the platform is outside the soft limits, the platform may move to positions that are inside the soft limits.
All soft limits are initialized with values stored in the configuration files; factory defaults are same as travel range limits.

Format: PLM [X] [Y] [Z] [U] [V] [W]
X, Y, Z, U, V, W linear and rotary axis designators of the Hexapod

Examples:
PLM X 1
PLM Y2 Z2 W2

Response: none

Troubleshooting: Parameter out of limits

PLM? (Get Positive Soft Limit)

Description: Gets the positive soft limit for the specified platform axis.

Format: PLM? [X] [Y] [Z] [U] [V] [W]
X, Y, Z, U, V, W linear and rotary axes of the Hexapod
PLM ? without any arguments is interpreted as PLM? X Y Z U V W

Examples: PLM?
Response : X=vvvvvSP LF
Y=vvvvvSP LF
Z=vvvvvSP LF
U=vvvvvSP LF
V=vvvvvSP LF
W=vvvvv LF
PLM? X W
Response : X=vvvvvSP LF
W=vvvvvLF
(SP space; LF line feed)

POS? (Get Position)

Description: Get Position of the F-206, or separate piezo or motor axes.
No response unitl motion caused by certain commands completes

Format: POS? [X] [Y] [Z] [U] [V] [W] [K] [L] [M][A] [B]

X, Y, Z, U, V, W linear and rotary axes of the F-206

K, L, M: Piezo axes (with P-611 NanoCube®, piezo axes K, L, M correspond in order *and direction* to X, Y, Z marked on stage. Handedness of P-611 differs from that of F-206).

A, B separate motorized axes

POS ? without any parameters is interpreted as POS ? X Y Z U V W

Examples: POS?

Response: X=vvvvvSP LF

Y=vvvvvSP LF

Z=vvvvvSP LF

U=vvvvvSP LF

V=vvvvvSP LF

W=vvvvvLF

POS? A X

Response: A=vvvvvSP LF

X=vvvvvLF

(SP space; LF line feed)

RBT (Reboot)

Description:	Restarts the hexapod controller. All operating parameters return to their power-up defaults
Format:	RBT
Arguments:	none

READ (Read file)

Description:	Reads a file on the controller file system; the file is sent line by line with a space and line feed added; after the last line, a blank line (line feed only) is sent indicating the end of transmission.
Format:	READ *file*
Arguments:	*file* is a relative or absolute path and filename. Relative paths are evaluated starting at C:\HEXAPOD.
Example	READ HEXBRATE.DAT
Remarks:	The error code is always set to 0. Only files with certain extensions can be read. Attempting to read a non-existent or disallowed file results in no response.

SCT (MOV! Timing Configuration)

Description:	Specifies the time in which the motion specified in MOV! commands is to complete. Allows MOV! commands to be sent periodically to avoid stutter effects in motion, such as when system motion is controlled by an external servo-loop. MOV! uses the cycle time set with SCT to adjust the velocity of the move so as to be close to the target at the end of the interval.
Format:	SCT [T]
Arguments:	T: cycle time [ms]; max. 10000, if omitted or 0 (default), MOV! will use the VEL velocity setting If T is omitted, SCT may need a trailing space SP to ensure command recognition.
Example:	SCT T29
Default	p=0
Response:	none
Troubleshooting:	Parameter out of limits, (t<0) or (t>10000).
Remarks:	When a cycle time has been set with the SCT command, the MOV! command will reach the target position at the end of the given cycle time by adjusting the velocity according to the target position distance. It is recommended to set a cycle time (SCT command) exceeding the real average cycle time in order to prevent any stutter effects caused by time period jitter. Set the cycle time to 0 if no cycle-time-dependant velocity changes are desired. As a consequence of this, the Hexapod struts will move with velocities that are limited only by the VEL command and the target position might be reached before the cycle time has ended. Though an appropriate velocity is calculated for each MOV! command, the real Hexapod velocity cannot fall below a certain minimum value nor will the strut velocities exceed the velocity set by the VEL command.

SCT? (Get MOV! Timing Configuration)

Description: Get cycle time setting (in ms) used by MOV!

Format: SCT?

Response: T=vvvvv

SGA (Set gain)

To use this command, an optical board or piezo controller (optional) must be installed.

Description: Set gain of the optical amplifier

Format: SGA N [A]

Arguments: N: Gain value, can be 1, 10, 100 or 1000
A: Optical board specifier (optional), can be A1,A2 or A5, if not specified, input 1 is used Default: N = 100, A1

Example: SGA 10 A2 Sets the gain of optical board 2 to a value of 10.

Response: none

Troubleshooting: Command awaiting execution in queue

SGA? (Get Gain Value)

To use this command, an optical board or piezo controller (optional) must be installed.

Description: Get optical gain value. Reports the gain setting of the specified analog in channel (optical input)

Format: SGA? [A]

Arguments: A: Analog channel specifier, can be A1, A2 or A5, if not specified, input 1 is used

Response: A= 1 or 10 or 100 or 1000

Troubleshooting: Command awaiting execution in queue

SPI (Set Pivot point)

Description:	Set pivot point (with R, S, T in mm). This command is only executed, if angular positions are U=V=W=0.
Format:	SPI [R] [S] [T]
Alternative Format:	SPI [X] [Y] [Z]
Troubleshooting:	Platform tilted (U, V or W not all 0)

NOTE

The pivot point and rotation axes move with the platform. This means that the physical location of the pivot point in space is equal to the sum of the coordinates specified in SPI and the X,Y,Z coordinates of the platform position. This is true even if the letters “X”, “Y”, and “Z” are used in the SPI command.

When the firmware is started, the pivot point value is set to the default values stored in lines 28-30 of the F206GEOM.DAT file on the controller file system, usually (0,0,0). INI commands do not change pivot point settings.

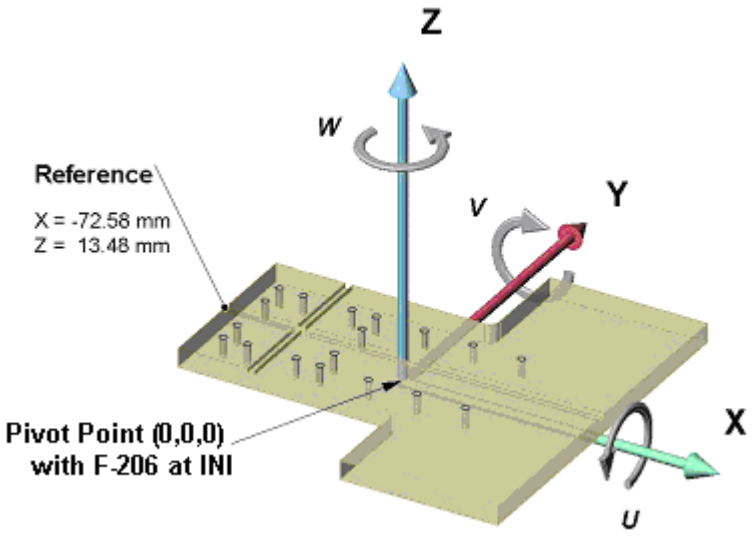


Fig. 53: Location of pivot point at start-up after initialization

NOTE

For the SPI command, X, Y and Z are simply aliases for R,S,T.

Example: SPI R0.3 S22 T12 (same as SPI X0.3 Y22 Z12) will set the pivot point to the position X=0.3 Y=22 Z=12.

Example: SPI R-72.58 S35.0 T13.48

sets the pivot point to the corner of the platform.

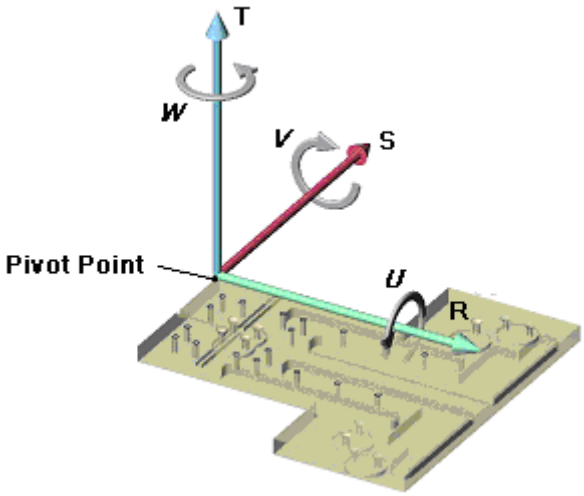


Fig. 54: Example showing how to set the pivot point to the corner of the platform

SPI? (Get Pivot point)

Description:	Get pivot point Reports coordinates of pivot point as R, S and T or X, Y and Z.
Format:	SPI? [XYZ]
Response to SPI?:	R= vvvvvSP LF S= vvvvvSP LF T= vvvvvLF
Response to SPI? XYZ:	X= vvvvvSP LF Y= vvvvvSP LF Z= vvvvvLF

NOTE

The pivot point moves with the platform, but its R,S,T coordinate values do not change when doing so.

