PZ195E User Manual

E-711/E-712 Modular Digital Multi-Channel Controller System

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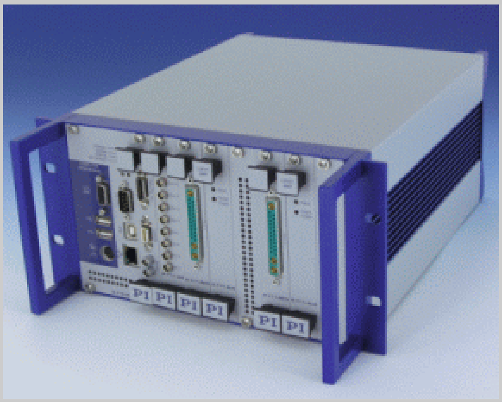

This document describes the following products:

- **E-711 and E-712**
  Digital multi-channel controller system. Modules and predefined configurations

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About this Document

This manual is valid for the hardware components and predefined configurations listed in "Model Survey". Furthermore, it is also valid for all customized hardware configurations if they are not accompanied by special documentation which supersedes this manual.

Users of this Manual

This manual is designed to help the reader to operate the E-711/E-712 modular digital multi-channel controller system. It assumes that the reader has a fundamental understanding of motion systems, as well as motion control concepts and applicable safety procedures.
The manual describes the physical specifications and dimensions of the controller system as well as the software and hardware installation procedures which are required to put the associated motion system into operation.

Symbols and Typographic Conventions

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

WARNING

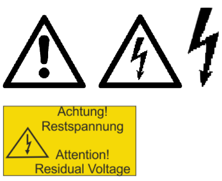
Calls attention to a procedure, practice or condition which, if not correctly performed or adhered to, could result in injury or death.

NOTICE

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

INFORMATION

Provides additional information or application hints.



Warning signs affixed to the product that refer to detailed information in this manual.

Symbol for the protective earth conductor, affixed to the product.

Contents

1 Introduction

- Modular design for highest flexibility
- PC-based; 50 kHz sensor sampling rate; low-noise, 20-bit D/A converters
- Ethernet (TCP/IP), USB, RS-232, SPI
- Optional high-bandwidth analog control inputs / sensor inputs
- Optional analog outputs for control of external amplifiers or position monitoring
- Digital input and output lines for triggering
- Comprehensive software package
- Support of capacitive sensors, strain gauge sensors (SGS) and encoders (incremental, absolute measuring)

Designations used in this document

The E-711/E-712 modular digital multi-channel controller system is also referred to as "E-711/E-712 system" or "controller". The mechanics to be used with the E-711/E-712 system is also referred to as "stage", "nanopositioning system", "piezo nanopositioning system", or "PiezoWalk® system".

Modular design

The number of axes and channels and the functionality of the controller can be configured flexibly:

- Digital processor modules with firmware for nanopositioning systems and PiezoWalk® systems; optional firmware upgrade for alternative control algorithm and advanced linearization
- Amplifier modules with output voltage ranges of -10 V to +45 V, -30 V to +135 V and -250 V to +250 V (with or without sensor input); external high-voltage amplifiers with up to 1100 V output can be integrated in the system
- DC motor driver module, 2 channels, with incremental encoder input

- Sensor modules for single- and dual-electrode capacitive sensors, strain gauge sensors and encoders; digital signal transmission for longer distances is possible
- Interface modules for analog and digital in- and output and SPI
- 9.5” and 19” housings with power supplies suitable for the individual amplifier output voltage ranges

The individual modules and housings can be ordered separately. Furthermore, predefined system configurations (E-712.3CD, .3CDA, .6CD, .6CDA, .6IDA, .1AM, .1AN, .2AN, .3AN) are available. See "Model Survey" (p. 18) for more information.

In this document, the predefined system configurations are also referred to as "controller".

Digital linearization and control algorithms for highest accuracy

Linearization algorithms based on higher-order polynomials will not only improve the positioning accuracy to 0.001% of the travel range but make possible simple replacement of the mechanics as well. With its outstanding computing power, the processor provides for optimal linearization procedure.

During fast periodic motion, as typical for scanning applications, the tracking accuracy can be further improved with the Dynamic Digital Linearization (DDL) option. DDL reduces the tracking error by a factor of up to 1000.

Higher velocity and bandwidth for dynamic applications

The controller is perfectly suited for high-dynamics operation, thanks to its high-resolution D/A converters and high-performance voltage amplifiers. The high-speed processor of the PC-based system with a sensor sampling rate of 50 kHz assures settling times in the millisecond range and below.

Flexibility for a variety of applications

PI nanopositioning systems which are equipped with an ID chip and calibrated with a digital controller have the mechanics-related calibration and control parameters saved in the chip. The controller automatically adapts to the connected mechanics by the appropriate use of this data, so that recalibration is not necessary when system components are replaced.

The interfaces enable command of the mechanics either from a PC, an SPI master or with an analog control signal connected directly to the device. The digital inputs and outputs can be programmed for the most diverse types of trigger tasks.

The integrated wave generators can output periodic motion profiles. In addition to sine and ramp curves, arbitrary, user-defined curves can be defined.

The flexibly configurable data recorder enables simultaneous recording and reading of up to 8 input and output signals, such as for sensor positions or control voltages. This makes the later association of events with saved data points possible.

Simple system integration

Finally, all parameters can be checked and reset via software. System setup and configuration is done with PIMikroMove. Interfacing to custom software is facilitated with included drivers and libraries. System programming is the same with all controllers from PI, so controlling a system with a variety of different controllers is possible without difficulty.

1.1 Other Applicable Documents

This manual is valid for the hardware components and predefined configurations listed in "Model Survey" (p. 18). Furthermore, it is also valid for all customized hardware configurations if they are not accompanied by special documentation which supersedes the information given in this manual.

GCS commands

The PI General Command Set (GCS) is used to command the E-711/E-712 system. The commands of the GCS are described in the PZ233 GCS commands manual, except the GCS commands for Fast Alignment which are described in the E712T0016 Fast Alignment user manual.

Some of the hardware modules and firmware features and all software tools mentioned in this manual are described in detail in their own manuals or technical notes (see tables below).

Hardware modules and firmware features

Hardware / Firmware	Document
E-712.N1 digital PiezoWalk® processor module E-712.1AM modular digital controller for NEXLINE® drives E-712.1AN, .2AN, .3AN digital controllers for PICMAWalk drives with incremental sensors	E712T0010 PiezoWalk description
Fast Multi-Channel Photonics Alignment	E712T0016 Fast Alignment user manual
SPI interface of E-712.M1 and E-712.N1 digital processor modules	SPIST0001 E-712 control via SPI master
E-712.U1 Advanced Piezo Control option	E712T0007 Advanced Piezo Control
E-712.U4 firmware update Advanced Linearization option	E712T0009

Hardware / Firmware	Document
E-711.IP PIO interface module	E711T0001 PIO interface
Hexapod firmware	E712T0011 Hexapod description
Autofocus functionality	E712T0017 Autofocus

Software tools

Tool	Document
Release news for the PI Software Suite	C-990.CD1 release news
PIMikroMove	SM148E software manual
GCS 2.0 drivers for use with NI LabVIEW software	SM158E software manual
Dynamic program library for GCS	SM151E software manual
GCS data format	SM146E software manual
PI MATLAB driver GCS 2.0	SM155E software manual
PIUpdateFinder: search and download updates	A000T0028 user manual

The latest versions of the relevant manuals and technical notes for your system are available for download on our website (www.pi.ws).

For inquiries and orders, contact your PI sales engineer or send us an e-mail (info@pi.ws).

1.2 Intended Use

The E-711/E-712 system is a laboratory device according to DIN EN 61010. It is intended to be used in interior spaces and in an environment which is free of dirt, oil, and lubricants.

Corresponding to its design, the E-711/E-712 system is intended for driving capacitive loads (e.g., piezo ceramic actuators) and DC motors. The drive type to be used depends on the hardware configuration of the E-711/E-712 system.

The E-711/E-712 system must not be used for purposes other than those named in this manual.

The E-711/E-712 system can be used for static as well as dynamic applications.

Position sensors must be used for closed-loop operation. The sensor type to be used depends on the hardware configuration of the E-711/E-712 system (single- and dual-electrode capacitive sensors, strain gauge sensors (SGS) and encoders (incremental, absolute measuring)). PI mechanics intended for closed-loop operation already have the corresponding sensors. Other sensors can only be used with PI approval.

Only authorized and qualified personnel must install, operate, maintain, and clean the E-711/E-712 system. Only PI service personnel must repair the E-711/E-712 system.

Observe the safety instructions in this manual.

1.3 Safety Instructions

WARNING—READ INSTRUCTIONS

Install and operate the E-711/E-712 system only when you have read the operating instructions. Keep the instructions readily available close to the device in a safe place. When the instructions are lost or have become unusable, ask the manufacturer for a new copy. Add all information given by the manufacturer to the instructions, e.g., supplements or technical notes.

WARNING

The housing of the E-711/E-712 system requires a supply voltage of 100 to 240 VAC. The supply voltage may cause serious or even lethal injury. Strictly observe the following:

Use a standard mains supply socket with protective earth contacts (e.g., according to DIN VDE 0100-410) as power supply because the E-711/712 system is grounded via its mains supply line.

Install the E-711/E-712 system near the power supply so that the plug of the power cord can be quickly and easily disconnected from the mains supply socket.

Use the supplied power cord (p. 83) to connect the E-711/E-712 system to the power supply. If the supplied power cord must be replaced, use a sufficiently dimensioned power cord with protective earth contacts.

To disconnect the E-711/E-712 system from the power supply completely, remove the plug of the power cord from the mains supply socket, or remove the power cord from the housing of the E-711/E-712 system.

See "AC Power and Line Fuses" (p. 302) for how to replace the line power fuses.

WARNING

If a sensor box is used that also has connections for piezo actuators (digital sensor signal transmission with E-711.0CT, E-711.0CT0, E-711.0ET, E-711.0ET0, E-711.S3XC):

If a protective earth conductor is not or not properly connected to the sensor box, dangerous contact voltages can occur on the sensor box in the case of malfunction or failure. If dangerous contact voltages exist, touching the sensor box can result in serious injury or death from electric shock.

- Connect the sensor box to a protective earth conductor before switching on the E-711/E-712 system (p. 94).
- Do not remove the protective earth conductor during operation.
- If the protective earth conductor must be removed temporarily (e.g., in the case of modifications or repair), reconnect the sensor box to the protective earth conductor before switching on the E-711/E-712 system again.

WARNING

If stages with piezo actuators are used:

Temperature changes and compressive stresses can induce charges in piezo actuators. After being disconnected from the electronics, piezo actuators can also stay charged for several hours. Touching or short-circuiting the contacts in the connector of the piezo actuator can lead to minor injuries. In addition, piezo actuators can be destroyed by an abrupt contraction.

- Do **not** touch the contacts in the connector of the stage.
- Do **not** pull out the connector of the stage from the E-711/E-712 system during operation.
- Secure the connector of the stage with screws against accidental disconnection.

If a sensor box is used that also has connections for piezo actuators (digital sensor signal transmission with E-711.0CT, E-711.0CT0, E-711.0ET, E-711.0ET0, E-711.S3XC):

- Do **not** touch the contacts in the *PZT* D-sub 15 (m) connector of the sensor box when piezo actuators are connected to the sensor box.
- Before you connect the sensor box to the corresponding sensor or interface module, make sure that the E-711/E-712 system is switched off.
- During operation, do **not** disconnect the sensor box from the corresponding sensor or interface module.
- Secure the connections on the sensor box and on the corresponding sensor or interface module with screws against accidental disconnection.

