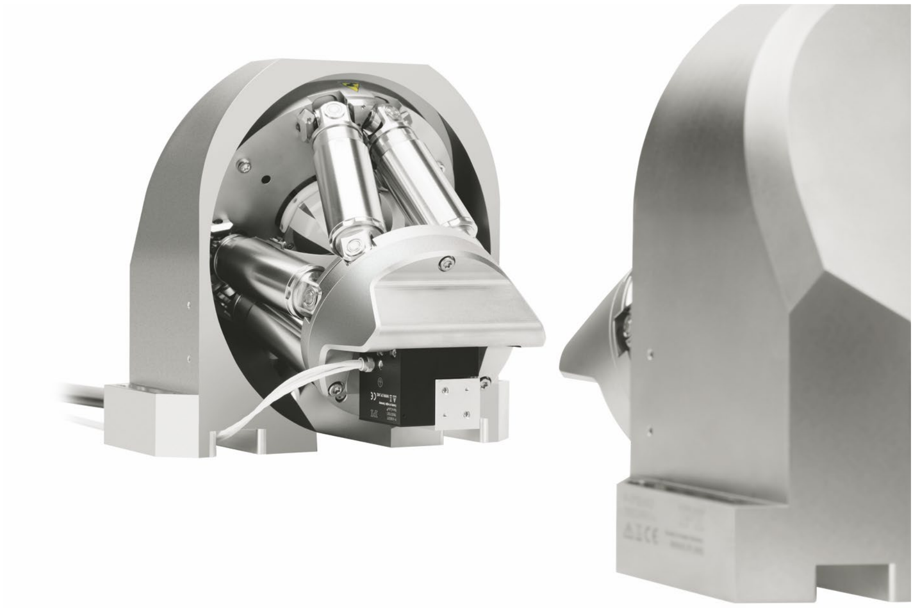
User Manual

E712T0016, valid for Fast Multi-Channel Photonics Alignment (FMPA)

BRo, ABo, 2024-02-29

Fast Multi-Channel Photonics Alignment (FMPA)

Routines for Fast Alignment of Optoelectronic Components



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Subject to change. This manual is superseded by any new release. The latest respective release is available for download on our website (http://www.pi.ws).

Contents

Customer Service

For inquiries and orders, contact your PI sales engineer or send us an email (mailto:service@pi.de).

- If you have any questions concerning your system, provide the following information:
  - Product and serial numbers of all products in the system
  - Firmware version of the controller (if applicable)
  - Version of the driver or the software (if applicable)
  - Operating system on the PC (if applicable)
- If possible: Take photographs or make videos of your system that can be sent to our customer service department if requested.

The latest versions of the user manuals are available for download (p. 9) on our website.

About this Document

Objective and Target Audience of this User Manual

Today's fast pace of innovation means every alignment application is different. So, there is no universal 'best' approach to aligning an arbitrary device. There is, however, a best practice: exploratory experimentation. Our F-712 alignment systems are very versatile and integrate a wealth of alignment functionality. You will find that some sequence of function calls will be optimal for your situation.

Consequently, this document approaches the fast alignment topic for F-712 systems from different perspectives:

- Overview of hardware and firmware provided by PI and steps of the procedure: “Fast Optical Alignment—Introduction”, p. 12
- Instructions for system preparation, optimization, and analysis: “Preparing and Analyzing the Alignment System”, p. 19
- Handling and examples of fast alignment routines: “Working with Fast Alignment Routines”, p. 30
- Application notes and best practice for concrete tasks: “Frequently Asked Questions”, p. 50
- Command reference: “Fast Alignment Commands”, p. 77
- Parameter reference: “E-712 only—Fast Alignment Parameter Groups”, p. 106

This document assumes that the reader has a fundamental understanding of photonics alignment as well as motion control concepts and applicable safety procedures.

As far as PIMikroMove is used for photonics alignment and system parametrization, it is assumed that the reader has extended knowledge of PIMikroMove.

Other Applicable Information

Service Parts

PI offers a series of service parts dedicated to FMPA systems. For inquiries and orders, contact your PI sales engineer or send us an email (mailto:service@pi.de).

Videos

“PI Fast Multi-Channel Photonics Alignment System” at https://youtu.be/b9zLiwuwB9s

“PI - Automated Multi-Channel Fiber Array Alignment” at https://youtu.be/HhwHfR_YC2I

Whitepapers

“Practical Examples of Parallel Alignment Automation” by Scott Jordan

https://www.physikinstrumente.com/en/?type=5600&downloadUid=8242&downloadFileUid=3304

Examples for Various Programming Languages

The fast alignment commands provided by E-712 and C-887 are supported by PI drivers for various programming languages, e.g., C++, LabVIEW, MATLAB or Python. Several programming examples are available. The examples can be found in the \Samples subfolders on the installation media of the PI Software Suite.

Documentation

For F-712.MA1 and F-712.MA2 alignment systems with P-616K001 NanoCube® and M-122K025 XYZ stacked linear stages, see also the following document:

Description	Documents
F-712.MA1, .MA2 Fast Alignment systems	F712T0002 user manual Provides safety precautions and information on installation and operation.

For F-712.HA1 and F-712.HA2 alignment systems with P-616K001 NanoCube® and H-811 hexapod, see also the following documents:

Description	Documents
F-712.HA1, .HA2 Fast Alignment systems	F712T0003 user manual Provides safety precautions and information on installation and operation.
H-811 hexapods	MS235E user manual Provides general information on H-811 hexapods.

For F-712.HU1 alignment systems with P-616K001 NanoCube® and H-811 hexapod, see also the following documents:

Description	Documents
F-712.HU1 Fast Alignment system	F712T0007 user manual Provides safety precautions and information on installation and operation.
H-811 hexapods	MS235E user manual Provides general information on H-811 hexapods.

For H-811.F2 hexapods, see also the following documents:

Description	Documents
H-811 hexapods	MS235E user manual Provides general information on H-811 hexapods.

For the F-712 power meters (available as optional accessory), see also the following documents:

Description	Documents
F-712.PM1 optical power meter	MP165 user manual Provides safety precautions and information on installation and operation.
F-712.IRPx high-resolution photometer	MP192 user manual Provides safety precautions and information on installation and operation of F-712.IRP1 single-channel benchtop devices and F-712.IRP2 two-channel modules for E-712 controller.

For the C-887.MC2 manual control unit (available as optional accessory), see also the following documents:

Description	Documents
C-887.MC2 manual control unit, USB connector, 3 m cable	C887T0036 user manual Provides product description and information on startup and operation with a hexapod system.

For general descriptions of the commands and functionality supported by the E-712 controller, see the following documents:

Description	Documents
E-711/E-712 modular digital multi-channel controller system	PZ195E user manual
E-712 commands	PZ233E commands manual

For general descriptions of the commands and functionality supported by the C-887 controller, see the following documents :

Description	Documents
C-887.5xx hexapod controller	MS244E user manual
Hexapod coordinate systems	C887T0007 user manual
Motion of the hexapod	C887T0021 technical note

For general descriptions of the PIMikroMove PC software, see the following documents:

Description	Documents
PIMikroMove	SM148E software manual

Downloading Documentation

If a manual is missing or problems occur with downloading, contact our customer service department (p. 6).

1. Open the website **www.pi.ws**.
2. Search the website for the product number (e.g., C-887).
3. In the search results, select the product to open the product detail page.
4. Select ***Downloads***.

   The manuals are shown under ***Documentation***. Software manuals are shown under ***General Software Documentation***.
5. For the desired manual, select ***ADD TO LIST*** and then ***REQUEST***.
6. Fill out the request form and select ***SEND REQUEST***.

   The download link will be sent to the email address entered in the form.

Safety Instructions

- Read the “Safety” chapter in the user manual of your alignment system.

Collisions can damage the equipment.

- Determine and establish limits for the permissible travel range of the axes in your application.
  - When defining area scan routines, set the scan range so that it does not exceed the permissible travel range of the axes.
  - With the hexapod controller C-887, set soft limits using the NLM and PLM commands and activate them with the SSL command. To keep the limit values when the controller is power-cycled or rebooted, save them to nonvolatile memory using the WPA command. Check the soft limits using the NLM?, PLM? and SSL? commands before you start fast alignment routines.
    For further details on the commands, see the C-887 user manual (MS244E).
  - With the E-712 controller, set soft limits for the axes using the parameters 0x70000000 and 0x70000001 and activate them for the fast alignment routines with parameter 0x20002F00. Note that a routine is only started if all axes involved are within the soft limits. If necessary, first use motion commands to move the axes to a target position within the soft limits.
- F-712.MA1 and .MA2 systems:
  - For the stacked M-122K025 XYZ linear stages (spindle-driven axes), use the safety shutdown functionality of the E-712 to abort motion if the position error exceeds a specified value. As the safety shutdown is **not** a contactless limitation, carefully check the distances and permissible loads in your application before you specify the position error for safety shutdown.
  - Do **not** use the safety shutdown functionality for the axes of the P-616K001 NanoCube® nanopositioner (piezo-driven axes).
  - For further details, see the E-712 user manual (PZ195E).
- F-712.HA1, .HA2 and .HU1 systems: High accelerations can occur during routine execution, e.g. due to high scan frequencies. For the hexapod axes, these high accelerations can cause large position deviations. The hexapod controller C-887 stops the hexapod motion not until the position deviation exceeds the specified maximum value (***Maximum Position Error (mm)*** parameter, ID 0x8).
  - Test the routine definitions with a setup where no collisions can occur.
  - If necessary, adjust the ***Maximum Position Error (mm)*** parameter to your application.

- F-712.HA1, .HA2 and .HU1 systems: Larger motions of the hexapod platform can result in deviations of its actual position and orientation from the specifications in the dimensional drawing. Possible causes and solutions:
  - If the deviation is caused by mechanical tolerances or installation errors, define a leveling coordinate system for permanent correction of the deviation in the hexapod controller C-887. For further details on coordinate systems, see the C887T0007 user manual.
  - Reduce the path velocity, if limit values in the hexapod controller C-887, e.g. acceleration limits, lead to path deviations during the motion.
- Avoid collisions during the reference move:
  - With the stacked M-122K025 XYZ linear stages of F-712.MA1 and .MA2 systems, first perform the reference move for the X and Y axes, then move X and Y to a safe position and perform the reference move for the Z axis. For further details, see “Perform a Reference Move” (p. 19).
  - F-712.HA1, .HA2, .HU1 systems: Note that the hexapod moves unpredictably during a reference move. A collision check or prevention does not take place. Soft limits that have been set for the motion platform of the hexapod with the NLM and PLM commands are ignored during the reference move.

Oscillations can damage the equipment.

- Before you start gradient search routines, identify the resonant frequencies of the overall system. Do not use a resonant frequency as frequency for the gradient search definition. For further details, see p. 25.
- Adjust the closed-loop performance of the piezo-driven axes before you start fast alignment routines. For further details, see p. 30.
- Use the piezo-driven axes (P-616K001 NanoCube® nanopositioner) whenever possible because they are friction-free. Use the spindle-driven axes (H-811 hexapod or the stacked M-122K025 XYZ linear stages) only for larger motions and for angular optimization (hexapod).

Fast Optical Alignment—Introduction

A Typical Alignment Setup

Sender and receiver of the alignment system are optical fibers at the end of which light source and detector are coupled. During the alignment of sender and receiver, the power of the optical signal is measured on the receiver side with a power meter. The power meter converts the optical power into an analog signal. Goal is to align sender and receiver to the optical path so that the maximum optical power is measured on the receiver side.

Systems with alignable sender and receiver are referred to as “double-sided system”, while systems with only one alignable side are referred to as “single-sided system”.

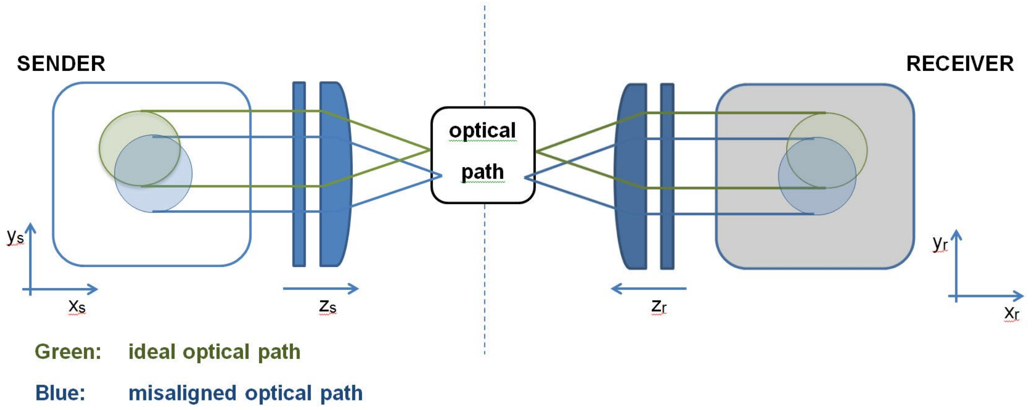


Figure 1 Example of a double-sided alignment system

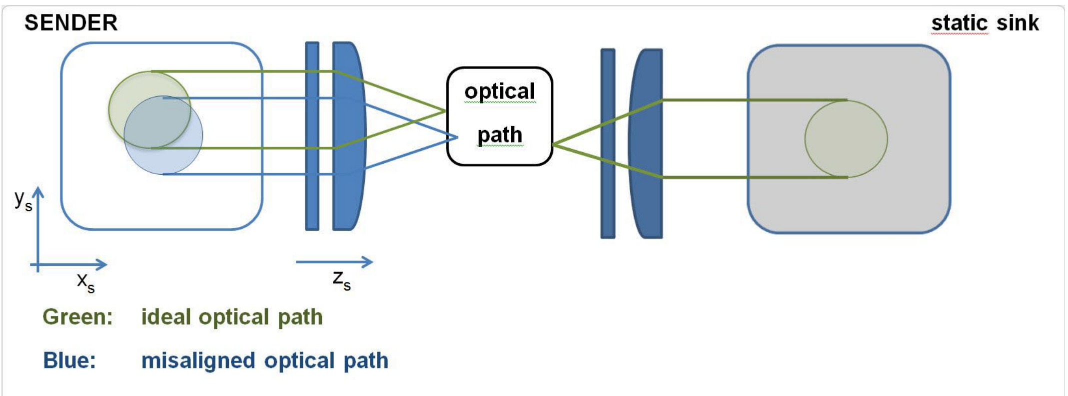


Figure 2 Example of a single-sided alignment system

Alignment Hardware Provided by PI

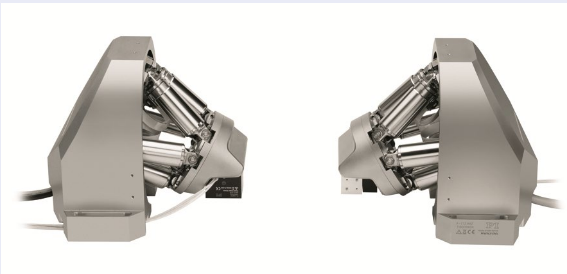
Systems intended for alignment tasks in the silicon photonics market must meet the following requirements:

- The positioners must be designed for frequent, high-dynamics motion over a limited travel range. This is the case, for example, with piezo-driven nanopositioners. The nanopositioner may sit on a micropositioning system that performs the larger-travel tasks.
- Each controller must provide at least one high-resolution analog input.

To meet these requirements, PI provides the F-712 family of Fast Multi-Channel Photonics Alignment (FMPA) systems. There are single-sided and double-sided systems available. Furthermore, the H-811.F2 hexapod is available for alignment tasks.

In this document, the short desginations “E-712” and “C-887” are used for the controllers that are included with F-712 FMPA systems.

Example of an F-712 alignment system:

F-712.HA2	Double-sided alignment system with two H-811 hexapods and two P-616K001 NanoCube® nanopositioners, E-712 digital controller with 4 analog inputs, two C-887 hexapod controllers with 2 BNC analog inputs each, firmware routines for ultrafast alignment tasks	 Figure 3 Hexapods with NanoCube® nanopositioners

Available Firmware Routines

The E-712 and C-887 controllers which are part of the F-712 systems provide routines for fast alignment of sender and receiver.

Goal of the routines is to align sender and receiver so that the maximum value of the signal is measured on the receiver side. The following types of fast alignment routines are provided by the E-712 and C-887 controllers:

- “Area scan”: Spiral or sinusoidal scan to characterize the signal and find the position of the signal maximum
- “Gradient search”: Circular scan travelling to the signal maximum using the gradient of the signal

C-887 controllers support gradient search routines only for selected hexapod types that are suitable for frequent, high-dynamics motion. In some cases, e.g. with H-811.F2, it may be necessary to explicitely activate the gradient search routines.

If you are not sure which routines your controller supports, send the HLP? command. A routine is supported if the corresponding command is contained in the controller's HLP? response. See p. 30 for a list of commands. If you still have any questions concerning your system, contact our customer service department (p. 6).

The position of the signal maximum found by an area scan routine can be used as the start position for a gradient search routine. Multiple fast alignment routines can run simultaneously.

The measured signal values are fed into the controller(s) as analog input signal. See "Analog Input Characteristics" (p. 16) for details.

The controllers can apply calculations to the analog input signal, e.g. to convert a logarithmic output of the power meter to (linear) power, see p. 50 for details.

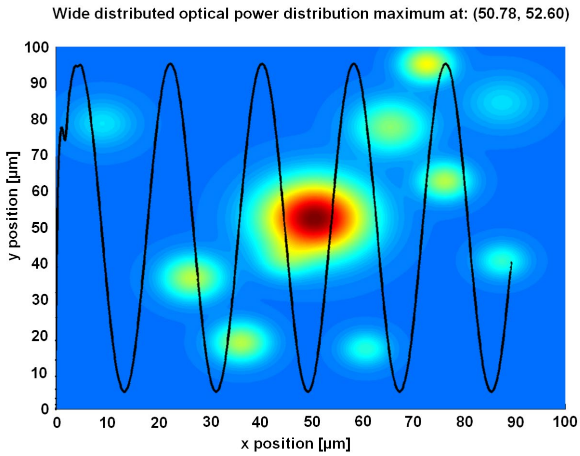


Figure 4 Example: Sinusoidal area scan for axes x, y; the scan axis follows the sine curve

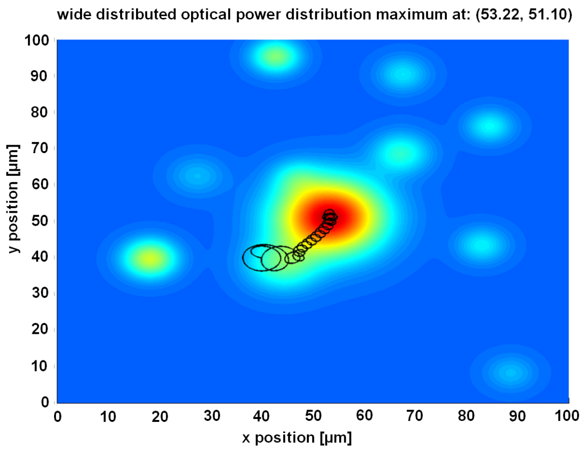


Figure 5 Example: Gradient search for axes x, y

Differences between E-712 and C-887 Controllers

Firmware Differences

The implementation of the fast alignment routines in principle is identical with E-712 and C-887 controllers, but there are some differences in the detail:

- Routine names with C-887 are strings, up to 100 routines can be defined. With E-712, the number of routines is limited by the number of axes, and the routine names are 1, 2, 3, …, n (n = number of axes).
- With C-887, only gradient search routines can be paused and resumed with the FRP command.

- E-712 and C-887 use different axis units:
  - E-712: µm
  - C-887: mm, degree

  Therefore, the numerical values to be used for the routine definition may differ by a factor of 1000. This is the case, for example, with the speed factor used for gradient search. Note that the axis unit can be queried with the PUN? command.
- C-887 only: When starting routines with FRS, the following applies:
  - If the routines to be started together with FRS are of different types, then only one area scan routine may be among these routines.
  - When starting an area scan routine, the controller checks if the data recorder provides enough memory. If the available number of points is not sufficient, the routine does not start and error 67 occurs.
- With C-887, the maximum routine duration is limited to approximately 90 s. This limitation also applies to gradient search routines that are to continuously track the signal maximum.
- Parameter 0x20001C00 is the only fast alignment parameter that is supported by E-712 as well as by C-887. The parameter selects the axis signal type that is recorded and used for calculations, but its implementation differs at follows:
  - E-712: The selection only affects gradient search routines.
  - C-887: The selection affects all fast alignment routines.
- With E-712, an input signal channel can be used to stop a fast alignment routine. The stop function is triggered if the input exits a permissible range. The stop function is configured via fast alignment parameters (p. 108). Note that even if the routine is not running, the specified input signal channel stops any motion of the axes included in the definition of the routine.
- Soft limits:
  - C-887: Soft limits can be set and activated via commands.
  - E-712: Soft limits can be set and activated via parameters. The soft limits are specifically activated for fast alignment routines.
- Routine definitions and settings for analog inputs can be permanently stored on the controller so that they are retained when the controller is switched off or restarted. The procedure differs for E-712 and C-887. For details, see the FAQ section “Q: Where are my defined routines stored?” (p. 55).
- With C-887, customized coordinate systems can be used (not possible with E-712). Note that a routine does not contain information on the coordinate system that was active during routine definition.
- How to query the available options of the fast alignment commands:
  - C-887: MAN? command for FDR and SIC
  - E-712: HPV? command for the parameters of the Fast Alignment parameter groups

Further information on differences between E-712 and C-887 can be found in the command descriptions (p. 78).

Analog Input Characteristics

Usable analog input channels:

	E-712	**C-887**
Connection	**In 1** to **In 4** sockets of the E-711.IA4 analog interface module	**Analog In 5** and **Analog In 6** sockets
Channel identifiers	Four channels. For possible identifiers, see “Fast Alignment Input Channels Group” (p. 107).	5 and 6
Input voltage range	|AIN+ - AIN-| $\leq$ 10 V in the range of -10 V to +10 V	-5 V to 5 V
Resolution ADC	18 bit	16 bit
Bandwidth	25 kHz	5 kHz
Input impedance	150 kΩ	15 kΩ
Connector	LEMO EPG.00.302.NLN	BNC

Available PC Software

PI is constantly improving the PC software. Always install the latest version of the PC software. Use the PI Update Finder which is included in the PI Software Suite.

PIMikroMove

The PIMikroMove PC software provides the ***Fast Alignment*** tab card as a graphic user interface for the fast alignment routines of E-712 and C-887. Routines can be defined, and results can be displayed graphically. The ***Fast Alignment*** tab card also allows to import and export routine definitions to/from the PC.

- In the main window of PIMikroMove, use the menu sequences ***E-712 > Show Fast Alignment Window*** and ***C-887 > Show Fast Alignment Window*** to open the ***Fast Alignment*** tab cards for the axes that are connected to E-712 and C-887.

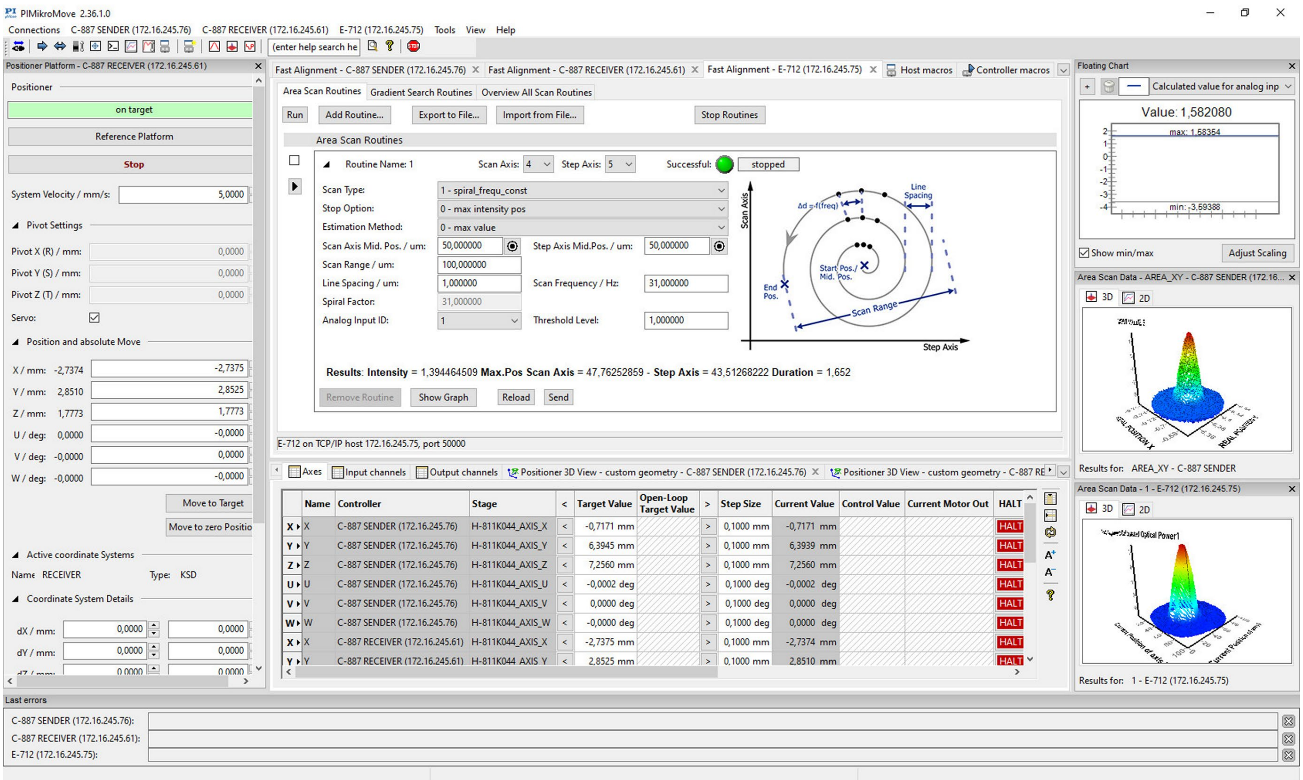


Figure 6 PIMikroMove main window with Fast Alignment tab cards and graphical displays

The ***Log window...*** item is on the ***E-712*** and ***C-887*** menus and opens a controller-specific ***Log...*** window. In this window, you can monitor the commands which are sent to the controller when you use the controls of PIMikroMove. This is a good way to see what commands are required for certain actions and to learn the command syntax.

The analog input signal can be monitored in a separate window. Open the monitor window using the ***View > New floating chart*** menu item in the main window of PIMikroMove, and select the corresponding analog input with calculation.

For further details, see the FAQ section "Q: How can I prepare and use PIMikroMove for fast alignment?" on p. 67.

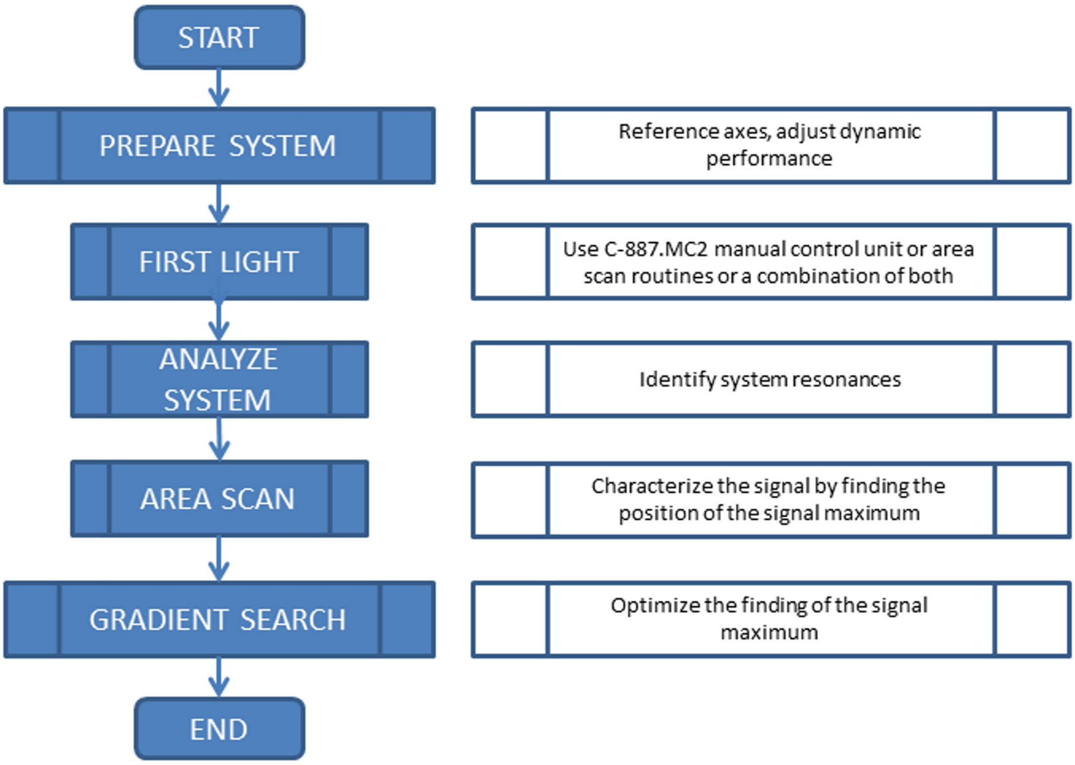
PIMikroMove is required to optimize and analyze the fast alignment system, i.e., to adjust the dynamic performance of the piezo-driven axes, and to identify the resonant frequency of the overall system. For further details, see p. 19.

Drivers and Examples for Various Programming Languages

The fast alignment commands provided by E-712 and C-887 are supported by PI drivers for various programming languages, e.g., C++, LabVIEW, MATLAB or Python. Several programming examples are available. The examples can be found in the \Samples subfolders on the installation media of the PI Software Suite.

Typical Steps of a Fast Alignment Procedure

Typically, fast alignment with an F-712 system from PI includes the following steps:



Preparing and Analyzing the Alignment System

When you have installed your alignment system according to its user manual, the following steps are necessary to prepare the system for fast alignment tasks:

- Perform reference move
- Adjust closed-loop performance of piezo-driven axes

When the first-light search (p. 56 et seq.) has finished successfully:

- Identify resonant frequencies of the overall system

Perform a Reference Move

A reference move is required for axes with incremental position sensors before absolute target positions can be commanded and reached.

- Avoid collisions during the reference move; for details, see “Safety Instructions” on p. 10.

With the spindle-driven axes (M-122K025 linear stages or H-811 hexapod), use the FRF command to perform the reference move. If you work with PIMikroMove, click ***Ref. switch*** in the ***Start up axes*** step of the ***Start Up Controller*** window.

With the piezo-driven axes (P-616K001), do **not** use the FRF command to perform the reference move. The reference move with P-616K001 has to be performed by an **AutoZero** procedure using the ATZ command. If you work with PIMikroMove, click ***Auto Zero*** in the ***Start up axes*** step of the ***Start Up Controller*** window. See the E-712 commands manual (PZ233E) for ATZ details. The settings used for the AutoZero procedure (AutoZero Low Voltage and AutoZero High Voltage) are set by PI before delivery. You do not have to change these settings as long as you do not change the orientation of the P-616K001 axes in your system.

Adjust the Closed-Loop Performance of the Piezo-Driven Axes

Because the alignment routines include fast circular motion of the piezo-driven axes, the following is important for optimal performance:

- The frequency response characteristics of the axes used in the same routine must be identical.
- System resonances must be identified to avoid oscillations.

The dynamic performance of the piezo-driven axes has therefore to be adjusted before they are used in fast alignment routines.

A new adjustment of the closed-loop performance is **absolutely necessary whenever you change the load** on the P-616K001 NanoCube® nanopositioner, e.g., by attaching, removing or replacing a fiber holder.

If the mechanical assembly, load and orientation of your system and the ambient conditions (temperature) remain unchanged, you do not have to repeat the adjustment after every switch-on or reboot. Once you have found the optimal settings, you should keep them by saving them to the nonvolatile memory of the E-712.