For the SPI? command, X, Y and Z are simply aliases for R,S,T. The values reported are always the same.

Troubleshooting: Command awaiting execution in queue

SSL (Activate/Deactivate Soft Limits)

Description:	Activates or deactivates soft limits (set by the commands NLM and PLM) for the specified hexapod axes
Format:	SSL [X] [Y] [Z] [U] [V] [W] X, Y, Z, U, V, W linear and rotary axis keywords for the Hexapod axes, each followed by a value of “0” for OFF or “1” for ON
Examples:	SSL X 1 Soft limits for Axis X are set ON (activated). SSL Y0 Z1 W1 Soft limits for axis X are set OFF, soft limits for axes Z and U are set ON.

SSL? (Get Soft Limit Status)

Description: Gets the soft limit status for the specified platform axes.

Format: SSL? [X] [Y] [Z] [U] [V] [W]
X, Y, Z, U, V, W linear and rotary axes of the Hexapod
SSL? without any arguments is interpreted as SSL? X Y Z U V W

Examples:
SSL?
Response :
X=0SP LF
Y=0SP LF
Z=1SP LF
U=1SP LF
V=1SP LF
W=1 LF

SSL? X W
Response :
X=0SP LF
W=1LF

(SP space; LF line feed)

SST (Set Step Size)

Description:	Set step size for optional manual position control pad. Units for X,Y,Z: mm, U,V,W: deg. The values are interpreted as floating point format. It is sufficient to set new values only for the axes to be changed. Range: X, Y, Z: 0.0001 – 0.5 mm; U, V, W: 0.0001 – 0.5 deg
Format:	SST [X] [Y] [Z] [U] [V] [W] X, Y, Z, U, V, W linear and rotary axis designators; follow each keyword by numeric value in [mm] or [deg] defaults are all 0.01
Example:	SST Y0.002 U0.05 Sets the step size for axis Y to 2 µm and for U to 50 mdeg.
Response:	none
Troubleshooting:	Parameter out of limits

SST? Get Step Size

Description:	Get step size setting being used for manual position control pad
Format:	SST?
Response:	X= vvvvv[SP] [LF] Y= vvvvv[SP] [LF] Z= vvvvv[SP] [LF] U= vvvvv[SP] [LF] V= vvvvv[SP] [LF] W= vvvvv[LF] [SP] space; [LF] line feed

STOP (Stop Motion)

Description:	Stops all motion immediately (except fast scan motion)—including motion of separate axes A & B, if present—clears any unexecuted commands from the queue, and sets the error code to 10. This command is executed immediately, not queued behind other commands awaiting execution. STOP and #24 are identical, but #24 is to be preferred, because under certain conditions STOP may not be recognized at typing speed. With current firmware the command queue is flushed and the actual position calculated so that a subsequent POS? command will give the correct value and other motion commands can be allowed.
Format:	STOP
Arguments:	none
Troubleshooting:	Communication breakdown
Remarks	With firmware older than 6.0, the queue is not cleared In case of a MOV or INI failure as a consequence of a hardware faliure, use the #24 command to quit these commands in order to continue with diagnostic commands.

SVO (Set Servo on or off)

Description: Set servo-loop of the F-206 ON or OFF.

NOTE

With the servo-control loop OFF, no positioning of the F-206 or axes A and B is possible. Servo OFF is recommended during nanopositioning with piezo axes K, L, and M to prevent servo dither (1 encoder count equals up to 34 nm) that could otherwise interfer.

The SVO command always affects both the F-206 and the separate axes A and B.

To move the F-206 again, the servo loop must be turned on again. The INI command automatically turns servo on.

Format: SVO *n*

Or

SVO [X] [Y] [Z] [U] [V] [W] [K] [L] [M] [A] [B]

Arguments: 0 for servo off

1 for servo on

Example: SVO 1

Turns the servo-loop on

SVO U0

Turns the servo-loop off

Response: none

Troubleshooting: Incorrect parameters

NOTE

The servo-loop setting affects both F-206 and separate motor and piezo axes. Therefore, the following commands are identical:

SVO1

SVO X1

SVO A1

SVO M1

SVO? (Get Servo State)

Description:	Reports the servo state of the F-206 and axes A and B
Format:	SVO? [X][Y][Z][U][V][W][K][L][M][A][B]
Response, if evoked without any parameters:	0 for servo is off 1 for servo is on
Example:	SVO? XYUAB Response (in case servo is on): X= 1SP LF Y= 1SP LF U= 1SP LF A= 1SP LF B= 1LF SP space LF line feed

NOTE

Axes X, Y, Z, U, V, W, A, and B always have the same servo state.

Troubleshooting: Command awaiting execution in queue

TAV (Settings for use by TAV?)

This command addresses F-361 Optical Power Meters (OPM) only and can not be used to address an optical board.

To use this command, an F-361 configuration file with an entry for the specified OPM must be present in the C:\HEXAPOD directory of the controller, and an F-361 must be properly connected and switched on. See the F-361 User Manual for details.

Description:	Sets measuring unit and measuring range for an F-361 OPM (optical power meter).
Format:	TAV [A] [UuW/UmW/UdBm] [R0/R1]
Arguments:	A: Optical Power Meter, can be 1 or 2, if not specified, OPM 1 will be addressed. U (Unit) where Unit = uW, dBm or mW UuW: Sets the measuring unit to µW (1E-6 watt) UmW: Sets the measuring unit to mW (1E-3 watt) UdBm: Sets the measuring unit to dBm ([dBm] = 10 log10 (Power / 1mW)) R (Sensitivity) where Sensitivity = 0 or 1 R0: Achieves high accuracy with low signals, should be selected if the signal power is extremely low R1: Should be selected to enlarge the measurement range in order to measure higher power signals.
Default values:	The default value of R (Sensitivity) is set by the corresponding entry in the “F-361.dat” configuration file, which is located in the c:\HEXAPOD directory of the controller. The factory default value for U is mW.
Background:	The F-361 has 9 power ranges and switches from one to another automatically when necessary. The highest range and the lowest range, however, cannot both be made available at the same time. R0 enables measuring in the lowest power range and disables measuring in the highest power range. R1 enables measuring in the highest power range and disables measuring in the lowest power range.

TAV? (Tell Analog Value)

NOTE

This command can address either an optical board or an F-361 optical power meter. The presence of an F-361.DAT configuration file in the C:\HEXAPOD directory on the controller deactivates access to any optical board that might be present.

Description: Tell analog value.

Reports the level of the analog signal at the specified device in floating point with 12-bit resolution.

With an OPM the value reported will include the units of measure, which can be specified in a TAV command. Value of 10000 indicates invalid reading.

With an optical board, value is in volts (unit not included in response), in a 0-10 V range.

Format: TAV? [A] [U] [R]

Arguments: [A] indicates which analog input or which optical power meter (F-361) to use. Can be 1, 2 or 5. If omitted, A1 is used.

If that file does not exist, A1 and A2 will address the corresponding optical board and A5 the optical input on the E-760 piezo axis controller, if installed.

U (Unit, OPM only)

R (Sensitivity, OPM only)

Response: If “U” and “R” are omitted:

{<InputID>"="<float> LF}

If “U” is present:: no analog value will be returned, but the measuring unit instead:

U = uW or U=dBm or U=mW.
UuW: measuring unit is µW (1E-6 Watt)
UmW: measuring unit is mW (1E-3 Watt)
UdBm: measuring unit is dBm
([dBm] = 10 $\log_{10}$ (Power/1 mW))

If R is present, no analog value will be returned but the measuring range instead: R=0 or R=1.

Troubleshooting :

Attempt to address device A1 when device A2 is desired or vice versa.