WARNING

The E-711/E-712 system does not contain any user-serviceable parts. Any system modification or configuration may be done solely by PI service personnel.

- Never disassemble any part of the E-711/E-712 system. Hazardous voltage can be present on the internal components.

NOTICE

Both line power fuses are active and must be checked if there is a fault.

NOTICE

Place the system in a location with adequate ventilation to prevent internal heat build-up. Allow at least 15 cm clearance from the front and the rear of the housing and 1 cm from the bottom (ensured by the feet of the housing).

Never cover any ventilation openings as this will impede ventilation.

! **NOTICE**

Thermally stable systems have the best performance. For a thermally stable system, switch on the E-711/E-712 system at least one hour before you start working with it.

! **NOTICE**

If the internal temperature goes out of range, the voltage output of the E-711/E-712 system will be deactivated. In that case communication with the E-711/E-712 system is still possible, but any control values will be ignored, and the connected mechanics will not move.

! **NOTICE**

Make sure that boxes for transmission or splitting of sensor signals are connected to the corresponding sensor or interface module before switching on the E-711/E-712 system. Connecting a box or removing it while the system is already powered on can cause damage to the electronics.

! **NOTICE**

Incorrect parameter values may lead to improper operation or damage to your hardware. Be careful when changing parameters.

It is strongly recommended to save the parameter values of the E-711/E-712 system to a file on the PC before you make any changes. This way the original settings can be restored if the new parameter settings will not prove satisfactory. To save the parameter values and to load them back to the E-711/E-712 system, use the *Device Parameter Configuration* window of PIMikroMove. See "Creating Backups for Parameter Values" (p. 109) for more information.

NOTICE

If the stage starts oscillating (humming noise):

Immediately switch to open-loop operation or stop the motion. Adjust the notch filters and the control parameters (Servo-Loop P-Term, Servo-Loop I-Term). See "Optimization for Dynamic Operation" (p. 263) for more information.

Do not operate the stage at its resonant frequency because the notch filters are not active in open-loop operation by default. You can measure the resonant frequency using the *Piezo Dynamic Tuner* window of PIMikroMove. See "Optimization for Dynamic Operation" (p. 263) for more information.

Otherwise, the stage could be damaged.

NOTICE

Before you work with Dynamic Digital Linearization (DDL), eliminate any residual oscillations by adjusting the notch filters and the control parameters (Servo-Loop P-Term, Servo-Loop I-Term; see "Optimization for Dynamic Operation" (p. 263)). Using DDL could be critical if there are any residual oscillations in the system; DDL will then cause the oscillations to build up—the more wave generator output cycles are used for DDL initialization, the stronger the effect.

1.4 Model Survey

The E-711/E-712 digital multi-channel controller system can be adapted to many different applications. All devices are assembled and calibrated by PI and come ready for use.

1.4.1 Customized Hardware Configurations

Contact your PI sales engineer or write info@pi.ws if you need a customized configuration or want to upgrade your hardware with additional modules. Any system modification or configuration may be done solely by PI service personnel.

INFORMATION

Customized hardware configurations are not listed here in detail.

The product code for a customized configuration consists of "E-712K", followed by three digits. See the type plate on the rear panel of the housing for the product code of your configuration.

The individual modules, the housing, and the external components (e.g., sensor boxes) of the system can be identified via the configuration list which is delivered separately.

1.4.2 Standard Hardware Components

Housing		Details on
E-712.R1	9.5'' housing, 3 to 6 channels, for piezo voltages to 135 V	p. 23
E-712.R2	19'' housing, 3 to 6 channels, for piezo voltages to ±250 V	
E-712.R3	19" housing, 3 to 6 channels, for piezo voltages to 135 V	
E-712.R4	9.5" housing, 3 to 6 channels, for piezo voltages to ±250 V	
E-712.R5	Universal housing 19" 4 RU with cPCI bus	p. 25

Digital Processor Modules		Details on
E-712.M1	Digital processor and interface module with Ethernet interface, USB, RS-232	p. 27
E-712.N1	Digital PiezoWalk® processor and interface module with Ethernet interface, USB, RS-232	

Amplifier Modules		Details on
E-711.AL4P	High-power amplifier module, 4 channels, 8 W, for E-712 modular digital controller system, -30 V to +135 V	p. 30
E-711.AL41	High-power amplifier module, 4 channels, 8 W, for E-712 modular digital controller system, -30 V to +135 V, D-sub mixed 25W3 (f)	
E-711.AL4A	High-power amplifier module, 4 channels, 8 W, for E-712 modular digital controller system, -30 V to +135 V, incremental sin/cos sensor input, D-sub 37 (f)	p. 33
E-711.AM4	Amplifier module for NEXLINE®, for E-712 modular digital controller system, -250 V to +250 V, D-sub mixed	p. 35
E-711.AM5	Amplifier module for NEXLINE®, for E-712 modular digital controller system, -250 V to +250 V, D-sub 25 (f)	
E-711.AM6	Amplifier module for NEXLINE®, for E-712 modular digital controller system, -250 V to +250 V, without external connector	

Amplifier Modules		Details on
E-711.AM5A	Amplifier module for NEXLINE®, for E-712 modular digital controller system, -250 V to +250 V, incremental sin/cos sensor input	p. 38
E-711.AM5B	Amplifier module for NEXLINE®, for E-712 modular digital controller system, -250 V to +250 V, absolute encoder via BiSS interface	
E-711.AN4	NEXACT® amplifier module, for E-712 modular digital controller system	p. 40
E-711.AN40	NEXACT® amplifier module, for E-712 modular digital controller system, without external connector	

Driver Modules		Details on
E-711.C82	DC motor driver, 2 channels, for E-712 modular digital controller system	p. 42

Sensor Electronics		Details on
E-711.SA3	Module for incremental sensors, 3 channels, for E-712 modular digital controller system	p. 44
E-711.SA6	Module for incremental sensors, 6 channels, for E-712 modular digital controller system	
E-711.SAP	Sensor signal splitter, 3 channels, PIOne incremental sensors, for E-712 digital controller	p. 45
E-711.SAH	Sensor signal splitter, 3 channels, incremental sensors, for E-712 digital controller, version H	
E-711.SAN	Sensor signal splitter, 3 channels, incremental sensors, for E-712 digital controller, version N	
E-711.SAX1	Connection cable for digital piezo controllers and sensor signal splitter, HD D-sub 26, 3 m	p. 47
E-711.SAX2	Connection cable for digital piezo controllers and sensor signal splitter, HD D-sub 26, 5 m	
E-711.SAX5	Connection cable for digital piezo controllers and sensor signal splitter, HD D-sub 26, 15 m	
E-711.0ATS	Digital sensor signal transmission, 8 channels, encoders with BiSS interface, for E-712 digital controller, without cable	p. 47
E-711.SS3	Module for strain gauge sensors, 3 channels, for E-712 modular digital controller system	p. 50
E-711.SC3H	Module for capacitive sensors, 3 channels, for E-712 modular digital controller system	p. 52
E-711.SE3	Module for PISeca capacitive single-electrode sensors, 3 channels, for E-712 modular digital controller system	p. 53
E-711.0CT	Digital sensor signal transmission, 3 channels, capacitive sensors, for E-712 digital controller	p. 54
E-711.0CT0	Digital sensor signal transmission, 3 channels, capacitive sensors, for E-712 digital controller, without cable	

Sensor Electronics		Details on
E-711.S3XC	Digital sensor signal transmission, 3 channels, capacitive sensors, for E-712 digital controller, without cable	p. 59
E-711.0ET	Digital sensor signal transmission, 3 channels, PISeca sensors, for E-712 digital controller, including 10 m cable	p. 64
E-711.0ET0	Digital sensor signal transmission, 3 channels, PISeca sensors, for E-712 digital controller, without cable	

Analog Interface Module		Details on
E-711.IA4	Analog interface module, 4 inputs, 4 outputs	p. 70

SPI Interface Modules		Details on
E-711.iS3	SPI interface module for E-712 modular digital controller system, 3 channels	p. 71
E-711.iS6	SPI interface module for E-712 modular digital controller system, 6 channels	

PIO Interface Module		Details on
E-711.IP	PIO interface module for E-712 modular digital controller system	p. 72

Predefined System Configurations		Details on
E-712.3CD	Modular digital piezo controller, 3 channels, capacitive sensors	p. 73
E-712.3CDA	Modular digital piezo controller, 3 channels, capacitive sensors, analog inputs and outputs	
E-712.6CD	Modular digital piezo controller, 6 channels, capacitive sensors	
E-712.6CDA	Modular digital piezo controller, 6 channels, capacitive sensors, analog inputs and outputs	
E-712.6IDA	Modular digital multi-channel piezo controller, 6 channels, incremental sensors, analog inputs and outputs	p. 76
E-712.1AM	Digital motion controller, 1 channel, for NEXLINE® nanopositioning linear drives with incremental encoder	p. 78
E-712.1AN E-712.2AN E-712.3AN	Digital controller for PICMAWalk drives with incremental sensors	p. 80

1.5 Specifications and Product Descriptions

1.5.1 Ambient Conditions and Classifications

The E-711/E-712 system meets the following ambient conditions and classifications:

- Indoor use only
- Max. altitude for operation 2000 m
- Operating temperature range 5 °C to 40 °C (up to 50 °C possible with loss of performance)
- Storage temperature range 0 °C to +70 °C
- Shipping temperature range -25 °C to +85 °C
- Max. relative humidity 80 % for temperatures up to 31 °C, decreasing linearly to 50 % relative humidity at 40 °C
- Line voltage fluctuations not greater than ±10% of the line voltage
- Transient overvoltages as typical for public power supply. Note: The nominal level of the transient overvoltage is the standing surge voltage according to the overvoltage category II (IEC 60364-4-443).
- Overvoltage category: II
- Protection class: I
- Degree of pollution: 2
- Degree of protection according to IEC 60529: IP20

1.5.2 E-712.R1, .R2, .R3, .R4 Housing

The housing can be identified via the configuration list which is delivered separately with the E-711/E-712 system.