The dynamic performance of the piezo-driven axes has to be adjusted per stack. This means that in a double-sided system, the piezo-driven axes of the sender side (probably axis 1 to 3) have to be adjusted together in one adjustment procedure, and the piezo-driven axes of the receiver side (probably axis 4 to 6) have to be adjusted together in a second adjustment procedure. Do **not** mix the piezo-driven axes of sender and receiver side in one common adjustment procedure because there is no mechanical relation between them.

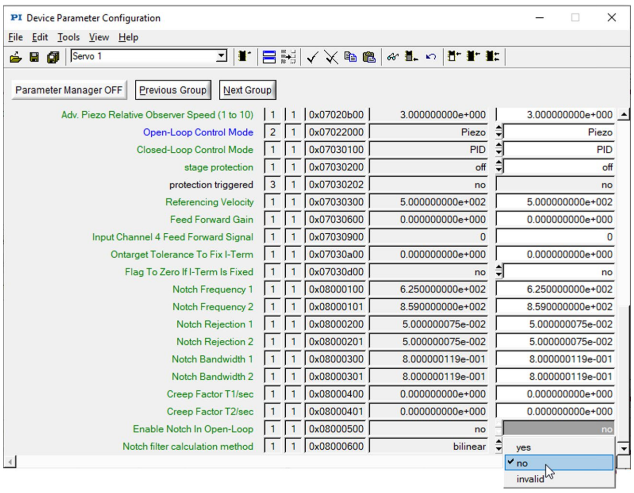
Adjust the dynamic performance of the **three piezo-driven axes that belong to the same stack** (sender or receiver side) as described below using PIMikroMove. With a double-sided system: When finished, repeat the adjustment for the three piezo-driven axes of the second stack.

Note the following when working with PIMikroMove:

- Before you change parameter values of the E-712, create a backup file. See "Create Backup File for Controller Parameters" in the E-712 user manual for more information.
- Enter the password “advanced” when prompted to change to command level 1.
- For general information, see the FAQ section “Q: How can I prepare and use PIMikroMove for fast alignment?” on p. 67.
- For further application notes regarding the usage of PIMikroMove, see p. 75.

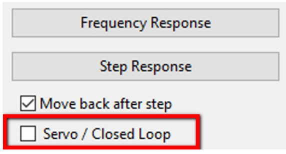
Adjust the dynamic performance as follows:

1. Make sure that the notch filters of the three piezo-driven axes are **not** enabled in open-loop operation.
   To do this, check the value of the ***Enable Notch In Open Loop*** parameter, ID 0x08000500, for all piezo-driven axes (0 = disable notch filter in open-loop operation; 1 = enable notch filter in open-loop operation). You can do this in the *Servo* parameter groups of the ***Device Parameter Configuration*** window in PIMikroMove. Open the ***Device Parameter Configuration*** window via the ***E-712… > Parameter Configuration …*** menu item in the main window of PIMikroMove.



2. In the ***Piezo Dynamic Tuner*** window, identify the resonant frequencies for each of the three piezo-driven axes as follows:
   Important: Use exactly the same settings (panels ***Parameter Settings***, ***Step***, ***Recording***) for all axes, except for the ***Offset*** value in the ***Step*** panel!

   a. Make sure that the axis is in open-loop operation, i.e. that the ***Servo / Closed Loop*** box is **not** checked.

   b. In the ***Parameter Settings*** panel, make the following settings:

   – *Servo-Loop P-Term:* 0.05
   – *Notch Frequency 1, Notch Frequency 2:* 1000
   – *Notch Rejection 1, Notch Rejection 2:* 0.05
   – *Notch Bandwidth 1, Notch Bandwidth 2:* 0.8

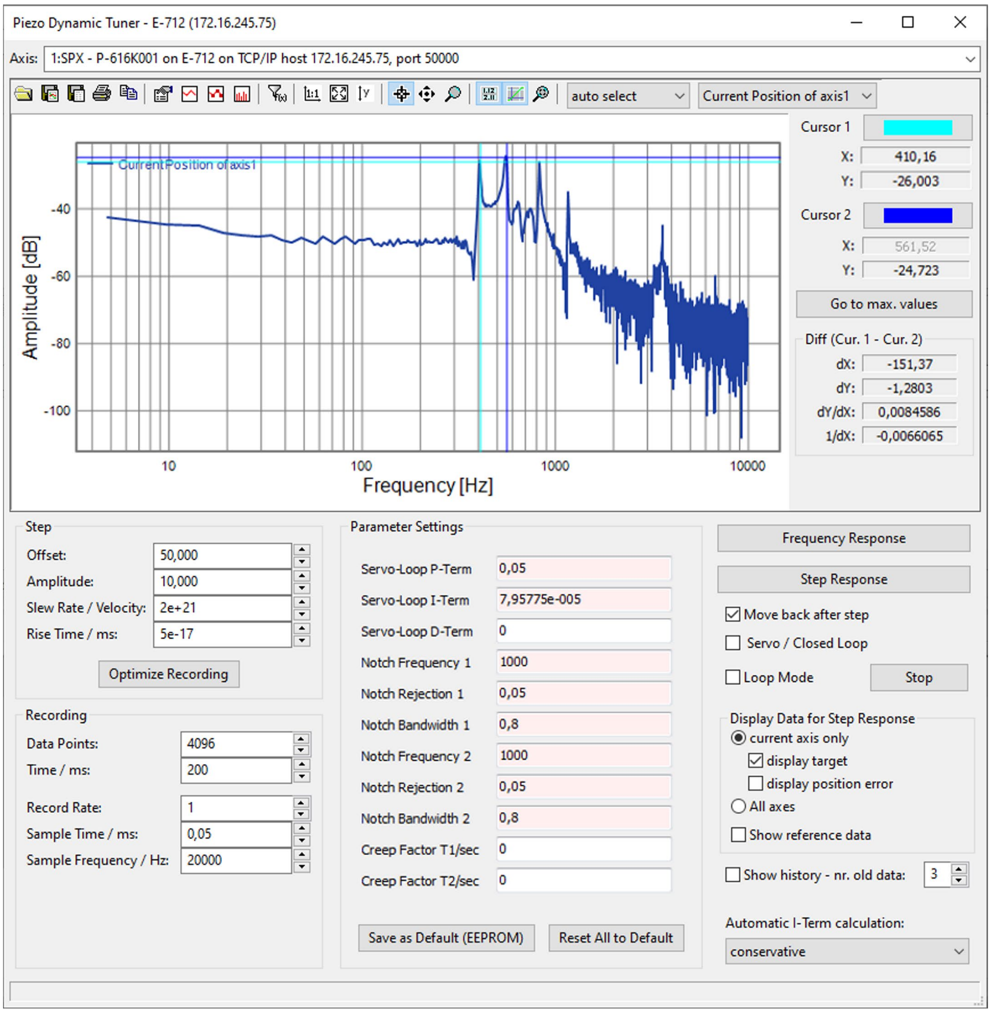
   c. In the ***Step*** panel, make the following settings:

   – *Offset:* Half the value of the axis travel range, with positive or negative sign (50 or -50). Important: The sign of the offset value depends on the sign of the corresponding driving factor in the output matrix: If the driving factor of the axis has a negative sign in the output matrix, the sign of the offset value must also be negative!
     Note: You can check the matrix coefficients (***Driving Factor of Piezo* n**) in the ***Axis Matrices*** window which is accessible from the ***Device Parameter Configuration*** window via the ***View -> Axis Matrices*** menu item.
   – *Amplitude:* 10 % of the axis travel range (10)
   – *Slew Rate / Velocity*: $10e^{20}$ (infinitely large value)

   d. In the ***Recording*** panel, set the values for the number of data points to be read (*Data Points*) and the record table rate (*Record Rate*) to suitable values.

   e. Perform a frequency response measurement by clicking the ***Frequency Response*** button. Do this twice because the first response will not show reliable values.
   Note: In the ***Output channels*** tab card of the PIMikroMove main window, check the output voltage value for the channel that is assigned to the axis. If the correct offset value was used, the voltage value is about 50 V, with a positive sign.

   f. Make a note of the measured resonant frequency.
   Identify the resonance peak(s) in the graphics pane. To do so, place a cursor on the peak and read out the cursor value which is displayed on the right hand side of the graph. If there is more than one resonance peak, start identifying at the lowest frequency.



3. Adjust the notch filter settings for the three piezo-driven axes in the ***Piezo Dynamic Tuner*** window:

    a. Compare the measured resonant frequencies and identify the axis with the lowest frequency ("F_{res_1}") and the axis with the next higher frequency ("F_{res_2}").

    b. For both axes, set *Notch Frequency 1* to F_{res_1} and *Notch Frequency 2* to F_{res_2}.

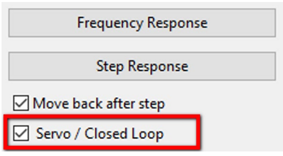
    c. For the third axis, set *Notch Frequency 1* to F_{res_1} and *Notch Frequency 2* to the resonant frequency that was measured for this axis.

    Note: If you have identified two resonant frequencies per axis, set *Notch Frequency 1* for all axes to F_{res_1}. (i.e. to the smallest measured frequency across all axes). Set the *Notch Frequency 2* value of each axis to the next higher resonant frequency that was measured for this axis.

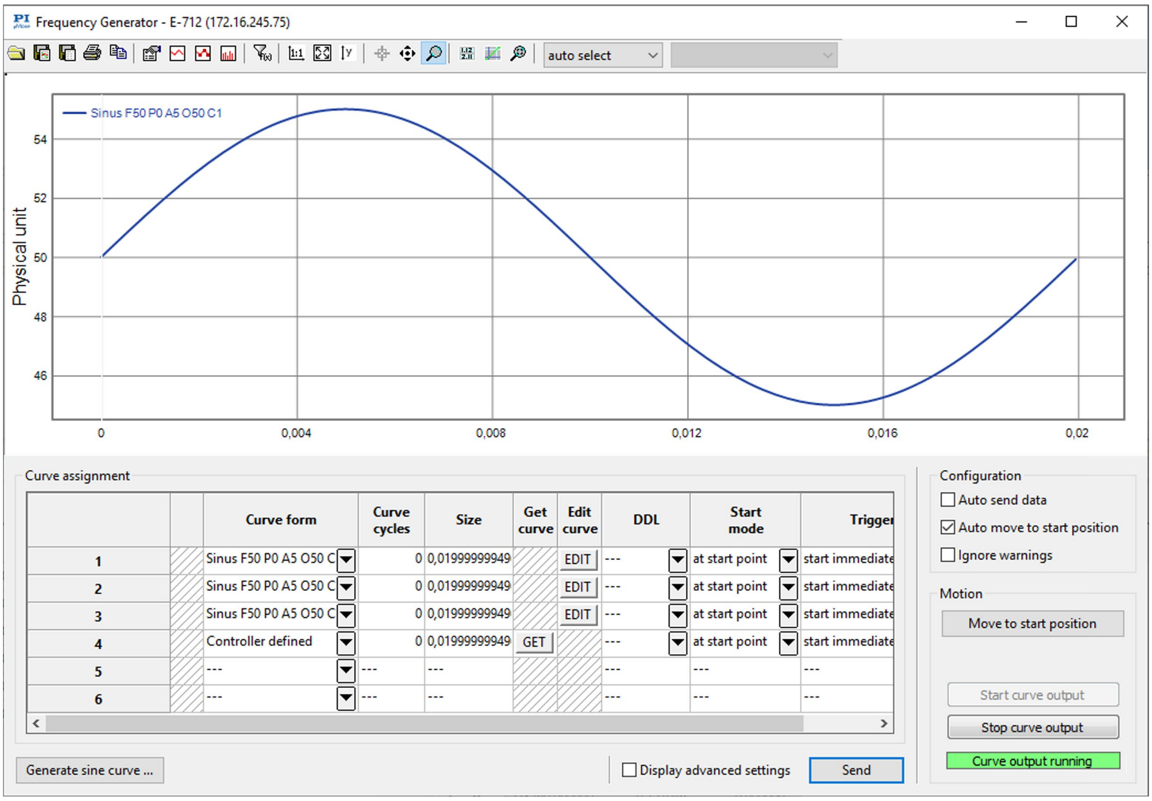
4. Adjust the servo-loop parameters for the three piezo-driven axes:

    a. In the ***Piezo Dynamic Tuner*** window, set the values for *Servo-Loop P-Term*, *Servo-Loop I-Term* and *Servo-Loop D-Term* **for all three axes** to the values of the axis with the lowest resonant frequency.

b. Make sure that all three axes are in closed-loop operation, i.e. that the *Servo / Closed Loop* box is checked in the ***Piezo Dynamic Tuner*** window.



c. Use the ***PI Frequency Generator Tool*** of PIMikroMove to move all three axes simultaneously by a sine curve with the following settings:
Frequency = 50 Hz*, Offset = 50 µm, Amplitude = 5 µm
With a P-611 NanoCube® nanopositioner which may be part of some customized fast alignment systems instead of the P-616K001, the frequency has to be about 20 Hz*.
*The frequency must not exceed ¼ of the lowest resonant frequency F_{res_1}.



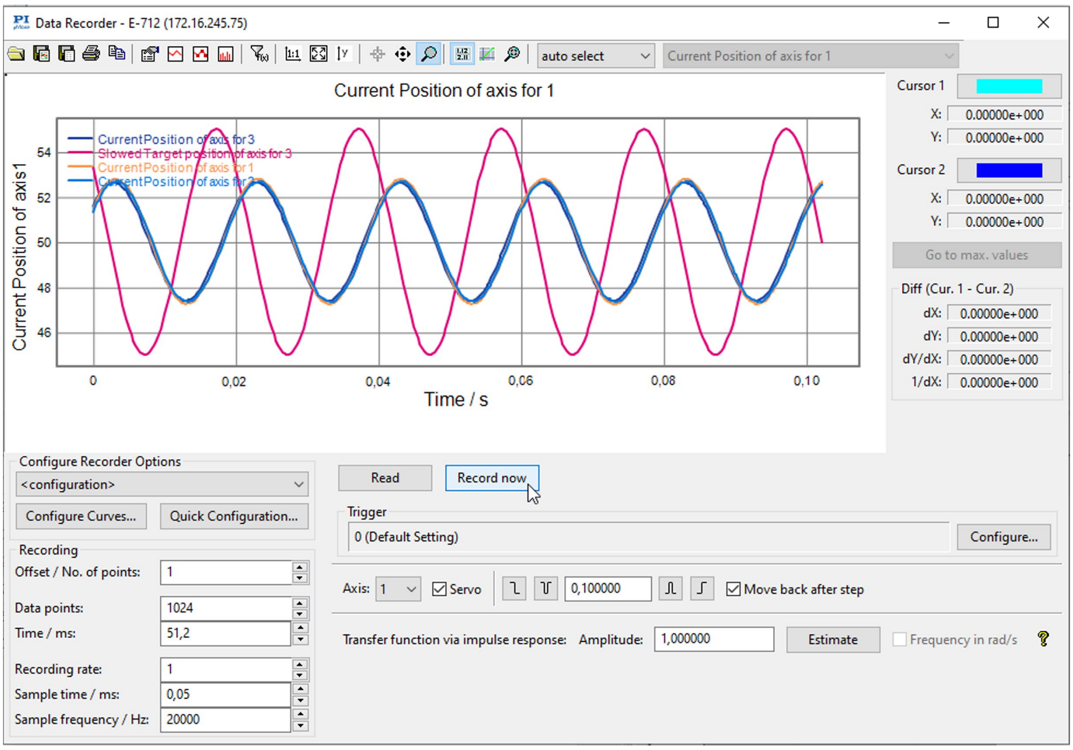
d. While all three axes are moving, change their *Servo-Loop P-Term* values in the ***Piezo Dynamic Tuner*** window (always change all three P-terms to the same value) and observe the behavior of the axes in the ***Data Recorder*** window of PIMikroMove. Details:

Open the ***Data Recorder*** window via the ***E-712… > Show data recorder …*** menu item in the main window of PIMikroMove. Click the ***Configure Curves…*** button in the ***Data Recorder*** window to open a separate dialog where you can configure the data recorder settings. For a basic overview of how to proceed, see p. 25. But for the P-term adjustment, make sure that the slowed target position of one axis and the current positions of all three axes are recorded and displayed.

Every time you have entered new P-term values, click ***Record now*** in the ***Data Recorder*** window to start a new recording.

Use the cursors in the graphics pane of the ***Data Recorder*** window to evaluate the effect of the P-term adjustment on the amplitude and phase shift of the current positions. The P-term adjustment is finished when the amplitudes of the current positions are 50 to 60% of the target amplitude and the phase shift between the current positions does not exceed ±10° (which is about ±0.56 ms with a 50 Hz signal).

Important: If the amplitudes of the current positions are greater than 50 to 60% of the target amplitude, they have to be damped by the P-term adjustment. Decreasing the amplitudes of the current positions ensures a sufficient output voltage swing during the fast alignment scan routines.



The ***Data Recorder*** window in this example shows that the three axes of a P-616K001 NanoCube® nanopositioner are moving (sine with 50 Hz); the current positions of the axes and one target position are recorded. No further adjustment of the P-terms is necessary.

e. Recommended when you have found the optimal settings: Save the settings in the ***Parameter Settings*** panel of the ***Piezo Dynamic Tuner*** window to the nonvolatile memory of the E-712 with the ***Save as Default (EEPROM)*** button. This way, the optimized settings are still available after the next switch-on or reboot.

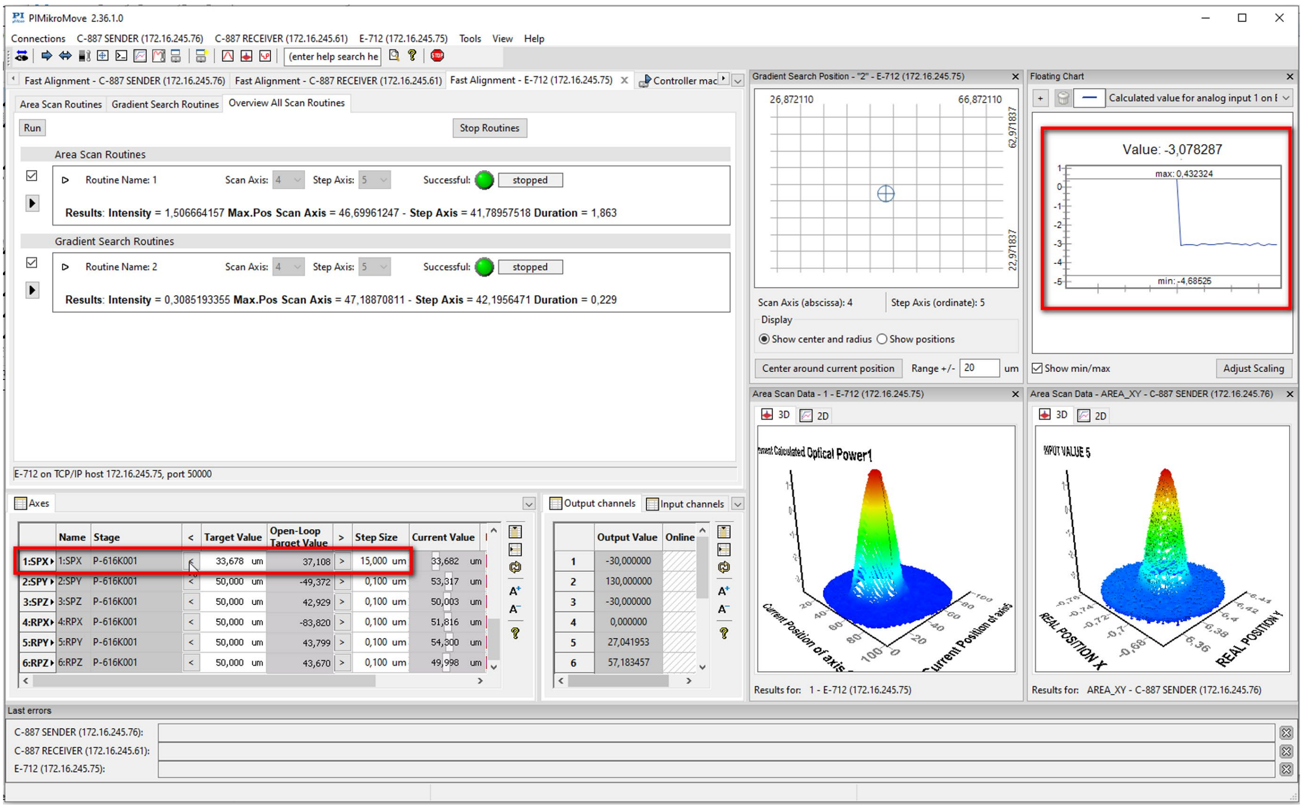
Identify the Resonant Frequencies of the System

When defining fast alignment routines, frequencies must be specified. To avoid oscillations, the system's resonant frequencies, frequencies near the resonances, and harmonics of the resonant frequencies should not be used for the definition of fast alignment routines. The resonant frequencies of the system result from the whole setup including passive parts like screws, brackets, or fiber holders.

You can identify the resonant frequencies of the overall system by a frequency analysis of the measured signal. Therefore, the first-light search has to be finished successfully before a frequency analysis can be performed.

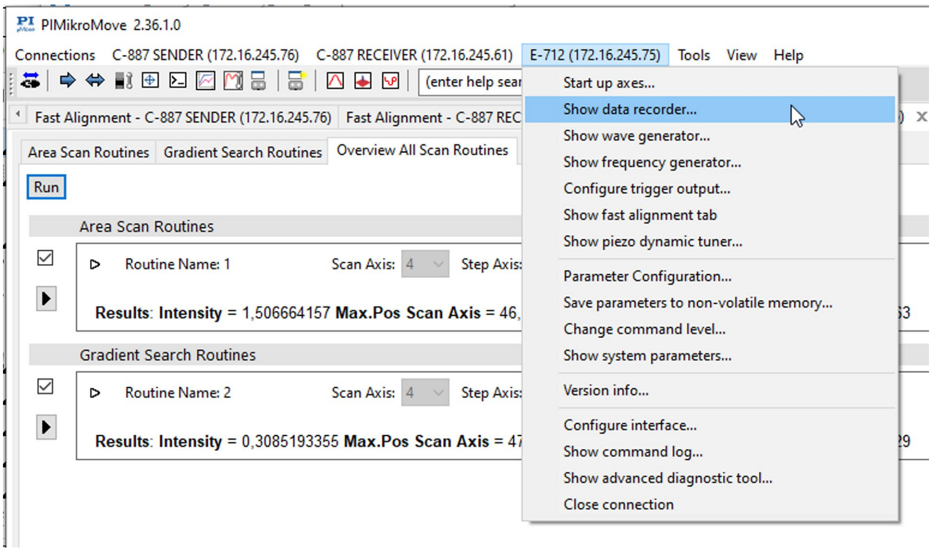
Identify the resonant frequencies **per stack** (sender or receiver side). With a double-sided system, therefore repeat the measurement for the second stack when finished for the first stack.

1. In order to see the greatest possible effect in the measured signal with very small mechanical oscillations (position changes), a piezo-driven axis must first be positioned so that the signal is reduced significantly (to about half). In the following example, axis 1 is moved by 15 µm in negative direction.
   - Use the arrow buttons and the ***Step size*** column in der main window of PIMikroMove to move the piezo-driven axis.
   - Check the signal in the floating chart.

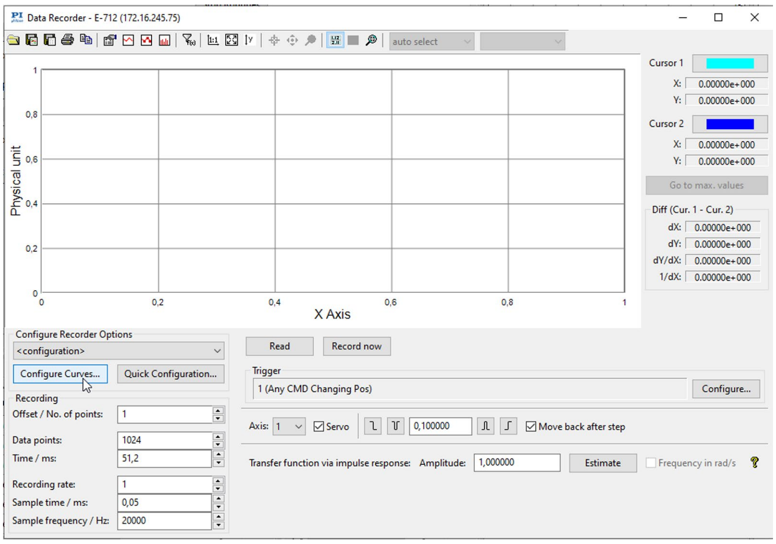


2. Configure the data recorder to record the signal:

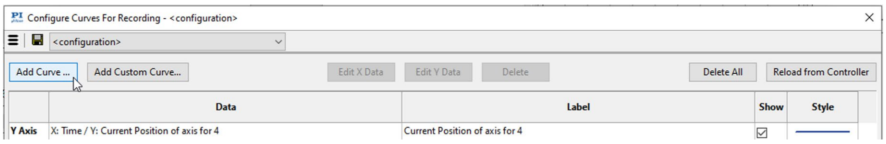
a. In the main window of PIMikroMove, open the ***Data Recorder*** window for E-712 via the ***E-712… > Show data recorder …*** menu item.



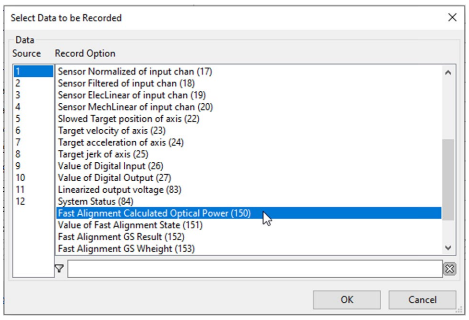
b. In the ***Data Recorder*** window, click the ***Configure Curves…*** button to open the ***Configure Curves For Recording*** window.



c. In the ***Configure Curves For Recording*** window, click the ***Add Curve …*** button to open the ***Select Data to be Recorded*** window.

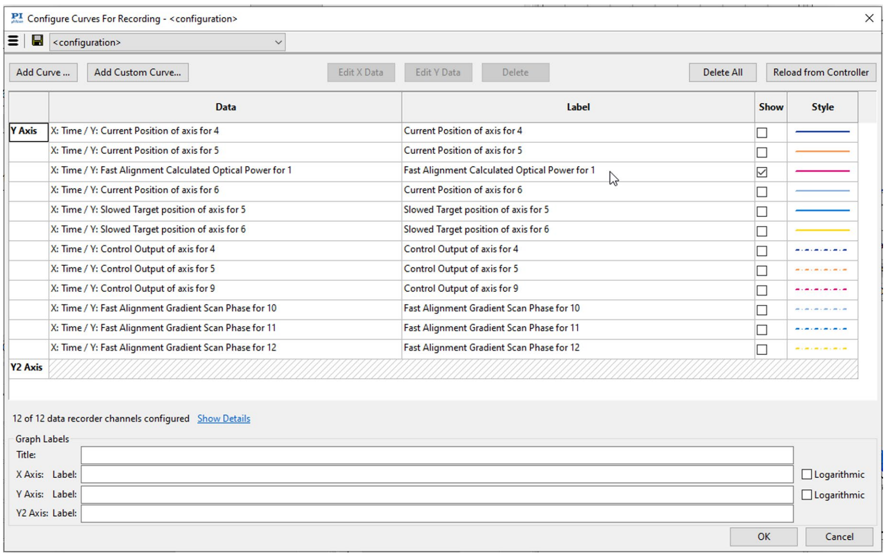


d. In the ***Select Data to be Recorded*** window, select the ID of the fast alignment input channel for the ***Source*** and *Fast Alignment Calculated Optical Power (150)* for the ***Record Option***, and click ***OK***. In this example, the source ID is 1 since the analog input signal is connected to the first analog input of the E-712.



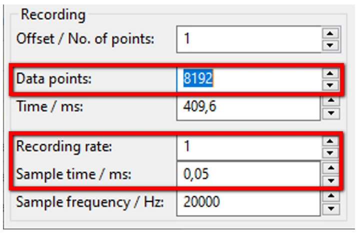
e. In the ***Add Curve*** dialog, click ***Add X/Y*** or ***Add X/Y2*** to add the new curve definition to the table in the ***Configure Curves For Recording*** window (and hence assign to the first or second Y-axis of the graphics pane in the ***Data Recorder*** window).

f. In the ***Configure Curves For Recording*** window, make sure that the newly defined curve is selected for the display in the graphics pane (set check mark in the ***Show*** column). If you want to change the style of the curve, click in the ***Style*** column to get access to the configuration options.

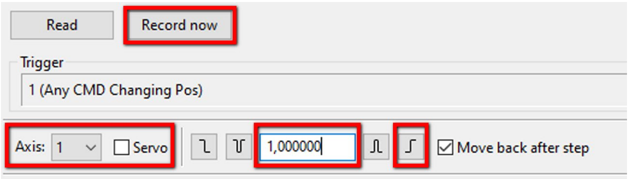


g. Click ***OK*** to accept the settings and close the ***Configure Curves For Recording*** window.

h. If necessary, adapt the number of data points to be read from the controller (***Data points:***) and the duration of the recording (***Sample time / ms:***) in the ***Recording*** panel of the ***Data Recorder*** window.



3. Start the recording in the ***Data Recorder*** window:



a. Select the axis for which the recording is to be performed. Make sure to select the piezo-driven axis that you have moved in step 1 to reduce the signal.

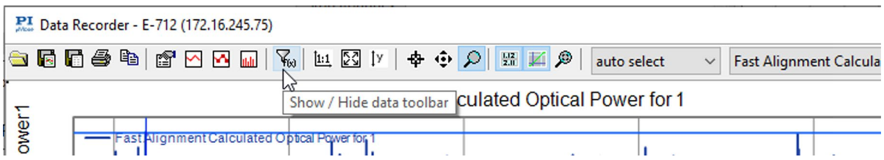
b. Switch off the servo mode for the axis by removing the check mark in the ***Servo*** box.

c. Start the recording. Options:

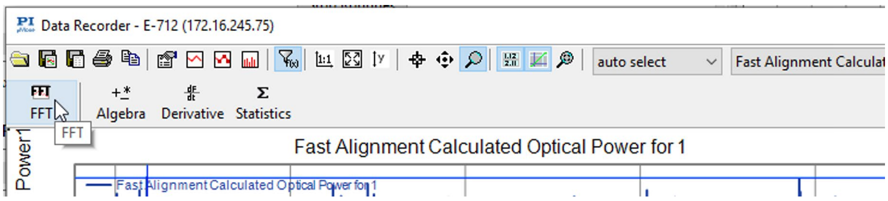
– To start recording without axis motion, i.e., without additional excitation of the system, click the ***Record now*** button.
– To excite the system by a step of the axis, click the button to let the axis perform a step of the specified size in positive direction.

4. Evaluate the recording:

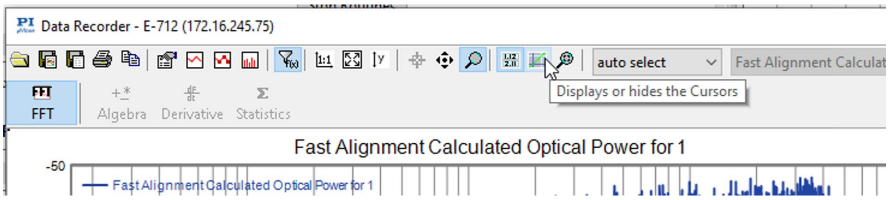
a. Show the data toolbar to get access to the ***FFT*** button.

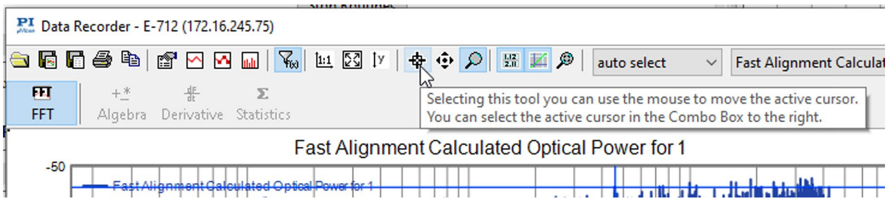


b. Perform an FFT (Fast Fourier transform) of the recorded data by clicking the ***FFT*** button.