With F-361 OPM:

F-361 device is not powered up.

Connect the power supply and turn on the F-361 device by pressing the power on button. Since this button is also used to access configuration menus, it is labeled “menu enter.”

Inconsistent baud rate settings at F-361 and in the F-361.DAT configuration file.

F-361 connected to / configured for incorrect serial port.

With optical board:

F-361.DAT file exists in controller C:\HEXAPOD directory, thus deactivating access to any optical boards. Rename this file.

VEL Set Velocity

NOTE

Even though F-206 axis designators can be specified, the F-206 velocity as a whole is set, not the speeds in the specific directions.

Description: Set velocity to be used for moves

Range: 0.004 to 10 mm/sec.

For platform, motion VEL is the speed in the direction of the velocity vector. For moves with rotation components, the velocity considered is that of the fastest “joint point” on the platform.

The allowable velocity settings for separate axes A and B depend on stages configured.

Format: VEL [X][Y][Z][U][V][W] [K] [L] [M] [A] [B]

VEL *v*

Arguments: No matter which (if any) of the F-206 axis designator keywords (X,Y,Z,U,V,W) is used, the value following the keyword (if present at all) in mm/s is the velocity limit for the platform as a whole. If more than one of these axes is specified, the associated values must be the same.

K,L,M piezo axes designators will be ignored

A,B separate axis designator keywords; the allowable velocity settings and units depend on the stages configured.

Examples: VEL 3 sets the velocity of the F-206 to 3 mm/s.

VEL X3 sets the velocity of the F-206 to 3 mm/s.

VEL W3 sets the velocity of the F-206 to 3 mm/s.

VEL A0.02 sets the velocity of the separate axis A to 0.02 units (as defined for that axis).

VEL X3 U3 sets the velocity of the F-206 to 3 mm/s.

VEL X1 U3 will cause an error message since velocity settings are inconsistent.

Response: none

Troubleshooting: Parameter out of limits

Specified separate axis not configured, or F-206.AC8 software option not installed

Specified separate axis unit-size parameter incorrect

VEL? Get Velocity Setting

Description:	Reports the current velocity setting for the F-206 as a whole in mm/s and/or for the specified separate axes in [mm/s] or [deg/s], depending on stages configured (rounded to 3 decimal places).
Format:	VEL? [X] [Y] [Z] [U] [V] [W] [K] [L] [M] [A] [B]
Arguments:	X, Y, Z, U, V, W linear and rotary axes of the F-206 K, L, M NanoCube® axes (return 0.0) A, B separate axes
Response:	Axis = vvvvSP LF ... Axis = vvvv LF Value of the velocity setting(s) currently in effect. Even though F-206 axis designators can be specified and reported, the F-206 velocity setting as a whole is given, not speeds for specific directions. The A and B velocities do, however, refer to the individual separate axes. Piezo axes K, L and M will always be reported as 0.0 since the piezo velocity cannot be set or reported at present.
Troubleshooting:	Command awaiting execution in queue
Example:	VEL? XUA X=3.716 SP LF U=3.716 SP LF A=21.028 LF VEL? 3.716 LF

VER? Get Version

Description: Get firmware version The system reports the firmware version of the controller, as well as some additional information for internal use.

Format: VER?

Arguments: none

Response: Firmware version

Troubleshooting: Command awaiting execution in queue

VMO Virtual Move

Description: Virtual Move

The system reports whether or not the target position is reachable directly from the current position. The command can be used to check the F-206 workspace and the travel ranges of axes A and B.

No motion occurs.

The current target position is not changed.

Format: VMO [X] [Y] [Z] [U] [V] [W] [A] [B]

Similar to MOV command, except that no motion occurs

Arguments: Coordinates of position to test, each preceeded by its axis keyword; current position is used for any omitted axes.

Response: 0 indicates target position can be reached

1 indicates target position cannot be reached directly from the current position.

Troubleshooting: Command is executed only after all previous commands have executed and any associated motion finished.

(#5) Query Motion Status

Description: Polls the motion status immediately.

Format: #5 (ASCII character 5)

Arguments: none

Response: Response sent immediately, even if there are other commands waiting to be executed.

0: motion complete, system ready for new command.
1: Platform is moving (state of axes A and/or B, if present, is not indicated)
2: Only separate axis A is moving
4: Only separate axis B is moving
6: Only separate axes A and B are moving

(#6) Position Change?

Description: Asks if position has changed since last POS? query.

Format: #6 (ASCII character 6)

Arguments: none

Response: Response sent immediately, even if there are other commands waiting to be executed.

1 Position of X, Y, Z, U, V, W, A, B, K, L, or M has changed

0 No position change.

Remarks During an INI command, "platform moving" is always reported, even if only the separate axes are being initialized.

(#24) Stop Motion

Description: Stops all motion immediately (except fast scan motion)—including motion of separate axes, if present—clears any unexecuted commands from the queue, and sets the error code to 10.

This command is executed immediately, not queued behind other commands awaiting execution, but may wait for fast scan motion to finish.

STOP and #24 are identical, but #24 is to be preferred, because under certain conditions STOP may not be recognized at typing speed.

With current firmware the command queue is flushed and the actual position calculated so that a subsequent POS? command will give the correct value and other motion commands can be allowed.

Format: #24 (ASCII character 24)

Arguments: none

Response: none

Remarks With firmware older than 6.0, the queue is not cleared

In case of a MOV or INI failure as a consequence of a hardware failure, use the #24 command to quit these commands in order to continue with diagnostic commands.

(#27) (ESC) System Abort

Description: System abort; this command is executed immediately, not queued behind other commands awaiting execution; may wait for current fast scan command to finish.

Motion of the platform stops immediately (except, all servo registers are reset, the servo-loop is disabled. The controller emits a continuous beep at 300 Hz. For restart, the controller must be manually reset or turned off and on (power switch).

Format: #27 (ASCII-character 27)

Arguments: none

Response: none

8 Operating Examples

The following two examples show how to communicate with the F-206 system using PASCAL. In both cases, a line scan with 10 steps is performed.

Version #1 waiting for motion-ready answer

```
procedure y_scan_m;
const check_str: string[2] ='1'+#10; { "1" + linefeed      }
var ch:               char;
              i:            integer;
              pos:          double;
              str_pos:      string;
              temp_str:     string;
begin
 pos:=0;                    { set position to zero }
 for i:=1 to 10 do    { 10 steps, loop              }
 begin
       pos:=pos+0.1;  { increment position          }
       str(pos:1:4,str_pos); { make a string        }
       set_output('MOV Y'+str_pos); { send CMD to the controller }
       set_output('MOV?'); { request for move complete }
       temp_str:='';
       repeat               { loop, waiting for "1" }
              if readinputbuf(ch) then
                     temp_str:=temp_str+ch;
       until (temp_str= check_str); { until move complete }
 end;
 set_output('MOV X0 Y0 Z0 U0 V0 W0');
end;
```

Version #2 polling until movement ready

```
procedure y_scan_5;
const  check_str: string[2] ='0'+#10; { "0" + Linefeed }
var ch:        char;
       i:      integer;
       pos:    double;
       str_pos: string;
       temp_str: string;
begin
 pos:=0;              { set position to zero       }
 for i:=1 to 10 do    { 10 steps, loop             }
 begin
       pos:=pos+0.1;  { increment the position     }
       str(pos:1:4,str_pos); { make a string       }
       set_output('MOV Y'+str_pos); { send CMD to the controller }
       repeat         { loop until move complete   }
              temp_str:='';
              ch:=' ';
              sendcharrs232(#5); { send an ascii 5 }
              repeat { loop for RS232 until LF     }
                     if readinputbuf(ch) then
              temp_str:=temp_str+ch;
       until ch=#10; { until linefeed (LF) comes   }
       until (temp_str= check_str); { until move complete }
end;
 set_output('MOV X0 Y0 Z0 U0 V0 W0');
end;
```

9 Troubleshooting

9.1 RS-232 Communication

Check the configuration of the COM: port.
Is it set to 57600 baud, 8 data bits, 1 stop bit, no parity on both sides?
Connect a keyboard and a monitor to the controller and watch the boot procedure. During the firmware startup process, the communication settings appear on the screen. All commands sent via RS-232 can be seen in the firmware status line.
The data file hexbrate.dat, which is located in the C:\HEXAPOD directory of the controller file system (see p. 29), must have the following structure:

PHYSIK INSTRUMENTE (PI) GmbH
Auf der Römerstraße 1
76228 Karlsruhe / Germany
Baudrate
57600

and must not contain a 6th line.