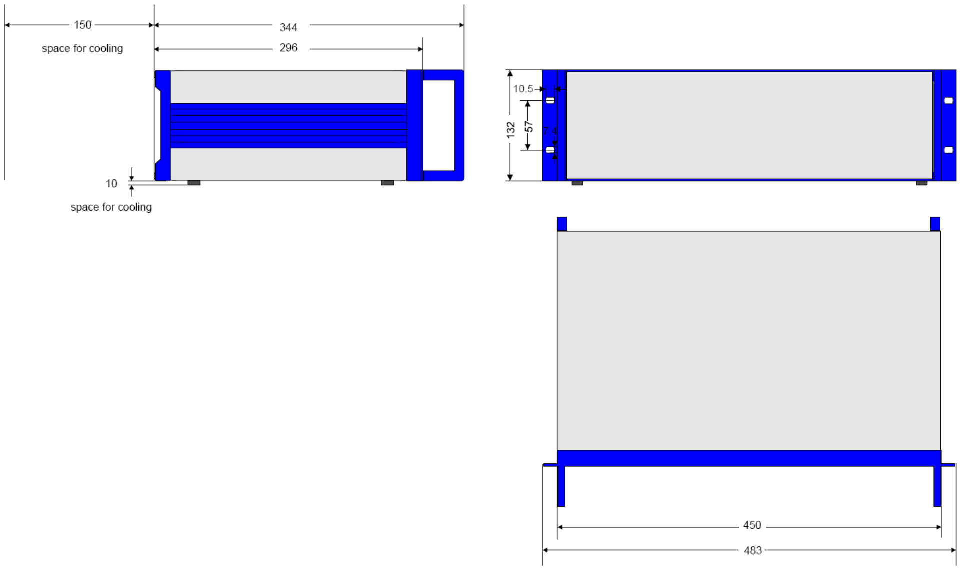


Figure 1: E-712.R2 and E-712.R3 dimensions in millimeters

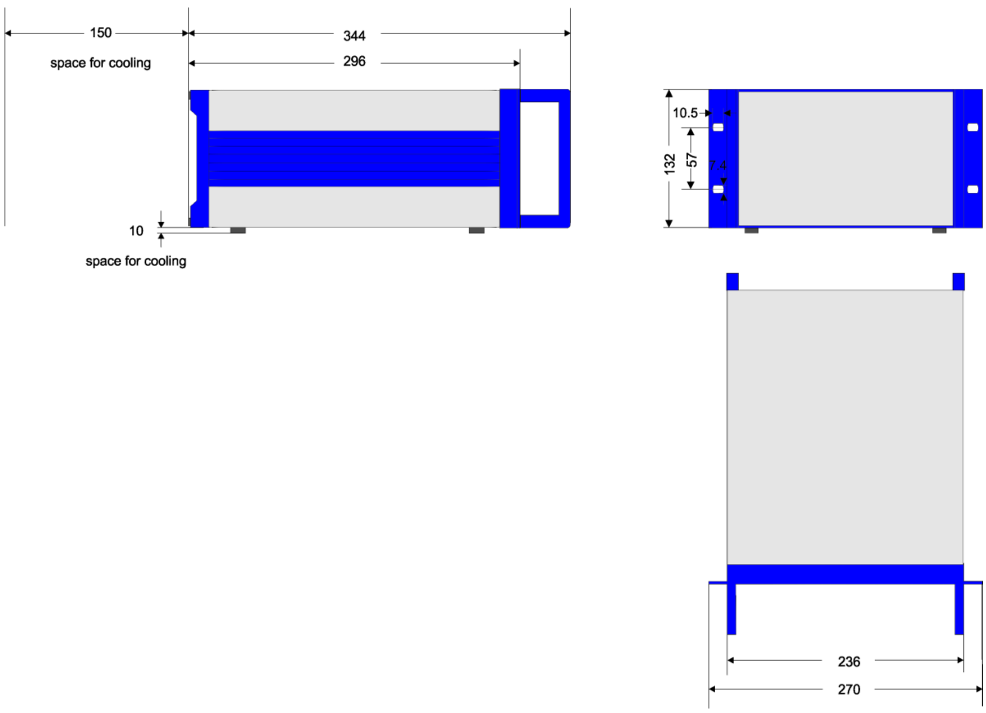


Figure 2: E-712.R1 and E-712.R4 dimensions in millimeters

Operating Elements of E-712.R1, .R2, .R3, and .R4 housing

All elements described below are located on the rear panel.

Element	Function
	⚠ On/Off switch (|—| means ON, |O| means OFF), integrated in line fuse carrier. See "Sequence when Switching On and Rebooting" (p. 114) and "AC Power and Line Fuses" (p. 302) for more information.
	AC power cord socket See "AC Power Connection" (p. 93) for more information.
SERVICE	This connector is for PI service personnel only.

Specifications

	E-712.R1 / .R2 / .R3 / .R4
Function	Housing with power supply
Supported piezo voltage range	-30 V to +135 V / -250 V to +250 V / -30 V to +135 V / -250 V to +250 V
Channels	3 to 6 channels
Dimensions	9.5" / 19" / 19" / 9.5" See figures above.
Mass	4.16 kg / 6.7 kg / 6.7 kg / 4.16 kg
Operating voltage	100 V to 240 V AC, 50-60 Hz
Line power fuses	2 x T2.5AH, 250 V*
Power consumption	max. 225 VA
Output power	max. 100 W

* Unless otherwise noted on the type plate on the rear panel of the housing.

1.5.3 E-712.R5 Housing

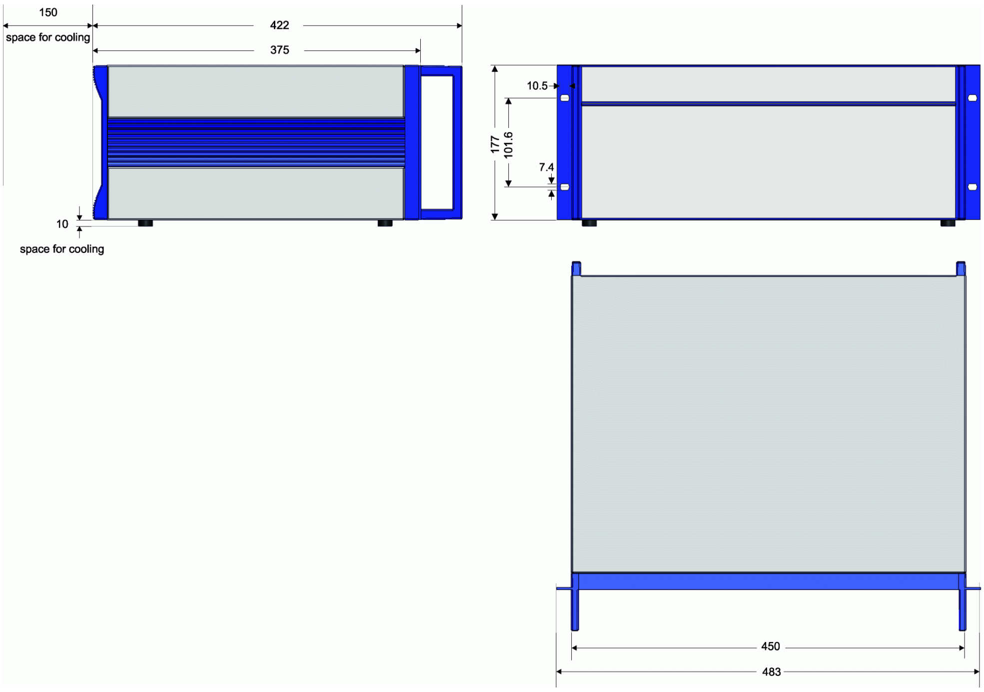


Figure 3: E-712.R5 dimensions in millimeters

Operating Elements of E-712.R5 housing

The following elements are located on the rear panel:

Element	Function
	Line fuse carrier See "Sequence when Switching On and Rebooting" (p. 114) and "AC Power and Line Fuses" (p. 302) for more information.
	AC power cord socket See "AC Power Connection" (p. 93) for more information.
SERVICE	This connector is for PI service personnel only.

The following elements are located on the front panel:

Element	**Function**
	On/Off switch (|O| means OFF; green light means ON) See "Sequence when Switching On and Rebooting" (p. 114) for more information.
Actuators *-250V to +250V* 	This connector is present only if amplifier modules which do not have their own output connectors are present in the E-711/E-712 system. The output voltage can be: With NEXLINE® (E-711.AM6 modules present): -250 V to +250 V With NEXACT® (E-711.AN40 modules present): -10 V to +45 V See "E-712.R5: Connector for NEXLINE® Drives" (p. 322) and "E-712.R5: Connector for NEXACT® Drives" (p. 323) for pinout.

Specifications

	E-712.R5
Function	Housing with cPCI bus
Supported piezo voltage range	Up to -250 V to 250 V
Channels	Up to 12 channels
Dimensions	19", 4 U; see figure above
Mass	4.4 kg
Operating voltage**	100 to 240 VAC, 50-60 Hz
Line power fuses**	2 x T3.15AH, 250 V*
Power consumption**	max. 450 VA
Output power**	max. 200 W

* Unless otherwise noted on the type plate on the rear panel of the housing.

** A suitable power supply is added by PI according to the requirements of the E-711/E-712 digital multi-channel controller system.

1.5.4 E-712.M1 and .N1 Digital Processor Modules

The digital processor module can be identified via the configuration list which is delivered separately with the system.

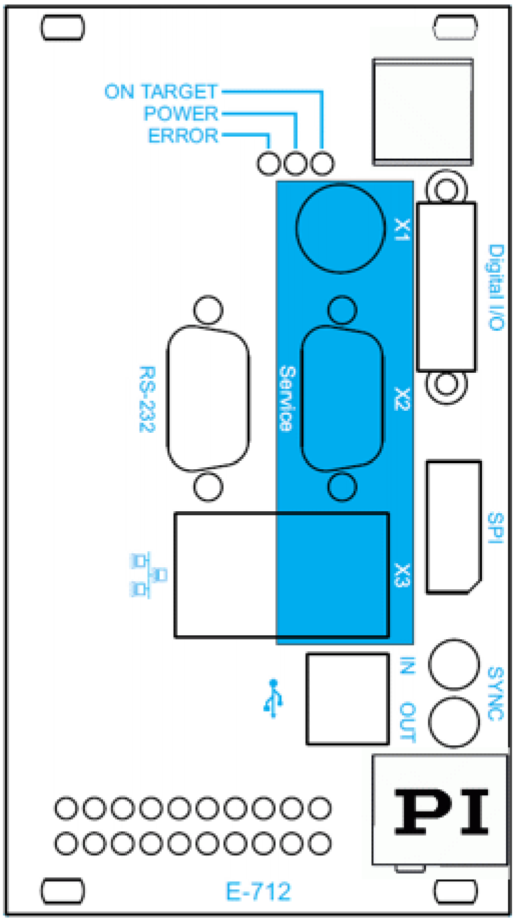
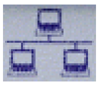


Figure 4: Front panel of E-712.M1 and E-712.N1 digital processor and interface modules

Operating elements of E-712.M1 and .N1 digital processor modules

Name	Function
ON TARGET LED (yellow)	On-target indicator (only relevant in closed-loop operation); lights up if all axes are on target; the on-target state can also be queried with the ONT? command.
POWER LED (green)	Switch-on and ready indicator. The LED blinks when switching on or rebooting which takes about 40 seconds (the more modules, the longer the duration). When switching on or rebooting is finished, the LED glows permanently. Note that depending on the communication interface used, it might take another period of about 30 seconds before communication can be established.

Name	**Function**
ERROR LED (red)	Error indicator; when LED lights up, error code is non-zero and can be queried and cleared using the ERR? command (p. 275).
RS-232	RS-232 interface to the PC. See "RS-232 Connector" (p. 336) for pinout.
	Network connection over TCP/IP interface. See "TCP/IP " (p. 156) for more information.
	USB Type-B socket for connection to the PC. See "USB " (p. 163) for more information.
X1 *Service* *X2* *X3*	The interfaces in the *Service* pane are for PI service personnel only (system setup and service). The E-711/E-712 system cannot be used like a PC.
Digital I/O	MDR20 socket for digital input and output lines; can be used to trigger external devices and to send start/stop signals to the wave generator. See "Digital I/O Connector" (p. 335) for the availability of the lines and for pinout.
SPI	DisplayPort socket for SPI slave interface. Via the SPI slave interface, the E-711/E-712 system receives the target positions from an SPI master and sends the real positions of the axes to this SPI master. See "Control via SPI Master" (p. 210) for more information.
SYNC IN	Lemo connector for synchronization of multiple E-711/E-712 systems. Connects to the previous E-711/E-712 system. See "Synchronization of Multiple Controllers" (p. 124) for more information and "SYNC IN Connector" (p. 337) for pinout.
SYNC OUT	Lemo connector for synchronization of multiple E-711/E-712 systems. Connects to the next E-711/E-712 system. See "Synchronization of Multiple Controllers" (p. 124) for more information and "SYNC OUT Connector" (p. 337) for pinout.