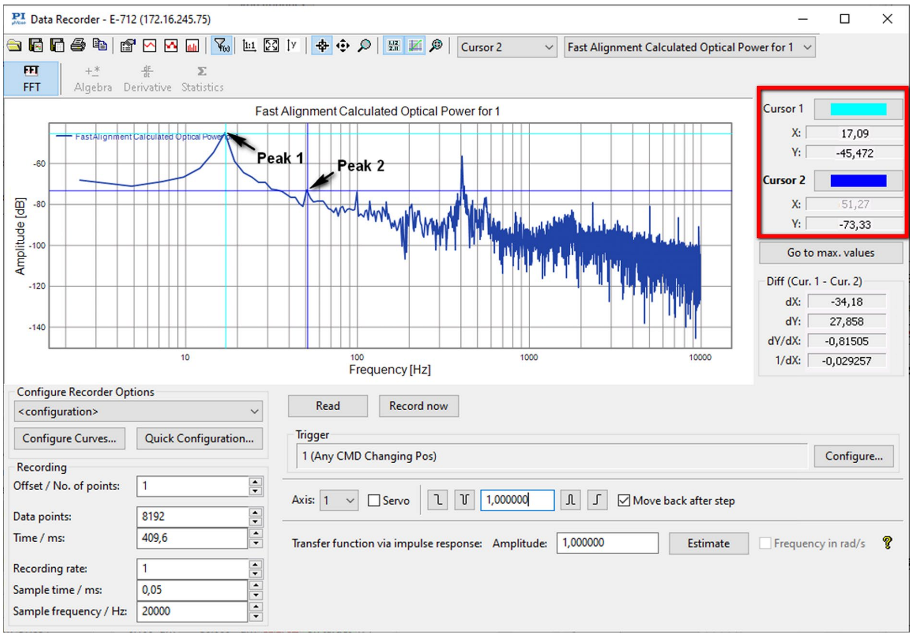
c. Show cursors and enable cursor motion using the buttons shown in the figures below.

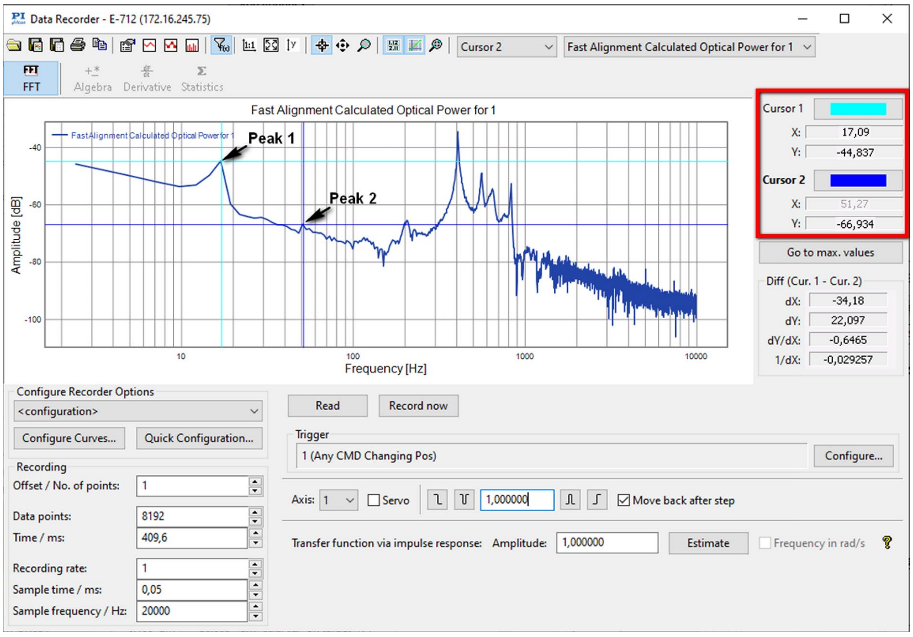




d. Identify the resonance peak(s) in the FFT display. To do so, place a cursor on the peak and read out the cursor value which is displayed on the right hand side of the graph. If there is more than one resonance peak, peak 1 is always the one with the lowest frequency.
The resonant frequencies, frequencies near the resonances, and harmonics of the resonant frequencies should not be used for the definition of fast alignment routines.

In this example, a first recording was started with the ***Record now*** button. The FFT display with the resonance peaks is shown below in the first figure. Then a second recording was started as step response measurement. See the second figure below for the FFT display. Both FFT displays show resonance peaks at about 17 Hz and 51 Hz.





Working with Fast Alignment Routines

The following types of fast alignment routines are provided by the E-712 and C-887 controllers:

- “Area scan”: Spiral or sinusoidal scan to characterize the signal and find the position of the signal maximum
- “Gradient search”: Circular scan travelling to the signal maximum using the gradient of the signal

The end position of an area scan routine can be used as the start position for a gradient search routine to fully optimize the alignment.

Defining Routines

Use the FDR command (p. 78) to define area scan routines and the FDG command (p. 87) to define gradient search routines. The tables in “Examples for Area Scan Routines” (p. 33) and “Examples for Gradient Search Routines” (p. 43) list the arguments of the commands with their value range, default and example values.

Basic rules for routine definition with fast alignment systems:

- The axes to be used together in one routine must be connected to the same controller.
- The axes to be used together in one routine must belong to the same stack (i.e. to the same side of the system—sender or receiver).
- The axes to be used together in one routine must have identical dynamic behaviour. Therefore, it is not recommended to use piezo-driven axes and spindle-driven axes together in one routine.

- For the two axes used in one routine, the distribution of the signal should differ only slightly. For axes with great differences in the signal distribution, separate routines with different configurations should be defined.
- Avoid collisions and oscillations; for details, see “Safety Instructions” on p. 10.

In principle, routine definitions are stored in the volatile memory of the controller. For information on how to store definitions permanently, see the FAQ section “Where are my defined routines stored?” (p. 55).

For information on how to change an already defined routine, see the FAQ section “Q: How can I change a routine definition?” (p. 54).

For details on axis orientation and assignment, see the user manual of your F-712 system.

For more information on the calculation options for the analog signal used in the routines, see the FAQ section “How can I convert the logarithmic output of my F-712 power meter to (linear) power in an F-712 system?” (p. 50), and the description of the SIC command (p. 102).

You can use the ***Fast Alignment*** tab card(s) of PIMikroMove (p. 67) to define the routines if you do not want to type commands in a terminal. In a log window, you can monitor the commands which are sent to the controller when you use the controls of PIMikroMove.

Excursus: Properties of the Mechanics

For a better understanding of the routine definition examples in this manual, the most important properties of the mechanics are listed here. For further details, see the user manual of your alignment system.

Figure 7 P-616K001 NanoCube® nanopositioner

P-616K001 NanoCube® nanopositioner		
Active axes	X, Y, Z	
Axis unit	µm	
Closed-loop travel in X, Y, Z	100	µm
Min. incremental motion, open-loop	0.3	nm
Min. incremental motion, closed-loop	2.5	nm
Resonant frequency with 38 g load X / Y / Z	380	Hz
Resonant frequency with 100 g load X / Y / Z	250	Hz
Controller type	E-712	

Figure 8 F-712.MA2 double-sided fiber alignment system

M-122K025 stacked linear axes in F-712.MA1 and F-712.MA2 systems		
Active axes	X, Y, Z	
Axis unit	mm	
Travel range in X, Y, Z	25, 25, 25	mm
Minimum incremental motion	3	µm
Max. velocity	20	mm/s
Controller type	E-712	

Figure 9 F-712.HA2 double-sided fiber alignment system

H-811 hexapod in F-712.HA1 and F-712.HA2 systems		
Active axes	X, Y, Z, θX, θY, θZ	
Axis unit	mm, degree	
Travel range* in X, Y, Z	±6.5, ±16, ±8.5	mm
Travel range* in θX, θY, θZ	±14.5, ±10, ±10	°
Minimum incremental motion in X, Y, Z	0.1	µm
Max. velocity in X, Y, Z	10	mm/s
Controller type	C-887	

* The travel ranges of the individual coordinates (X, Y, Z, θ_X, θ_Y, θ_Z) are **inter**dependent. The data for each axis in this table shows its maximum travel range, where all other axes and the pivot point are at the reference position.

See the dimensional drawings of the F-712.HA1 and F-712.HA2 systems for the default coordinate system and pivot point coordinates of the hexapod. Changing the pivot point will reduce the travel range in θ_X, θ_Y, θ_Z. Changing the orientation of the coordinate system (e.g., when the optical axis is to be the Z axis) will change the travel range in X, Y, and Z.

Examples for Area Scan Routines

Overview: Supported Area Scan Types

This section lists routine definition examples for piezo-driven axes (P-616K001 NanoCube® nanopositioner), and spindle-driven axes (M-122K025 stacked linear axes, H-811 hexapods), subdivided by the supported area scan types:

- Sinusoidal scan (p. 34)
- Spiral with constant frequency (p. 37)
- Spiral with constant path velocity (p. 40)

To decide which type of area scan fits best for your application, see the corresponding FAQ section on p. 54.

Due to the different dynamics characteristics of the drives, scan frequency and velocity of spindle-driven axes must be reduced compared to piezo-driven axes. Due to their larger travel ranges, however, the spindle-driven axes can scan a larger range than the piezo-driven axes. In every case, the line spacing of the scan should not exceed the width of the optical signal at half intensity.

C-887 only:

During area scan routines, for both scan axis and step axis a signal is recorded and used for calculation.

The type of the axis signal can be selected via the value of the Fast Alignment Axis Signal Type parameter (ID 0x20001C00). Possible options:

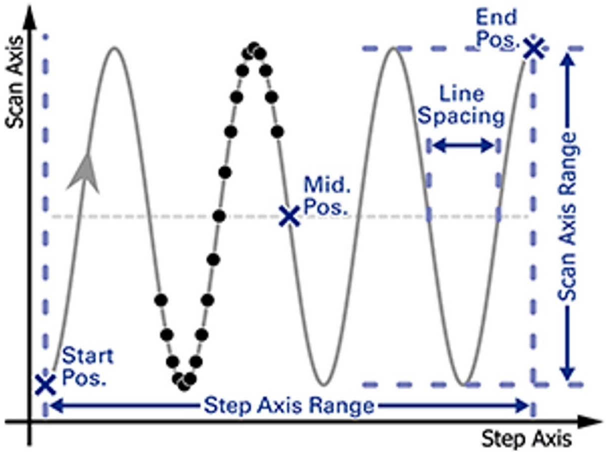
0 = current position

1 = dynamics profile created by the profile generator (default)

Choosing the current position can be useful, for example, if the signal maximum found is to be approached at the end of an area scan routine. In this case, the analog signal deviation when approaching the signal maximum can be minimally reduced compared to the deviation when using the dynamics profile.

Note that the setting affects all routines in the C-887, i.e. also gradient search routines.

Sinusoidal Scan



The scan routine has to be defined with the FDR command (p. 78), TT <target type> = 0

Arguments in square brackets are optional. If the argument is omitted in the FDR command, its last valid value will be taken from the volatile memory of the E-712. With C-887, the default value of the argument will be taken[6].

Note: You can use the sinusoidal scan type to define a line scan (single-axis routine). In this case, set <step axis> identical to <scan axis>, and set <step axis range> identical to <scan axis range>.

	Sinusoidal scan					
	E-712			**C-887**		
Scan setting: Argument of FDR	**Range/Default**	**Piezo-driven axes (e.g., P-616K001)**	**Spindle-driven axes, e.g., M-122K025**	**Range/Default**	**Hexapod (spindle-driven)**	**Hexapod (spindle-driven), line scan**
ID of the routine: <routine name>	UINT; 1, 2, …, n, (n = number of axes of the controller)	1	2	String of characters. Blanks or special characters are not allowed.	SINUS7	LINEX
Scan axis, follows a sine curve: <scan axis>	UINT; 1, 2, …, n, (n = number of axes of the controller) Default: 0	1 (SPX)	7	X, Y, Z, U, V, W	X	X
Scan axis range[1]: <scan axis range>	FLOAT; in [axis unit] Default: 100	100 µm	1.2 mm	FLOAT; ≥ 0.000001 (X, Y, Z: mm; U, V, W: degrees)	0.75 mm	1 mm
Step axis, follows a ramp: <step axis>	UINT; 1, 2, …, n, (n = number of axes of the controller) Default: 0	2 (SPY)	8	X, Y, Z, U, V, W	Y	X
Step axis range[2]: <step axis range>	FLOAT;in [axis unit] Default: 100	100 µm	0.5 mm	FLOAT; ≥ 0.000001 (X, Y, Z: mm; U, V, W: degrees)	1.5 mm	1 mm

	Sinusoidal scan					
	E-712			**C-887**		
Scan setting: Argument of FDR	**Range/Default**	**Piezo-driven axes (e.g., P-616K001)**	**Spindle-driven axes, e.g., M-122K025**	**Range/Default**	**Hexapod (spindle-driven)**	**Hexapod (spindle-driven), line scan**
Minimum signal threshold; success criterion for the scan[3]: [L <threshold level>]	FLOAT; > 0 Default: 0.004	0.2	0.2	FLOAT; Default: 0	0.2	0.2
Identifier of the analog input channel: [A <alignment signal input channel>]	1 to number of analog inputs Default: 0	1	1	5, 6 Default: 5	5	5
Frequency of the sine curve for the scan axis[4]: [F <frequency>]	FLOAT; ≥ 0 Hz Default: 15	30 Hz	5 Hz	FLOAT; 0.1 to 100 Hz Default 15 Hz	7 Hz	7 Hz
Velocity of the step axis[4], [5]: [V <velocity>]	FLOAT; ≥ 0 [axis unit]/s Default: 20	120 µm/s	0.1 mm/s	FLOAT; (X, Y, Z: mm/s; U, V, W: degrees/s) Default: 1	0.14 mm/s	0.14 mm/s
Middle position of the scan axis range[1]: [MP1 <scan axis middle position>]	FLOAT; min position to max position of axis in [axis unit] Default: 50	*XX* µm	*XX* mm	FLOAT; min position to max position of axis in [axis unit][6]	*XX* mm	*XX* mm
Middle position of the step axis range[2]: [MP2 <step axis middle position>]	FLOAT; min position to max position of axis in [axis unit] Default: 50	*YY* µm	*YY* mm	FLOAT; min position to max position of axis in [axis unit][6]	*YY* mm	*XX* mm
Type of area scan: [TT <target type>]	0 = sinusoidal 1 = spiral with const. frequency 2 = spiral with const. path velocity Default: 1	0	0	0 = sinusoidal 1 = spiral with const. frequency 2 = spiral with const. path velocity Default: 0	0	0
Estimation method for the position of the global signal maximum: [CM <estimation method>]	0 = global maximum 1 = Gaussian LS fit 2 = center-of-gravity calculation Default: 0	0	0	0 = global maximum 1 = Gaussian LS fit 2 = center-of-gravity calculation Default: 0	0	0
Minimum signal value to be used for estimation method 1 or 2: [MIIL <minimum level of fast alignment input>]	FLOAT32; 1 % to 100 %[7] Default: 1 %	1	1	FLOAT32; 0 % ≤ MIIL < MAIL[7] Default: 10 %	10	10
Maximum signal value to be used for estimation method 1 or 2: [MAIL <maximum level of fast alignment input>]	FLOAT32; 1 % to 100 %[7] Default: 99 %	99	99	FLOAT32; MIIL < MAIL ≤ 100 %[7] Default: 80 %	80	80

	Sinusoidal scan					
	E-712			**C-887**		
Scan setting: Argument of FDR	**Range/Default**	**Piezo-driven axes (e.g., P-616K001)**	**Spindle-driven axes, e.g., M-122K025**	**Range/Default**	**Hexapod (spindle-driven)**	**Hexapod (spindle-driven), line scan**
Position to be approached when the scan routine has been completed: [ST <stop position option>]	0 = move to position of signal maximum 1 = end position of the scan 2 = start position of the scan 3 = stop at position of minimum signal threshold[8)] 4 = continuously scan and stop at the position of the minimum signal threshold Default: 0	0	0	0 = move to position of signal maximum 1 = end position of the scan 2 = start position of the scan 3 = stop at position of minimum signal threshold[8)] Default: 0	0	0

Corresponding commands	
Piezo-driven axes (e.g., P-616K001):	FDR 1 1 100 2 100 L 0.2 A 1 F 30 V 120 MP1 XX MP2 YY TT 0 CM 0 MIIL 1 MAIL 99 ST 0
Spindle-driven axes, e.g., M-122K025	FDR 2 7 1.2 8 0.5 L 0.2 A 1 F 5 V 0.1 MP1 XX MP2 YY TT 0 CM 0 MIIL 1 MAIL 99 ST 0
Hexapod (spindle-driven)	FDR SINUS7 X 0.75 Y 1.5 L 0.2 A 5 F 7 V 0.14 MP1 XX MP2 YY TT 0 CM 0 MIIL 10 MAIL 80 ST 0
Hexapod (spindle-driven), line scan	FDR LINEX X 1 X 1 L 0.2 A 5 F 7 V 0.14 MP1 XX MP2 XX TT 0 CM 0 MIIL 10 MAIL 80 ST 0

In this manual, the decimal separator is always a period. Note that the decimal separator to be used with the ***Fast Alignment*** tab card(s) of PIMikroMove depends on the regional settings of your computer's Windows operating system.

1. The scan axis range value is used to calculate the start and end position (with stop position option = 1) for the scan axis as follows (middle position is given by MP1):
Start position = scan_axis_middle_position – scan_axis_range/2
End position = scan_axis_middle_position + scan_axis_range/2

2. The step axis range value is used to calculate the start and end position (with stop position option = 1) for the step axis as follows (middle position is given by MP2):
Start position = step_axis_middle_position – step_axis_range/2
End position = step_axis_middle_position + step_axis_range/2

3. The threshold is applied to the signal after it has been subjected to the calculations set with the SIC command (p. 102).

4. A suitable line spacing of the scan is important for the success of an area scan. The line spacing depends on the expected distribution of the signal. Specify the frequency f and velocity v of the scan so that the desired line spacing Δx results on the basis of the following equation:

$$\Delta x = \frac{1}{2} \cdot v \cdot \frac{1}{f}$$

5. The velocity value gives the velocity with which the step axis follows a ramp from (step_axis_middle_position – step_axis_range/2) to (step_axis_middle_position + step_axis_range/2)).

If the velocity set with VEL or VLS for the step axis is lower than the value given by <velocity>, the velocity is limited to the VEL or VLS value.

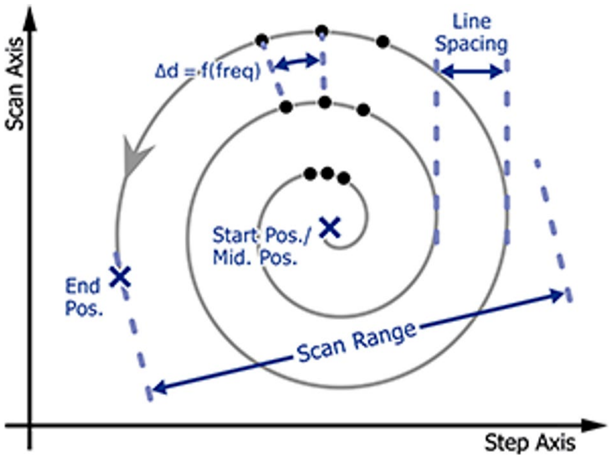
For motion to the start position or to the end position (with stop position option = 1), the velocity set with VEL or VLS is used. A too high VEL or VLS value can lead to jerky movements before and after the scan.

6. C-887 only: If the start position of the scan is omitted in the FDR command, the current target position of the axis is used.

7. The value is given in % of the signal range that is measured during the runtime of the routine.

8. If the scan has been unsuccessfully completed, move back to the start position.

Spiral Scan with Constant Frequency



Δd is the distance between the data points recorded during the scan

The scan routine has to be defined with the FDR command (p. 78), TT <target type> = 1

Arguments in square brackets are optional. If the argument is omitted in the FDR command, its last valid value will be taken from the volatile memory of the E-712. With C-887, the default value of the argument will be taken[3)].

	Spiral scan with constant frequency				
	E-712			**C-887**	
Scan setting: Argument of FDR	**Range/Default**	**Piezo-driven axes (e.g., P-616K001)**	**Spindle-driven axes, e.g., M-122K025**	**Range/Default**	**Hexapod (spindle-driven)**
ID of the routine: <routine name>	UINT; 1, 2, …, n, (n = number of axes of the controller)	3	4	String of characters. Blanks or special characters are not allowed.	SPIRALCFR
Scan axis: <scan axis>	UINT; 1, 2, …, n, (n = number of axes of the controller) Default: 0	1 (SPX)	7 (SMX)	X, Y, Z, U, V, W	X
Scan range (= final diameter of the spiral): <scan axis range>	FLOAT;in [axis unit] Default: 100	100 µm	1 mm	FLOAT; ≥ 0.000001 (X, Y, Z: mm; U, V, W: degrees)	1 mm
Step axis: <step axis>	UINT; 1, 2, …, n, (n = number of axes of the controller) Default: 0	2 (RPY)	8 (SMY)	X, Y, Z, U, V, W	Y
- <step axis range>	Not used, but must be present in the FDR command. Specify a dummy, e.g., repeat the <scan axis range> value.	100 µm	1 mm	Not used, but must be present in the FDR command. Specify a dummy, e.g., repeat the <scan axis range> value.	1 mm

	Spiral scan with constant frequency				
Scan setting: Argument of FDR	**E-712**			**C-887**	
	Range/Default	**Piezo-driven axes (e.g., P-616K001)**	**Spindle-driven axes, e.g., M-122K025**	**Range/Default**	**Hexapod (spindle-driven)**
Minimum signal threshold; success criterion for the scan[1)]: [L <threshold level>]	FLOAT; > 0 Default: 0.004	0.2	0.2	FLOAT; Default: 0	0.2
Identifier of the analog input channel: [A <alignment signal input channel>]	1 to number of analog inputs Default: 0	1	1	5, 6 Default: 5	5
Scan frequency; used to calculate the line spacing[2)]: [F <frequency>]	FLOAT; ≥ 0 Hz Default: 15	50 Hz	3 Hz	FLOAT; 0.1 to 100 Hz Default: 15	5 Hz
Scan velocity; used to calculate the line spacing[2)]: [V <velocity>]	FLOAT; ≥ 0 [axis unit]/s Default: 20	100 µm/s	0.03 mm/s	FLOAT; (X, Y, Z: mm/s; U, V, W: degrees/s) Default: 1	0.05 mm/s
Start position for the scan axis: [MP1 <scan axis middle position>]	FLOAT; min position to max position of axis in [axis unit] Default: 50	*XX* µm	*XX* mm	FLOAT; min position to max position of axis in [axis unit][3)]	*XX* mm
Start position for the step axis: [MP2 <step axis middle position>]	FLOAT; min position to max position of axis in [axis unit] Default: 50	*YY* µm	*YY* mm	FLOAT; min position to max position of axis in [axis unit][3)]	*YY* mm
Type of area scan: [TT <target type>]	0 = sinusoidal 1 = spiral with const. frequency 2 = spiral with const. path velocity Default: 1	1	1	0 = sinusoidal 1 = spiral with const. frequency 2 = spiral with const. path velocity Default: 0	1
Estimation method for the position of the global signal maximum: [CM <estimation method>]	0 = global maximum 1 = Gaussian LS fit 2 = center-of-gravity calculation Default: 0	0	0	0 = global maximum 1 = Gaussian LS fit 2 = center-of-gravity calculation Default: 0	0
Minimum signal value to be used for estimation method 1 or 2: [MIIL <minimum level of fast alignment input>]	FLOAT32; 1 % to 100 %[4)] Default: 1 %	1 %	1 %	FLOAT32; 0 % ≤ MIIL < MAIL[4)] Default: 10 %	10 %
Maximum signal value to be used for estimation method 1 or 2: [MAIL <maximum level of fast alignment input>]	FLOAT32; 1 % to 100 %[4)] Default: 99 %	99 %	99 %	FLOAT32; MIIL < MAIL ≤ 100 %[4)] Default: 80 %	80 %

	Spiral scan with constant frequency				
Scan setting: Argument of FDR	**E-712**			**C-887**	
	Range/Default	**Piezo-driven axes (e.g., P-616K001)**	**Spindle-driven axes, e.g., M-122K025**	**Range/Default**	**Hexapod (spindle-driven)**
Position to be approached when the scan routine has been completed: [ST <stop position option>]	0 = move to position of signal maximum 1 = end position of the scan 2 = start position of the scan 3 = stop at position of minimum signal threshold[5)] 4 = continuously scan and stop at the position of the minimum signal threshold Default: 0	0	0	0 = move to position of signal maximum 1 = end position of the scan 2 = start position of the scan 3 = stop at position of minimum signal threshold[5)] Default: 0	0
Corresponding commands					
Piezo-driven axes (e.g., P-616K001)	FDR 3 1 100 2 100 L 0.2 A 1 F 50 V 100 MP1 XX MP2 YY TT 1 CM 0 MIIL 1 MAIL 99 ST 0				
Spindle-driven axes, e.g., M-122K025	FDR 4 7 1 8 1 L 0.2 A 1 F 3 V 0.03 MP1 XX MP2 YY TT 1 CM 0 MIIL 1 MAIL 99 ST 0				
Hexapod (spindle-driven)	FDR SPIRALCFR X 1 Y 1 L 0.2 A 5 F 5 V 0.05 MP1 XX MP2 YY TT 1 CM 0 MIIL 10 MAIL 80 ST 0				

In this manual, the decimal separator is always a period. Note that the decimal separator to be used with the ***Fast Alignment*** tab card(s) of PIMikroMove depends on the regional settings of your computer's Windows operating system.

For motion to the start position or to the end position (with stop position option = 1), the velocity set with VEL or VLS is used. A too high VEL or VLS value can lead to jerky movements before and after the scan.

1. The threshold is applied to the signal after it has been subjected to the calculations set with the SIC command (p. 102).

2. A suitable line spacing of the spiral is important for the success of an area scan. The line spacing depends on the expected distribution of the signal. Specify the frequency f and velocity v of the scan so that the desired line spacing Δx results on the basis of the following equation:

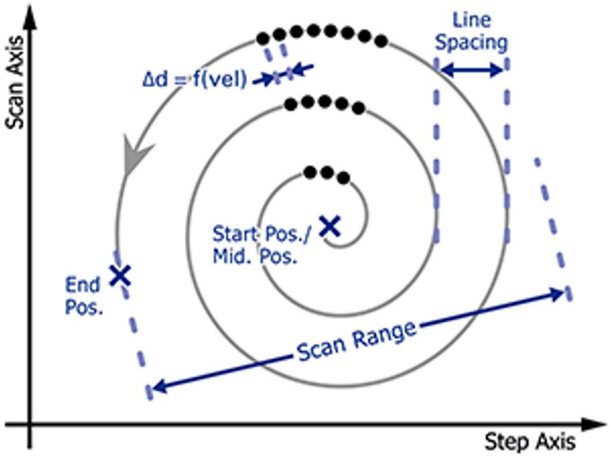
$$\Delta x = v \cdot \frac{1}{f}$$

3. C-887 only: If the start position of the scan is omitted in the FDR command, the current target position of the axis is used.

4. The value is given in % of the signal range that is measured during the runtime of the routine.

5. If the scan has been unsuccessfully completed, move back to the start position.

Spiral Scan with Constant Path Velocity



Δd is the distance between the data points recorded during the scan

The scan routine has to be defined with the FDR command (p. 78), TT <target type> = 2

Arguments in square brackets are optional. If the argument is omitted in the FDR command, its last valid value will be taken from the volatile memory of the E-712. With C-887, the default value of the argument will be taken[2)].

	Spiral scan with constant path velocity					
	E-712			**C-887**		
Scan setting: Argument of FDR	**Range/Default**	**Piezo-driven axes (e.g., P-616K001)**	**Spindle-driven axes, e.g., M-122K025**	**Range/Default**	**Hexapod (spindle-driven), with Gaussian LS fit**	**Hexapod (spindle-driven), angular scan**
ID of the routine: <routine name>	UINT; 1, 2, …, n, (n = number of axes of the controller)	5	6	String of characters. Blanks or special characters are not allowed.	SPIRALVEL	SPIRALUV
Scan axis: <scan axis>	UINT; 1, 2, …, n, (n = number of axes of the controller) Default: 0	1 (SPX)	7 (SMX)	X, Y, Z, U, V, W	X	U
Scan range (= final diameter of the spiral): <scan axis range>	FLOAT; in [axis unit] Default: 100	100 µm	1 mm	FLOAT; ≥ 0.000001 (X, Y, Z: mm; U, V, W: degrees)	1 mm	1 degree
Step axis: <step axis>	UINT; 1, 2, …, n, (n = number of axes of the controller) Default: 0	2 (SPY)	8 (SMY)	X, Y, Z, U, V, W	Y	V
Line spacing of the spiral: <step axis range>	FLOAT; in [axis unit] Default: 100	2 µm	0.01 mm	FLOAT; ≥ 0.000001 (X, Y, Z: mm; U, V, W: degrees)	0.01 mm	0.05 degree

	Spiral scan with constant path velocity					
	E-712			**C-887**		
Scan setting: Argument of FDR	**Range/Default**	**Piezo-driven axes (e.g., P-616K001)**	**Spindle-driven axes, e.g., M-122K025**	**Range/Default**	**Hexapod (spindle-driven), with Gaussian LS fit**	**Hexapod (spindle-driven), angular scan**
Minimum signal threshold; success criterion for the scan [1]: [L <threshold level>]	FLOAT; > 0 Default: 0.004	0.2	0.2	FLOAT; Default: 0	0.2	0.2
Identifier of the analog input channel: [A <alignment signal input channel>]	1 to number of analog inputs Default: 0	1	1	5, 6 Default: 5	5	5
- [F <frequency>]	Not used. Specify a dummy value or omit the argument in the FDR command.	1	1	Not used. Specify a dummy value or omit the argument in the FDR command.	1	1
Path velocity: [V <velocity>]	FLOAT; ≥ 0 [axis unit]/s Default: 20	2000 µm/s	5 mm/s	FLOAT; (X, Y, Z: mm/s; U, V, W: degrees/s) Default: 1	5 mm/s	2 degrees/s* *depends on pivot point setting
Start position for the scan axis: [MP1 <scan axis middle position>]	FLOAT; min position to max position of axis in [axis unit] Default: 50	*XX* µm	*XX* mm	FLOAT; min position to max position of axis in [axis unit][2]	*XX* mm	*UU* degree
Start position for the step axis: [MP2 <step axis middle position>]	FLOAT; min position to max position of axis in [axis unit] Default: 50	*YY* µm	*YY* mm	FLOAT; min position to max position of axis in [axis unit][2]	*YY* mm	*VV* degree
Type of area scan: [TT <target type>]	0 = sinusoidal 1 = spiral with const. frequency 2 = spiral with const. path velocity Default: 1	2	2	0 = sinusoidal 1 = spiral with const. frequency 2 = spiral with const. path velocity Default: 0	2	2
Estimation method for the position of the global signal maximum: [CM <estimation method>]	0 = global maximum 1 = Gaussian LS fit 2 = center-of-gravity calculation Default: 0	0	0	0 = global maximum 1 = Gaussian LS fit 2 = center-of-gravity calculation Default: 0	1	0
Minimum signal value to be used for estimation method 1 or 2: [MIIL <minimum level of fast alignment input>]	FLOAT32; 1 % to 100 %[3] Default: 1 %	1	1	FLOAT32; 0 % ≤ MIIL < MAIL[3] Default: 10 %	20	10
Maximum signal value to be used for estimation method 1 or 2: [MAIL <maximum level of fast alignment input>]	FLOAT32; 1 % to 100 %[3] Default: 99 %	99	99	FLOAT32; MIIL < MAIL ≤ 100 %[3] Default: 80 %	80	80

	Spiral scan with constant path velocity					
Scan setting: Argument of FDR	**E-712**			**C-887**		
	Range/Default	**Piezo-driven axes (e.g., P-616K001)**	**Spindle-driven axes, e.g., M-122K025**	**Range/Default**	**Hexapod (spindle-driven), with Gaussian LS fit**	**Hexapod (spindle-driven), angular scan**
Position to be approached when the scan routine has been completed: [ST <stop position option>]	0 = move to position of signal maximum 1 = end position of the scan 2 = start position of the scan 3 = stop at position of minimum signal threshold[4] 4 = continuously scan and stop at the position of the minimum signal threshold Default: 0	0	0	0 = move to position of signal maximum 1 = end position of the scan 2 = start position of the scan 3 = stop at position of minimum signal threshold[4] Default: 0	0	0
Corresponding commands						
Piezo-driven axes (e.g., P-616K001)	FDR 5 1 100 2 2 L 0.2 A 1 F 1 V 2000 MP1 XX MP2 YY TT 2 CM 0 MIIL 1 MAIL 99 ST 0					
Spindle-driven axes, e.g., M-122K025	FDR 6 7 1 8 0.01 L 0.2 A 1 F 1 V 5 MP1 XX MP2 YY TT 2 CM 0 MIIL 1 MAIL 99 ST 0					
Hexapod (spindle-driven), with Gaussian LS fit	FDR SPIRALVEL X 1 Y 0.01 L 0.2 A 5 F 1 V 5 MP1 XX MP2 YY TT 2 CM 1 MIIL 20 MAIL 80 ST 0					
Hexapod (spindle-driven), angular scan	FDR SPIRALUV U 1 V 0.05 L 0.2 A 5 F 1 V 2 MP1 UU MP2 VV TT 2 CM 0 MIIL 10 MAIL 80 ST 0					

In this manual, the decimal separator is always a period. Note that the decimal separator to be used with the ***Fast Alignment*** tab card(s) of PIMikroMove depends on the regional settings of your computer's Windows operating system.