Is the right cable being used? Use the original null-modem cable that comes with the device.

If no communication can be established, interface settings on the host PC should be checked (Try disabling the infrared port, if any, and make sure the serial port is enabled).

If the host is running LabVIEW under Linux, consult the included A000T0021 Technical Note.

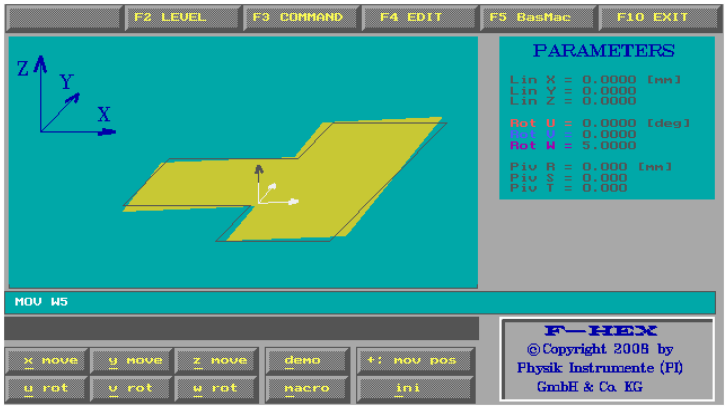


Fig. 55: Main screen of the F-206 firmware

9.2 Testing Actuators and OPM

A program named F206TEST.EXE is available on the controller for testing the individual strut actuators and for testing the optical power meter (OPM). To run it, proceed as follows:

1 Unless you have a controller with a built-in keyboard that you wish to use, connect a keyboard (included) and monitor (not included) to the F-206 hexapod controller

2 Start the controller and choose F206TEST from the startup menu, or exit the control program with F10 and enter "F206TEST" followed by ENTER at the C:\HEXAPOD> prompt.

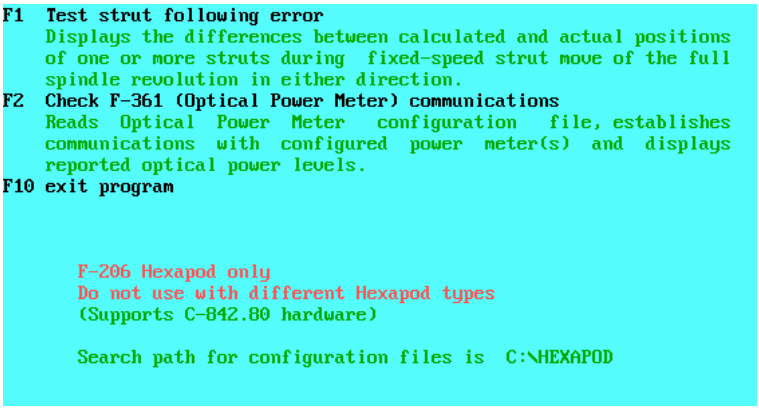


Fig. 56: F-206TEST.EXE program; press F1 for strut test, F2 for OPM test

9.2.1 Strut Test

Irregularities in the strut mechanics cause slight differences between the targeted and actual positions during motion. Under static conditions these divergences are eliminated by the servo-control loop, but the higher the velocity the greater they become.

The test program allows control over the individual F-206 actuators struts, and allows you to preposition the strut and set the velocity as desired before a test. The following-error test itself covers a displacement equal to one full revolution of the spindle which drives the strut.

To use the strut test program, press the F1 key at the main screen..

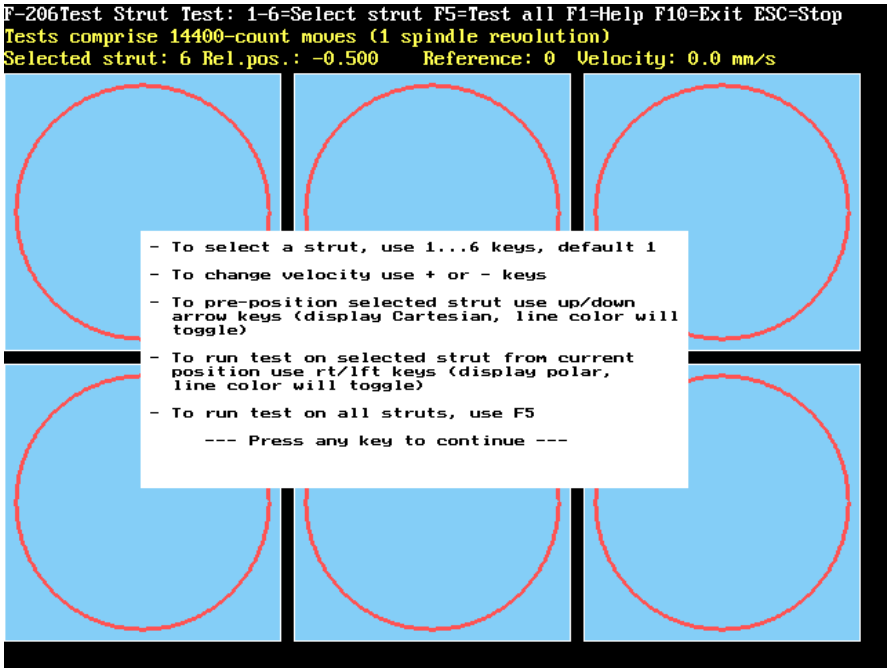


Fig. 57: F206TEST strut following-error test screen (as seen on F-206 controller), showing HELP window displayed

9.3 Optical Power Meter Test

Press F2 to choose the optical power meter test.

The OPM can also be tested on the host computer via its plug-and-play USB interface. A Windows test program, LP-METER01.exe is included on the product CD for this purpose (see the F-361 User Manual for details).

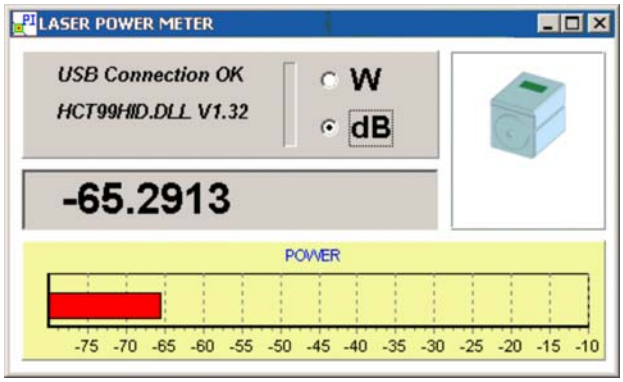


Fig. 58: LPMeter01.exe display

Note that no software is provided to coordinate the OPM on the host with the Hexapod during operation.

10 Maintenance

10.1 Fuses (rear panel, lower left)

Use IEC-Standard T-class (slow blow) fuses (other fuse standards are defined differently and equivalent fuses may have higher current ratings)

Fuse Rating: IEC 4 AT

To access fuses, push tab (circle) down and pull out carrier

Fig. 59: Rear panel fuse carrier and fuses

10.2 Dust Filter

The venltilation holes at the left of the controller front panel are protected by a dust filter which can be replaced if necessary.

To access the dust filter, remove the 8 screws which hold the front panel and tip it slightly forward (the on-off switch connection prevents the panel from being removed). Remove and replace the dust filter as shown in Fig. 60. Be sure that it does not extend over the keyboard connector socket at the bottom of the front panel.

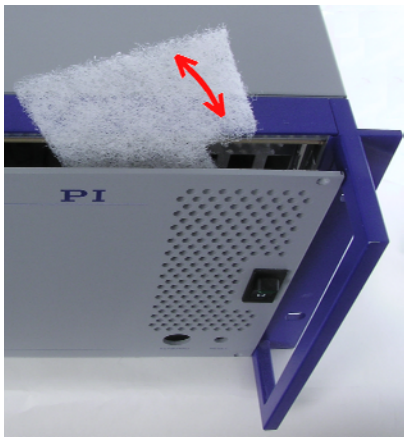


Fig. 60: Dust filter replacement

10.3 Disposal

In accordance with EU directive 2002 / 96 / EC (WEEE), as of 13 August 2005, electrical and electronic equipment may not be disposed of in the member states of the EU mixed with other wastes.