Specifications

	E-712.M1 / E-712.N1
Function	Digital processor and interface module / Digital PiezoWalk® processor and interface module
Supported positioning systems	Nanopositioning systems / nanopositioning systems and PiezoWalk® systems
Axes	Support of up to 16 axes

	E-712.M1 / E-712.N1
Processor	PC-based
Sampling rate, control loop	max. 50 kHz
Sampling rate, sensor	max. 50 kHz
Ext. sensor synchronization	Yes
Communication interfaces	Ethernet, USB, RS-232, SPI
Digital input	8 x TTL on MDR20
Digital output	8 x TTL on MDR20
Command set	PI General Command Set (GCS) 2.0
Supported functionality	Wave generator, trigger I/O, data recorder Several control algorithms can be selected, e.g.: ▪ PI, two notch filters ▪ Advanced Piezo Control, must be ordered separately (order # E-712.U1) ▪ PID position control with subordinated velocity control, two notch filters ▪ PID velocity control, two notch filters
Display	LEDs for OnTarget, Err, Power
Linearization	4th order polynomials DDL (Dynamic Digital Linearization) option, must be ordered separately (order # E-710.SCN)
Mass	500 g

For the support of PiezoWalk® systems (i.e., systems driven by NEXLINE®, NEXACT® or PICMAWalk drives) by the E-712.N1 Digital PiezoWalk® processor and interface module see the E712T0010 user manual.

1.5.5 E-711.AL4P, E-711.AL41 Amplifier Modules

The E-711.AL4P and .AL41 amplifier modules are intended for driving up to four piezo actuators.

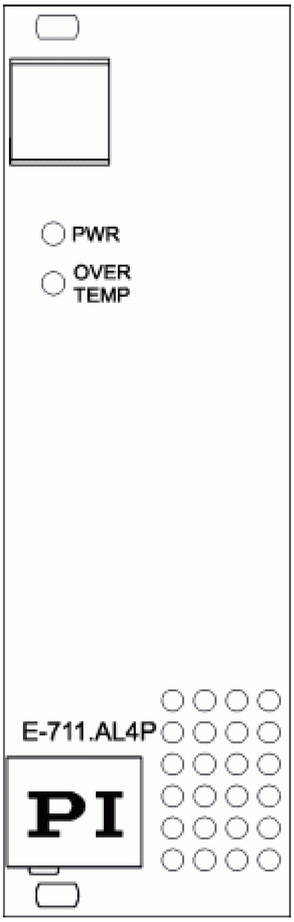


Figure 5: Front panel of E-711.AL4P amplifier modules

Operating elements of E-711.AL4P amplifier modules

Name	Function
PWR LED (green)	Switch-on and ready indicator.
OVER TEMP LED (red)	Deactivation indicator for the piezo voltage output; glows if the output is deactivated (e.g., during system initialization after switching on or rebooting, or due to internal overheating). See "Troubleshooting" (p. 305) for more information on overheating.

INFORMATION

For each E-711.AL4P amplifier module, an E-711.SS3 (p. 50) or E-711.SC3H (p. 52) sensor module is required too because the connector of the sensor module carries the output voltage lines.

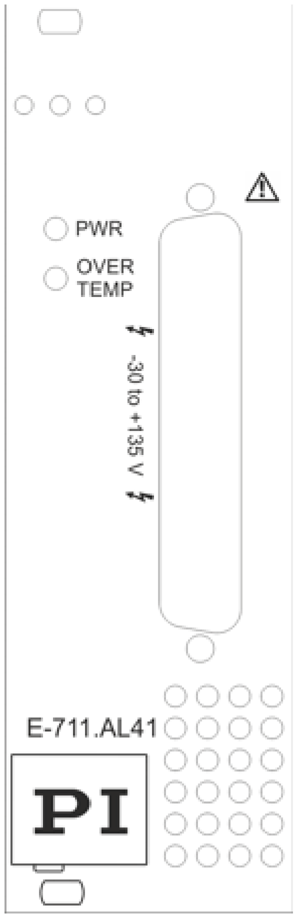


Figure 6: Front panel of E-711.AL41 amplifier modules

Operating elements of E-711.AL41 amplifier modules

Name	Function
PWR LED (green)	Switch-on and ready indicator.
OVER TEMP LED (red)	Deactivation indicator for the piezo voltage output; glows if the output is deactivated (e.g., during system initialization after switching on or rebooting, or due to internal overheating). See "Troubleshooting" (p. 305) for more information on overheating.
-30 to +135 V	D-sub mixed 25W3 connector for piezo stages; carries the voltage lines (-30 V to +135 V) for up to four piezo actuators. See "E-711.AL41: Connector for Piezo Actuators" (p. 316) for pinout.

Specifications

	E-711.AL4P / .AL41
Min. output voltage	-30 V
Max. output voltage	+135 V
Amplifier channels	4
Peak output power per channel	25 W*
Average output power per channel	8 W
Peak output current per channel	250 mA
Average output current per channel	150 mA
Current limitation	Short-circuit proof
Resolution DAC	20 bit (effective)

	E-711.AL4P / .AL41
Temperature sensor	Max. 75 °C, deactivation of the piezo voltage output
Connector	No connector / D-sub mixed 25W3
Dimensions	8 TE
Mass	515 g

* The maximum output power is limited by the power supply of the housing and by the number of channels present. See housing specifications for more information.

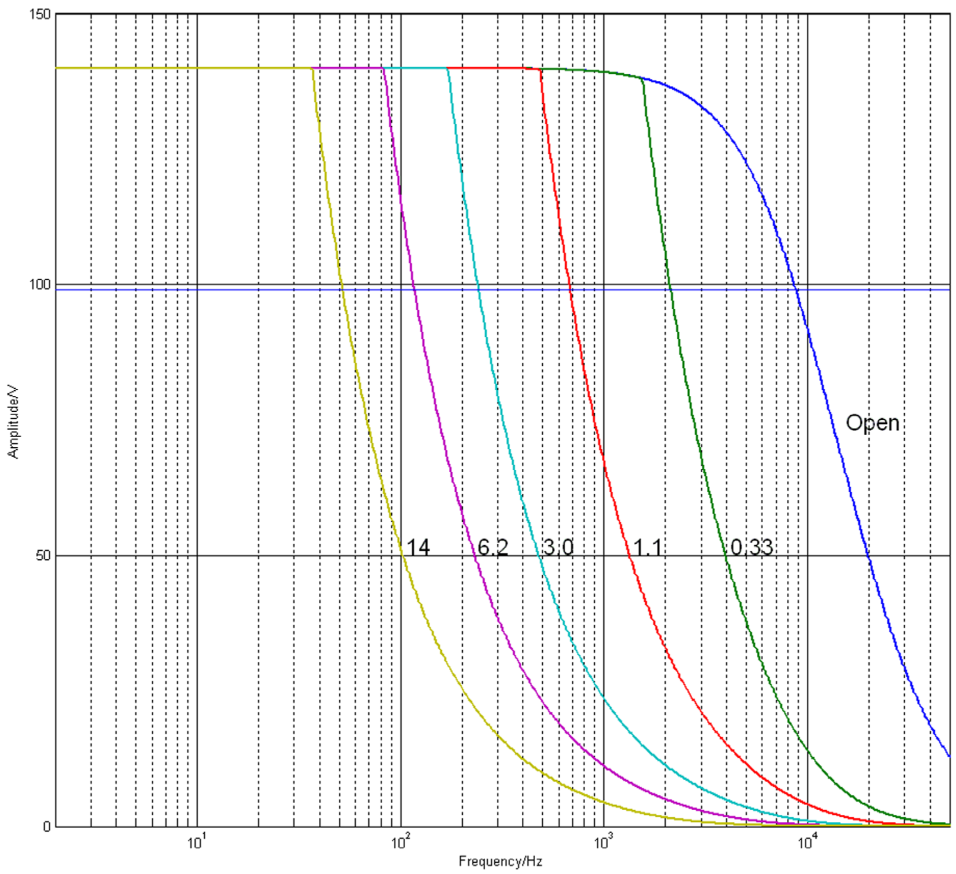


Figure 7: Operating limits with different piezo loads, capacitance is measured in µF

1.5.6 E-711.AL4A Amplifier Module

The E-711.AL4A amplifier module is intended for driving one PICMAWalk drive with incremental sensor (i.e., four piezo actuators, and one encoder).

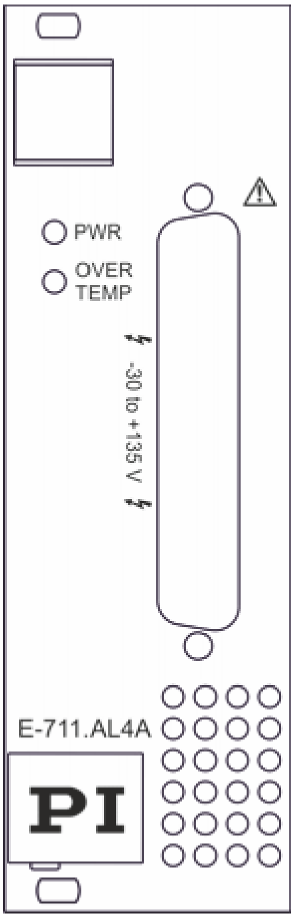


Figure 8: Front panel of E-711.AL4A amplifier module

Operating elements of E-711.AL4A amplifier modules

Name	Function
PWR LED (green)	Switch-on and ready indicator.
OVER TEMP LED (red)	Deactivation indicator for the piezo voltage output; glows if the output is deactivated (e.g., during system initialization after switching on or rebooting, or due to internal overheating). See "Troubleshooting" (p. 305) for more information on overheating.
-30 to +135 V ⚠	D-sub 37 (f) connector for a mechanics with piezo actuators and encoder; the output lines carry the piezo voltages in the range of -30 V to +135 V. See "E-711.AL4A: Connector for Piezo-Driven Mechanics with Encoder" (p. 317) for pinout.

Specifications

	E-711.AL4A
Amplifier	
Amplifier channels	4
Min. output voltage	-30 V
Max. output voltage	+135 V
Peak output power per channel	25 W*
Average output power per channel	8 W
Peak output current per channel	250 mA
Average output current per channel	150 mA
Current limitation	Short-circuit proof
Resolution DAC	20 bit, interpolated
Temperature sensor	Max. 75 °C, deactivation of the piezo voltage output
Sensor	
Sensor channels	1
Encoder input	Incremental encoder analog sin/cos; 1 Vpp, 2.5 V offset
Interpolation factor	2^{16}-fold interpolation
Reference switch and limit switches	TTL
Miscellaneous	
Connector	D-sub 37 (f)
Dimensions	8 TE
Mass	515 g

* The maximum output power is limited by the power supply of the housing and by the number of channels present. See housing specifications for more information.

1.5.7 E-711.AM4, .AM5, .AM6 Amplifier Modules

The E-711.AM4, .AM5 and .AM6 amplifier modules are intended for driving one NEXLINE® drive.

In combination with an E-712.M1 digital processor module and an E-712.R5 housing, each of the amplifier modules can also be used to drive up to four conventional piezo actuators.