For motion to the start position or to the end position (with stop position option = 1), the velocity set with VEL or VLS is used. A too high VEL or VLS value can lead to jerky movements before and after the scan.

1. The threshold is applied to the signal after it has been subjected to the calculations set with the SIC command (p. 102).

2. C-887 only: If the start position of the scan is omitted in the FDR command, the current target position of the axis is used.

3. The value is given in % of the signal range that is measured during the runtime of the routine.

4. If the scan has been unsuccessfully completed, move back to the start position.

Examples for Gradient Search Routines

What does a Gradient Search?

A gradient search is a circular scan travelling to the signal maximum using the gradient of the measured signal. This means that there MUST be a signal present (i.e., the first light search must have been successfully completed before), and this signal must have a gradient and a maximum such as it is the case, for example, with a Gaussian shaped signal.

It is not possible to define an area for a gradient search. Before you run a gradient search routine, you should therefore determine and establish limits for the permissible travel range of the axes in your application. For details, see “Safety Instructions” on p. 10.

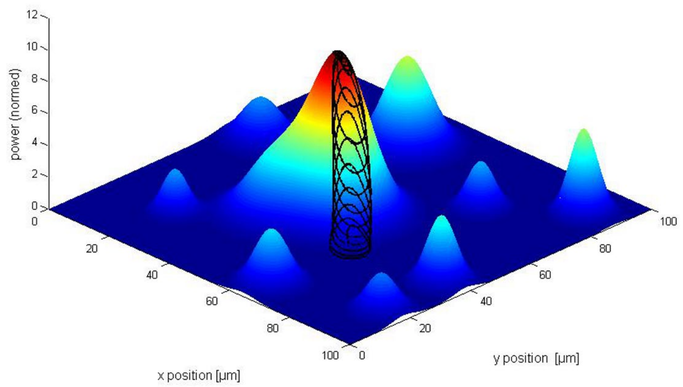


Figure 10 Gradient search using axes x and y

During the routine, the scan axis and step axis each follow a sine curve so that a circular motion results. Furthermore, offsets are added to the sine curves. To move in the direction of the signal maximum, the amplitude of the sine curve and the offset values are continuously changed depending on the current result of the gradient calculation. The number of direction changes of the motion is counted during the routine. Counting is necessary to stop the routine after a given number of changes if no gradient can be calculated (e.g., when the routine was started far away from the position of the signal maximum).

When a gradient search routine is started, the current position of scan axis and step axis is used as initial center position of the circular motion.

A gradient search routine is stopped and considered to be successfully completed when the following condition has been met:

- The length of the normalized gradient vector has fallen below a specified stop level (the smaller the gradient, the smaller is the current distance to the signal maximum).

A gradient search routine is stopped and considered to be unsuccessful when one of the following conditions has been met:

- The number of direction changes during the routine has reached the specified maximum value.
- FRP with stop action, #24, STP or HLT has been sent.

- The routine was stopped because at least one of the axes involved reached a soft limit.
- E-712 only: The routine has been stopped via an input signal channel.

Find more details in the description of the FDG command on p. 87.

The signal used in the routine results from a calculation applied to the analog input signal. For details, see description of the SIC command (p. 102).

Gradient search routines can be coupled to each other so that they do not stop until the length of the normalized gradient vector has fallen below the specified stop level for all of them. The coupling is done using the FRC command (p. 94).

Gradient Search Definition

The gradient search routine has to be defined with the FDG command (p. 87).

The table below lists the arguments of the FDG command with their value range, default and example values. Arguments in square brackets are optional. If the argument is omitted in the FDG command, its last valid value will be taken from the volatile memory of the controller.

	Gradient search					
Routine setting: Argument of FDG	**E-712—use only the piezo-driven axes**				**C-887**	
	Range/Default	**Focus adjustment; tracking of the signal maximum, for further details, see p. 62**	**Focus adjustment; Gaussian distribution in XY, flat-top distribution in Z, for further details, see p. 62**		**Range/Default**	**Single-axis angular gradient search with hexapod**
ID of the routine: <routine name>	UINT; 1, 2, …, n, (n = number of axes of the controller)	7	8	9	String of characters. Blanks or special characters are not allowed.	GRADIENT
First axis of the gradient search: <scan axis>	UINT; 1, 2, …, n, (n = number of axes of the controller) Default: 0	1 (SPX)	1 (SPX)	3 (SPZ)	X, Y, Z, U, V, W	U
Second axis of the gradient search: <step axis>	UINT; 1, 2, …, n, (n = number of axes of the controller) Default: 0	2 (SPY)	2 (SPY)	3 (SPZ)	X, Y, Z, U, V, W	U
Length of the normalized gradient vector; stop criterion for the gradient search routine[1)]: [ML <stop level>]	FLOAT; 0 to 1[2)] Default: 0.05	0	0.05	0.05	FLOAT; 0 to 1[2)] Default: 0.05	0.05
Identifier of the analog input channel: [A <alignment signal input channel>]	1 to number of analog inputs Default: 0	1	1	1	5, 6 Default: 5	5

	Gradient search					
	E-712—use only the piezo-driven axes				**C-887**	
Routine setting: Argument of FDG	**Range/Default**	**Focus adjustment; tracking of the signal maximum, for further details, see p. 62**	**Focus adjustment; Gaussian distribution in XY, flat-top distribution in Z, for further details, see p. 62**		**Range/Default**	**Single-axis angular gradient search with hexapod**
Minimum radius of the circular motion for scan axis and step axis (= amplitude of the sine curve) 3): [MIA <min radius>]	FLOAT; > 0 [axis unit] Default: 1.0	1 µm	1 µm	5 µm	FLOAT; 0 to 0.5 (X, Y, Z: mm; U, V, W: degrees); must be smaller than maximum radius Default: 0.001	0.1 degree
Maximum radius of the circular motion for scan axis and step axis (= amplitude of the sine curve) 3): [MAA <max radius>]	FLOAT; > 0 [axis unit] Default: 5.0	5 µm	5 µm	25 µm	FLOAT; 0 to 0.5 (X, Y, Z: mm; U, V, W: degrees); must be greater than minimum radius Default: 0.05	0.2 degree
Frequency of the sine curves for scan axis and step axis4): [F <frequency>]	FLOAT; > 2 Hz Default: 15	49 Hz	47 Hz	37 Hz	FLOAT; 1 to 1000 Hz Default: 15	3 Hz
Speed factor, can be used to speed up the offset change5): [SP <speed factor>]	FLOAT; > 0 Default: 15	60.0	50.0	50.0	FLOAT; 0.01 to 1000 Default: 0.05	0.5
Velocity limit for the offset change: [V <max velocity>]	FLOAT; > 0 [axis unit]/s Default: 20	200 µm/s	50.0 µm/s	20.0 µm/s	FLOAT; > 0 (X, Y, Z: mm/s; U, V, W: degrees/s) Default: 100	1.5 degree/s
Number of direction changes during the routine; stop criterion for the gradient search routine6): [MDC <max direction changes>]	INT; > 0 Default: 50	100	100	100	INT; 2 to 1000 Default: 25	50
Offset for the velocity calculation7): [SPO <speed offset>]	FLOAT32; 0 to < 1 Default: 0.1	0.2	0.3	0.3	FLOAT32; 0 to 1 Default: 0.1	0.3

Correponding commands:	
Focus adjustment; tracking of the signal maximum, for further details, see p. 62	FDG 7 1 2 ML 0 A 1 MIA 1 MAA 5 F 49 SP 60 V 200 MDC 100 SPO 0.2
Focus adjustment; Gaussian distribution in XY, flat-top distribution in Z, for further details, see p. 62	FDG 8 1 2 ML 0.05 A 1 MIA 1 MAA 5 F 47 SP 50.0 V 50.0 MDC 100 SPO 0.3
	FDG 9 3 3 ML 0.05 A 1 MIA 5 MAA 25 F 37 SP 50.0 V 20.0 MDC 100 SPO 0.3
Single-axis angular gradient search with hexapod	FDG GRADIENT U U ML 0.05 A 5 MIA 0.1 MAA 0.2 F 3 SP 0.5 V 1.5 MDC 50 SPO 0.3

In this manual, the decimal separator is always a period. Note that the decimal separator to be used with the ***Fast Alignment*** tab card(s) of PIMikroMove depends on the regional settings of your computer's Windows operating system.

1. When the length of the normalized gradient vector falls below the given stop level, the routine stops, and FRR? will report "successful". After stopping as "successful", the scan axis and step axis will move to the last valid center position of the circular motion.

2. If the stop level is set to 0, the routine will continuously track the signal maximum. With C-887, the tracking duration is limited to approximately 90 s.

3. Typical minimum radius R_{min} is around 1/10 the FWHM of the signal.
Typical maximum radius R_{max} is perhaps 2-5 times R_{min}. For some applications, a fixed radius is desired; in such a case set R_{min} and R_{max} identically.

4. The entered frequency value will automatically be adapted to a multiple of the sampling time of the controller.

5. The greater the speed factor, the faster is the circular motion in the direction of the signal maximum. The routine can become instable when the value of the speed factor is too high.

6. When the number of direction changes during the routine reaches the given maximum value, the routine stops, and FRR? will report "not successful".

7. To avoid that the velocity of the offset change becomes very low or zero during the gradient search procedure, an offset can be applied in the velocity calculation. This is useful to avoid a very slow position change near the signal maximum if there is no gradient.

Application Notes for Gradient Search Routines

Safety:

NOTICE: It is not possible to define an area for a gradient search. Before you run a gradient search routine, you should therefore determine and establish limits for the permissible travel range of the axes in your application. For details, see "Safety Instructions" on p. 10.

Start position:

The position of the signal maximum found by an area scan routine can be used as the start position for a gradient search routine.

When a gradient search routine is started, the current position of scan axis and step axis is used as initial center position of the circular motion. When the gradient search routine is running, you can query the current center position of the circular motion using the FGC? command. As long as the routine is still running, you can also change the center position of the circular motion using the FGC command (p. 92). This can be useful when you suppose the signal maximum far away from the area where the circular motion currently takes place.

Axes used in a routine:

For the two axes used in one routine, the distribution of the signal should differ only slightly. For axes with great differences in the signal distribution, separate routines with different configurations should be defined.

Spindle-driven mechanics such as the hexapod should only be used for gradient searches if no other solution is possible, e.g. for angular gradient searches. For long-term use of gradient search routines, mechanics should be used which are free of backlash, maintenance, and wear, like piezo-driven nanopositioning systems.

Axis units:

E-712 and C-887 use different axis units:

- E-712: µm
- C-887: mm, degree

Therefore, the numerical values to be used for the routine definition may differ by a factor of 1000. This is the case, for example, with the speed factor used for gradient search. Note that the axis unit can be queried with the PUN? command.

Speed factor:

During the gradient search routine, for both scan axis and step axis a signal is recorded and used for gradient calculation.

The type of axis signal can be selected via the value of the parameter with ID 0x20001C00. Note that the name of parameter 0x20001C00 is FA Gradient Search Type Of ***Axis Signal*** with E-712 but ***Fast Alignment Axis Signal Type*** with C-887. Possible options:

0 = current position (default with E-712)

1 = target position (E-712) / dynamics profile created by the profile generator (default with C-887)

The number of values used for gradient calculation differs for E-712 and C-887. Therefore, the influence of the speed factor with C-887 is greater than with E-712.

The higher the frequency of the sine curves for a gradient search, the greater the speed factor may be. At low frequencies the speed factor should also be reduced in order to be able to move reliably to the signal maximum.

For adjustment of the speed factor, see also the FAQ section "Q: How can I minimize the gradient search time?" on p. 66.

Frequency

Before you start gradient search routines, identify the resonant frequencies of the overall system. Do not use a resonant frequency as frequency for the gradient search definition. For further details, see p. 25.

To achieve maximum reliability for coupled routines (see FRC, p. 94), their frequencies should differ by a reasonable value and should not be harmonics. With a double-sided system, this applies to all frequencies used on both sides.

C-887: The routines work best in a frequency range of 10 to 50 Hz.

Starting and Stopping Routines

Overview: Starting, Stopping, Pausing

Use the FRS command (p. 95) to start a routine.

You can stop a routine with the FRP command (p. 97) and also with #24, STP or HLT. With E-712, you can also use an input signal channel to stop a routine, see p. 109 for more information. Note that the specified input signal channel stops any motion of the axes included in the definition of the routine.

You can use FRP also to pause or resume a gradient search routine.

Using the FRP? command (p. 98), you can query the current state of the routine (running or not).

A paused routine will be resumed with the routine variable values that were valid at the time of pausing, even if values (e.g. target value) have been changed in the meantime.

A stopped routine will be considered to be unsuccessful.

When a routine is stopped or paused with FRP, the axes will stay at the following position:

Area scan routine: current target position

Gradient search routine:

- E-712: current center position of the circular motion
- C-887: current target position

The response to FRP? may show that a routine is still running if the FRP? command has been sent immediately after stopping the routine with FRP. Before proceeding, query FRP? until it returns 0, indicating that the routine has successfully been stopped.

A routine to be stopped or paused must have been started with FRS (p. 95) before.

A routine to be resumed with FRP must have been paused with FRP before.

Running Routines Simultaneously

Multiple fast alignment routines can run simultaneously when started with **one** FRS command.

Application notes for running area scan and gradient search routines simultaneously:

- In the case of a joint start, the durations of gradient search routines and area scan routines may be the same or may differ from each other. Some scenarios:
  - Gradient search routines do not wait for the end of area scan routines. It is therefore possible that the gradient search routine has been successfully completed while the area scan is still running.
    → Different duration

- The number of direction changes during a gradient routine has reached the specified maximum value so that the gradient search routine has been stopped unsuccessfully. The area scan is still running.
  → Different duration
- One of the routines has been stopped with the FRP command (p. 97).
  → Different duration
- After successful completion of the area scan, a gradient search for continuous tracking of the signal maximum was stopped with FRP (therefore not successful).
  → Same duration
- The gradient search could only be completed successfully after the area scan was completed successfully.
  → Same duration
- All routines have been stopped with FRP (therefore not successful).
  → Same duration

- C-887 only: If the routines to be started together with FRS are of different types, then only one area scan routine may be among these routines.

In addition to being able to start routines simultaneously with FRS, gradient search routines can also be coupled to each other with FRC (p. 94).

- If you want to couple gradient search routines to each other, configure the coupling with FRC **before** you start these routines simultaneously with FRS.

Routine Results

With the FRR? command (p. 99), you can read out the definition and the results of the routine.

When evaluating the routine results, first of all check the success of the routine. When the routine was not successful (result ID 1 has the value 0), all other results of the routine are invalid.

Frequently Asked Questions

Q: How can I convert the logarithmic output of my F-712 power meter to (linear) power in an F-712 system?

We recommend power metrology with a logarithmic response, such as the output signal of our F-712 power meters (available models: F-712.PM1, F-712.IRP1, F-712.IRP2). This provides the largest dynamic range, which is important for capture when far from optimum. It has another advantage: the logarithmic response flattens the steep sides of the typically Gaussian-like coupling profile, allowing a smoother approach to maximum with less risk of overshoot. But our F-712 alignment systems also allow (via the SIC command – see below) an automatic conversion to power for such a logarithmic signal, when desired. You can easily switch the exponential scaling on and off by issuing the SIC command accordingly. This allows you to take advantage of the smoothing of the logarithmic scaling yet query optical power accurately.

For many applications, this is a fine approach. Whether it is best for your devices can easily be determined as you initially work with the system and explore.

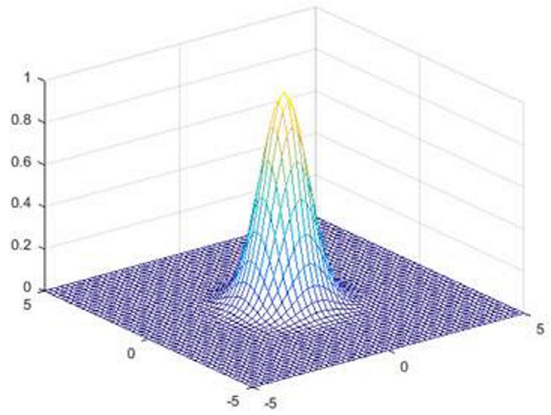


Figure 11: Gaussian-like coupling profile

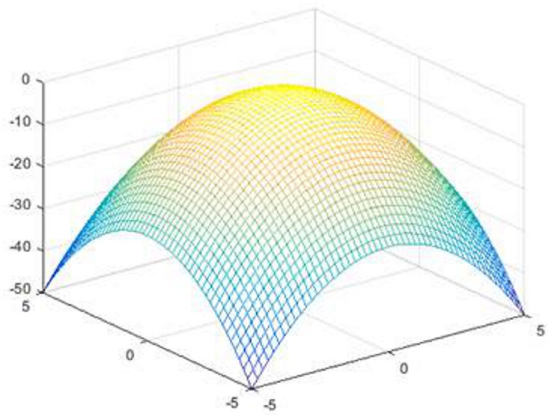


Figure 12: Logarithmic scaling of the coupling profile

How does the SIC command work (for further details, see p. 102):

The measured power is fed into the controller as an analog input signal. The calculation settings defined with SIC are applied to the analog input signal before it is used in the fast alignment routines. The input values before and after the conversion with SIC can be queried with the TAV? and TCI? commands.

If you want to use the logarithmic output of the F-712 power meter as input for the alignment routines in an F-712 system (recommended because routines usually work better with it), make sure you have (re)set the SIC calculation to type “0” (= no calculation) before starting an alignment routine.

If you want to convert the logarithmic output of the F-712 power meter to (linear) power in an F-712 system, set the SIC command as follows:

SIC <FA input channel ID> 1 a b c d

Where

<FA input channel ID> is the identifier of an analog input channel of the controller.

“1” is the type of calculation to be applied—exponential scaling as follows:
Power in W = a + b * $c^{(d*\text{analog input in V})}$

“a”, “b”, “c” and “d” are the terms of the exponential equation for power calculation which have to be set as follows:

- a = 0
- b = **E** / $10^{(\mathbf{c}/\mathbf{m})}$
- c = 10
- d = 1/**m**

The values displayed in bold are taken from the documentation of the F-712 power meter (F-712.PM1: calibration certificate; F-712.IRPx: user manual):

c	Intercept / V, see calibration certificate (value for logarithmic output signal, page 5)
m	Slope / V/A, see calibration certificate (value for logarithmic output signal, page 5)
E	Spectral responsivity / W/(A*nm) If the optical input of the power meter is used: See calibration certificate (pages 6 and 7). If the current input of the power meter is used with a photodiode, refer to the spectral responsivity in the documentation of this photodiode.

Note that the designation “c” is used for two different values, namely a term in the exponential equation of the SIC command (set in regular font), and also for the intercept/V in the calibration certificate of the power meter (set in bold).

Example:

Select power calculation for fast alignment input channel 1, with a = 1.234, b = 3.124, c = 2.234 and d = 0.9. Query the power value of the channel, and afterwards set SIC back to “no calculation” to use the logarithmic signal for the fast alignment routines. Send:

SIC 1 1 1.234 3.124 2.234 0.9

TCI? 1

SIC 1 0

If you want to use the SIC calculation as a convenient conversion tool, without at the same time changing the alignment routine input, you have to physically connect the power meter output to two separate channels of the controller and use one channel for the SIC conversion and the other for logarithmic alignment input, i.e. with SIC set to 0. Query the converted value with the TCI? command.

Q: How can I identify my system’s resonances?

You can use the measured signal to identify the system resonances of your setup. For further details, see p. 25.

Q: What should I keep in mind when I change the mechanical assembly of my system, e.g. replace the fiber holder?

Adjust the closed-loop performance of the piezo-driven axes as described on p. 19.

Q: How can I assign the center of rotation to the tip of my fiber with my F-712.HA1/2?

You need to determine the dimensional values in regard to the hexapod origin, either using a CAD program or with a scale. Then you need to define customer-specific coordinate systems in the hexapod controllers for the sender and receiver side. See the example below for how to proceed.

Example for defining an operating coordinate system with the KSD command

Figure 1: F-712.HA2 high-precision fiber alignment system: Application example

Customer-specific fiber holders are used in a high-precision F-712.HA2 fiber alignment system that contains one H-811 hexapod each on the sender and receiver side. The factory-set coordinate systems for sender and receiver are active upon delivery of the fiber alignment system (sender, receiver coordinate systems). However, the center of rotation for hexapod motion should be on the fiber tip each time. For this reason, customer-specific coordinate systems are defined in the hexapod controllers for the sender and receiver side. These systems are used to shift the center of rotation from the standard position to the fiber tip. In the following example, the distance between the default center of rotation and the fiber tip is 85.37 mm in the X direction and 71.88 mm in the Z direction; see also the figure below. The new coordinate systems are to be called fibertip1s (sender) and fibertip1r (receiver) and become immediately active when the fiber alignment system is switched on or rebooted.

The following commands are transmitted for the hexapod controller on the sender side:

Command	Function
KSD fibertip1s X 85.37 Z 71.88	Defines the new coordinate system
KLN fibertip1s sender	Links the new coordinate system to the sender coordinate system as child
KEN fibertip1s	Activates the new coordinate system
WPA SKS	Saves the settings in the nonvolatile memory

The default receiver coordinate system for the receiver side is rotated so that its X axis points in the opposite direction with respect to the sender side. For this reason, a negative offset value has to be specified for the X axis when the new coordinate system for the receiver side is defined. The following commands are transmitted for the hexapod controller on the receiver side:

Command	Function
KSD fibertip1r X -85.37 Z 71.88	Defines the new coordinate system
KLN fibertZp1r receiver	Links the new coordinate system to the receiver coordinate system as child
KEN fibertip1r	Activates the new coordinate system
WPA SKS	Saves the settings in the nonvolatile memory

The following figure shows the coordinate systems and their definition using the sender side as an example. For better understanding, not only is the resulting fibertip1s coordinate system displayed but also the other operating coordinate systems, from which fibertip1s takes its characteristics by linking: ZERO and sender (based on ZERO). The implementation of individual adapting steps as separate coordinate system definitions and the subsequent linking of these coordinate systems transfer the complex calculations for the resulting coordinate system into the C-887. The individual adapting steps can also be flexibly combined.

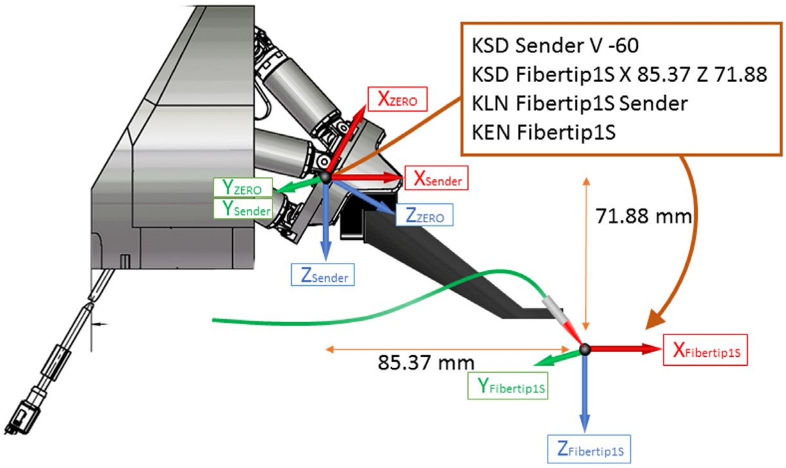


Figure 2: F-712.HA2: Shifting the center of rotation for the sender side to the fiber tip

Q: How are the fast alignment routines defined?

See “Working with Fast Alignment Routines” (p. 30) for details.

The tables in “Examples for Area Scan Routines” (p. 33) and “Examples for Gradient Search Routines” (p. 43) list the routine definition commands with their value range, default and example values.

Q: When should I use which type of area scan?

For an overview of the supported area scan types, see the description of the FDR command (p. 78).

A spiral scan omits the corners of the scan area and thus only covers about 70 % of the scan area. Therefore, a spiral scan is useful when the point of interest is in the center of the scan area. Furthermore, a spiral scan is faster than a sinusoidal scan.

When to use which type of spiral scan:

Spiral scans with constant frequency are suitable for piezo-driven axes because a constant frequency minimizes the risk of oscillations.

Spiral scans with constant path velocity should be used if the scan area is large and a spindle-driven mechanics is used (e.g., a hexapod).

Q: How can I change a routine definition?

E-712 only:
To change an already defined routine, you only have to send the changed values and can omit all unchanged optional arguments from the command.

C-887 only:
To change an already defined routine, it is recommended to send a complete definition. If you omit an optional argument, the C-887 takes the default value of this argument which could lead to undesirable effects.
If the start position of an area scan is omitted in the FDR command, the current target position of the axis is used.
The coupling settings of a gradient search routine remain unchanged when its definition is overwritten by a definition with the same routine name.

Note: In the command descriptions in this document, optional arguments are indicated by square brackets.

Q: How can I define a line scan?

To define a line scan (single-axis routine), use the FDR command (p. 78) with the sinusoidal scan type. Set <step axis> identical to <scan axis>, and set <step axis range> identical to <scan axis range>.

Q: Where are my defined routines stored?

In principle, routine definitions are stored in the volatile memory of the controller.

You can permanently store routine definitions and settings for analog inputs on the controller so that they are retained when the controller is switched off or restarted. The procedure differs for E-712 and C-887.

E-712 only:

- Use the WPA command (`WPA 100`) to save routine definitions made with FDR and FDG, and settings made with SIC for input channels.
- Routine definitions and input configurations can also be made and saved via controller parameters; for details, see “E-712 only—Fast Alignment Parameter Groups” (p. 106).
- You can also save the settings for routines and input channels via controller macros. For details, see “Controller Macros” in the E-712 user manual (PZ195E).
- In the E-712, routine definitions cannot be deleted but only overwritten. However, a routine is no longer listed with the FRR? command (p. 99) if its values for <scan axis> and <step axis> both are set to 0. To do this, switch to command level 1 and set the corresponding FA Axis parameters (0x20000000, 0x20000001) using the SPA command. Send
  - `CCL 1 advanced`
  - `SPA <Routine Name> 0x20000000 0`
  - `SPA <Routine Name> 0x20000001 0`

  where <routine name> is the identifier of the routine to be removed from the FRR? response.

  For further information on parameter handling, see “E-712 only—Fast Alignment Parameter Groups” on p. 106.

C-887 only:

- Save settings for routines and input channels via controller macros. For details, see “Controller Macros” in the C-887 user manual (MS244).
- A scan routine is deleted in the volatile memory of the controller and afterwards no longer listed with the FRR? command (p. 99), if the following is sent:
  - Area scan routines: `FDR <routine name> 0 0 0 0`
  - Gradients search routines: `FDG <routine name> 0 0`

  where <routine name> is the identifier of the routine to be deleted in the C-887.

If you work with the ***Fast Alignment*** tab card of PIMikroMove (p. 67), you can import and export routine definitions to/from the PC. This is possible regardless of whether you use an E-712 or C-887 controller.

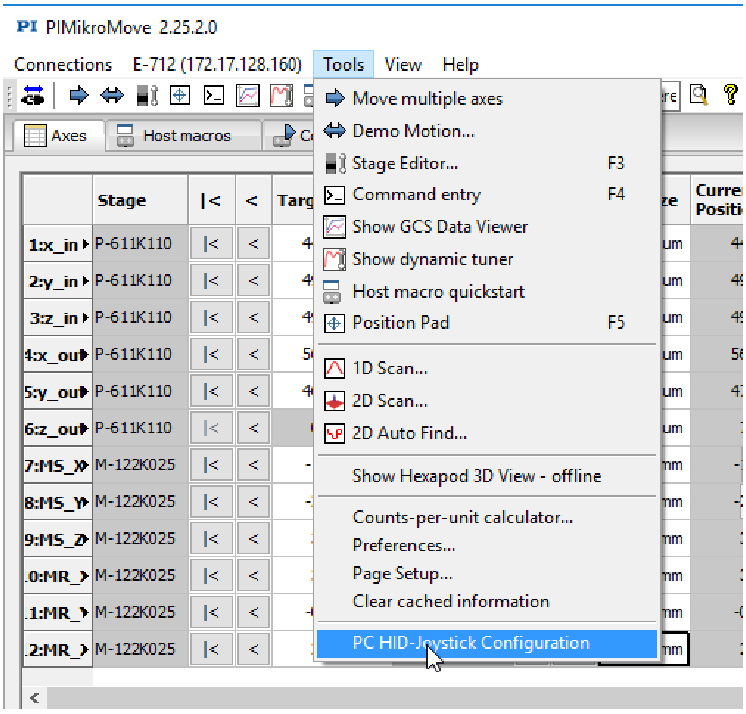
Q: How can I prepare the manual control unit for first light search?

The manual control unit was originally developed for the C-887 controller. It can be directly connected to and used with the C-887.

Now the manual control unit can also be connected to a PC and used in PIMikroMove to control axes.

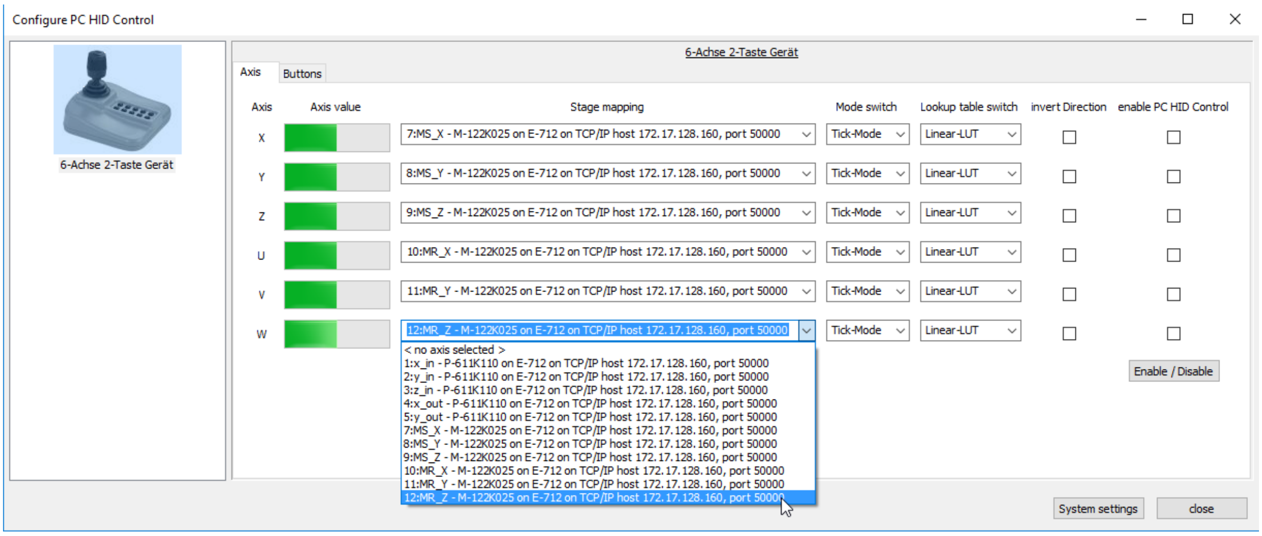
Proceed as follows to assign the axes of your alignment system to the rotary knobs of the manual control unit in PIMikroMove:

1. Connect the manual control unit to the PC via USB.
2. In the main window of PIMikroMove, open the configuration window for the manual control unit using the ***Tools > PC HID-Joystick Configuration*** menu item.