To meet the manufacturer's product responsibility with regard to this product, Physik Instrumente (PI) GmbH & Co. KG will ensure environmentally correct disposal of old PI equipment that was first put into circulation after 13 August 2005, free of charge.

If you have such old equipment from PI, you can send it to the following address postage-free:

Physik Instrumente (PI) GmbH & Co. KG
Auf der Römerstr. 1
76228 Karlsruhe, Germany

11 PC Cards & Options

If your system was ordered together with any of the optional ISA-bus add-on cards, it should be delivered with them installed and configured. If you order the cards separately, refer to the corresponding section for installation.

11.1 TCP/IP Interface

The TCP/IP interface is standard in current-production Hexapod controllers. It is implemented with the C-880.TCP ISA-bus add-on card. Be sure to use the RJ 45 socket on the back of the card to connect to the network or host; other RJ45 sockets that may be present are inactive. See Section 4.2 for communicating with the controller and configuring the card.

Most older Hexapod controllers can be retrofitted for TCP/IP, but it may be necessary to return the unit to PI. Contact your PI Sales Engineer or write info@pi.ws for information.

11.2 Control for Additional Separate Axes

Adding control for additional motion axes is a software option or upgrade (order number F-206.AC8). You must specify the stage type(s) to be connected when ordering the option or upgrade. If ordered together with the system, it will be delivered preconfigured. If ordered separately, you will receive instructions for the required firmware update

When using two additional axes of different types, be sure not to interchange axes A and B. The CST? command provides the name(s) of the configured stages.

Control of the piezo axes requires installation of an add-on card in the controller as well. See Section 11.7 for instructions if you order the card separately. Typically, a NanoCube® 3-axis nanopositioner is connected to axes K, L and M. Note that the NanoCube® axes are left-handed.

11.3 GPIB (IEEE 488) Communications Option

A GPIB (also known as IEEE 488) interface card is available as F-206.I3E. When installed and configured in the F-206 controller, the controller will use that interface as its remote ASCII command

interface.

1 Install the card as described in Section 11.7 below. The default address setting is 4.

2 Change the command interface configuration in the controller to GPIB, as described in Section 4.4.2, p. 31.

11.4 Manual Control Pad

The Manual Control Pad (F-206.MC6) option is a useful addition for simplifying test, setup and manual alignment procedures. It consists of an interface board (C-855.60) that installs in the F-206 controller and a control pad with six digital “potentiometer” knobs. The control pad allows manual control in all 6 degrees of freedom with a variable step size.
Firmware versions newer than hex0030.exe support this option.

Fig. 61: Six-axis manual position control pad and interface board for the F-206 system

1 Verify that jumpers JP1 and JP2 on the C-855.60 manual pad control interface board are both open (base address 0340 hex).

2 Install the interface board in the F-206 controller (see Section 11.7 below).

3 Connect the cable of the manual control pad to the newly installed control board.

4 Switch on the controller (firmware versions newer than hex0030.exe required). The manual pad should be recognized automatically.

The step size to use for each axis can be set using the SST command, (p. 88).

Troubleshooting
If the controller does not have a built-in display, connect a standard VGA monitor to it. Switch on the controller and observe the controller boot process on the monitor. The firmware detects the board automatically and a green colored “Manual control board available” message appears. If no such board is installed, a red colored message reading “Manual control board not available” can be seen.

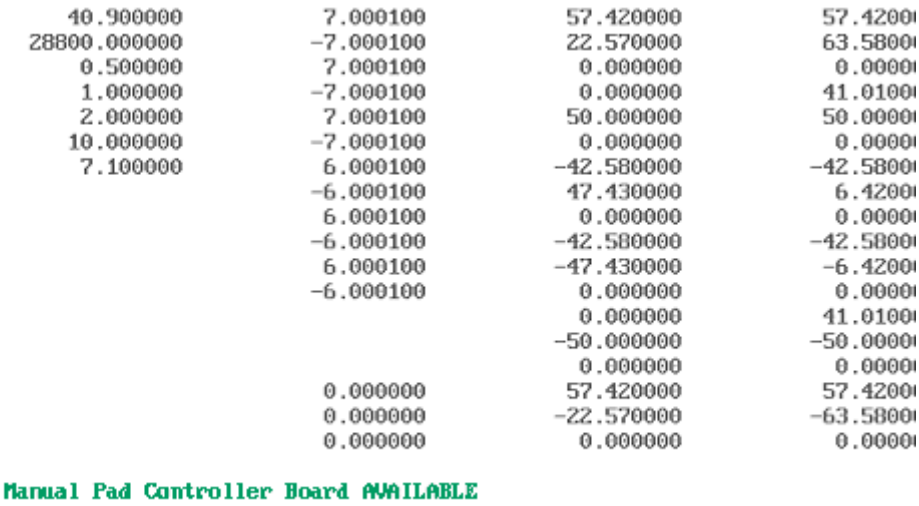


Fig. 62: Bottom of firmware boot screen when manual pad controller board is installed

11.5 Optical (Analog) Signal Inputs

Available for use with the F-206 are highly stable, configurable, external F-361 optical power meters (maximum 2 per controller), F-206.VVU and F-206.iiU 2-channel optical boards (max. 1 per controller) and E-760 piezo controllers with optical input (1 per controller). These devices make the power level of optical signals (on an FC connector) or other analog signal available to the program. The various optical/analog inputs can be configured/accessed by the TAV?, TAV, SGA, SGA?, NAV, NAV? commands and fast scan algorithms as devices A1, A2 and A5.

NOTE

F-206.VVU (visual) and F-206.iiU (infrared) 2-channel boards cannot both be installed in the same system.

Optical Power Meters (OPM) cannot be operated on the same system with other optical inputs at the same time. The presence of the OPM configuration file, F-361.DAT in the C:\HEXAPOD directory of the controller deactivates recognition of the optical input of an E-760 card and any optical board installed.

The discontinued F-206.00U and F-206.IRU single-channel optical boards are no longer supported.

11.5.1 Optical Power Meter

One or two external F-361 Optical Power Meters can be connected to the system. The F-361 is highly flexible, configurable, can be delivered with a certificate of accuracy, and is equipped with three photo diodes each having different sensitivities and different built-in ranges, so that a wide range of power can be measured precisely. The F-361 is described in detail a separate User Manual.

Fig. 63: Optical Power Meter and serial interface card.

F-361s are connected to the controller over RS-232 interfaces. See Section 11.7 for installation of the included serial port interface card in the controller, and see the F-361 User Manual for other installation and configuration details. For testing purposes, the OPM can be connected to the host computer via the USB plug-and-play interface. A Windows test program is included on the product CD for this purpose (see p. 104).

NOTE

No software is provided to coordinate an OPM cpmmected to the host with the F-206.. For operation, the F-361 must be connected to the F-206 controller via an RS-232 port.

The OPM(s), when configured in and connected to the *controller*, can be accessed using the TAV, TAV?, NAV and NAV? commands.

11.5.2 Optical Board with 0-10 V Analog Input

The single-channel F-206.00U and F-206.iRU optical boards are no longer available because of ROHs regulations. They are not supported by the current firmware and have been replaced by the two-channel F-206.VVU (visual) and F-206.iiU (IR) optical boards. Only one of the new optical boards can be installed in the controller at a time.

The optical photodiodes simply drive the optical-converter analog outputs, while the on-board analog-to-digital converters are connected to the electrical analog inputs. The digitized input voltage is made available by the TAV? command. As a result, either an optical or electrical input can be used.

FC optical inputs 1 and 2

Reserved

A-to-D converter analog inputs 1 and 2

Optical converter analog outputs 1 and 2

Fig. 64: F-206.iiU or F-206.VVU optical board, bracket face with connections

NOTE

To use the optical FC input, the optical converter analog OUT must be looped back to the A-to-D converter IN connector on the card (see schematic diagram, p. 118). A BNC cable for this purpose is included.

11.5.3 Optical Input on E-760 Piezo Controller Board

In addition to its piezo controller, the E-760 has an optical/analog input which can be accessed as optical device A5. This input, however, is not accessible if an external optical power meter is configured in the controller firmware.

DANGER

Warning: Electric Shock Hazard

Systems with the E-760 Piezo Axis (NanoCube®) Controller

Piezo stages are driven by amplifiers generating HIGH VOLTAGES. The output power on the (optional) E-760 card and connected stage may cause serious injuries.