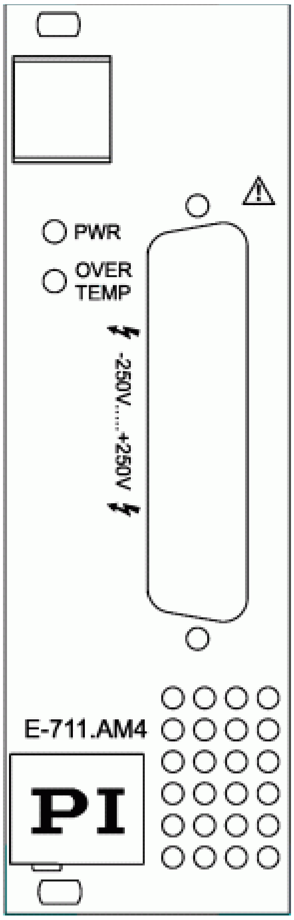


Figure 9: Front panel of E-711.AM4 amplifier modules

Operating elements of E-711.AM4 and .AM5 amplifier modules

Name	Function
PWR LED (green)	Switch-on and ready indicator.
OVER TEMP LED (red)	Deactivation indicator for the piezo voltage output; glows if the output is deactivated (e.g., during system initialization after switching on or rebooting, or due to internal overheating). See "Troubleshooting" (p. 305) for more information on overheating.
-250 V……+250 V ⚠	Connector for a NEXLINE® drive or for up to four conventional piezo actuators. The output lines carry piezo voltages in the range of -250 V to +250 V. See "E-711.AM4: Connector for NEXLINE® Drive" (p. 319) or "E-711.AM5: Connector for NEXLINE® Drive" (p. 320) for pinout.

INFORMATION

The front panel of the E-711.AM5 module is identical with that of the E-711.AM4 module. Both modules differ only in the connector type:

E-711.AM4: D-sub mixed 24W7 connector for 7 coax lines and 17 single pins

E-711.AM5: D-sub 25 (f)

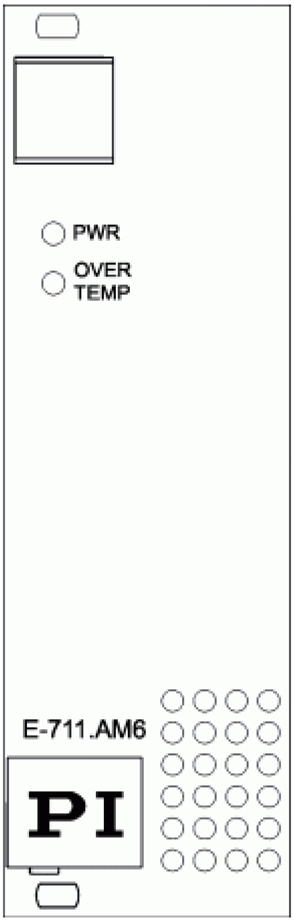


Figure 10: Front panel of E-711.AM6 amplifier modules

Operating elements of E-711.AM6 amplifier modules

Name	Function
PWR LED (green)	Switch-on and ready indicator.
OVER TEMP LED (red)	Deactivation indicator for the piezo voltage output; glows if the output is deactivated (e.g., during system initialization after switching on or rebooting, or due to internal overheating). See "Troubleshooting" (p. 305) for more information on overheating.

INFORMATION

The E-711.AM6 amplifier module is identical in function with the E-711.AM4 module but has no connector on the front panel.

The output voltage of up to 6 E-711.AM6 amplifier modules is available via a HD D-sub 50 (f) connector on the E-712.R5 housing (see p. 322 for pinout).

Specifications

	E-711.AM4 / .AM5 / .AM6
Min. output voltage	-250 V
Max. output voltage	+250 V
Amplifier channels	4
Peak output power per channel	45 W*

	E-711.AM4 / .AM5 / .AM6
Average output power per channel	15 W
Peak output current per channel	180 mA
Average output current per channel	60 mA
Current limitation	Short-circuit proof
Resolution DAC	20 bit
Temperature sensor	Max. 75 °C, deactivation of the piezo voltage output
Connector	D-sub mixed 24W7 / D-sub 25 (f) / no connector
Dimensions	8 TE
Mass	515 g / 515 g / 500 g

* The maximum output power is limited by the power supply of the housing and by the number of channels present. See housing specifications for more information.

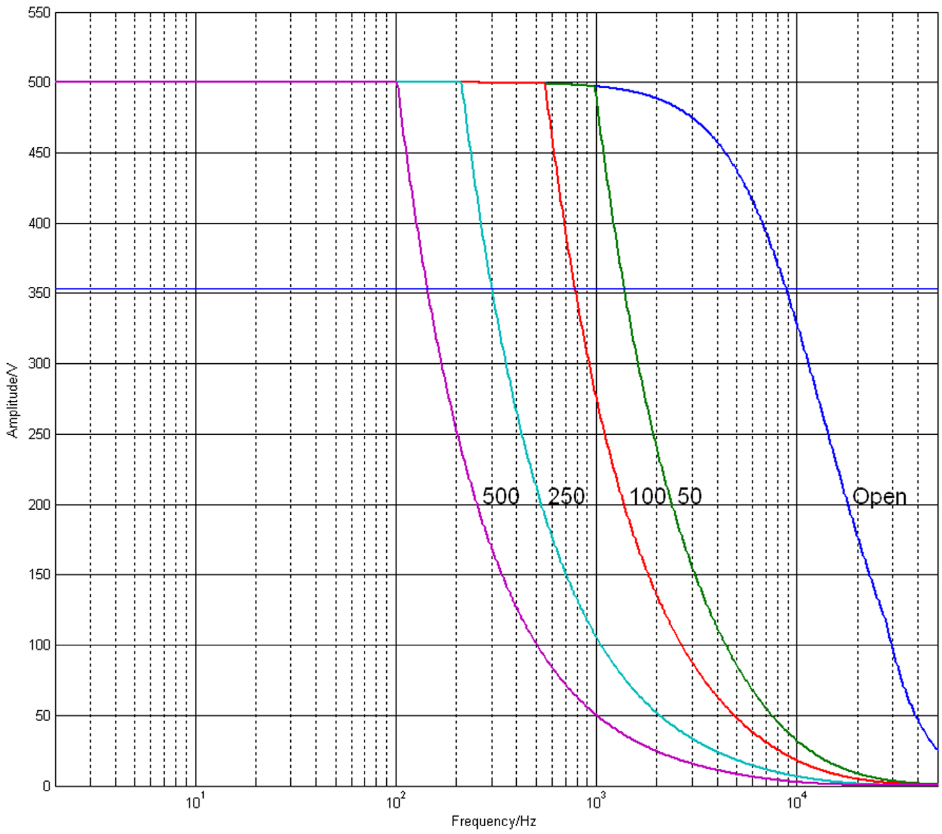


Figure 11: Operating limits with different piezo loads, capacitance is measured in µF

1.5.8 E-711.AM5A, .AM5B Amplifier Modules

The E-711.AM5A and .AM5B amplifier modules are intended for driving one NEXLINE® drive which is equipped with an encoder.

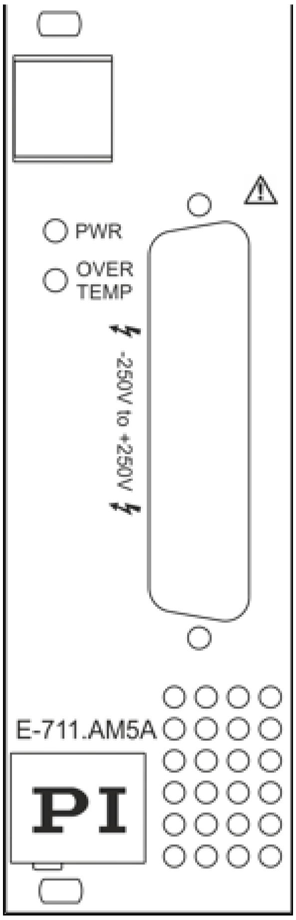


Figure 12: Front panel of E-711.AM5A amplifier modules

Operating elements of E-711.AM5A and .AM5B amplifier modules

Name	Function
PWR LED (green)	Switch-on and ready indicator.
OVER TEMP LED (red)	Deactivation indicator for the piezo voltage output; glows if the output is deactivated (e.g., during system initialization after switching on or rebooting, or due to internal overheating). See "Troubleshooting" (p. 305) for more information on overheating.
-250 V to +250 V	D-sub 25 (f) connector for a NEXLINE® drive with encoder; the output lines carry the piezo voltages for the shearing and clamping segments of the NEXLINE® stack actuator pairs in the NEXLINE® drive, in the range of -250 V to +250 V. See "E-711.AM5A and .AM5B: Connector for NEXLINE® Drive with Encoder" (p. 321) for pinout.

INFORMATION

The front panel of the E-711.AM5B module is identical with that of the E-711.AM5A module. Both modules differ only in the supported sensor type:

E-711.AM5A: Incremental encoder

E-711.AM5B: Absolute measuring encoder via BiSS interface

Specifications

	E-711.AM5A / .AM5B
Amplifier	
Amplifier channels	4
Min. output voltage	-250 V
Max. output voltage	+250 V
Peak output power per channel	45 W*
Average output power per channel	15 W
Peak output current per channel	180 mA
Average output current per channel	60 mA
Current limitation	Short-circuit proof
Resolution DAC	20 bit, interpolated
Temperature sensor	Max. 75 °C, deactivation of the piezo voltage output
Sensor	
Sensor channels	1
Encoder input	E-711.AM5A: Incremental encoder (analog sin/cos; 1 Vpp, 2.5 V offset) E-711.AM5B: Absolute measuring encoder via 32-bit BiSS C interface
Interpolation factor	2^{16}-fold interpolation / 16 to 32 bit
Reference switch and limit switches	TTL
Miscellaneous	
Connector	D-sub 25 (f)
Dimensions	8 TE
Mass	515 g

* The maximum output power is limited by the power supply of the housing and by the number of channels present. See housing specifications for more information.

1.5.9 E-711.AN4, .AN40 Amplifier Modules

The E-711.AN4 and .AN40 amplifier modules are intended for driving one NEXACT® drive.

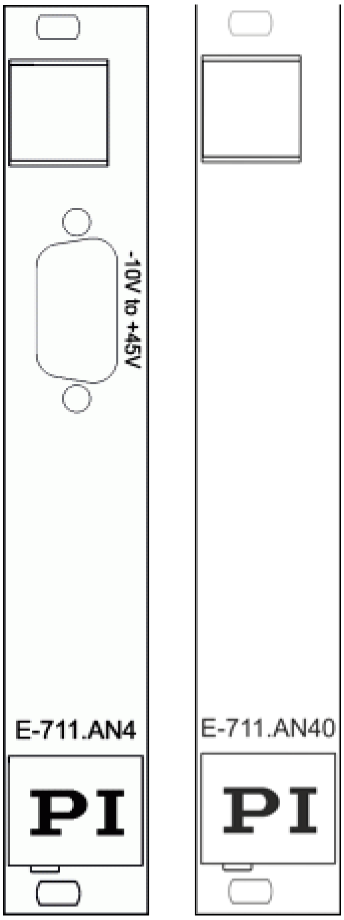


Figure 13: Front panels of E-711.AN4 and .AN40

Operating elements of E-711.AN4 amplifier modules

Name	Function
-10 V to +45 V	HD D-sub 15 (f) connector for a NEXACT® drive; the output lines carry the piezo voltages for the actuator segments of the NEXACT® drive, in the range of -10 V to +45 V. See "E-711.AN4: Connector for NEXACT® Drive" (p. 324) for pinout.