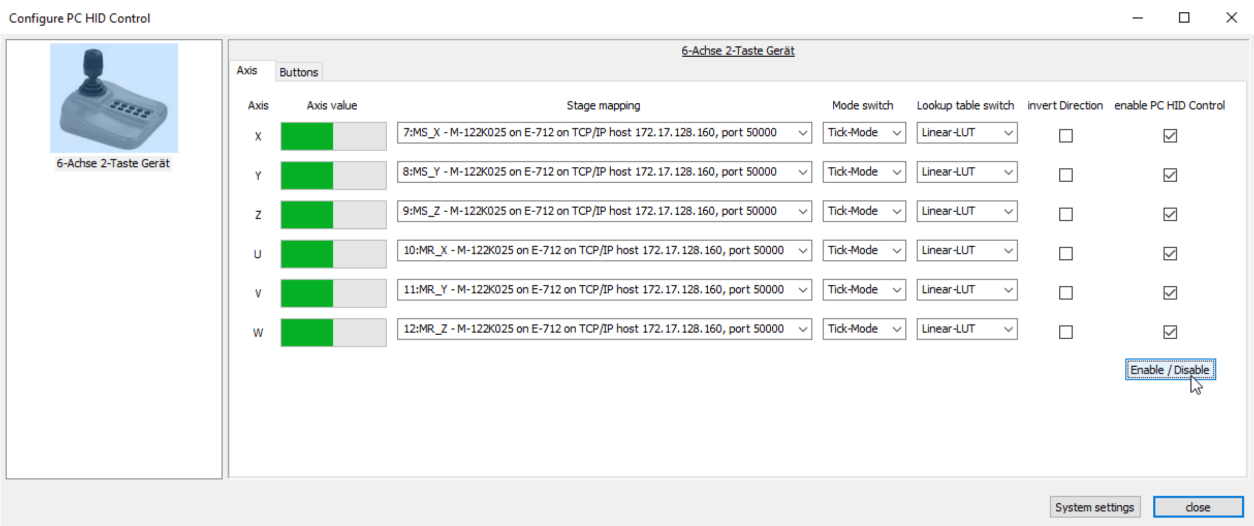


3. In the ***Configure PC HID Control*** window, assign the axes of your fast alignment system to

the rotary knobs of the manual control unit via the corresponding drop-down lists. Note that the knobs in the window are referred to as axes with the designations X to W.



4. To enable control by the manual control unit for all assigned axes, click the ***Enable/Disable*** button.

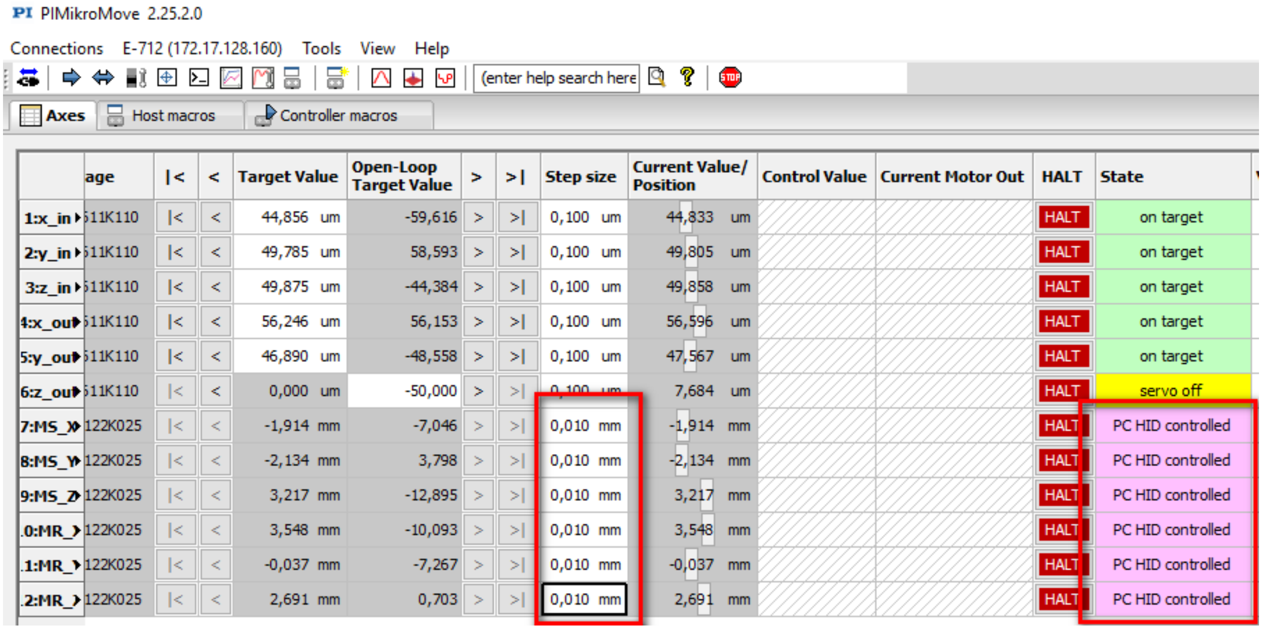


5. Click ***close*** to close the ***Configure PC HID Control*** window.

6. Move the axes using the manual control unit.

   The ***Axes*** tab card in the main window of PIMikroMove now shows that the axes are controlled by the manual control unit.

   When you turn a rotary knob, the axis is moved with each step of the knob by the distance specified in the ***Step size*** column. In the example below the distance is 10 µm per step.



7. If the adjustment of the axes is finished, open the ***Configure PC HID Control*** window again and click the ***Enable/Disable*** button to disable control by the manual control unit.

Q: Which is the best method for first light search?

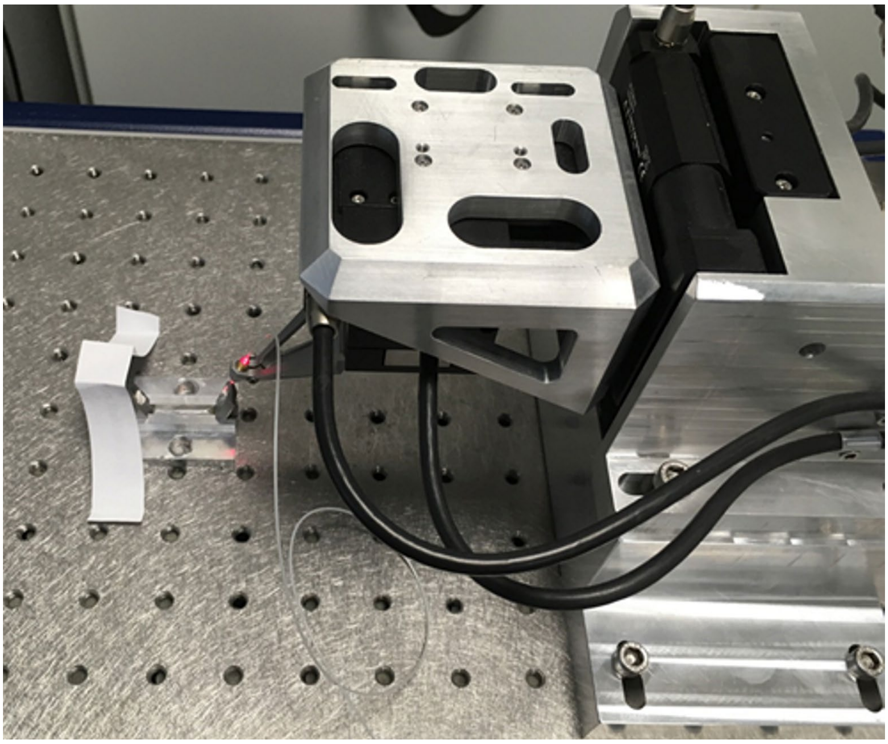
When the reference move is finished and the closed-loop performance of the piezo-driven axes has been optimized (see p. 19), the first-light search can be started. This can be done using area scan routines or by visual inspection using the C-887.MC2 manual control unit or as a combination of both methods. Typically, a first very rough adjustment is made by approaching the first light position manually within an uncertainty of ±0.5 mm and checking the alignment with the naked eye (see “Q: How do I perform the manual first light search?” below). If a microscope is used the uncertainty can probably be reduced to a range of ±50 µm. Area scan routines defined for first light search should cover this area of uncertainty (see “Q:_How do I define area scan routines for first light search?”, p. 60).

Q: How do I perform the manual first light search?

Approaching the first light position using the C-887.MC2 manual control unit is time-consuming and can require a lot of patience. In addition to the manual control unit, you need a laser source with visible light (e.g., 650 nm), a sheet of paper, and PIMikroMove if the manual control unit is connected to the PC. The workplace should be darkened.

The manual first light search with a single-sided system is described as an example. For a double-sided system, repeat the procedure for the second stack. The laser source must be installed on the stack to be adjusted, i.e. you have to move the laser source from the first stack to the second stack before you start the adjustment of the second stack.

A single-sided setup could look like that:



Principle procedure:

1. If you have connected the manual control unit to the PC and use it in PIMikroMove, prepare it as described on p. 56.
2. Connect the laser source to the fiber and position the fiber close to the optical path. If you use a lensed fiber, position the Z axis so that the focal spot is located at the height of the optical path and is as small and sharp as possible.
3. Cover the other end of the optical path with a “paper bridge” as shown in the figure above.
4. Adjust the axes using the manual control unit so that the spot can be seen on the paper bridge.

Q:_How do I define area scan routines for first light search?

The number of area scan routines to be defined depends on the system setup.

Example 1: First-Light Search with F-712.MA2

Figure 13 F-712.MA2 double-sided fiber alignment system

Three routines should run at the same time: A fast scan (routine 1) and a slow scan (routine 2) on the receiver side, and a slow scan on the sender side (routine 3).

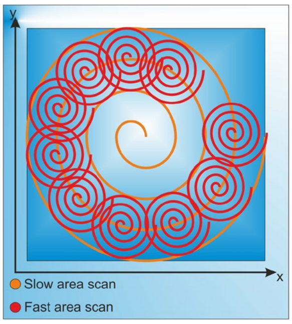


Figure 14 Fast scan and slow scan on the receiver side

While the slow scans are both defined as spiral scans with constant path velocity, the fast scan is defined as spiral scan with constant frequency.

Fast scan on the receiver side (routine 1):

The piezo-driven axes X and Y of the receiver side (identifiers 4 and 5 in the controller) are to be used for a fast area scan. The axis unit is µm. The outer diameter of the spiral should be 100 µm which is the travel range of the P-616K001 NanoCube®. The optical signal has at half intensity a width of 20 µm so that the line spacing of the spiral should be 20 µm. The spiral motion should run continuously (from inside to outside and back to inside again) until the minimum signal threshold (0.2) is reached.

FDR 1 4 100 5 100 L 0.2 A 1 F 25 V 500 MP1 50 MP2 50 TT 1 CM 0 MIIL 25 MAIL 95 ST 4

Slow scan on the receiver side (routine 2):

The spindle-driven axes X and Y of the receiver side (identifiers 10 and 11 in the controller) are to be used for the slow scan. The unit for the spindle-driven axes is mm. The outer diameter of the spiral should be 2 mm. The line spacing of the spiral should be 0.1 mm which is the travel range of the P-616K001 NanoCube®. Velocity definition: The slow scan on the sender side takes approx. 32 s to completely cover the scan area. Therefore, the spindle-driven scan axes on the receiver side may move further by a maximum of 0.1 mm (travel range of the NanoCube®) during this time. This results in a velocity of 0.003125 mm/s. The values *XX* for MP1 and *YY* for MP2 have to be replaced by suitable position values (in mm) so that the motion starts as close as possible to the optical path. The spiral motion should run only once from inside towards outside and stop immediately if the minimum signal threshold (0.2) is reached.

FDR 2 10 2 11 0.1 L 0.2 A 1 F 1 V 0.003125 MP1 *XX* MP2 *YY* TT 2 CM 0 MIIL 25 MAIL 95 ST 3

Slow scan on the sender side (routine 3):

The spindle-driven axes X and Y of the sender side (identifiers 7 and 8 in the controller) are to be used for the scan. The axis unit is mm. The outer diameter of the spiral should be 2 mm. The optical signal has at half intensity a width of 20 µm so that the line spacing of the spiral should be 0.02 mm. A constant path velocity of 5 mm/s should be used. The values *XX* for MP1 and *YY* for MP2 have to be replaced by suitable position values (in mm) so that the motion starts as close as possible to the optical path. The spiral motion should run continuously (from inside to outside and back to inside again) until the minimum signal threshold (0.2) is reached.

FDR 3 7 2 8 0.02 L 0.2 A 1 F 1 V 5 MP1 *XX* MP2 *YY* TT 2 CM 0 MIIL 25 MAIL 95 ST 4

Example 2: First-Light Search with Hexapod

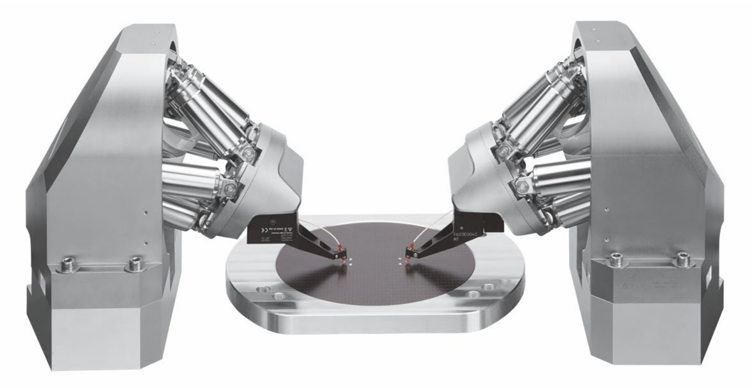


Figure 15 F-712.HA2 double-sided fiber alignment system

With an F-712.HA1, .HA2, or .HU1 system, or with H-811.F2, an area scan is defined as spiral scan with constant path velocity.

The hexapod axes X and Y are to be used for the scan. The axis unit is mm. The outer diameter of the spiral should be 2 mm. The optical signal has at half intensity a width of 15 µm so that the line spacing of the spiral should be 0.015 mm. A constant path velocity of 7.5 mm/s should be used.

The values *XX* for MP1 and *YY* for MP2 have to be replaced by suitable position values (in mm) so that the motion starts as close as possible to the optical path. The spiral motion should run only once from inside towards outside and stop immediately if the minimum signal threshold (0.2) is reached.

FDR SPIRALVEL X 2 Y 0.015 L 0.2 A 5 F 1 V 7.5 MP1 *XX* MP2 *YY* TT 2 CM 0 MIIL 10 MAIL 80 ST 3

Note for double-sided systems like F-712.HA2:

The maximum scan duration with C-887 is limited to approximately 90 s. The limitation also applies, for example, to routines that are to continuously track the signal maximum. Furthermore, the routines for the hexapods on sender and receiver side run on separate controllers.

Therefore, a first-light search with two hexapods can be defined by creating a host macro in PIMikroMove. The host macro does the following:

The sender hexapod is commanded in such a way that the X and Y axes approach individual points of a spiral path, each 20 µm apart. At each of these points, the receiver hexapod performs an area scan such as the SPIRALVEL defined above. The macro is aborted if the scan was successful.

Examples for corresponding host macros can be found on the installation media of the PI Software Suite in \Development\Macros\Samples\FastAlignment\FirstLight.

Q: How do I perform focus adjustment for a lensed fiber?

With lensed fibers, the fiber’s distance to the optical path is especially important. To make the spot as small and sharp as possible, focus adjustment may be necessary before the signal maximum can be found.

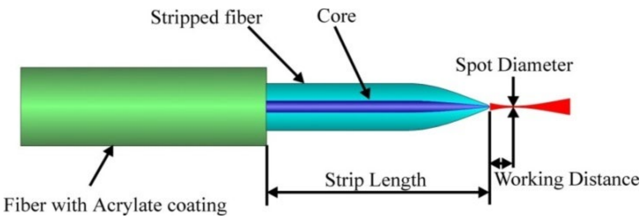


Figure 16 Spot size and working distance with a lensed fiber.
Source: http://www.nanonics.co.il/products/lensed-fiber (14.05.2019)

If the Z axis of your system is not exactly the focus axis you also need to correct axes X and Y when changing the Z axis for focus optimization.

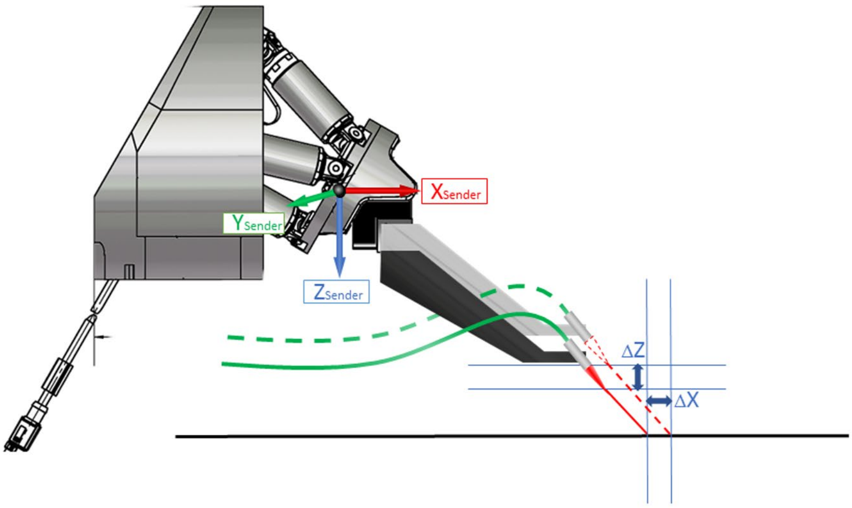


Figure 17 Motion in the direction of the fiber requires ΔX and ΔZ in the hexapod coordinate system

There is no universal 'best' approach for focus adjustment. Rather, there are different, application-dependent options, two of which are presented here:

1) Gradient search for piezo-driven axes X and Y combined with manual adjustment of the spindle-driven axis Z, and, if necessary, of spindle-driven axes X and Y.

2) Gradient search for piezo-driven axes X and Y combined with a separate, single-axis gradient search for the piezo-driven Z axis.

With a double-sided system, apply the procedure per stack.

Preparatory steps:

1. If you want to use PIMikroMove: Prepare PIMikroMove as described on p. 67 so that the necessary tabs, graphs and the floating chart of the optical signal are available.

2. Successfully complete the first-light search; see p. 58 et seq.

3. Position the piezo-driven axes in the middle of their travel ranges for maximum movement space.

4. Perform an area scan using the spindle-driven axes X and Y to analyze the optical distribution and move the axes to the found maximum.

   Focus optimization is required if the optical distribution is very wide and no distinct maximum can be seen.

Option 1—Gradient search combined with manual adjustment:

5. Define a gradient search with stop level 0 for the piezo-driven axes X and Y (the axis identifiers are 1 and 2 in this example).

   It is important that the stop level (ML <stop level>) argument of the gradient search routine has the value 0. The routine will then continuously track the maximum signal value.

   The routine definition could be as follows (routine ID is 7):
   FDG 7 1 2 ML 0 A 1 MIA 1 MAA 5 F 49 SP 60 V 200 MDC 100 SPO 0.2
6. Start the gradient search routine.
7. Optimize the focus:
   a. Move the spindle-driven Z axis using its arrow buttons on the ***Axes*** tab (the ***Step size*** column defines the distance per step). Alternatively, you can use the C-887.MC2 manual control unit (see pages 56 and 58) or send MOV commands.
   b. Check the optical signal in the floating chart. Moving the spindle-driven Z axis will change the signal.
   c. Check whether the piezo-driven axes X and Y are still moving approximately in the middle of their travel ranges.
   d. If necessary, adjust the spindle-driven axes X and Y so that the piezo-driven axes X and Y move in the middle of their travel ranges again.
   e. Repeat steps a to d until the optical signal has reached its maximum.
8. Stop the gradient search routine.

Option 2—Combined gradient searches:

5. Define the gradient search routines:

   Two gradient search routines should run simultaneously using the piezo-driven axes. It is assumed that the distribution of the optical signal differs strongly in axes X and Z, while there is only a slight difference in axes X and Y. Therefore, one routine uses axes X and Y, while the other routine uses only axis Z (the axis identifiers are 1, 2 and 3 in this example). The frequencies of both routines must differ by a reasonable value for maximum reliability. The routine definitions could be as follows:

   Routine 8 for axes X and Y:
   FDG 8 1 2 ML 0.05 A 1 MIA 1 MAA 5 F 47 SP 50.0 V 50.0 MDC 100 SPO 0.3

   Routine 9 for the Z axis:
   FDG 9 3 3 ML 0.05 A 1 MIA 5 MAA 25 F 37 SP 50.0 V 20.0 MDC 100 SPO 0.3
6. Couple the routines to each other so that they do not stop until the length of the normalized gradient vector has fallen below the given stop level for both routines.

   The coupling is done using the FRC command (p. 94) as follows:
   FRC 1 2
   FRC 2 1
7. Start the gradient search routines.

Q: How can I optimize the results of area scan routines?

Optimize the results of area scan routines via the definition settings made with the FDR command. Note that any optimization has to be made while being in focus and having light.

For the scan optimization, make sure to know the shape of the signal distribution:

- How is the signal distribution?
  - With a Gaussian distribution, set the CM argument of the FDR command to the value 1 (estimation method for the position of the signal maximum = Gaussian LS fit).
  - Adjust the values of the MIIL and MAIL arguments to exclude invalid data from the estimation. Increase the MIIL value and decrease the MAIL value.

  Example: The signal has a Gaussian distribution. All signal values that are smaller than 20 % and greater than 80 % of the recorded signal range are to be excluded from the Gaussian LS fitting. Corresponding routine definition:
  FDR … CM 1 MIIL 20 MAIL 80 …

- How is the expected signal maximum?
  - Set the L argument of the FDR command to half the expected signal maximum.

  Example: The expected signal maximum is 2.5 V. Corresponding routine definition:
  FDR … L 1.25 …
- How is the width of the optical signal at half intensity (FWHM)?
  - Set the line spacing of the scan so that it does not exceed the FWHM of the measured signal.

  Example: The optical signal has at half intensity a width of 20 µm so that the line spacing of the scan should be 20 µm. Because a hexapod is to be used, the axis unit is mm.
  Routine definition for a sinusoidal scan (line spacing = V/2*F):
  FDR … F 3.5 V 0.14 …
  Routine definition for a spiral scan with constant frequency (line spacing = V / F):
  FDR … F 7 V 0.14
  Routine definition for a spiral scan with constant path velocity (line spacing = <step axis range>
  FDR <routine name> <scan axis> <scan axis range> <step axis> 0.02 …

  If piezo-driven axes are used for sinusoidal scans or spiral scans with constant frequency: Make sure that the frequency value does not exceed the frequency used during the adjustment of the closed-loop performance (p. 19; e.g. ≤50 Hz for P-616K001).

Q: How can I optimize the results of gradient search routines?

Optimize the results of gradient search routines via the definition made with the FDG command. Note that any optimization requires that a signal maximum has already been found before.

- The typical minimum radius R_{min} of the circular motion (MIA argument of FDG) is around 1/10 the width of the optical signal at half intensity (FWHM).
- The typical maximum radius R_{max} of the circular motion (MAA argument of FDG) is perhaps 2-5 times R_{min}.
  E-712 only: If a fixed radius is desired, set R_{min} and R_{max} identically.
- Frequency setting (F argument of FDG):
  - Make sure that the frequencies differ by reasonable values for all routines which should run at the same time in the same system.
  - Do not use a frequency that excites resonances in your setup (see “Identify the Resonant Frequencies of the System”, p. 25).
  - For piezo-driven axes, make sure that the frequency value does not exceed the frequency used during the adjustment of the closed-loop performance (p. 19; e.g. $\leq$50 Hz for P-616K001).
- The typical alignment satisfaction criterion (ML argument of FDG) is around 0.05.

Q: How can I minimize the gradient search time?

You can adjust the speed factor of the gradient search (SP argument of the FDG command). The greater the speed factor, the faster is the circular motion in the direction of the signal maximum. The routine can become instable when the value of the speed factor is too high, while a speed factor that is too low can lead to creep effects.

Note that the speed factor value and its influence differ for piezo-driven axes and spindle-driven axes, for details, see “Application Notes for Gradient Search Routines” on p. 46.

1. Define a gradient search routine with a medium speed factor, e.g., 25 for piezo-driven axes.
2. Start the routine.
3. When the routine is finished, query the routine results. Result ID 5 gives the routine time.
4. Minimize the routine time:
   1. Increase the speed factor of the routine; for piezo-driven axes, by the value 10.
   2. Restart the routine.
   3. When the routine is finished, check the routine time.
   4. Adjust the speed factor this way until the routine time is minimized.

   - E-712 only: Note that you can also change the speed factor while the gradient search is running. Use the SPA command with the FA Gradient Search Speed Factor parameter (ID 0x20000700).

Q: What should I consider in terms of the mechanics lifetime?

Working with F-712 alignment systems means that *you* define and perform multiple fast alignment routines. In principle, you can use every axis for every alignment task—there are no axis restrictions or preselections stored in the system. But in terms of the mechanics lifetime (and, of course, also in terms of the routine optimization), you should consider some general recommendations:

You should solve the alignment tasks as far as possible using the piezo-driven axes, i.e. the axes of the P-616K001 NanoCube® nanopositioner. With the NanoCube®, in contrast to motorized drives, there are no rotating parts or friction. The piezo actuators are therefore free of backlash, maintenance, and wear. In addition, the flexure guides of the NanoCube® are maintenance and wear free.

Use the spindle-driven axes, i.e. the axes of the H-811 hexapod or the stacked M-122K025 XYZ linear stages, only for the rough optimization during the first-light search, and if focus adjustment is necessary during fine alignment. Keep in mind that with motorized axes, frequent motions over a limited travel range can cause the lubricant to be unevenly distributed in the drive train:

- For the axes of the H-811 hexapod or the stacked M-122K025 XYZ linear stages, carry out a maintenance run over the entire travel range at regular intervals (see documentation of the mechanics). The more often motions are carried out over a limited travel range, the shorter the time between the maintenance runs has to be.

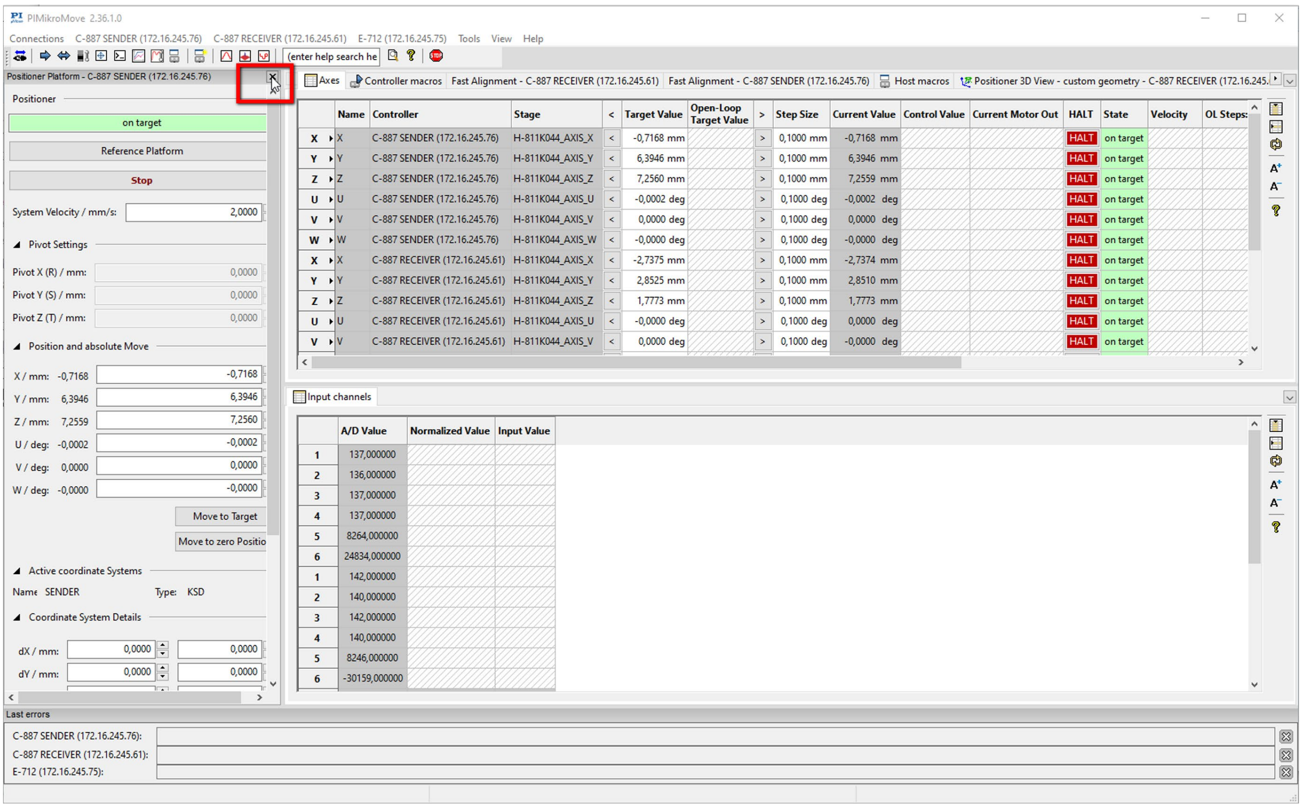
Q: How can I prepare and use PIMikroMove for fast alignment?

In the example below, an F-712.HA2 alignment system is connected (one E-712 controller, two C-887 controllers). All axes are ready for operation.

If you use the ***Fast Alignment*** tab card(s) of PIMikroMove to define routines, note that the decimal separator depends on the regional settings of your computer's Windows operating system, whereas in the examples in this manual and in the ***Command entry*** window of PIMikroMove it is always a period.