All work done with and on the modules described here requires adequate knowledge and training in handling High Voltages.

11.6 E-760 Piezo Axis (NanoCube®) Controller Board

The F-206 controller can be equipped to control three piezo-driven nanopositioning axes with an E-760 controller board. If your E-760 was not delivered preinstalled, refer to Section 11.7 below and to any technical notes included with the shipment. If the card is installed, the firmware will also have been configured.

Fig. 65: E-760 piezo axis controller with NanoCube® in background.

CAUTION

If You Have a NanoCube® Protect It from Damage

Read the NanoCube® Handling Instructions Before Unpacking

In addition to the piezo controller, the E-760 has an optical input which can be accessed as optical device A5. This input, however, is

not accessable if an external optical power meter is configured in the controller firmware.

The optical intensity can be processed with a settable gain factor of 1,10,100 or 1000.

Input range: 0 to 5 V (0x0000 to 0x1FFF)

Resolution: 13-bit

If a PI NanoCube® is connected to the E-760, its X, Y and Z axes are addressed as axes K, L and M by the commands which support them. The directions of motion are those marked on the NanoCube: note that the handedness of the P-611 differs from that of the F-206. Refer to the P-611 User Manual and any included Technical Notes for details on this device.

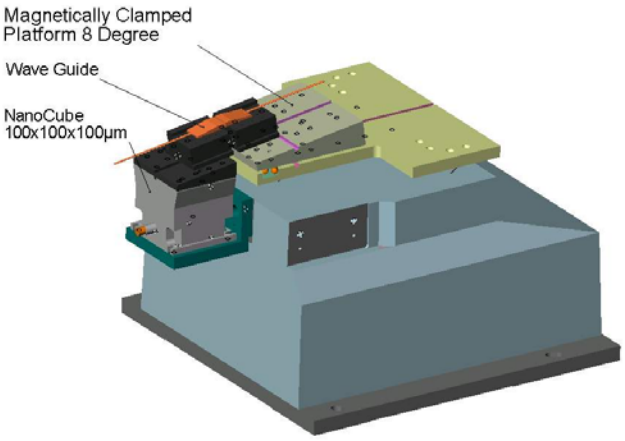


Fig. 66: Example of a setup for aligning a 8-deg waveguide using the F-206, the NanoCube® and PI's standard holders for 8-deg optical devices

11.7 Installing Add-On Cards in the F-206 Controller

CAUTION—Electrostatic Hazard

Add-In Cards Subject to Damage

Electronic components are sensitive to electrostatic electricity. Take appropriate electrostatic protection measures when installing or removing boards or opening the controller for any other reason.

A number of available options require installation of an associated add-on card in the F-206 controller. To install such cards, follow the steps below:

1 Prior to opening the controller case, disconnect the power cable.

2 Open the controller housing by removing the four Torx screws inside the plastic decorations on the back panel of the controller, using the Torx driver TX8 (#3683) that comes with the system.

3 Lift the cover slightly and disconnect the ground cable. Remove the cover.

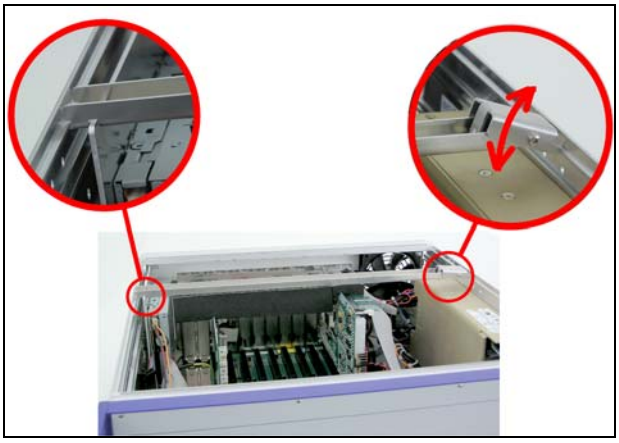


Fig. 67: Daughterboard clamp removal/replacement

4 Lift the lever to release the daughterboard retaining clamp. Remove the clamping plate.

5 Remove the screw and cover bracket from a free ISA slot.

6 Carefully insert the new card into a free ISA slot and fasten it with the screw.

CAUTION

Be gentle when inserting the card: use of excessive force can cause hairline cracks.

7 Replace the clamping plate and relatch using the lever.

8 Make sure that no internal header connectors have been dislodged.

9 Connect the ground cable to the controller cover, slide the cover carefully into position, then insert and tighten the screws. Replace the plastic decorations with the Torx screws.

12 Technical Data

12.1 F-206 Mechanics Specifications

Models	F-206.S0 / F-206.SD
* Travel range X	-8 to +5.7 mm
* Travel range Y	-5.7 to +5.7 mm
* Travel range Z	-6.7 to +6.7 mm
* Travel range θ_X	-5.7 to +5.7°
* Travel range θ_Y	-6.6 to +6.6°
* Travel range θ_Z	-5.5 to +5.5°
Actuator design resolution	33 nm
** Minimum incremental motion X, Y, Z	0.1 µm (6-axis move!)
** Minimum incremental motion θ_X, θ_Y, θ_Z	2 µrad (0.4 arc seconds) (6-axis move!)
Bidirectional repeatability X, Y, Z	0.3 µm
Bidirectional repeatability θ_X, θ_Y, θ_Z	3.6 µrad
Speed X, Y, Z	0.003 to 10 mm/s
Maximum load in Z	2 kg (centered on platform)
Mass	5.8 kg
Material	Aluminum
Operating temperature range	-50 to 50°C

* Travel ranges in the coordinate directions (X, Y, Z θ_X, θ_Y, θ_Z) are interdependent. The data given shows maximum travel range of the axis in question (i.e. its travel when all other axes are at their zero positions). If this is not the case, the available travel may be less.
** Move involving all 6 actuators. No moving cables, unlike serial kinematics (stacked) systems. Eliminates bending, inertia and friction, improving accuracy.

12.2 F-206 Controller

Model	F-206
Function	Hexapod Controller
Display	Built-in display (".D" versions only) + connection for VGA
Keyboard	BuitIt-in keypad (".D" versions only) + external, US-keyboard included
Host Communication	RS-232, TCP/IP & optional GPIB (IEEE)
Command Interfaces	Over host link or direct via keyboard / monitor
Operating voltage	100-240 VAC, 50/60 Hz
Software	LabView™ drivers, software for alignment of arrays, DLL and PIMikroMove™, terminal software
Operating Temperature	5°C to 50°C
Power consumption	Max. 340 W incl. mechanics and all built-in options
Fuses	2 x IEC 4 AT (see p. 105)
Dimensions	180 x 450 x 460 mm (19" rack)
Mass	11 kg

Optical / Analog Boards*	F-206.VVU (visible range)	F-206.iiU (IR range)
Channels	2	2
Optical Power Range:	5 nW – 10 mW	5 nW – 10 mW
Analog Input Range:	0 – 10 V	0 – 10 V
A/D Resolution:	12 bit	12 bit
Sample Rate:	10 kHz	10 kHz
Bandwidth:	300 Hz (optical input), 10 kHz (analog input)	300 Hz (optical input), 10 kHz (analog input)

*either 1 F-206.VVU or 1 F-206.iiU can be installed in the controller

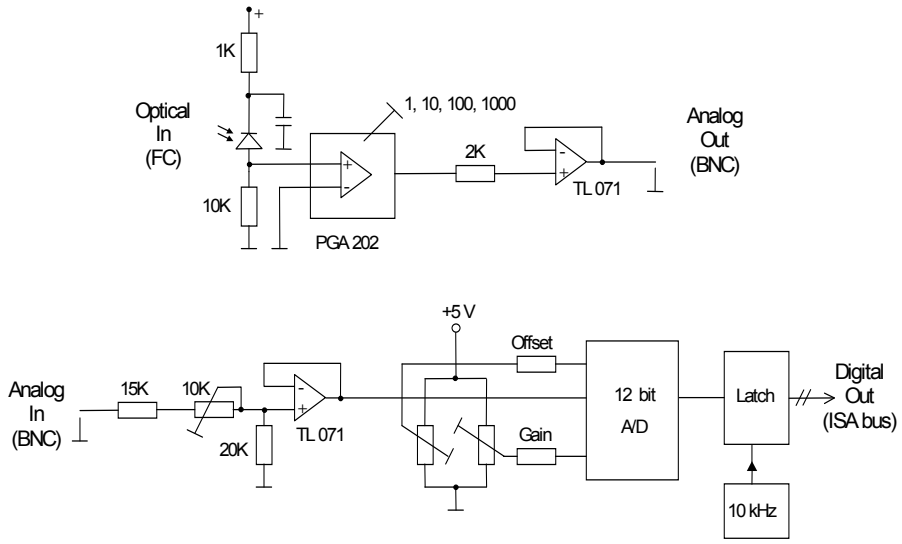


Fig. 68: Optical board schematic diagram, showing the separate optical and analog to digital converters.