INFORMATION

The E-711.AN40 amplifier module is identical in function with the E-711.AN4 module but has no connector on the front panel.

The output voltage of up to 6 E-711.AN40 amplifier modules is available via an HD D-sub 78 (f) connector on the E-712.R5 housing (see p. 323 for pinout).

Specifications

	E-711.AN4 / .AN40
Min. output voltage	-10 V
Max. output voltage	+45 V
Amplifier channels	4
Peak output power per channel	30 W*
Average output power per channel	4 W
Peak output current per channel	750 mA
Average output current per channel	250 mA
Current limitation	Short-circuit proof
Resolution DAC	16 bit
Temperature sensor	Max. 160 °C
Connector	HD D-sub 15 (f) / no connector
Dimensions	8 TE
Mass	347 g

* The maximum output power is limited by the power supply of the housing and by the number of channels present. See housing specifications for more information.

1.5.10 E-711.C82 DC Motor Driver Module

The E-711.C82 DC motor driver module is intended for driving two DC motor channels which are each equipped with an incremental encoder.

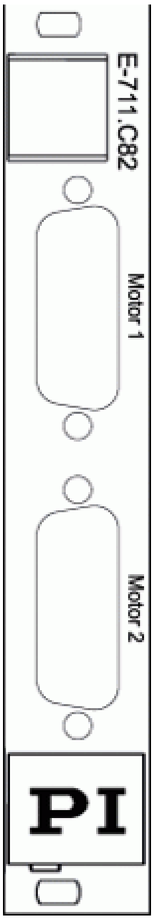


Figure 14: Front panel of E-711.C82 DC motor driver modules

Operating elements of E-711.C82 modules

Name	Function
Motor 1 *Motor 2*	D-sub 15 (f) connector for stage axis. Only for DC motors! • Output of PWM signals for the motor • Input of the signals of the incremental position sensor • Input of the signals from the limit switches and reference switch

NOTICE

!

Connecting a stage with stepper motor to a DC motor driver can cause irreparable damage.

Only connect to the E-711.C82 a stage with DC motor.

INFORMATION

The E-711.C82 supports stages with a PWM amplifier as well as stages without a PWM amplifier. Separate lines on the connectors *Motor 1* and *Motor 2* (p. 325) are available for both stage versions. The selection of the proper lines must be ensured via the connector of the stage. With stages from PI the proper connection is ensured.

Specifications

	E-711.C82
Function	DC motor driver, 2 channels
Channels	2
Encoder input	Selectable via parameter: ▪ Incremental sensor: AB (quadrature) single-ended or differential TTL signal according to RS-422; 60 MHz ▪ Incremental sensor: Analog sin/cos; 1 Vpp ▪ Absolute measuring sensor via 32-bit BiSS interface
Interpolation factor	2^{16}
Limit switches	2 × TTL (polarity programmable)
Reference switch	1 × TTL
Motor brake	1 × TTL, software controlled
Max. output voltage	0 to 24 V for direct control of DC motor
Max. output power	30 W
Current limitation	2 A
Motor connector	D-sub 15 (f)
Dimensions	4 TE
Mass	0.3 kg
Measurement category	II

1.5.11 E-711.SA3 and .SA6 Modules for Incremental Sensors

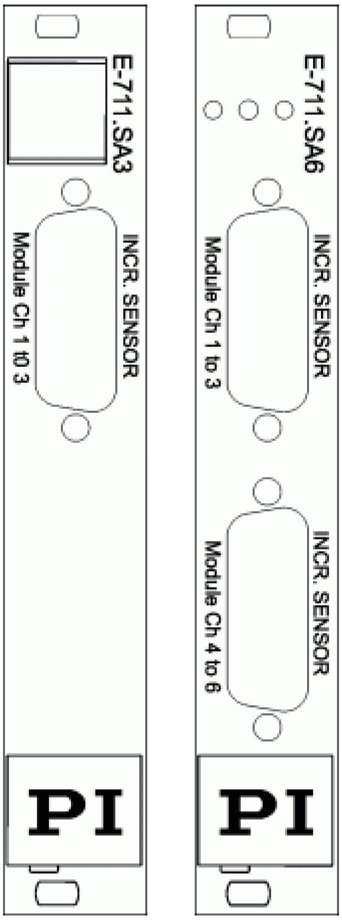


Figure 15: Front panels of E-711.SA3 (left) and E-711.SA6 (right)

Operating elements of E-711.SA3 and .SA6 sensor modules

Name	Function
INCR. SENSOR Module Ch 1 to 3	HD D-sub 26 (m) connector for sensor connection. Depending on the mechanics, sensors can be connected directly or via an E-711.SAx sensor signal splitter box of the suitable type (x = P, H or N depending on the sensor type) and an E-711.SAX connection cable (see p. 99). See "E-711.SA3 and E-711.SA6: Connector for Incremental Sensors" (p. 327) for pinout.
INCR. SENSOR Module Ch 4 to 6	With E-711.SA6 only; HD D-sub 26 (m) connector for sensor channels 4 to 6. See above for details.

Specifications

	E-711.SA3 / .SA6
Function	Module for incremental sensors (analog sin/cos; 1 Vpp)
Channels	3 / 6
Sampling rate	250 kHz (max. sin/cos frequency)
Interpolation factor	512 to 524288
Adjustment	Automatic adjustment for highest accuracy, see p. 117

	E-711.SA3 / .SA6
Sensor connector	1 x HD D-sub 26 (m) / 2 x HD D-sub 26 (m) Sensors can be connected directly or via an E-711.SAx splitter box of the suitable type (x = P, H or N depending on the sensor type) and an E-711.SAX connection cable.
Dimensions	4 TE
Mass	150 g
Measurement category	II

1.5.12 E-711.SAP, .SAH, .SAN Splitter Boxes for Incremental Sensors

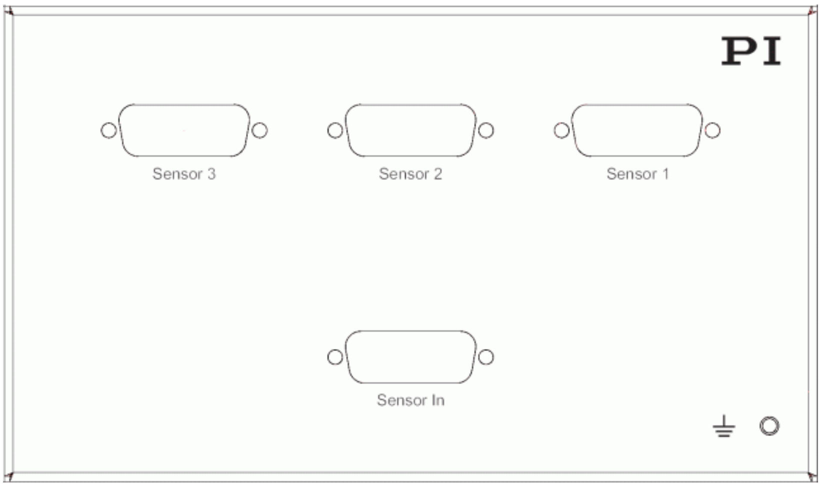


Figure 16: Front panel of E-711.SAP, E-711.SAH and E-711.SAN sensor signal splitter box for incremental sensors

Operating elements of E-711.SAP, .SAH and .SAN sensor splitter boxes

Name	Function
Sensor In	HD D-sub 26 (f) connector for connection to a sensor module via an E-711.SAX connection cable (see p. 99). See "E-711.SA3 and E-711.SA6: Connector for Incremental Sensors" (p. 327) for pinout.
Sensor 1 *Sensor 2* *Sensor 3*	D-sub 15 connectors for sensor connection; each connector is for one sensor of the suitable type. See p. 328 (E-711.SAH), p. 329 (E-711.SAN), or p. 330 (E-711.SAP) for connector types and pinouts.

Specifications

	E-711.SAP / .SAH / .SAN
Function	Distribution of incremental sensor signals
Channels	3
Sensor type	PIOne / type H / type N
Sensor connector	3 x D-sub 15 (f) for connection of up to three sensors 1 x HD D-sub 26 (m) for connection to E-711.SA3 or E-711.SA6 via an E-711.SAX connection cable.
Dimensions	See figure below
Mass	582 g
Measurement category	II

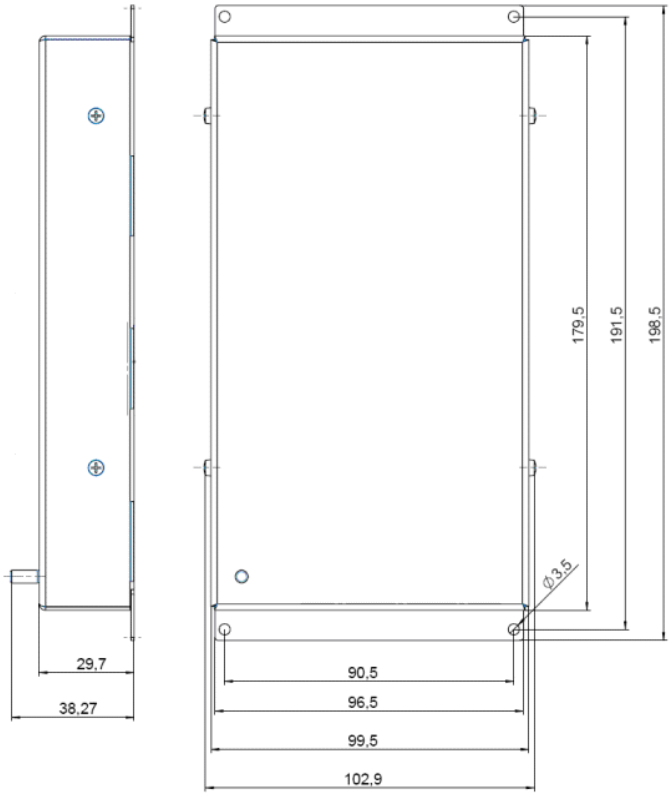


Figure 17: Dimensions of E-711.SAP, E-711.SAH and E-711.SAN sensor signal splitter box for incremental sensors; decimal places separated by commas

1.5.13 E-711.SAX, .SAX1, .SAX2, .SAX5 Connection Cables for Modules and Splitter Boxes for Incremental Sensors

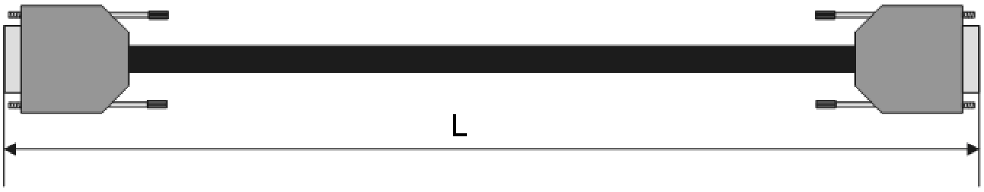


Figure 18: Connection cable for modules and splitter boxes for incremental sensors