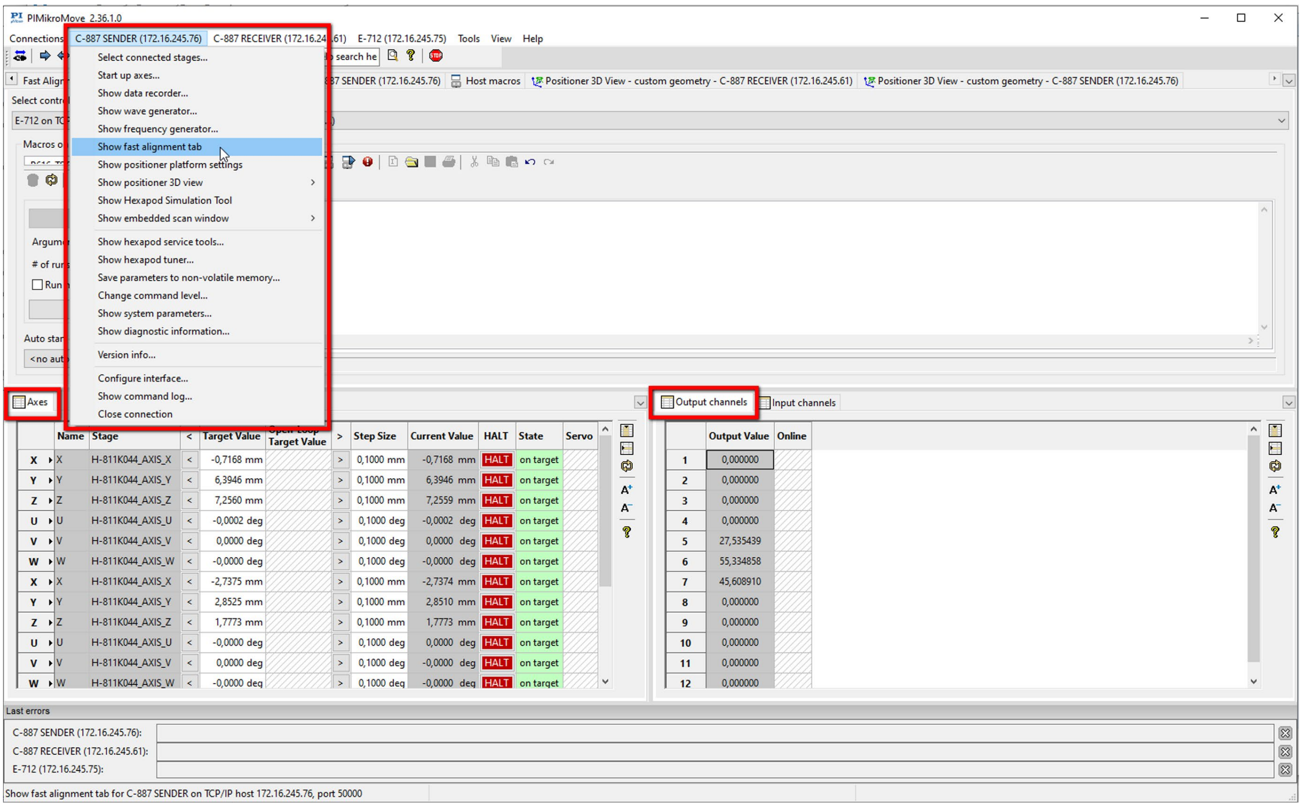
Adapt the main window layout as follows:

Close the ***Positioner Platform*** windows (if you need them later, e.g., to check coordinate system definitions for the hexapods, open them via the ***C-887 > Show Positioner Platform Settings*** menu item).

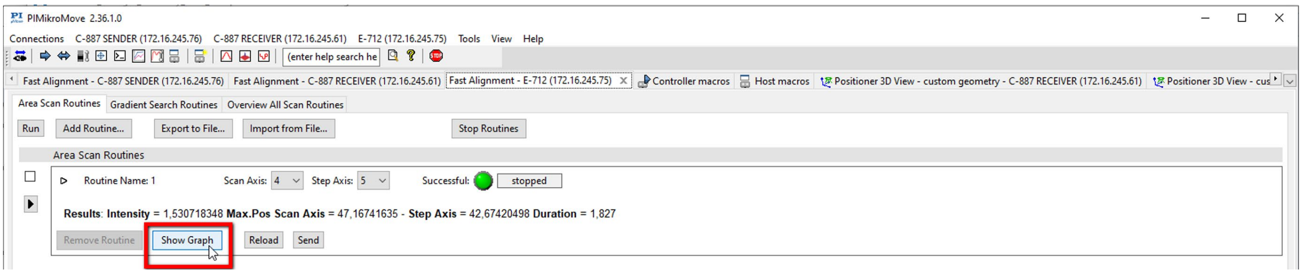


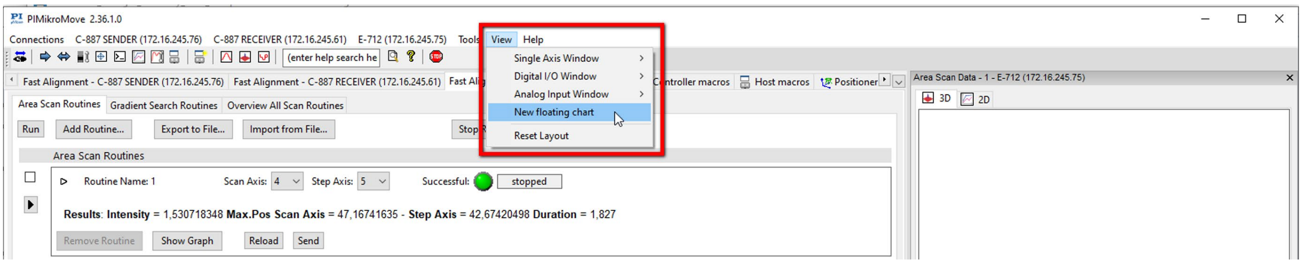
PIMikroMove 2.36.1.0
Connections C-887 SENDER (172.16.245.76) C-887 RECEIVER (172.16.245.61) E-712 (172.16.245.75) Tools View Help
Positioner Platform - C-887 SENDER (172.16.245.76)
Positioner
on target
Reference Platform
Stop
System Velocity / mm/s:
Pivot Settings
Position and absolute Move
Move to Target
Active coordinate Systems
Coordinate System Details
Axes
Controller macros
Fast Alignment - C-887 RECEIVER (172.16.245.61)
Fast Alignment - C-887 SENDER (172.16.245.76)
Host macros
Input channels
Last errors

Show the ***Fast Alignment*** tab cards for each controller. Move the tab cards for axes, fast alignment and channels to the desired positions by drag and drop.

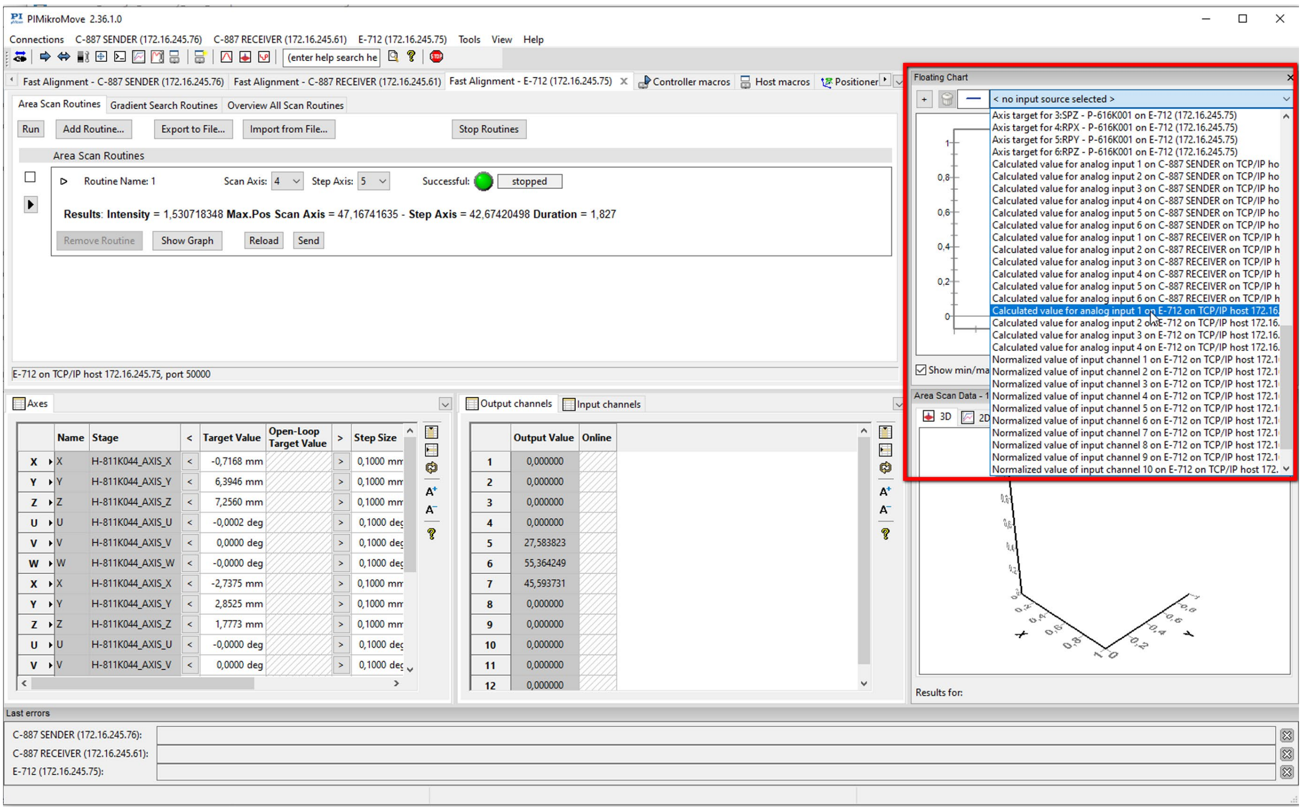


Show the graphs for the routines and the floating chart for the analog input.

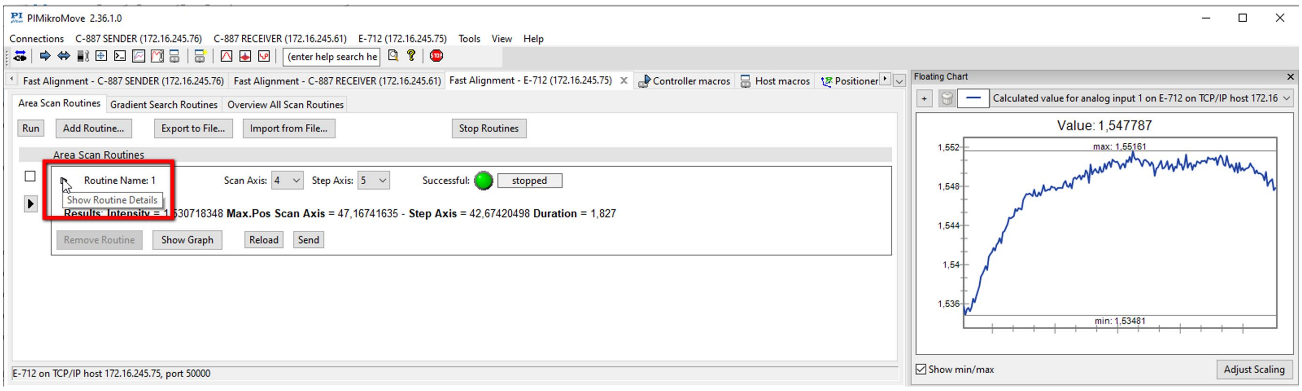


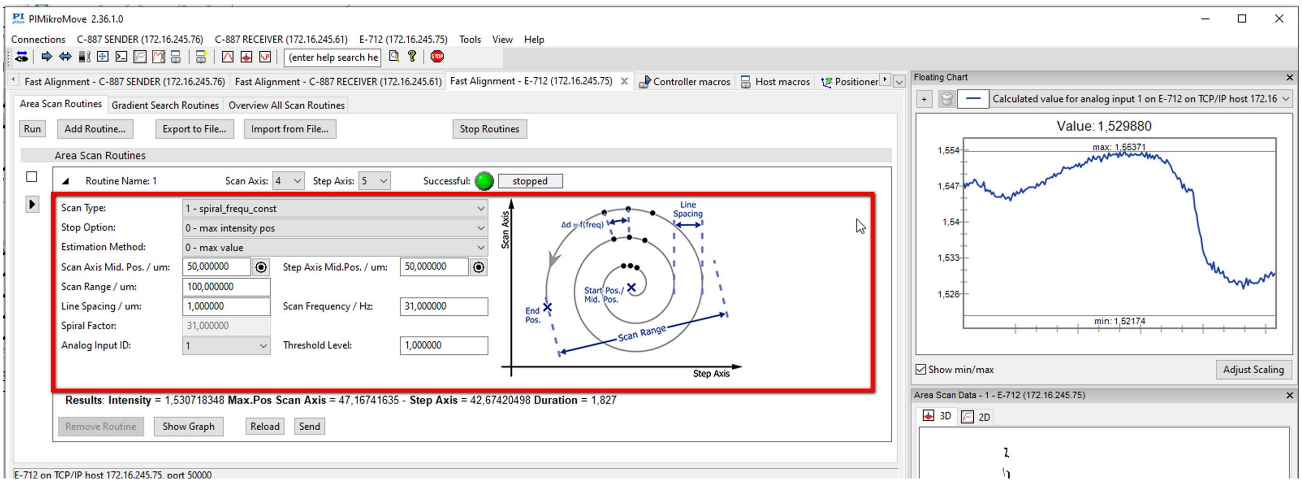


Dock the floating chart in the main window. Select an analog input that carries the output of the measurement device, and to which the calculation by the controller (p. 102) has been applied (*Calculated value for analog input …*). In this example, the input of the E-712 is selected, but you could also select input 5 of one of the C-887 controllers. Note that the signal values can differ if the controllers use different calculation settings.



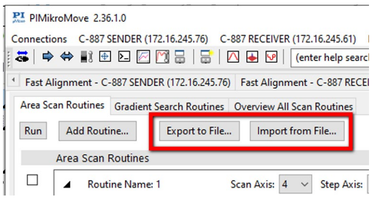
Show routine details.



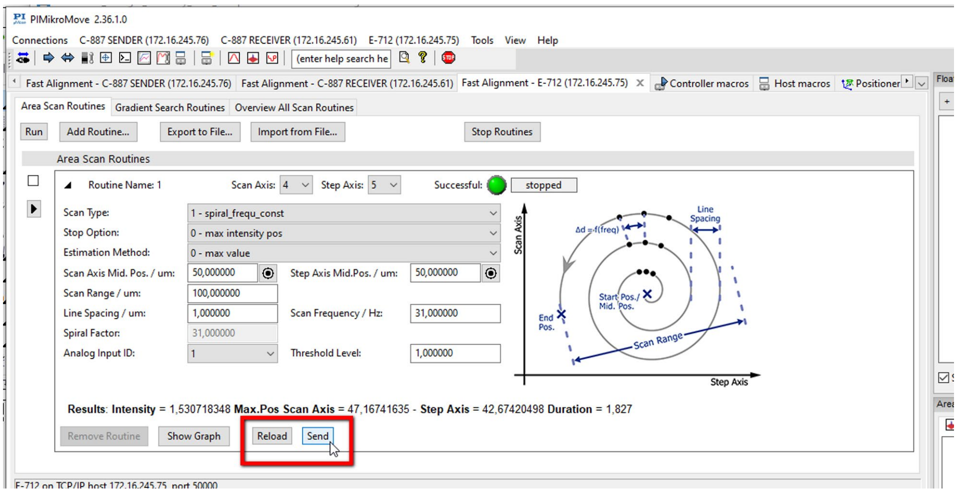


On the ***Fast Alignment*** tab cards, define routines as desired. Each card belongs to one controller. A ***Fast Alignment*** tab card has tabs for area scan routines, gradient search routines, and for an overview of all routines that are currently defined for the controller. For details on routine definition, see p. 30.

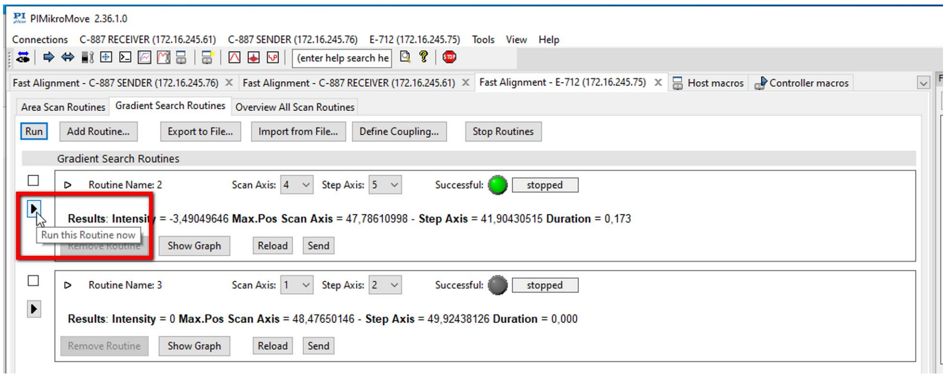
On the ***Fast Alignment*** tab cards, you can export routine definitions to files on the PC and import them from the PC into PIMikroMove.



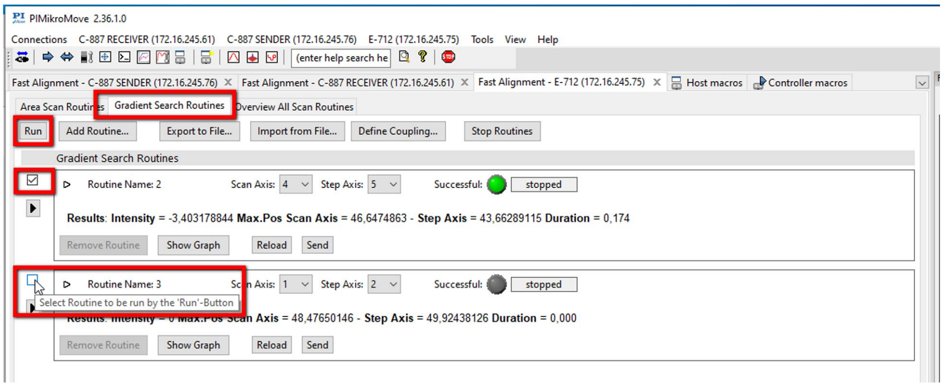
Before you can run a routine, you have to send the definition to the controller using the ***Send*** button (to read the current routine settings from the controller, use the ***Reload*** button).



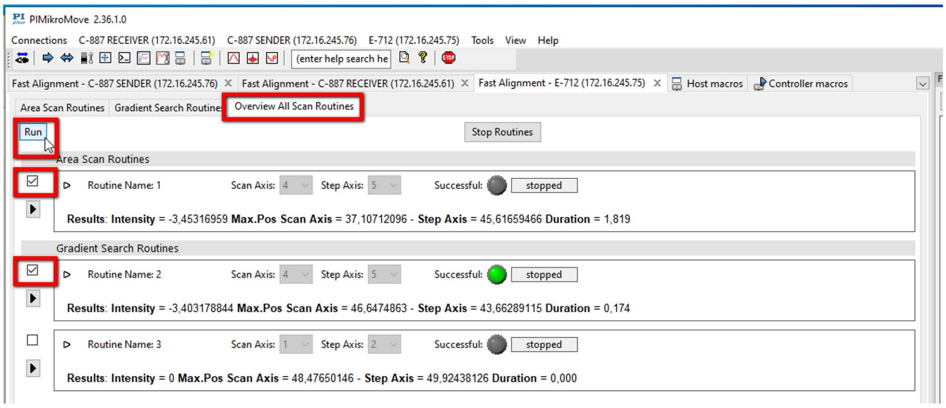
To run a single routine, click the ***Run this Routine now*** button of the routine.



To start multiple gradient search routines of one controller simultaneously, check its boxes on the tab for gradient search routines, and then click the ***Run*** button. To start multiple area scan routines simultaneously, proceed in the same way on the tab for area scan routines.

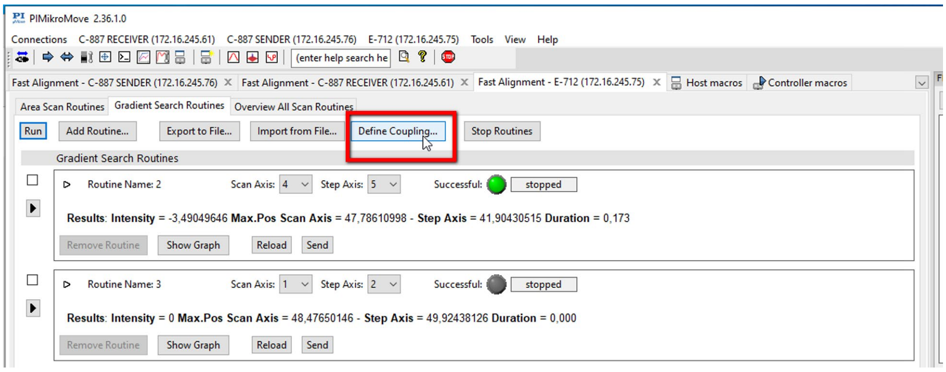


You can also start area scan routines together with gradient search routines. To do this, check the corresponding boxes on the ***Overview All Scan Routines*** tab and then click the ***Run*** button.



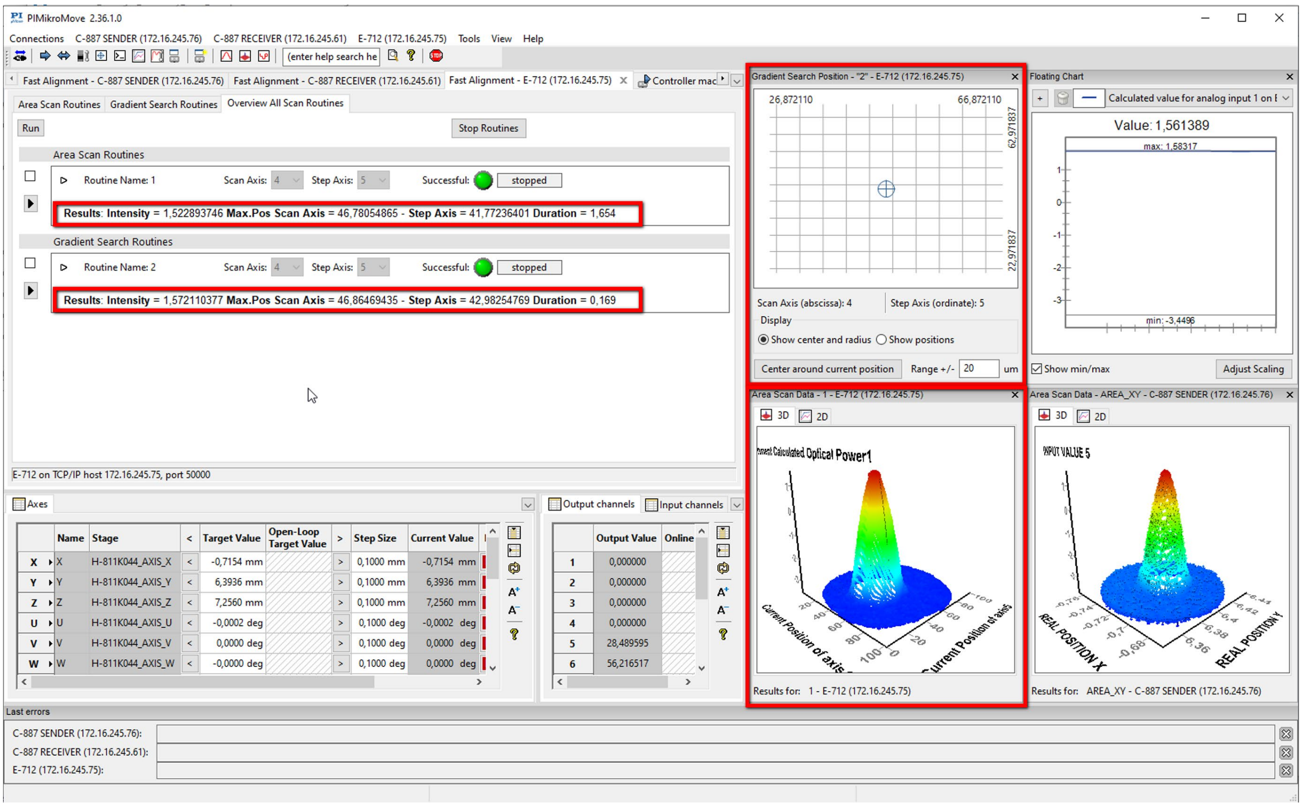
For further details on starting multiple routines simultaneously, see the FRS command (p. 95).

If you want to couple gradient search routines to each other, configure the coupling **before** you start these routines simultaneously. To configure the coupling, open a corresponding dialog using the ***Define Coupling…*** button on the tab for gradient search routines. For details on coupling of gradient search routines, see the FRC command (p. 94).

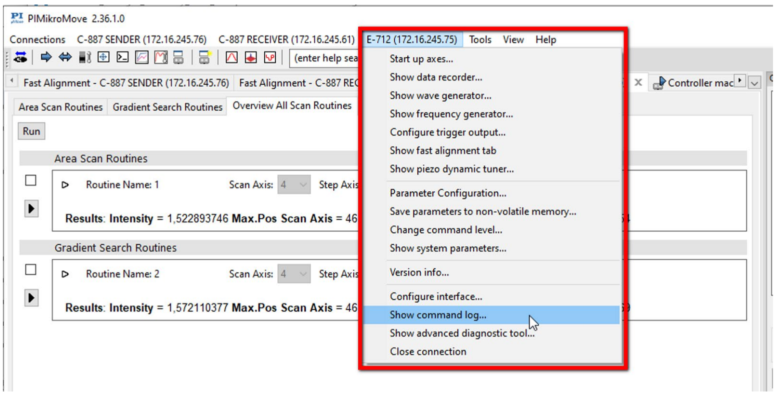


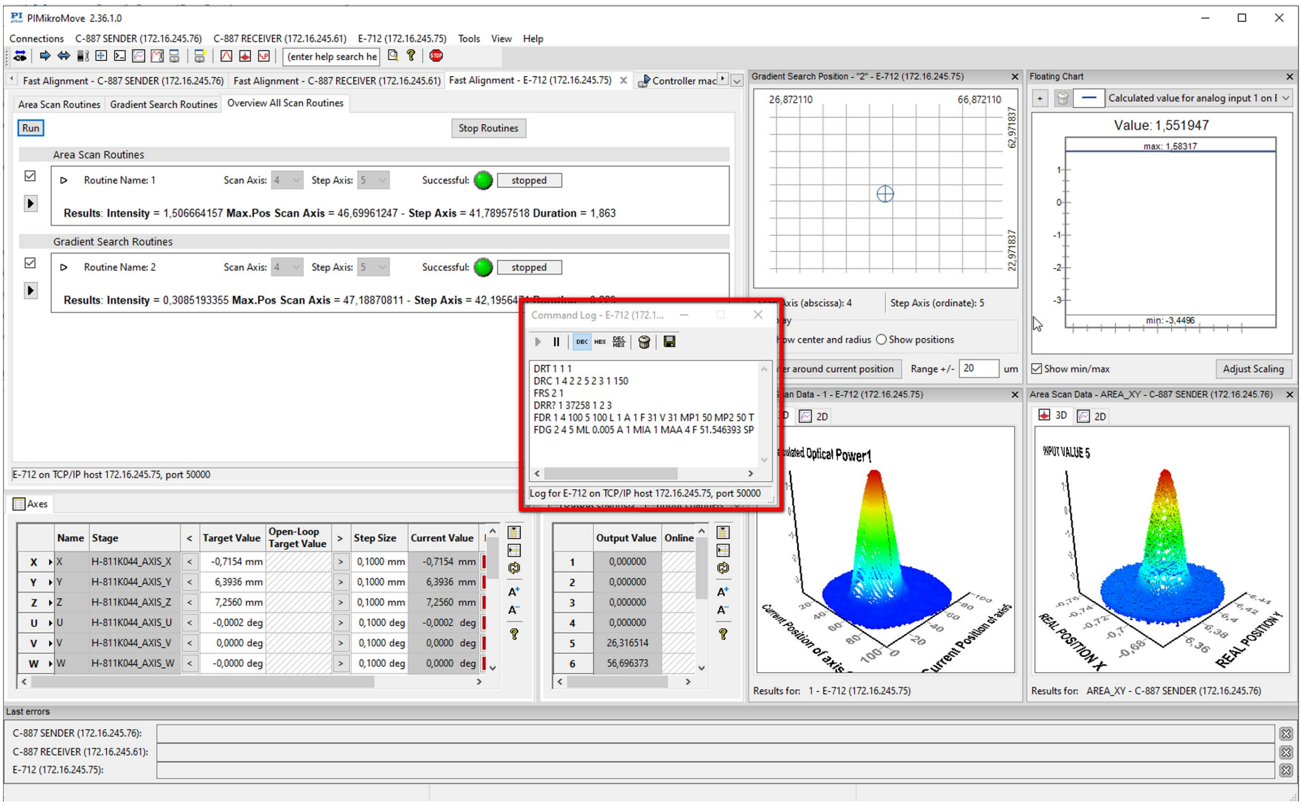
The results of the routines are shown on the corresponding routine tabs. The ***Overview All Scan Routines*** tab shows the results for *all* routines of a controller. Furthermore, see the graphs for the routines.

Results for the area scan and gradient search routines, shown here on the ***Overview All Scan Routines*** tab using the example of E-712:



If you want to see the commands sent by PIMikroMove when you use the program's controls, open the log window. A log window is provided for each controller connected to PIMikroMove.





Q: What should I consider when using PIMikroMove to optimize and analyze the system?

Backup

Before you change parameter values of the E-712, create a backup file. See "Create Backup File for Controller Parameters" in the E-712 user manual for more information.

Password

Enter the password “advanced” when prompted to change to command level 1.

Preparation of PIMikroMove

For general information, see the FAQ section “Q: How can I prepare and use PIMikroMove for fast alignment?” on p. 67.

Make sure that the main window of PIMikroMove shows the tab card ***Output channels***. The ***Output channels*** tab card is required to monitor the output voltage for the piezo actuators of the piezo-driven axes during the adjustment of the dynamic performance.

Depending on the task to be solved, you need the following windows of PIMikroMove in addition to the main window:

- ***Data Recorder***
- ***Piezo Dynamic Tuner***
- ***PI Frequency Generator Tool***
- ***Device Parameter Configuration*** (needs LabWindows™/CVI™ 2012 that is provided with the PI Software Suite)

Data recording

- In the main window of PIMikroMove, open the ***Data Recorder*** window via the ***E-712… > Show data recorder …*** menu item. Click the ***Configure Curves…*** button in the ***Data Recorder*** window to open a separate dialog where you can configure the data recorder settings. For details on the ***Data Recorder*** window, see the PIMikroMove software manual (SM148E).
- You can save some of the data recorder settings to the nonvolatile memory of the E-712 to keep them when the controller is switched off or rebooted, see “Data Recording” in the E-712 user manual for more information.

Piezo Dynamic Tuner

- In the main window of PIMikroMove, open the ***Piezo Dynamic Tuner*** window via the ***E-712… > Show piezo dynamic tuner …*** menu item.
- If you change a parameter by entering a value: The value is displayed in a blue font until you press Enter on your keyboard. Pressing Enter sends the value to the E-712 and changes the font color from blue to black. For fields highlighted by a red background, the parameter values in volatile and nonvolatile memory of the E-712 differ.

- The axis to be tuned is selected via the ***Axis*** selection field at the top of the window.
- The settings in the ***Parameter Settings*** panel can be saved to the nonvolatile memory of the E-712 with the ***Save as Default (EEPROM)*** button so that they are still available after the next switch-on or reboot.
- For a general description of how to work with the ***Piezo Dynamic Tuner*** window, see "Servo-Controller Dynamic Tuning" in the E-712 user manual (PZ195E). But do **not** follow the adjustment instructions for notch filter and servo-control parameters in the E-712 user manual because they are based on different requirements which do **not** match the requirements of fast alignment routines. Follow the instructions on p. 19 for the adjustment of the piezo-driven axes instead.

PI Frequency Generator Tool

- This tool is recommended to move the axes simultaneously by a sine curve during the adjustment of the servo-loop parameters.
- In the main window of PIMikroMove, open the ***PI Frequency Generator Tool*** window via the ***E-712… > Show frequency generator …*** menu item.
- For details on the ***PI Frequency Generator Tool***, see the PIMikroMove software manual (SM148E).

Device Parameter Configuration

- In the main window of PIMikroMove, open the ***Device Parameter Configuration*** window via the ***E-712… > Parameter Configuration …*** menu item.
- You can create a backup file for the controller parameters.
- You can check, modify or save parameters that are not accessible in the ***Piezo Dynamic Tuner*** window.
- In the ***Axis Matrices*** window (open via ***View -> Axis Matrices*** menu item), you can identify the assignment of the output channels (piezo actuators) to the piezo-driven axes. Knowledge of the assignment is required when you monitor the piezo output voltage during the adjustment of the dynamic performance.
- For details on the ***Device Parameter Configuration*** window, see the PIMikroMove software manual (SM148E).