NOTE

To use the optical FC input, the optical converter analog OUT must be looped back to the A-to-D converter IN connector on the card. A BNC cable for this purpose is included.

12.2.1 Responsivity

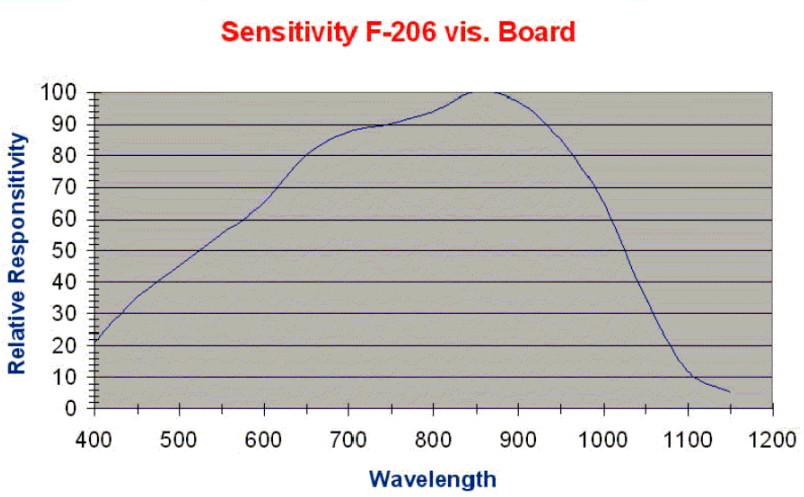


Fig. 69: Relative responsivity curve for visible diode[1]

[1] Responsivity curves same as those of optical board, see Section 12.2.1.

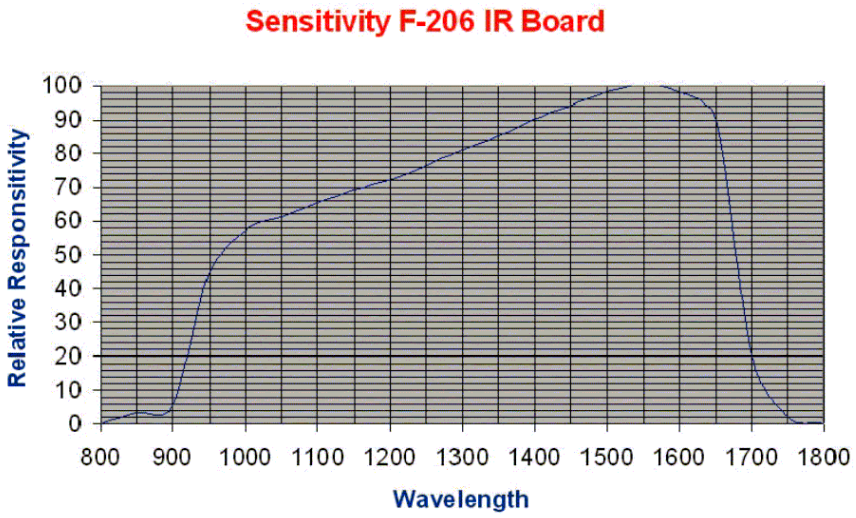


Fig. 70: Relative responsivity curve for infrared diode, valid for both optical boards and optical input of E-760 piezo controller

12.3 F-361 Optical Power Meters (OPM)

Using the OPM F-361, absolute light-power measurements can be performed and the results made available to the software. The F-361 is delivered with a calibration certificate and spectral responsitivity table. This table is stored in the F-361 EEPROM and will be used to perform a built-in auto-correction.

OPMs are equipped with three photo diodes each having different sensitivities and different built-in ranges, so that a wide range of power can be measured precisely.

Two OPMs can be installed. It is necessary to install the included serial card in the controller as an interface to the OPMs. The OPM USB interface, which can be connected to the host computer, is for testing purposes only.

To assure serial communication, the baud rate setting on the device must agree with those in the configuration file, F-361.dat in the C:\HEXAPOD directory of the controller. Use the F-361 device keys to change baud rate.

The required RS-232 null-modem cable comes with the system.

See the F-361 User Manual for details.

12.4 E-760 Piezo (NanoCube®) Controller with Optical Input

Model	E-760
Piezo axes and sensors	3
Maximum output power	9 W
Average output power	3 W
Peak output current < 5 ms	90 mA
Average output current > 5 ms	30 mA
Current limitation	Short-circuit proof
Voltage gain	10 ±0.1
Polarity	Positive
Control input voltage	-2 to +12 V
Output voltage	-20 to 120 V
PZT voltage output socket	25 pin sub-D on rear
Position Servo-Control	
Sensor Type	Strain Gauge
Servo Characteristics	P-I (analog) + notch filter
Sensor socket	25 pin sub-D on rear (same as PZT voltage)
Optical Metrology1	I
Detector input via FC connector	IR detector (E-760.3Si), Vis detector (E-760.3SV)
Optical Power Range	5 nW – 1 mW
A/D Resolution	12-bit
Bandwidth	300 Hz (optical Input)

13 Connectors and Pinouts

13.1 F-206 Mechanics

- Power Connector

  Motor power for all six F-206 motors is provided over a separate supply line. Standard is 24 V DC. The other end of the supplied cable is designed to be plugged into the controller, where 24 V is available.

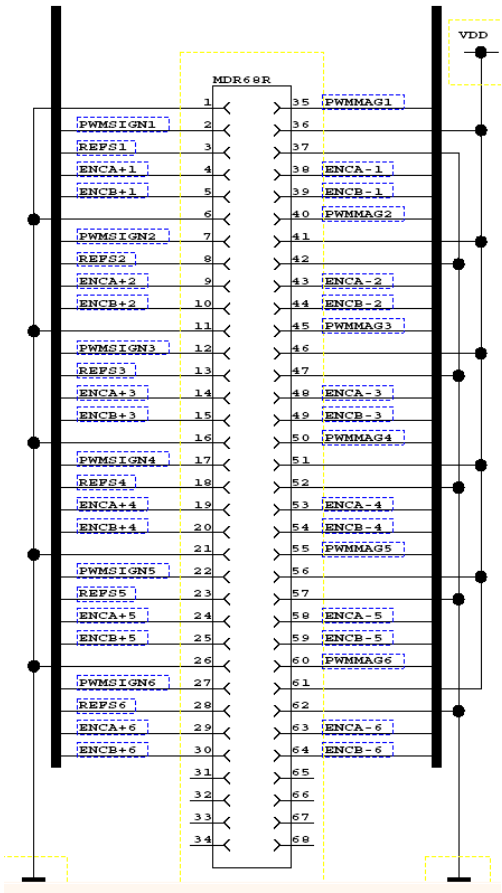
1	GND
2	+24 V
3	n.c.

F-206 Power Connector

- Controller-Mechanics cable and connectors

  The cable carrying control signals between the controller and mechanics has identical 68-pin MDR connectors on both ends and is wired one-to-one. The pinout is shown here. Signals are TTL level. Power for the PWM amplifiers in the mechanics is supplied over a separate cable.

MDR 68 Socket



13.2 Controller and Options

Fig. 71: Controller rear-panel connections and removable media reader. (Note: rear-panel KBD connector inactive on units with built-in keyboard and display).