E-711.SAX: L = 1 m

E-711.SAX1: L = 3 m

E-711.SAX2: L = 5 m

E-711.SAX5: L = 15 m

1.5.14 E-711.0ATS Sensor Box for Encoders with BiSS Interface

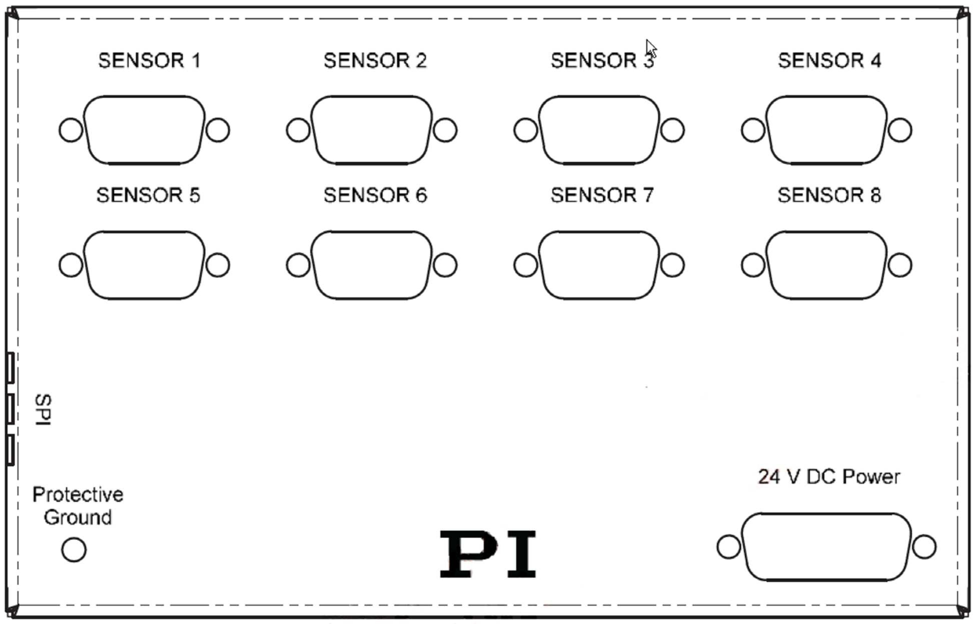


Figure 19: Front panel of E-711.0ATS sensor box for encoders with BiSS interface

Operating elements of E-711.0ATS sensor box

Name	Function
Sensor 1 to *Sensor 8*	D-sub 9 (f) connectors for sensor connection. See p. 331 for pinout.
24 V DC Power	D-sub 3W3 panel plug for the supply voltage. See p. 331 for pinout.
SPI	DisplayPort socket on the side panel of the sensor box. For connection to an SPI master unit via a DisplayPort cable.
-	USB Mini-B on the side panel of the sensor box. For PI service personnel only (setup and service).

INFORMATION

The SPI interface of the E-711.0ATS sensor box runs in SPI slave mode. The SPI master unit connected to the E-711.0ATS box can be an E-711.iS3 or E-711.iS6 SPI interface module (p. 71) from PI.

Specifications

	E-711.0ATS
Function	Digital sensor signal transmission
Channels	8
Sensor type	Encoder via 32-bit BiSS interface (absolute measuring or incremental)
Sensor connector	8 x D-sub 9 (f) for connection of up to eight sensors 1 x DisplayPort socket for connection to E-711.iS3 or E-711.iS6 via a DisplayPort cable (not included).
Dimensions	See figure below
Mass	338 g
Operating voltage	24 V DC, max. 0.6 A from external power supply (not included)
Measurement category	II

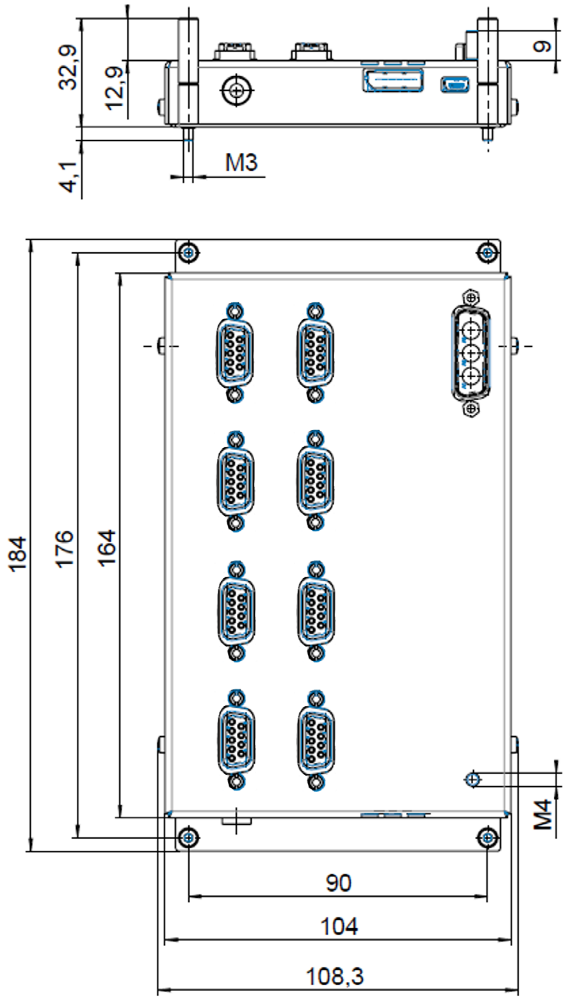


Figure 20: Dimensions of E-711.0ATS sensor box for encoders with BiSS interface; decimal places separated by commas

1.5.15 E-711.SS3 Module for Strain Gauge Sensors

Figure 21: Front panel of E-711.SS3

Operating elements of E-711.SS3 sensor modules

Name	Function
Ch1 to Ch4 *-30 to +130 V*	D-sub 37 (f) connector for piezo stages; carries the signals of up to four strain gauge sensors, one PT1000 temperature sensor and the voltage lines (-30 to +130 V) for up to four piezo actuators (E-711.AL4P must be present in the system). See p. 318 for pinout.

Specifications

	E-711.SS3
Function	Module for transmission of strain gauge and temperature sensor signals
Sensor channels	4
Connector type	D-sub 37 (f), carries also the 4 piezo voltage lines of E-711.AL4P amplifier modules
SGS / Position	
Sensor resolution, 1 σ, @ 300 Hz	1:20000
Sensor bandwidth (-3dB)	max. 10 kHz
Reference signal, per channel	5 V, max. 15 mA
PT1000 / Temperature	
Sensor resolution	8 bit, -50 °C to 150 °C
Current of reference signal	0.25 mA
Miscellaneous	
Dimensions	4 TE
Mass	164 g
Measurement category	II

1.5.16 E-711.SC3H Module for Capacitive Sensors

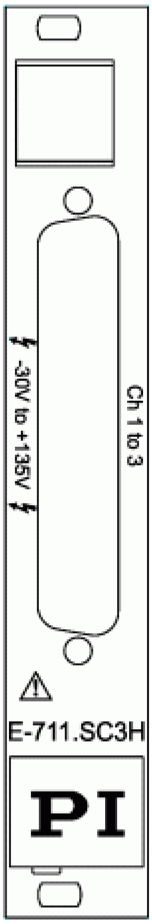


Figure 22: Front panel of E-711.SC3H

Operating elements of E-711.SC3H sensor modules

Name	Function
Ch 1 to 3 *-30V to +135V*	D-sub mixed 25W3 connector for piezo stages; carries the signals of up to three capacitive sensors and the voltage lines (-30 V to +135 V) for up to four piezo actuators (E-711.AL4P must be present in the system). See "E-711.SC3H: Connector for Piezo Actuators and Capacitive Sensors" (p. 314) for pinout.

Specifications

	E-711.SC3H
Function	Module for capacitive sensors
Sensor type	Capacitive dual-electrode
Sensor channels	3
Sensor bandwidth (-3dB)	10 kHz
Sensor resolution	18 bit (interpolated: 20 bit)
Ext. synchronization	Yes, via E-712.M1 or E-712.N1 digital processor module
Sensor connector	D-sub mixed 25W3, carries also the 4 piezo voltage lines of E-711.AL4P amplifier modules

	E-711.SC3H
Dimensions	4 TE
Mass	177 g
Measurement category	II

1.5.17 E-711.SE3 Module for Capacitive Sensors

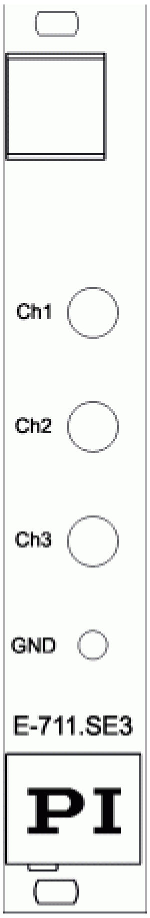


Figure 23: Front panel of E-711.SE3

Operating elements of E-711.SE3 sensor modules

Name	Function
Ch1 *Ch2* *Ch3*	Triaxial LEMO connectors for connection of up to three sensor probes (with active shielding). See "E-711.SE3: Connectors for Capacitive Sensor Probe" (p. 332) for pinout.
GND	Common grounding stud for all target surfaces.

Specifications

	E-711.SE3
Function	Module for PISeca capacitive single-electrode sensors
Sensor type	Capacitive single-electrode
Sensor channels	3
Sensor bandwidth (-3dB)	max. 5 kHz

	E-711.SE3
Static resolution*	0.0005 % of nominal measurement range
Dynamic resolution*	0.002 % of nominal measurement range
Ext. synchronization	Yes, via E-712.M1 or E-712.N1 digital processor module
Sensor connector	3 x Lemo Triax, grounding stud for target surfaces
Dimensions	4 TE
Mass	195 g
Measurement category	II

*Static: bandwidth 10 Hz; dynamic: bandwidth 5 kHz; cable length 1 m

1.5.18 E-711.0CT, .0CT0 Digital Sensor Signal Transmission for Capacitive Sensors

Digital transmission of sensor signals is required for applications where the distance between mechanics and electronics is greater than 3 m (in principle, max. 30 m are possible without repeater).

E-711.0CT offers digital transmission for the signals of capacitive sensors over up to 10 m and comprises the following components:

- 3-channel box with sensor processing electronics (**1**) ("sensor box"), connects to the mechanics, item number E711B0036
- Interface module (**2**), comes usually installed in the E-712 modular digital controller, item number E711B0035
- Sensor cable HD D-sub 26 f/m 1:1, 10 m (**3**), connects the sensors lines of the interface module to the sensor box, item number K030B0322
- Piezo cable D-sub 15 f/m 1:1, 10 m (**4**), connects the piezo voltage lines of the interface module to the sensor box, item number K030B0328

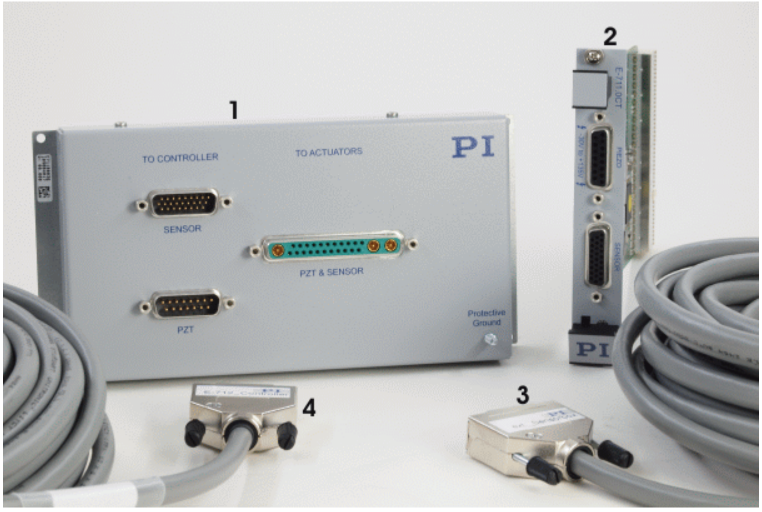
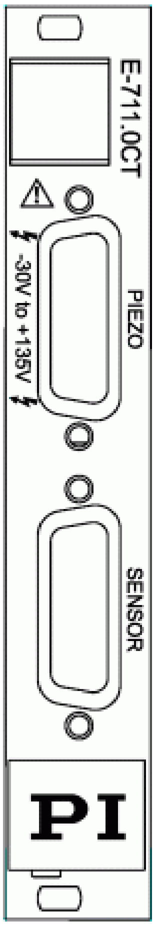


Figure 24: E-711.0CT components, see above for component description



INFORMATION

For greater flexibility in the distance between mechanics and electronics, E-711.0CT0 in contrast to E-711.0CT does not include cables.