Fast Alignment Commands

Command Overview

Command	Syntax	Description
FDR (p. 78)	FDR <routine name> <scan axis> <scan axis range> <step axis> <step axis range> [L <threshold level>] [A <alignment signal input channel>] [F <frequency>] [V <velocity>] [MP1 <scan axis middle position>] [MP2 <step axis middle position>] [TT <target type>] [CM <estimation method>] [MIIL <minimum level of fast alignment input>] [MAIL <maximum level of fast alignment input>] [ST <stop position option>]	Defines a fast alignment area scan routine. The current valid definition can be queried with FRR?
FDG (p. 87)	FDG <routine name> <scan axis> <step axis> [ML <stop level>] [A <alignment signal input channel>] [MIA <min radius>] [MAA <max radius>] [F <frequency>] [SP <speed factor>] [V <max velocity>] [MDC <max direction changes>] [SPO <speed offset>]	Defines a fast alignment gradient search routine. The current valid definition can be queried with FRR?
FGC (p. 92)	FGC {<routine name> <scan axis center position> <step axis center position>}	Changes the center position of a gradient search routine that is currently running.
FGC? (p. 93)	FGC? [{<routine name>}]	Gets the current center position of a gradient search routine.
FRC (p. 94)	FRC <routine name> {<routine name coupled>}	Couples fast alignment routines to each other.
FRC? (p. 95)	FRC? [{<routine name>}]	Gets coupled fast alignment routines.
FRS (p. 95)	FRS {<routine name>}	Starts a fast alignment routine.
FRP (p. 97)	FRP {<routine name> <routine action>}	Stops, pauses or resumes a fast alignment routine.
FRP? (p. 98)	FRP? [{<routine name>}]	Gets the current state of a fast alignment routine.
FRR? (p. 99)	FRR? [<routine name> [<result ID>]]	Gets the results of a fast alignment routine.
FRH? (p. 101)	FRH?	Lists descriptions and physical units for the routine results that can be queried with the FRR? command.
SIC (p. 102)	SIC <FA input channel ID> <calculation type> [{<calculation parameter>}]	Defines calculation settings for an analog input channel.

Command	Syntax	Description
SIC? (p. 104)	SIC? [{<FA input channel ID>}]	Gets the calculation settings for an analog input channel.
TAV? (p. 105)	TAV? [{<FA input channel ID>}]	Gets voltage value of an analog input channel.
TCI? (p. 105)	TCI? [{<FA input channel ID>}]	Gets calculated value of an analog input channel.

Command Descriptions

FDR (Set FA Area Scan Definition)

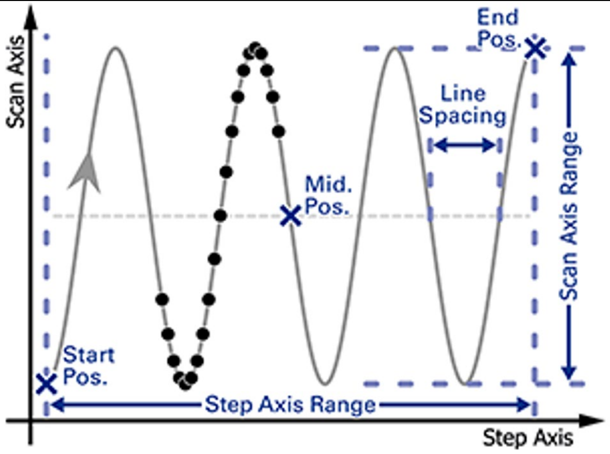
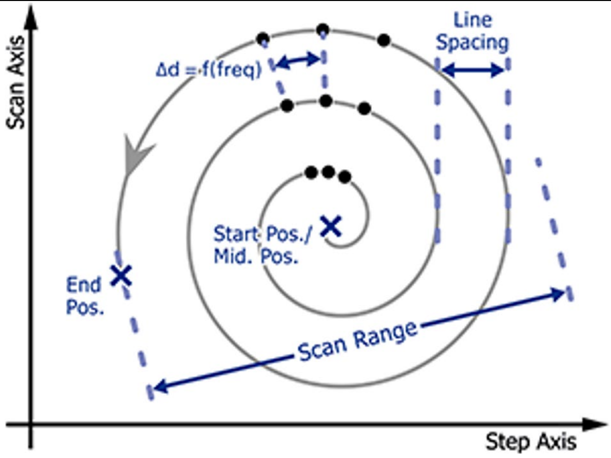
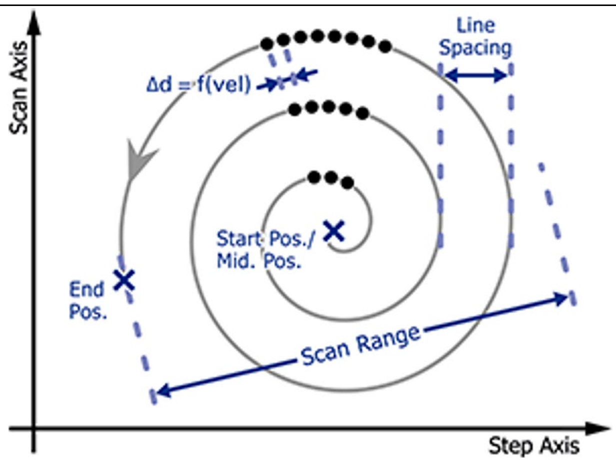
Description: Defines a fast alignment area scan routine.

Area scan routine details:

An area scan is performed to find the position of the global signal maximum of the measured signal in a given area. The unit of the signal depends on the calculation settings made with the SIC command (p. 102).

The routine determines the position of the signal maximum based on measurement data recorded during the scan. The distribution of the data points varies depending on the scan type, see the figures below.

The following types of area scans are supported:

Scan Types	
Sinusoidal scan (default with C-887)	
Spiral scan with constant frequency (default with E-712)	
Spiral scan with constant path velocity	

An area scan routine has been successfully completed when the following condition has been met:

- The signal has reached a given minimum threshold in the scanned area at least once.

An area scan has been unsuccessfully completed in the following cases:

- The given minimum threshold has not been reached in the scanned area.
- The found position of the global maximum results from an estimation method (see below for details) and is outside of the scan axis range and/or the step axis range.
- FRP with stop action, #24, STP or HLT has been sent: Scan and step axis remain in the current position.
- The routine was stopped because at least one of the axes involved reached a soft limit.
- E-712 only: The routine was stopped via an input signal channel. Scan and step axis remain in the current position.

The maximum number of routines that can be defined depends on the controller:

- E-712: The maximum number of routines is identical to the number of axes of the controller.
- C-887: The maximum number of routines is 100.

Use FRS to start the routine. With FRR?, you can read out the definition and the results of the routine.

Routine definitions can be stored in the controller, for details, see the FAQ section “Q: Where are my defined routines stored?” (p. 55).

The tables in “Examples for Area Scan Routines” (p. 33) list the arguments of the FDR command with their value range, default and example values.

Arguments in square brackets are optional. If an optional argument is omitted in the FDR command, the following value will be taken:

- E-712: The last valid value of the argument will be taken from the volatile memory of the controller.
- C-887: The default value of the argument will be taken. For the default values, see “Working with Fast Alignment Routines” (p. 30). If the start position is omitted, the current target position of the axis is used.

E-712 only: The settings defined with FDR can also be made by changing parameters with SPA (for the corresponding parameters see the tables on p. 108 and p. 111).

Format: FDR <routine name> <scan axis> <scan axis range> <step axis> <step axis range> [L <threshold level>] [A <alignment signal input channel>] [F <frequency>] [V <velocity>] [MP1 <scan axis middle position>] [MP2 <step axis middle position>] [TT <target type>] [CM <estimation method>] [MIIL <minimum level of fast alignment input>] [MAIL <maximum level of fast alignment input>] [ST <stop position option>]

Arguments: <routine name>

The identifier of the routine.
With E-712: Can be 1, 2, …, n, where n is the number of axes of the controller. Note that the <routine name> value is to be used as item identifier when changing parameters of the Fast Alignment Routines parameter group with SPA or SEP commands.
With C-887: String consisting of characters. Blanks or special characters are not allowed.

<scan axis>

Identifier of the axis that is to be the master axis of the scan routine.

Sinusoidal scan: The scan axis follows a sine curve.

<scan axis range>

Scan range for the scan axis.

Spiral scans: The scan axis range value gives the final diameter of the spiral.

Sinusoidal scan: The range value is used to calculate the start and end position for the scan axis as follows (middle position is given by MP1, see below):
Start position = scan_axis_middle_position – scan_axis_range/2
End position = scan_axis_middle_position + scan_axis_range/2

<step axis>

Identifier of the step axis.

Sinusoidal scan: The step axis follows a ramp. To define a line scan (single-axis routine), set <step axis> identical to <scan axis>.

<step axis range>

Scan range for the step axis.

Spiral scan with constant frequency: The step axis range value is not used.

Spiral scan with constant path velocity: The step axis range value gives the line spacing of the spiral.

Sinusoidal scan: The range value is used to calculate the start and end position for the step axis as follows (middle position is given by MP2,

see below):
Start position = step_axis_middle_position – step_axis_range/2
End position = step_axis_middle_position + step_axis_range/2.
If <step axis> is set identical to <scan axis> to define a line scan (single-axis routine), <step axis range> must be identical to <scan axis range>.

[L <threshold level>]

L: Required keyword

<threshold level>: Minimum threshold of the analog input signal. If during an area scan routine no value of the analog input signal is equal to or greater than the given minimum threshold level, FRR? will report “not successful” for the routine. Note that <threshold level> is applied to the signal after it has been subjected to the calculations set with the SIC command (p. 102).

[A <alignment signal input channel>]

A: Required keyword

<alignment signal input channel>: Identifier of the analog input channel whose maximum value is sought:

- E-712: Identifier of a fast alignment input channel. For details, see “Fast Alignment Parameter Groups” (p. 106).
- C-887: 5 for the **Analog In 5** BNC socket, 6 for the **Analog In 6** BNC socket (present with C-887.5x1 and C-887.5x3 models)

[F <frequency>]

F: Required keyword

<frequency>: Frequency of the scan axis.

Spiral scan with constant frequency: The frequency value is used to calculate the line spacing of the spiral, see TT (p. 83).

Spiral scan with constant path velocity: The frequency value is ignored.

Sinusoidal scan: The frequency value gives the frequency of the sine curve for the scan axis.

[V <velocity>]

V: Required keyword

<velocity>: Velocity of the step axis.

Spiral scan with constant frequency: The velocity value is used to calculate the line spacing of the spiral, see TT (p. 83).

Spiral scan with constant path velocity: The velocity value gives the path velocity.

Sinusoidal scan: The velocity value gives the velocity with which the step axis follows a ramp from (step_axis_middle_position – step_axis_range/2) to (step_axis_middle_position + step_axis_range/2).

If the velocity set with VEL or VLS for the step axis is lower than the value given by <velocity>, the velocity is limited to the VEL or VLS value.

[MP1 <scan axis middle position>]

MP1: Required keyword

<scan axis middle position>: Middle position of the scan range for the scan axis.

Spiral scans: The value gives the start position for the scan axis.

Sinusoidal scan: The value is used to calculate the start and end position for the scan axis, see description of <scan axis range> above.

C-887 only: If [MP1 <scan axis middle position>] is omitted in the FDR command, the current target position of the scan axis is used instead.

[MP2 <step axis middle position>]

MP2: Required keyword

<step axis middle position>: Middle position of the scan range for the step axis.

Spiral scans: The value gives the start position for the step axis.

Sinusoidal scan: The value is used to calculate the start and end position for the step axis, see description of <step axis range> above.

C-887 only: If [MP2 <step axis middle position>] is omitted in the FDR command, the current target position of the step axis is used instead.

[TT <target type>]

TT: Required keyword

<target type>: ID of the area scan type. Possible values:

0 = sinusoidal scan (scan axis follows a sine curve, step axis follows a ramp). See p. 79 for a graphical representation.

1 = spiral scan with constant frequency.
The spiral is defined by:
<scan axis range> gives the final diameter
line spacing of the spiral = velocity/frequency
For velocity and frequency, see V and F above.
See p. 79 for a graphical representation.

2 = spiral scan with constant path velocity.
The spiral is defined by:
<scan axis range> gives the final diameter
<step axis range> gives the line spacing of the spiral

<velocity> gives the path velocity
See p. 79 for a graphical representation.
To keep the path velocity constant, the frequency is constantly changed during the spiral motion, and the frequency given by <frequency> (see F above) is ignored.

[CM <estimation method>]

CM: Required keyword

<estimation method>: ID of the estimation method for the position of the global signal maximum. There are several methods to estimate this position based on the measurement data recorded during the scan routine:

0 = global maximum is at the position where the maximum value was recorded

1 = position of global maximum is calculated from the recorded data using a Gaussian LS fit.

2 = position of global maximum is calculated from the recorded data using an analogy to a center-of-gravity calculation

With method 1 and 2, the data to be used for the calculation can be limited to a certain signal range via MIIL and MAIL, see below.

[MIIL <minimum level of fast alignment input>]

MIIL: Required keyword

<minimum level of fast alignment input>: Minimum signal value to be used for estimation method 1 or 2 (see CM above), in % of the signal range that has been recorded.

[MAIL <maximum level of fast alignment input>]

MAIL: Required keyword

<maximum level of fast alignment input>: Maximum signal value to be used for estimation method 1 or 2 (see CM above), in % of the signal range that has been recorded.

[ST <stop position option>]

ST: Required keyword

<stop position option>: ID of the position to be approached by scan axis and step axis when the area scan routine has been completed:

0 = move to scan axis and step axis position with the signal maximum
1 = stay at the end position of the area scan routine
2 = move to the start position of the area scan routine
3 = stop at the position where the minimum signal threshold is reached (given by <threshold level>).
If the area scan has been unsuccessfully completed, scan axis and step axis move back to the start position of the area scan routine.

E-712 only: 4 = continuously scan the area and stop at the position where the minimum signal threshold is reached (given by <threshold level>). The motion continues from start position to end position and back until the threshold is reached or the routine is stopped with FRP, #24, STP or HLT. If a stop command has been sent: Scan and step axis remain in the current position.

Additional setting: **E-712 only: Type of fast alignment routine:**

The routine type is defined via the value of the ***FA Routine Type*** parameter (ID 0x20000F00) as follows:

0 = idle routine (prevents the routine from running when started with FRS)

1 = area scan routine

2 = gradient search routine

The parameter value is set automatically in volatile memory when FDR or FDG commands are sent to configure a routine (sending FDR sets the value to 1; sending FDG sets the value to 2). You can also set the parameter with SPA or SEP commands.

E-712 only: Use an input signal channel for stop function:

An input signal channel of the controller can be used to stop the fast alignment routine. The ***FA Input Channel To Stop Motion*** parameter (ID 0x20002C00) specifies the ID of the input signal channel. The stop function is triggered if the input exits the permissible range specified by the parameters ***FA Input Lower Threshold To Stop Motion*** (ID 0x20002D00) and ***FA Input Upper Threshold To Stop Motion*** (ID 0x20002D01).

Notes:

Even if the routine is not running, the specified input signal channel stops any motion of the axes included in the definition of the routine.

It is important to specify an **input signal channel** for the stop function (NOT a fast alignment input channel!). For the difference between fast alignment input channels and input signal channels, see p. 107. For more information on input signal channels, see “Using the Analog Input” in the E-712 user manual (PZ195E).

You can set the parameters with SPA or SEP commands.

E-712 only: Activate soft limits during the fast alignment routine:

Using the ***FA Stop Routine At Soft Limits*** parameter (ID 0x20002F00), soft limits can be activated during the fast alignment routine. Possible values:

0 = No (default)

1 = Yes

The soft limits are specified by the parameters 0x7000000 and 0x7000001 of the axes that are involved in the fast alignment routine.

Note:

A routine is only started if all axes involved are within the soft limits. If necessary, first use motion commands to move the axes to a target position within the soft limits.

You can set the parameters with SPA or SEP commands.

C-887 only: Axis signal type used for calculation:

During area scan routines, for both scan axis and step axis a signal is recorded and used for calculation.

The type of the axis signal can be selected via the value of the ***Fast Alignment Axis Signal Type*** parameter (ID 0x20001C00). Possible options:

0 = current position

1 = dynamics profile created by the profile generator (default)

Choosing the current position can be useful, for example, if the signal maximum found is to be approached at the end of an area scan routine. In this case, the analog signal deviation when approaching the signal maximum can be minimally reduced compared to the deviation when using the dynamics profile.

Note that the setting affects **all** routines in the C-887, i.e. also gradient search routines.

Response: None

Notes: The physical unit in which <scan axis range>, <step axis range>, <scan axis middle position> and <step axis middle position> are to be given can be queried with the PUN? command.

The routine definition with FDR is only possible when the routine is not running.

E-712 only: While a routine is running, the routine definition can be changed via the SPA command and the corresponding parameters of the Fast Alignment Routines group (p. 106).

Example: For examples, see p. 33.

FDG (Set FA Gradient Search Definition)

Description:

Defines a fast alignment gradient search routine.

NOTICE: It is not possible to define an area for a gradient search. Before you run a gradient search routine, you should therefore determine and establish limits for the permissible travel range of the axes in your application. For details, see “Safety Instructions” on p. 10.

Gradient search routine details:

A gradient search is a circular scan travelling to the signal maximum using the gradient of the measured signal. During the routine, the scan axis and step axis each follow a sine curve so that a circular motion results. Furthermore, offsets are added to the sine curves. To move in the direction of the signal maximum, the amplitude of the sine curve and the offset values are continuously changed depending on the current result of the gradient calculation. The number of direction changes of the motion is counted during the routine. Counting is necessary to stop the routine after a given number of changes if no gradient can be calculated (e.g., when the routine was started far away from the position of the signal maximum).

A gradient search routine is stopped and considered to be successfully completed when the following condition has been met:

- The length of the normalized gradient vector has fallen below a specified stop level (the smaller the gradient, the smaller is the current distance to the signal maximum).

If the stop level is set to 0, the routine will continuously track the signal maximum. With C-887, the tracking duration is limited to approximately 90 s.

A gradient search routine is stopped and considered to be unsuccessful when one of the following conditions has been met:

- The number of direction changes during the routine has reached the specified maximum value.
- FRP with stop action, #24, STP or HLT has been sent.
- The routine was stopped because at least one of the axes involved reached a soft limit.
- E-712 only: The routine has been stopped via an input signal channel.

The maximum number of routines that can be defined depends on the controller:

- E-712: The maximum number of routines is identical to the number of axes of the controller.
- C-887: The maximum number of routines is 100.

Use FRS to start the routine. With FRR?, you can read out the definition and the results of the routine.

When a gradient search routine is started, the current position of scan axis and step axis is used as initial center position of the circular motion. When the gradient search routine is running, you can query the current center position of the circular motion using the FGC? command**.** As long as the routine is still running, you can also change the center position of the circular motion using the FGC command (p. 92). This can be useful when you suppose the signal maximum far away from the area where the circular motion currently takes place.

Gradient search routines can be coupled to each other with FRC (p. 94).

Routine definitions can be stored in the controller, for details, see the FAQ section “Q: Where are my defined routines stored?” (p. 55).

The table in “Examples for Gradient Search Routines” (p. 43) lists the arguments of the FDG command with their value range, default and example values.

Arguments in square brackets are optional. If an optional argument is omitted in the FDG command, the following value will be taken:

- E-712: The last valid value of the argument will be taken from the volatile memory of the controller.
- C-887: The default value of the argument will be taken. For the default values, see “Working with Fast Alignment Routines” (p. 30).

E-712 only: The settings defined with FDG can also be made by changing parameters with SPA (for the corresponding parameters see the tables on p. 108 and p. 115).

Format: FDG <routine name> <scan axis> <step axis> [ML <stop level>] [A <alignment signal input channel>] [MIA <min radius>] [MAA <max radius>] [F <frequency>] [SP <speed factor>] [V <max velocity>] [MDC <max direction changes>] [SPO <speed offset>]

Arguments: <routine name>

The identifier of the routine.
With E-712: Can be 1, 2, …, n, where n is the number of axes of the controller. Note that the <routine name> value is to be used as item identifier when changing parameters of the Fast Alignment Routines parameter group with SPA or SEP commands.
With C-887: String consisting of characters. Blanks or special characters are not allowed.

<scan axis>

Identifier of the axis that is to be the master axis of the gradient search routine.

<step axis>

Identifier of the axis that is to be the second axis of the gradient search routine. To define a single-axis routine, <step axis> must be identical to <scan axis>.

[ML <stop level>]

ML: Required keyword

<stop level>: Gives one stop criterion for the gradient search routine: When the length of the normalized gradient vector falls below the given stop level, the routine stops, and FRR? will report "successful". After stopping as "successful", the scan axis and step axis will move to the last valid center position of the circular motion.

Value range of <stop level>: 0 to 1. The greater the required accuracy of the routine, the smaller the stop level should be.

If the stop level is set to 0, the routine will continuously track the signal maximum. With C-887, the tracking duration is limited to approximately 90 s.

[A <alignment signal input channel>]

A: Required keyword

<alignment signal input channel>: Identifier of the analog input channel whose signal maximum is sought:

- E-712: Identifier of a fast alignment input channel. For details, see "Fast Alignment Parameter Groups" (p. 106).
- C-887: 5 for the **Analog In 5** BNC socket, 6 for the **Analog In 6** BNC socket (present with C-887.5x1 and C-887.5x3 models)

[MIA <min radius>]

MIA: Required keyword

<min radius>: Minimum radius of the circular motion for scan axis and step axis (= amplitude of the sine curve).

Typical minimum radius is around 1/10 the FWHM of the signal.

[MAA <max radius>]

MAA: Required keyword

<max radius>: Maximum radius of the circular motion for scan axis and step axis (= amplitude of the sine curve).

Typical maximum radius is perhaps 2-5 times the minimum radius. E-712 only: If a fixed radius is desired, set <min radius> and <max radius> identically.

[F <frequency>]

F: Required keyword

<frequency>: Frequency of the sine curves for scan axis and step axis. The entered frequency value will automatically be adapted to a multiple of the sampling time of the controller.

[SP <speed factor>]

SP: Required keyword

<speed factor>: The speed factor can be used to speed up the offset change. The greater the speed factor, the faster is the circular motion in the direction of the signal maximum. The routine can become instable when the value of the speed factor is too high.

[V <max velocity>]

V: Required keyword

<max velocity>: Velocity limit for the offset change.

E-712 only: If [V <max velocity>] is omitted in the FDG command, the velocity value will be set to V = MIA * F

[MDC <max direction changes>]

MDC: Required keyword

<max direction changes>: Gives one stop criterion for the gradient search routine: When the number of direction changes during the routine reaches the given maximum value, the routine stops, and FRR? will report “not successful”.

The <max direction changes> value will be ignored if <stop level> is set to 0 for continuous tracking of the signal maximum.

[SPO <speed offset>]

SPO: Required keyword

<speed offset>: To avoid that the velocity of the offset change becomes very low or zero during the gradient search procedure, an offset can be applied in the velocity calculation. This is useful to avoid a very slow position change near the signal maximum if there is no gradient.

Additional settings:

Axis signal type used for gradient calculation

During the gradient search routine, for both scan axis and step axis a signal is recorded and used for gradient calculation.

The type of axis signal can be selected via the value of the parameter with ID 0x20001C00. Note that the name of parameter 0x20001C00 is ***FA Gradient Search Type Of Axis Signal*** with E-712 but ***Fast Alignment Axis Signal Type*** with C-887. Possible options:

0 = current position (default with E-712)

1 = target position (E-712) / dynamics profile created by the profile generator (default with C-887)

Note that with C-887 the setting affects **all** routines in the controller, i.e. also area scan routines.

E-712 only: Type of fast alignment routine

The routine type is defined via the value of the ***FA Routine Type*** parameter (ID 0x20000F00) as follows:

0 = idle routine (prevents the routine from running when started with FRS)

1 = area scan routine

2 = gradient search routine

The parameter value is set automatically in volatile memory when FDR or FDG commands are sent to configure a routine (sending FDR sets the value to 1; sending FDG sets the value to 2). You can also set the parameter with SPA or SEP commands.

E-712 only: Use an input signal channel for stop function:

An input signal channel of the controller can be used to stop the fast alignment routine. The ***FA Input Channel To Stop Motion*** parameter (ID 0x20002C00) specifies the ID of the input signal channel. The stop function is triggered if the input exits the permissible range specified by the parameters ***FA Input Lower Threshold To Stop Motion*** (ID 0x20002D00) and ***FA Input Upper Threshold To Stop Motion*** (ID 0x20002D01).

Notes:

Even if the routine is not running, the specified input signal channel stops any motion of the axes included in the definition of the routine.

It is important to specify an **input signal channel** for the stop function (NOT a fast alignment input channel!). For the difference between fast alignment input channels and input signal channels, see p. 107. For more information on input signal channels, see “Using the Analog Input” in the E-712 user manual (PZ195E).

You can set the parameters with SPA or SEP commands.

E-712 only: Activate soft limits during the fast alignment routine:

Using the ***FA Stop Routine At Soft Limits*** parameter (ID 0x20002F00), soft limits can be activated during the fast alignment routine. Possible values:

0 = No (default)

1 = Yes

The soft limits are specified by the parameters 0x7000000 and 0x7000001 of the axes that are involved in the fast alignment routine.

Note:

A routine is only started if all axes involved are within the soft limits. If necessary, first use motion commands to move the axes to a target position within the soft limits.

You can set the parameters with SPA or SEP commands.

Response:	None

Notes: The measured signal is used in the gradient search routine after it has been subjected to the calculations set with the SIC command (p. 102).

The routine definition with FDG is only possible when the routine is not running.

E-712 only: While a routine is running, the routine definition can be changed via the SPA command and the corresponding parameters of the Fast Alignment Routines group (p. 106).

The physical unit in which <min radius> and <max radius> are to be given can be queried with the PUN? command.

Example: For examples, see p. 43.

FGC (Set FA Gradient Search Center Position of Circular Motion)

Description: Change center position of gradient search.

When a gradient search routine is started, the current position of scan axis and step axis is used as initial center position of the circular motion. When the gradient search routine is running, you can change the center position of the circular motion with FGC. This can be useful when you suppose the signal maximum far away from the area where the circular motion currently takes place.

You can query the current center position of the circular motion using the FGC? command**.**

E-712 only: The settings made with FGC can also be made by changing parameters with SPA (for the corresponding parameters see the table on p. 115).

Format: FGC {<routine name> <scan axis center position> <step axis center position>}

Arguments: <routine name>

The identifier of the routine.
With E-712: Can be 1, 2, …, n, where n is the number of axes of the controller.
With C-887: String without special characters.

<scan axis center position>

Center position of the circular motion for the scan axis.

<step axis center position>

Center position of the circular motion for the step axis.

For a single-axis routine, <step axis center position> must be identical to <scan axis center position>.

Response: None

Notes: The physical unit in which <scan axis center position> and <step axis center position> are to be given can be queried with the PUN? command.

FGC? (Get FA Gradient Search Center Position of Circular Motion)

Description: Gets the current center position of the circular motion of a gradient search routine.

When the routine has been successfully completed, the center position gives the position of the signal maximum.

The center position can also be queried with result ID 3 of the FRR? command.

Format: FGC? [{<routine name>}]

Arguments: <routine name>

The identifier of the routine.
With E-712: Can be 1, 2, …, n, where n is the number of axes of the controller.
With C-887: String without special characters.

Response: {<routine name>"="<scan axis center position> <step axis center position> LF}

where

<scan axis center position> is the current center position of the circular motion for the scan axis.

<step axis center position> is the current center position of the circular motion for the step axis.

FRC (Set FA Routine Coupling)

Description: Couples fast alignment routines to each other.

Routine types that can be coupled: gradient search routines.

Coupled routines are not allowed to stop until the length of the normalized gradient vector has fallen below the specified stop level for all routines coupled to them.

If a coupled gradient search routine is defined for continuous tracking of the signal maximum (stop level has the value 0.0), the routines coupled to this routine cannot be finished even if the criterion for stopping as "successful" is fulfilled for them.

E-712 only: The settings made with FRC can also be made by changing a parameter with SPA (for the corresponding parameter see the table on p. 115).

Format: FRC <routine name> {<routine name coupled>}

Arguments: <routine name>

The identifier of a routine.
With E-712: Can be 1, 2, …, n, where n is the number of axes of the controller.
With C-887: String without special characters.

<routine name coupled>

The identifier of a routine that is to be coupled to the routine given by <routine name>.
With E-712: Can be 1, 2, …, n, where n is the number of axes of the controller.
With C-887: String without special characters.
If <routine name coupled> = 0, the routine given by <routine name> is disconnected from any routine.

Response: None

Example: Couple routine 3 to routines 4, 5 and 6 (3, 4, 5 and 6 are gradient search routines):
FRC 3 4 5 6
Check the coupling for routine 3:
FRC? 3
3=4 5 6
Couple routine 4 to routines 1 and 2:
FRC 4 1
FRC 4 2
Check the coupling for routine 4:
FRC? 4
4=1 2
Disconnect routine 4 from any routine:
FRC 4 0
Check the coupling for routine 4:
FRC? 4
4=0

FRC? (Get FA Routine Coupling)

Description: Gets coupled fast alignment routines.

Format: FRC? [{<routine name>}]

Arguments: <routine name>

The identifier of the routine.
With E-712: Can be 1, 2, …, n, where n is the number of axes of the controller.
With C-887: String without special characters.

Response: {<routine name>"="<routine name coupled> [{<routine name coupled>}] LF}

where

<routine name coupled> is the identifier of a routine that is coupled to the routine given by <routine name>.
With E-712: Can be 1, 2, …, n, where n is the number of axes of the controller.
With C-887: String without special characters.
If <routine name coupled> = 0, the routine given by <routine name> is disconnected from any routine.

FRS (Set FA Routine Start)

Description: Starts a fast alignment routine.

The routine must have been defined before with FDR (p. 78) or FDG (p. 87) or via the appropriate parameters (p. 106).

With FRP (p. 97), you can stop, pause or resume a routine. Using FRP? (p. 98), you can query the current state of the routine (running or not).

With FRR? (p. 99), you can read out the definition and the results of the routine.

Format: FRS {<routine name>}

Arguments: <routine name>

The identifier of the routine.
With E-712: Can be 1, 2, …, n, where n is the number of axes of the controller.
With C-887: String without special characters.

Response: None

Notes:	Multiple fast alignment routines can run simultaneously. If the routines to be started together with FRS are of different types, then the area scan routine(s) should be specified first, followed by the gradient search routines. Gradient search routines can be coupled to each other with FRC (p. 94). C-887 only: If the routines to be started together with FRS are of different types, then only one area scan routine may be among these routines. C-887 only: When starting an area scan routine, the controller checks if the data recorder provides enough memory. If the available number of points is not sufficient, the routine does not start and error 67 occurs. E-712 only: The type of the routine to be started depends on the value of the ***FA Routine Type*** parameter (ID 0x20000F00). Possible types: 0 = Idle routine (prevents the routine from running when started with FRS) 1 = Area scan routine 2 = Gradient search routine E-712 only: Using the ***FA Stop Routine At Soft Limits*** parameter (ID 0x20002F00), soft limits can be activated during the fast alignment routine. Possible values: 0 = No (default) 1 = Yes A routine is only started if all axes involved are within the soft limits. If necessary, first use motion commands to move the axes to a target position within the soft limits.
Example:	See FRP (p. 97).

FRP (Set FA Routine Stop, Pause or Resume)

Description: Stops, pauses or resumes a fast alignment routine.

A paused routine will be resumed with the routine variable values that were valid at the time of pausing, even if values (e.g. target value) have been changed in the meantime.

A stopped routine will be considered to be unsuccessful.

When a routine is stopped or paused with FRP, the axes will stay at the following position:

Area scan routine: current target position

Gradient search routine:

- E-712: current center position of the circular motion
- C-887: current target position

The response to FRP? may show that a routine is still running if the FRP? command has been sent immediately after stopping the routine with FRP. Before proceeding, query FRP? until it returns 0, indicating that the routine has successfully been stopped.

A routine to be stopped or paused must have been started with FRS (p. 95) before.