Connectors from top to bottom, left to right:

- Line power to wide-range (100-240 V) power supply, see p. 105 for line fuses.
- Power sockets for F-206 mechanics

For some custom versions: 12 V, 4-pin socket:

1	GND
2	+12 V
3	unused
4	unused

Standard F-206s: 24 V, 3-pin socket

1	GND
2	+24 V
3	unused

- DB9 (unused)
- Connection for optional external VGA monitor, standard pinout
- RS-232 (DB-9m) COM1 for connection to host PC via null-modem cable, standard pinout.
- Connections for optional external keyboard, standard AT-type keyboard pinout (all keyboard connectors present should work properly, except the *rear-panel* connector on units *with a built-in keyboard*)
- Connection for TCP/IP interface Ethernet RJ 45 cable
- Optional: connections for 3-axis piezo stage and optical input A5 (on optional E-760 board, see also p. 112).

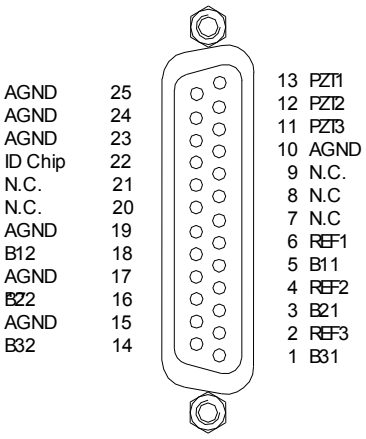


Fig. 72: J 4: 25-pin sub-D connector for NanoCube® stage

Pin	Function
Pin 1	GND
Pin 2	AUX0, TTL digital out, bit 0, max 20 mA
Pin 3	AUX1, TTL digital out, bit 1, max 20 mA
Pin 4	AUX2, TTL digital out, bit 2, max 20 mA
Pin 5	AUX3, TTL digital out, bit 3, max 20 mA
Pin 6	Analog out,16-bit-resolution analog output (0V to +5V)
Pin 7	Analog in, 14-bit-resolution analog input (-5V to +5V)
Pin 8	AGND

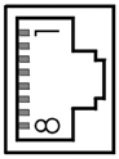


Fig. 73: Aux. signals

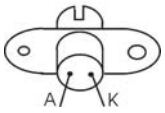


Fig. 74: Visible

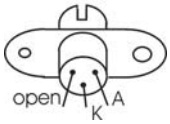


Fig. 75: Infrared

The E-760.3Si and E-760.3SV versions come with a photodiode already installed at J7. Wiring is as follows:

A=Anode (-), J7-2

K=Cathode (+), J7-1

Connector count starts with pin 1 closest to the bracket. Pins 3 and 4 are reserved and may not be used.

- Connections on optional 2-channel optical board (infrared F-206.iiU, or visible F-206.VVU)

  (For flexibility, the optical signal level is output electrically and a cable is provided to loop that output back to the analog input). See Optical (Analog) Signal Inputs, p. 109 for details.

- Connection for manual control pad

- Optional: GPIB (IEEE 488) interface connection

- Motor-control connectors for axes A and B (optional). Pinout is as follows:

Pins	Function
1	+ 12 V
9	
2	
10	PWM GND
3	MAGN (motor PWM, TTL level)
11	SIGN (motor direction)
4	output +5 V
12	negative limit (active high)
5	positive limit (active high)
13	REFS
6	Limit GND
14	Encoder: A(+) / ENCA
7	Encoder: A(-)
15	Encoder: B (+) / ENCB
8	Encoder: B (-)

- Connection for control of six F-206 motors. Pinout is as the same as on mechanics, see p. 121.

- Optional connections for up to two F-361 Optical Power Meters: industry standard RS-232 sub-D9(m), COM 3 and 4 to the controller OS. The upper connector is for OPM 1, the lower for OPM 2.

14 Dimensional Drawings

Decimal places separated by commas in drawings

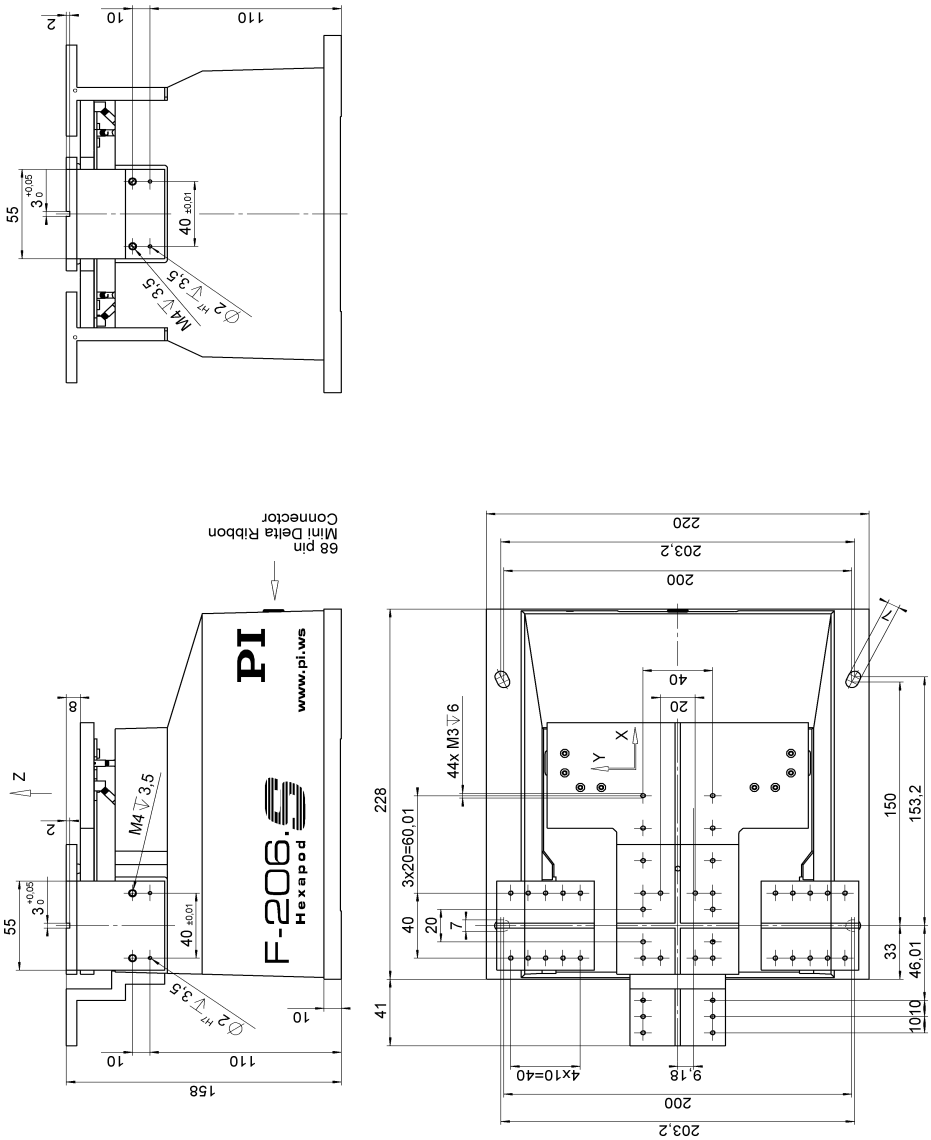


Fig. 76: F-206 Mechanics

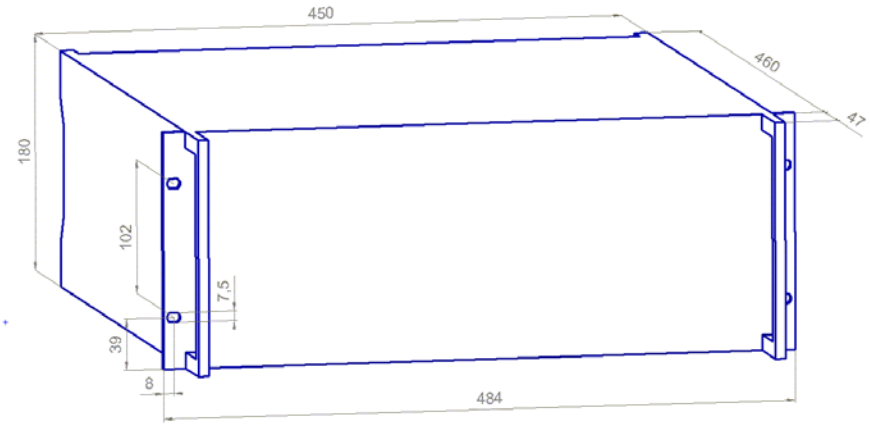


Fig. 77: F-206 controller dimensions