A routine to be resumed with FRP must have been paused with FRP before.

Format: FRP {<routine name> <routine action>}

Arguments: <routine name>

The identifier of the routine.
With E-712: Can be 1, 2, …, n, where n is the number of axes of the controller.
With C-887: String without special characters.

<routine action>

The action to be performed for the routine. Possible actions:

0 = stop the routine
1 = pause the routine. C-887 only for gradient search routines.
2 = resume the routine. C-887 only for gradient search routines.

Response: None

Note: E-712 only: Use an input signal channel for stop function:

An input signal channel of the controller can be used to stop the fast alignment routine. The ***FA Input Channel To Stop Motion*** parameter (ID 0x20002C00) specifies the ID of the input signal channel. The stop function is triggered if the input exits the permissible range specified by the parameters ***FA Input Lower Threshold To Stop Motion*** (ID 0x20002D00) and ***FA Input Upper Threshold To Stop Motion*** (ID 0x20002D01).

Notes:

Even if the routine is not running, the specified input signal channel stops any motion of the axes included in the definition of the routine.

It is important to specify an **input signal channel** for the stop function (NOT a fast alignment input channel!). For the difference between fast alignment input channels and input signal channels, see p. 107. For more information on input signal channels, see “Using the Analog Input” in the E-712 user manual (PZ195E).

You can set the parameters with SPA or SEP commands.

Example: Start routines 1 and 2:

FRS 1 2

Pause routine 2:

FRP 2 1

Pause routine 1 and resume routine 2:

FRP 1 1 2 2

Stop routines 1 and 2:

FRP 1 0 2 0

Query the state of routines 1 and 2:

FRP? 1 2

Receive the following response which shows that the routines are still running:

1=2

2=2

Query the routine state again for routines 1 and 2:

FRP? 1 2

Receive the following response which shows that the routines are stopped now:

1=0

2=0

FRP? (Get FA Routine State (Stopped/Paused/Resumed)

Description: Gets the current state of a fast alignment routine.

See FRP for an example.

Format: FRP? [{<routine name>}]

Arguments: <routine name>

The identifier of the routine.
With E-712: Can be 1, 2, …, n, where n is the number of axes of the controller.
With C-887: String without special characters.

Response: {<routine name>"="<routine state> LF}

where

<routine state> is the current state of the routine. Possible states:

0 = routine has been stopped / is not running
1 = routine has been paused
2 = routine is running

FRR? (Get FA Routine Results)

Description: Gets the results of a fast alignment routine.

Format: FRR? [<routine name>[<result ID>]]

In addition to the syntax listed above, the C-887 also supports the following syntax:

FRR? [{<routinename> <ResultID>}]

Arguments: <routine name>

The identifier of the routine.
With E-712: Can be 1, 2, …, n, where n is the number of axes of the controller.
With C-887: String without special characters.

If no routine identifier is given, all available results are queried.

<result ID>

The identifier of the result. See below for valid identifiers. Use the response to FRH? (p. 101) to get information on the supported result identifiers.

If no result identifier is given, all available results for the given routine are queried.

Response: {<routine name> <result ID>"="<resulting value> LF}

where
<resulting value> can be as follows for the individual result identifiers:

Result ID	Resulting value
1	Success of the routine: 0 = routine was not successful 1 = routine was successful
2	Maximum of the measured signal The unit of the signal maximum depends on the calculation settings for the analog input signal. See the description of the SIC command (p. 102) for details. E-712 only: The result can also be queried via the value of the ***FA Maximum Intensity Value*** parameter (ID 0x20001000).

3	Position of the maximum of the measured signal, in [axis unit] The ID “1” stands for scan axis, ID “2” stands for step axis. E-712 only: Area scan routines: The result can also be queried via the value of the ***FA Area Scan Position Of Intensity Maximum*** parameter (ID 0x20000B0n, n = 0 for scan axis, n = 1 for step axis). E-712 only: Gradient search routines: The result can also be queried with FGC? (p. 93) and via the value of the ***FA Gradient Search Center Position*** parameter (ID 0x20000C0n, n = 0 for scan axis, n = 1 for step axis).
4	Routine definition made with FDR (p. 78) or FDG (p. 87). The response includes the values of all settings, even if arguments have been omitted in the last sent definition command.
5	Routine time in s E-712 only: The result can also be queried via the value of the ***FA Routine Time*** parameter (ID 0x20002300).
6	Reason for abort of routine: 0 = routine was not aborted. This is the case when the routine is still running or when it has been successfully finished, paused with FRP, or never been running yet. 1 = area scan routine was not successful because the given minimum signal threshold has not been reached in the scanned area 2 = area scan routine was not successful because the found position of the global maximum results from an estimation method (see FDR for details) and is outside of the scan axis range and/or the step axis range 3 = gradient search routine was not successful because the number of direction changes during the routine has reached a given maximum value 4 = routine was not successful because an axis involved in the routine has reached its travel range limit 5 = routine has been stopped. E-712 only: Reason 5 is also reported if the routine was not running, but any motion of the axes included in the definition of the routine was stopped by an input signal channel. See p. 109 for more information.
7	Gradient search routines only: Current radius of the circular motion (0 if no gradient search is running) E-712 only: The result can also be queried via the value of the ***FA Gradient Search Current Radius*** parameter (ID 0x2000160n, n = 0 for scan axis, n = 1 for step axis).

8	Gradient search routines only: Current number of direction changes (reports the value of the last gradient search if no gradient search is running).
9	C-887 only: Gradient search routines only: Current length of the normalized gradient vector (reports the value of the last successful gradient search if no gradient search is running). E-712 only: 0 = routine was not stopped via an input signal channel 1 = routine was stopped via an input signal channel The value 1 is also reported if the routine was not running, but any motion of the axes included in the definition of the routine was stopped by an input signal channel. See p. 109 for more information.

Notes:

When evaluating the routine results, first of all check the success of the routine. When the routine was not successful (result ID 1 has the value 0), all other results of the routine are invalid.

Troubleshooting for area scan routines: If the estimation of the position of the global maximum failed, try to increase the value of the MIIL argument and to decrease the value of MAIL argument to get valid data. See FDR for details.

Troubleshooting for gradient search routines: If the gradient search failed due to the maximum number of direction changes, repeat the routine.

E-712 only: Routines can be removed from the FRR? response; for details, see p. 55.

C-887 only: Routines can be deleted and are no longer listed with the FRR? command. For deleting routines, see p. 55.

E-712 only: Several data recorder options are available for fast alignment routines, see the response to the HDR? command for details.

FRH? (Get Help for Interpretation of FRR? Response)

Description: Lists descriptions and physical units for the routine results that can be queried with the FRR? command (p. 99).

Format: FRH?

Arguments: none

Response: {<result ID>"="<description>TAB<phys unit> LF}

where

<result ID> is the identifier of the result.

<description> is the description of the result.

<phys unit> is the physical unit of the result.

SIC (Set FA Input Calculation)

Description: Defines calculation settings for the given analog input channel.

The measured values to be used for a fast alignment routine are fed into the controller as an analog input signal. The calculation settings defined with SIC are applied to the analog input signal before it is used in the routine. This way, e.g. a logarithmic output of the power meter can be converted to (linear) power (p. 50).

The current valid calculation settings can be queried with SIC? (p. 104).

The analog input before the calculation can be queried with TAV? (p. 105).

The calculated analog input can be queried with TCI? (p. 105) and recorded with record option 150 of the data recorder.

E-712 only: In the firmware, the usable analog input channels are available as “fast alignment input channels”, see “Fast Alignment Input Channels Group” (p. 107) for details.

E-712 only: Some of the settings defined with SIC can also be made by changing parameters with SPA (for the corresponding parameters see “Parameters for Fast Alignment Input Channels” (p. 117)).

Format: SIC <FA input channel ID> <calculation type> <calculation parameters>

Arguments: <FA input channel ID>

The identifier of an analog input channel of the controller:

- E-712: Identifier of a fast alignment input channel. For details, see “Fast Alignment Parameter Groups” (p. 106).
- C-887: 5 for the **Analog In 5** BNC socket, 6 for the **Analog In 6** BNC socket (present with C-887.5x1 and C-887.5x3 models)

<calculation type>

The type of calculation to be applied, can be:

-1 = Simulated Gauss distribution

0 = No calculation

1 = Exponential calculation

2 = Polynomial calculation

3 = Logarithmic calculation

<calculation parameters>

Parameters dependent on the calculation type; see below for details; float.

With calculation type -1, a Gauss distribution of a signal is simulated.
Amplitude a, sigma s, and the positions xs and ys must be given as <calculation parameters>:
SIC <FA input channel ID> -1 *a s xs ys*
The simulation is calculated with amplitude a and sigma s, based on the current positions of scan axis (xpos) and step axis (ypos), with the signal maximum at position xs for the scan axis and ys for the step axis.
The calculation is as follows:
k = 2*s*s
r = sqrt((xpos - xs) * (xpos - xs) + (ypos - ys) * (ypos - ys))
Analog input (simulated) = a * (exp(-(r * r) / k)) / (PI * k)
The simulation is useful for test purposes, if no meaningful analog input is available.
Note that the calculation parameters a, s, xs, and ys specified with SIC are only used with C-887. With E-712, the specified values are ignored and fixed values for amplitude (10) and sigma are used. For xs and ys, the values of the ***FA Area Scan Middle Position*** parameters (IDs 0x20000100 and 0x20000101) are used with E-712.
With E-712, the simulated signal can be recorded with the data recorder. This is not possible with C-887.

With calculation type 0, no <calculation parameters> are required:
SIC <FA input channel ID> 0

With calculation type 1, terms a, b, c and d of the exponential equation must be given as <calculation parameters>:
SIC <FA input channel ID> 1 *a b c d*
The calculation is as follows:
Analog input = a + b * $c^{(d*VOLT)}$
(VOLT is the analog input value). For further details, see p. 50.

With calculation type 2, the coefficients a_0 to a_4 of the polynomial must be given as <calculation parameters>:
SIC <FA input channel ID> 2 a_0 a_1 a_2 a_3 a_4
The calculation is as follows:
Analog input = $a_0 + a_1*VOLT + a_2*VOLT^2 + a_3*VOLT^3 + a_4*VOLT^4$
(VOLT is the analog input value).
E-712 only: Note that a polynomial of degree five can be defined via the corresponding parameter for coefficient a_5, see p. 117 for details.

With calculation type 3, terms a, b, c, and d of the equation must be given as <calculation parameters>:
SIC <FA input channel ID> 3 *a b c d*
The calculation is as follows:
Analog input = (a + b * exp(log(10) * (c * VOLT + d)))
(VOLT is the analog input value).

Response: None

Notes: E-712 only: SIC sets the values of the corresponding parameters in volatile memory, see “Parameters for Fast Alignment Input Channels” (p. 117) for details. While a fast alignment routine is running, the parameters can be changed with the SPA command.

Example 1: Disable calculation for fast alignment input channel 1:

SIC 1 0

Example 2: Simulate a signal with Gauss distribution for the input channel 1, with amplitude a = 0.8, sigma s = 0.05, and the positions xs = -0.0055 and ys = 0.0043:

SIC 1 -1 0.8 0.05 -0.0055 0.0043

Important: The distribution must be defined so that the routine sees a gradient of the signal. Otherwise the routine will be aborted.

Example 3: For the conversion of a logarithmic signal, see the FAQ section “Q: How can I convert the logarithmic output of my F-712 power meter to (linear) power in an F-712 system?”, p. 50.

SIC? (Get FA Input Calculation)

Description: Gets the calculation settings for the given analog input channel.

The calculation results can be queried with TCI? (p. 105).

Format: SIC? [{<FA input channel ID>}]

Arguments: <FA input channel ID>

The identifier of an analog input channel of the controller:

- E-712: Identifier of a fast alignment input channel. For details, see “Fast Alignment Parameter Groups” (p. 106).
- C-887: 5 for the **Analog In 5** BNC socket, 6 for the **Analog In 6** BNC socket (present with C-887.5x1 and C-887.5x3 models)

Response: {<FA input channel ID>"="<calculation type> [{<calculation parameters>}] LF}

where

<calculation type> is the calculation type, see SIC for details.

<calculation parameters> gives the settings for the calculation type, see SIC for details.

Notes: E-712 only: SIC? queries the values of the corresponding parameters in volatile memory, see “Parameters for Fast Alignment Input Channels” (p. 117) for details.

TAV? (Get Analog Input Voltage)

Description: Gets voltage value of given analog input channel.

The value reported by TAV? is used as input for the calculation done by SIC (p. 102).

Format: TAV? [{<FA input channel ID>}]

Arguments: <FA input channel ID>

The identifier of an analog input channel of the controller:

- E-712: Identifier of a fast alignment input channel. For details, see “Fast Alignment Parameter Groups” (p. 106).
- C-887: 5 for the **Analog In 5** BNC socket, 6 for the **Analog In 6** BNC socket (present with C-887.5x1 and C-887.5x3 models)

Response: {<FA input channel ID>"="<float> LF}

where

<float> is the current voltage at the analog input channel in volts.

Note: E-712: TAV? reports the voltage value after the mechanics linearization polynomial (see E-712 user manual for linearization details).

TCI? (Get Calculated FA Input)

Description: Gets calculated value of given analog input channel.

The calculation settings of an analog input channel can be defined with SIC (p. 102) and queried with SIC? (p. 104).

Format: TCI? [{<FA input channel ID>}]

Arguments: <FA input channel ID>

The identifier of an analog input channel of the controller:

- E-712: Identifier of a fast alignment input channel. For details, see “Fast Alignment Parameter Groups” (p. 106).
- C-887: 5 for the **Analog In 5** BNC socket, 6 for the **Analog In 6** BNC socket (present with C-887.5x1 and C-887.5x3 models)

Response: {<FA input channel ID>"="<float> LF}

where

<float> is the current value of the calculated input

Notes: The response consists of a line feed when the controller does not contain a fast alignment input channel.

E-712 only—Fast Alignment Parameter Groups

Parameter Basics and Handling

With E-712, the settings for configuration of routines or analog input signals can be made or queried via the fast alignment commands (p. 77), but also via the parameters of the “fast alignment” parameter groups. See the parameter lists below for the fast alignment commands that belong to certain parameters.

Generally, parameters can be changed / queried with SPA / SPA? and SEP /SEP? commands. Note that you have to switch to command level 1 with the CCL command before you can change a parameter value with SPA or SEP (this is not necessary with the fast alignment commands). Parameters which have command level 3 (see tables below) are used to display routine results and cannot be changed with commands.

If the settings made with fast alignment commands or with SPA are to be preserved when the E-712 is switched off or rebooted, they have to be saved to nonvolatile memory with the WPA command.

You can query the available parameters and their properties with the HPA? and HPV? commands. For further details regarding parameter handling, see “Controller Parameters” in the E-712 user manual (PZ195E).

The E-712 provides the following “fast alignment” parameter groups:

- **Fast Alignment Routines** group: Parameters of this group refer to fast alignment routines and are intended for routine configuration and display of routine results.
- **Fast Alignment Input Channels** group: Parameters of this group refer to fast alignment input channels and are intended for configuration of analog input signal calculation.

Fast Alignment Routines Group

With E-712, the maximum number of routines is identical to the number of motion axes that are present in the E-712 system. Note that you can query the number of axes using the ***Number Of System Axes*** parameter (ID 0x0E000B02).

The identifiers of the routines are 1, 2, …, n, where n is the number of axes. The routine identifier is to be used in commands as follows:

- Fast alignment commands: <routine name> argument, for examples see the command descriptions in this document
- SPA and SEP commands: <ItemID> argument
  Example: To set the speed offset for gradient search procedure 3 to the value 0.05 in volatile memory, you have to send the following commands:
  CCL 1 advanced
  SPA 3 0x20001D00 0.05

For descriptions of the parameters of the Fast Alignment Routines group, see the tables in the following sections:

- Global Parameters for Fast Alignment Routines (p. 108)
- Parameters for Area Scan Routines (p. 111)
- Parameters for Gradient Search Routines (p. 115)

Fast Alignment Input Channels Group

The measured signal values are fed into the E-712 as an analog input signal. The analog inputs are available as “fast alignment input channels” in the firmware of the E-712.

Note that the fast-alignment-input-channel concept is only used with respect to fast alignment routines. With all other functionality of the E-712, the analog inputs are counted as input signal channels as usual, see “Using the Analog Input” in the E-712 user manual (PZ195E).

The relation of fast alignment input channels to the input signal channels described in the E-712 user manual is as follows:

Fast alignment input channels are a subset of the input signal channels. Separate counting of fast alignment input channels has been introduced to facilitate identification of the channel IDs to be used in fast alignment routines: Channel counting for input signal channels starts with the sensors in the mechanics, so you would have to know the number of sensors in your system, and IDs like 10 or higher could be required for the analog input. For that reason, the counting of fast alignment input channels omits the sensor channels and comprises only the “residual” input signal channels present in the E-712. These are the analog inputs provided by E-711.IA4 analog interface modules, but can also be channels of SPI or fieldbus interfaces, if corresponding modules are present. Note that counting of fast alignment input channels starts with the leftmost module that provides “residual” input signals in the E-712 chassis (front view).

This means that the first analog input is counted as first fast alignment input channel only if it is positioned to the left of any module that provides SPI or fieldbus interfaces in the E-712 chassis!

The identifiers of the fast alignment input channels are 1, 2, …, n, where n is the total number of “residual” input signals. The channel identifier is to be used in commands as follows:

- Fast alignment commands: <alignment signal input channel> argument, for examples see the command descriptions in this document
- SPA and SEP commands: <ItemID> argument
  Example: Analog input 1 is counted as fast alignment input channel 1. To select polynomial calculation for the signal on analog input 1, you have to send the following commands:
  CCL 1 advanced
  SPA 1 0x21000000 2

Important: The identifiers of the fast alignment input channels are used with the data recorder option 150 (Fast Alignment Calculated Optical Power). With all other record options related to analog input, the analog inputs are counted as input signal channels and thus are available under their input signal channel ID when you query data with the DRR? command.

The table on p. 117 describes the parameters of the Fast Alignment Input Channels group.

Global Parameters for Fast Alignment Routines

ID	Description	Corres-ponding Fast Alignment command	Notes	Com-mand level for write access
0x2000000n	FA Axis	FDR, FDG (axis argument)	Axis involved in the routine; n = 0 for scan axis, n = 1 for step axis UINT; 0 to number of axes Default value: 0 Notes: If the value is 0 for scan axis and step axis, the routine is not listed with the FRR? command. The value 0 is not permissible for the FDR and FDG commands.	1
0x20000E00	FA Input Channel	FDR, FDG (A argument)	ID of the fast alignment input channel whose signal maximum is to be found, starts with 1 INT; 1 to number of analog inputs Default value: 0 Note: The parameter value in volatile memory is set to 1 when both of the following conditions are met: ▪ An FDR or FDG command is sent without the A argument. ▪ The current value of the parameter is invalid (e.g. 0).	1

ID	Description	Corres-ponding Fast Alignment command	Notes	Com-mand level for write access
0x20000F00	FA Routine Type	-	Possible types: 0 = Idle routine (default value; prevents the routine from running when started with FRS) 1 = Area scan routine 2 = Gradient search routine Note: The parameter value is set in volatile memory when FDR or FDG commands are sent to configure a routine (sending FDR sets the value to 1; sending FDG sets the value to 2).	1
0x20002300	FA Routine Time	FRR? (result ID 5)	Routine result: duration of the routine in s Read only FLOAT32; ≥ 0.0 s	3
0x20002C00	FA Input Channel To Stop Motion	-	Input signal channel for stop function Specifies the ID of an input signal channel that is to stop the fast alignment routine. The stop function is triggered if the input exits the permissible range specified by the parameters 0x20002D00 and 0x20002D01 (see below). Notes: If the routine is stopped by the input signal channel, it is considered to be unsuccessful. Even if the routine is not running, the specified input signal channel stops any motion of the axes included in the definition of the routine. It is important to specify an **input signal channel** for the stop function (NOT a fast alignment input channel!). For the difference between fast alignment input channels and input signal channels, see p. 107. For more information on input signal channels, see “Using the Analog Input” in the E-712 user manual (PZ195E).	1

ID	Description	Corres-ponding Fast Alignment command	Notes	Com-mand level for write access
0x20002D00	FA Input Lower Threshold To Stop Motion	-	Lower threshold for the stop function of the input signal channel If the input of the channel specified with parameter 0x20002C00 falls below this threshold, the stop function is triggered: The routine is stopped, or the axes included in the routine definition are stopped.	1
0x20002D01	FA Input Upper Threshold To Stop Motion	-	Upper threshold for the stop function of the input signal channel If the input of the channel specified with parameter 0x20002C00 exceeds this threshold, the stop function is triggered: The routine is stopped, or the axes included in the routine definition are stopped.	1
0x20002F00	FA Stop Routine At Soft Limits	-	Activate soft limits during the fast alignment routine. Possible values: 0 = No (default) 1 = Yes The soft limits are specified by the parameters 0x7000000 and 0x7000001 of the axes that are involved in the fast alignment routine. Notes: A routine is only started if all axes involved are within the soft limits. If necessary, first use motion commands to move the axes to a target position within the soft limits. If the routine is stopped because at least one of the axes involved has reached a soft limit, it is considered to be unsuccessful.	1

Parameters for Area Scan Routines

ID	Description	Corres-ponding Fast Alignment command	Notes	Com-mand level for write access
0x2000010n	FA Area Scan Middle Position	FDR (MP1, MP2 arguments)	n = 0 for scan axis, n = 1 for step axis The use of the parameter depends on the area scan type selected for the routine (parameter 0x20002B00): Spiral scans: Gives the start position for the axis. Sinusoidal scan: Used to calculate start position and end position of the routine, see scan range below. FLOAT; min position to max position of axis in [axis unit] Default value: 50 [axis unit] Note: If a Gauss distribution of a signal is simulated with the SIC command, the parameter values are used for the calculation parameters xs and ys.	1
0x2000020n	FA Area Scan Range	FDR (axis range arguments)	n = 0 for scan axis, n = 1 for step axis The use of the parameter depends on the area scan type selected for the routine (parameter 0x20002B00): Spiral scan with constant frequency: The scan axis range value gives the final diameter of the spiral. The step axis range value is not used. Spiral scan with constant path velocity: The scan axis range value gives the final diameter of the spiral. The step axis range value gives the line spacing of the spiral. Sinusoidal scan: Used to calculate start position and end position of the routine: Start position = middle position – scan range/2 End position = middle position + scan range/2 FLOAT; range value in [axis unit] See also the figures on p. 79. Default value: 100	1

ID	Description	Corres-ponding Fast Alignment command	Notes	Com-mand level for write access
0x20000300	FA Area Scan Step Velocity	FDR (V argument)	Velocity of step axis The use of the parameter depends on the area scan type selected for the routine (parameter 0x20002B00): Spiral scan with constant frequency: The velocity value is used to calculate the line spacing of the spiral. Spiral scan with constant path velocity: The velocity value gives the path velocity. Sinusoidal scan: The velocity value gives the velocity with which the step axis follows the ramp. FLOAT; ≥ 0 [axis unit]/s Default value: 20 [axis unit]/s Note: The parameter value in volatile memory is set to the current velocity of the step axis when an FDR command is sent without the V argument.	1
0x20000A00	FA Area Scan Stop Position Option	FDR (ST argument)	ID of the position to be approached by scan axis and step axis when the area scan routine has been completed: 0 = move to position with the signal maximum (default value) 1 = stay at the end position of the area scan routine 2 = move to the start position of the area scan routine 3 = stop at the position where the minimum signal threshold is reached (parameter 0x20002900) 4 = continuously scan the area and stop at the position where the minimum signal threshold is reached (parameter 0x20002900). The motion continues from start position to end position and back until the threshold is reached or the routine is stopped.	1

ID	Description	Corres-ponding Fast Alignment command	Notes	Com-mand level for write access
0x20000B0n	FA Area Scan Position Of Intensity Maximum	FRR? (result ID 3)	Routine result: position of the global signal maximum, n = 0 for scan axis, n = 1 for step axis Read only FLOAT; min position to max position of axis in [axis unit]	3
0x20000D00	FA Area Scan Frequency	FDR (F argument)	Frequency of the scan axis The use of the parameter depends on the area scan type selected for the routine (parameter 0x20002B00): Spiral scan with constant frequency: The frequency value is used to calculate the line spacing of the spiral. Spiral scan with constant path velocity: The frequency value is ignored. Sinusoidal scan: The frequency value gives the frequency of the sine curve for the scan axis. FLOAT; ≥ 0 Hz Default value: 15 Hz	1
0x20001000	FA Area Scan Maximum Intensity Value	FRR? (result ID 2)	Routine result: maximum of the measured signal Read only FLOAT; the unit depends on the calculation settings for the analog input signal, see “Parameters for Fast Alignment Input Channels” (p. 117)	3
0x20001700	FA Area Scan Maximum Estimation Method	FDR (CM argument)	Estimation method for position of global signal maximum: 0 = global maximum is at the position where the maximum value was recorded (default value) 1 = position of global maximum is calculated from the recorded data using a Gaussian LS fit. 2 = position of global maximum is calculated from the recorded data using an analogy to a center-of-gravity calculation	1

ID	Description	Corresponding Fast Alignment command	Notes	Command level for write access
0x20001800	FA Area Scan Min Level To Use Data	FDR (MIIL argument	With estimation method 1 and 2 (see above), the recorded data to be used for the calculation can be limited to a certain signal range. FLOAT32; 1 % to 100 % of the signal range that has been recorded Default value of MIIL: 1 % Default value of MAIL: 99 %	1
0x20001900	FA Area Scan Max Level To Use Data	FDR (MAIL argument)		1
0x20002900	FA Area Scan Minimum Threshold	FDR (L argument)	Minimum signal threshold of the analog input signal. Criterion for success of the routine. FLOAT; > 0; the unit depends on the calculation settings for the analog input signal, see “Parameters for Fast Alignment Input Channels” (p. 117) Default value: 0.004	1
0x20002B00	FA Area Scan Target Type	FDR (TT argument)	Type of area scan: 0 = sinusoidal scan (scan axis follows a sine curve, step axis follows a ramp). See p. 79 for a graphical representation. 1 = spiral scan with constant frequency (default value) The spiral is defined as follows: 0x20000200 gives the final diameter line spacing = velocity/frequency For velocity and frequency, see parameters 0x20000300 and 0x20000D00. See p. 79 for a graphical representation. 2 = spiral scan with constant path velocity The spiral is defined by the following parameters: 0x20000200 gives the final diameter 0x20000201 gives the line spacing of the spiral 0x20000300 gives the path velocity See p. 79 for a graphical representation. To keep the path velocity constant, the frequency is constantly changed during the spiral motion, and the frequency given by 0x20000D00 is ignored.	1

Parameters for Gradient Search Routines

ID	Description	Corres-ponding Fast Alignment command	Notes	Com-mand level for write access
0x20000400	FA Gradient Search Frequency	FDG (F argument)	Frequency of the sine curves for scan axis and step axis FLOAT; > 0 Hz Default value: 15 Hz	1
0x20000500	FA Gradient Search Maximum Radius	FDG (MAA argument)	Maximum radius of the circular motion FLOAT; > 0 [axis unit] Default value: 5.0 [axis unit]	1
0x20000600	FA Gradient Search Minimum Radius	FDG (MIA argument)	Minimum radius of the circular motion FLOAT; > 0 [axis unit] Default value: 1.0 [axis unit]	1
0x20000700	FA Gradient Search Speed Factor	FDG (SP argument)	Speeds up the offset change. The greater the speed factor, the faster the motion in the direction of the signal maximum. FLOAT; > 0 Default value: 15	1
0x20000800	FA Gradient Search Maximum Velocity	FDG (V argument)	Velocity limit for the offset change FLOAT; > 0 [axis unit]/s Default value: 20 [axis unit]/s Note: The parameter value in volatile memory is set to the result of MIA * F when an FDG command is sent without the V argument (MIA is the minimum radius of the circular motion, F is the frequency of the sine curves, see FDG description (p. 87) for details).	1
0x20000900	FA Gradient Search Stop Level	FDG (ML argument)	Criterion for success of the routine. FLOAT; 0 to 1 Default value: 0.05 Details see ML argument in the description of the FDG command (p. 87).	1

ID	Description	Corres-ponding Fast Alignment command	Notes	Com-mand level for write access
0x20000C0n	FA Gradient Search Center Position	FGC, FGC? FRR? (result ID 3)	Current center position of the circular motion. Can be changed when the routine is running. When the routine has been successfully completed, the center position gives the position of the signal maximum. n = 0 for scan axis, n = 1 for step axis FLOAT; min position to max position of axis in [axis unit] Default value: 0.0	1
0x20001400	FA Gradient Search Maximum Number Of Direction Changes	FDG (MDC argument)	Criterion for success of the routine. INT; positive values Default value: 50 Details see MDC argument in the description of the FDG command (p. 87).	1
0x20001500	FA Coupled Routines	FRC, FRC?	Bit pattern of the IDs of routines that are coupled to each other. Coupled gradient search routines are not allowed to stop until the length of the normalized gradient vector has fallen below the specified stop level for all of them. UINT32; 0 to 0xFFFF Bit 0 = routine with ID 1 Bit 1 = routine with ID 2 Bit 2 = routine with ID 3 ... In the bit pattern of a routine, at least the bit of the routine itself is set.	1
0x2000160n	FA Gradient Search Current Radius	FRR? (result ID 7)	Routine result: current radius of the circular motion, n = 0 for scan axis, n = 1 for step axis Read only FLOAT32; > 0 [axis unit]; 0 if no gradient search is running	3

ID	Description	Corres-ponding Fast Alignment command	Notes	Com-mand level for write access
0x20001C00	FA Gradient Search Type Of Axis Signal	-	Axis signal which is recorded and used for gradient calculation. Possible types: 0 = current position (default value) 1 = target position Note that parameter 0x20001C00 is also supported by C-887 where it affects **all** fast alignment routines. For further details, see FDR (p. 78) and FDG (p. 90).	1
0x20001D00	FA Gradient Search Speed Offset	FDG (SPO argument)	Offset for calculation of the velocity for the offset change (to avoid very slow motion near the signal maximum) FLOAT32; 0 to < 1 Default value: 0.1	1

Parameters for Fast Alignment Input Channels

ID	Description	Corres-ponding Fast Alignment command	Notes	Com-mand level for write access
0x21000000	FA Calculation Of Analog Input Signal	SIC, SIC?	Calculations can be applied to the voltage values of the analog input signal. This way, e.g. a logarithmic output of the power meter can be converted to (linear) power (p. 50). Possible calculation types: -1 = Simulated Gauss distribution 0 = No calculation 1 = Exponential calculation 2 = Polynomial calculation 3 = Logarithmic calculation The settings for types -1 and 3 can only be made with the SIC command (p. 102).	1

ID	Description	Corres-ponding Fast Alignment command	Notes	Com-mand level for write access
0x21000100	FA Analog Input Exponential Calculation Parameter a	SIC, SIC?	Terms of the exponential equation. The equation is as follows: Analog input = a + b * $c^{(d*VOLT)}$ (VOLT is the analog input value after mechanics linearization polynomial) FLOAT32 Amongst others, the terms of the equation depend on the device used to measure the signal. For further details, see "Q: How can I convert the logarithmic output of my F-712 power meter to (linear) power in an F-712 system?", p. 50	1
0x21000200	FA Analog Input Exponential Calculation Parameter b	SIC, SIC?		1
0x21000300	FA Analog Input Exponential Calculation Parameter c	SIC, SIC?		1
0x21000400	FA Analog Input Exponential Calculation Parameter d	SIC, SIC?		1
0x2100050n	FA Analog Input Polynomial Calculation Parameter a_n	SIC, SIC?	Coefficients a_n of the polynomial, n = 0, 1, …, 5. The equation is as follows: Analog input = $a_0 + a_1*VOLT + a_2*VOLT^2 + a_3*VOLT^3 + a_4*VOLT^4 + a_5*VOLT^5$ (VOLT is the analog input value after mechanics linearization polynomial) FLOAT32 Amongst others, the terms of the equation depend on the device used to measure the signal.	1