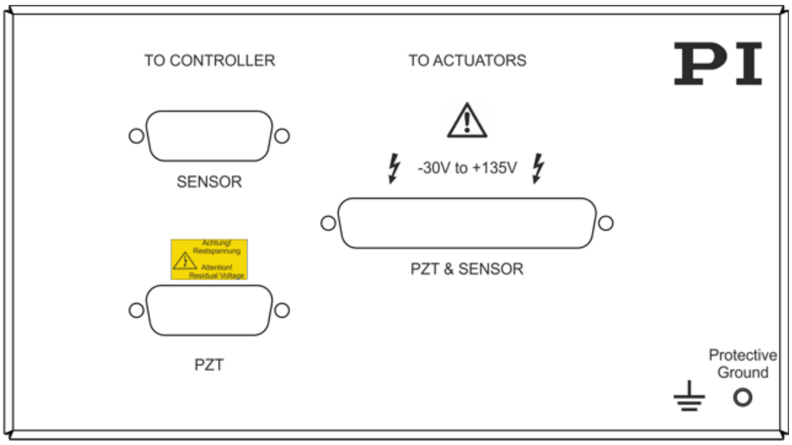


Figure 25: Front panels of E-711.0CT and .0CT0 digital sensor signal transmission for capacitive sensors: interface module (left) and sensor box (right)

Operating elements of the interface module

Name	Function
PIEZO *-30V to +135V* 	D-sub 15 (f) connector for connection to the *PZT* connector of the sensor box using a suitable piezo cable (with E-711.0CT, K030B0328 D-sub 15 f/m 1:1, 10 m is included). Four output voltage lines (-30 V to +135 V; E-711.AL4P must be present in the system). See p. 58 for pinout.
SENSOR	HD D-sub 26 (f) connector for connection to the *SENSOR* connector of the sensor box using a suitable sensor cable (with E-711.0CT, K030B0322 HD D-sub 26 f/m 1:1, 10 m is included). Three sensor input lines. See p. 59 for pinout.

Operating elements of the sensor box

Name	Function
SENSOR	HD D-sub 26 (m) connector for connection to the *SENSOR* connector of the interface module using a suitable sensor cable (with E-711.0CT, K030B0322 HD D-sub 26 f/m 1:1, 10 m is included). Three sensor output lines. See p. 59 for pinout.
 *PZT*	D-sub 15 (m) connector for connection to the *PIEZO* connector of the interface module using a suitable piezo cable (with E-711.0CT, K030B0328 D-sub 15 f/m 1:1, 10 m is included). Four input voltage lines (-30 V to +135 V). See p. 58 for pinout.
-30V to +135 V *PZT & SENSOR* 	D-sub mixed 25W3 connector for piezo stages. Three capacitive sensor lines and four output voltage lines (-30 V to +135 V; E-711.AL4P must be present in the system). See "E-711.SC3H: Connector for Piezo Actuators and Capacitive Sensors" (p. 314) for pinout.

Specifications

	E-711.0CT / .0CT0
Function	Set for digital sensor signal transmission, consists of: ▪ Interface module ▪ Sensor box with processing electronics ▪ E-711.0CT only: Connection cables
Sensor type	Capacitive dual-electrode
Sensor channels	3

	E-711.0CT / .0CT0
Sensor bandwidth (-3dB)	10 kHz
Sensor resolution	18 bit (interpolated: 20 bit)
Ext. synchronization	Yes, via E-712.M1 or E-712.N1 digital processor module
Connection between interface module and sensor box	Via sensor cable (HD D-sub 26 (f/m), 1:1) and piezo cable (D-sub 15 (f/m), 1:1) With E-711.0CT, appropriate cables with 10 m length are included.
Sensor connector	D-sub mixed 25W3, carries also the 4 piezo voltage lines of E-711.AL4P amplifier modules
Dimensions sensor box	198.5 x 102.9 x 38.3 mm (incl. mounting rail and ground stud); see also figure below
Mass sensor box	650 g
Dimensions interface module	4 TE
Mass interface module	150 g
Power consumption sensor box	8 W
Measurement category	II

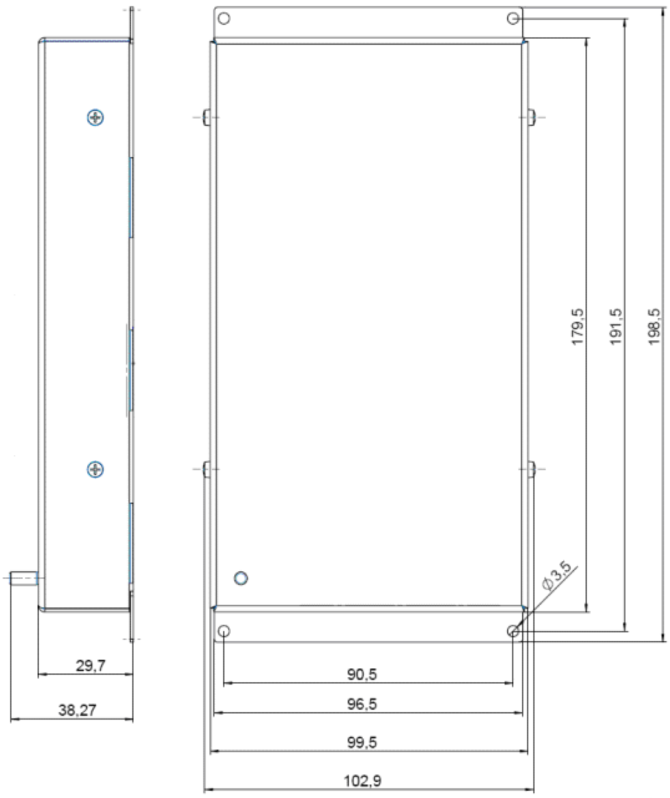


Figure 26: Dimensions of sensor box for E-711.0CT and .0CT0 digital sensor signal transmission; decimal places separated by commas

Piezo voltage connection: *PIEZO* D-sub 15 (f) on interface module, *PZT* D-sub 15 (m) on sensor box

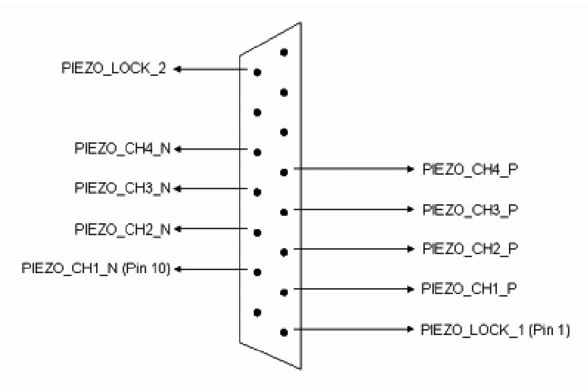


Figure 27: PZT *connector on E-711.0CT and .0CT0 sensor box, front view*

Sensor data and power connection: *SENSOR* HD D-sub 26 (f) on interface module, HD D-sub 26 (m) on sensor box

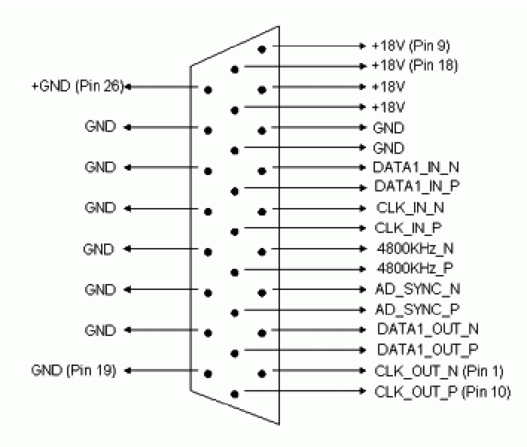


Figure 28: SENSOR *connector on on E-711.0CT and .0CT0 sensor box, front view*

1.5.19 E-711.S3XC Digital Sensor Signal Transmission for Capacitive Sensors

E-711.S3XC offers digital transmission for the signals of capacitive sensors where the distance between mechanics and electronics is greater than 3 m. It comprises the following components:

- 3-channel box with sensor processing electronics ("sensor box"), connects to the mechanics, item number E711B0113
- Interface module, comes usually installed in the housing of the E-711/E-712 system, item number E711B0112

The following cables for the connections between sensor box and interface module must be ordered separately:

- Sensor cable HD D-sub 26 f/m 1:1
- Piezo cable D-sub 15 f/m 1:1

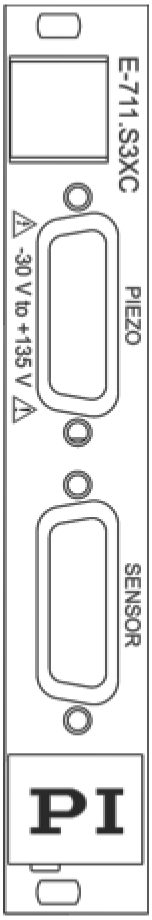
The maximum possible cable length depends on the control loop sampling time of the E-711/E-712 system:

Control loop sampling time	Cable length, max.
20 µs	25 m
30 µs	50 m
40 µs	60 m
≥50 µs	75 m

For inquiries and orders, contact your PI sales engineer or send us an e-mail (info@pi.ws).

INFORMATION

For greater flexibility in the distance between mechanics and electronics, E-711.S3XC does not include cables.



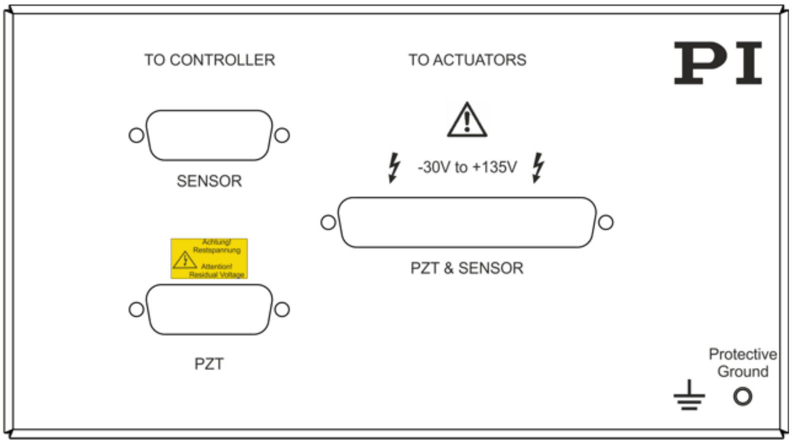


Figure 29: Front panels of E-711.S3XC digital sensor signal transmission for capacitive sensors: interface module (left) and sensor box (right)

Operating elements of the interface module

Name	**Function**
PIEZO *-30V to +135V*	D-sub 15 (f) connector for connection to the *PZT* connector of the sensor box using a suitable piezo cable. Four output voltage lines (-30 V to +135 V; E-711.AL4P must be present in the system). See p. 63 for pinout.
SENSOR	HD D-sub 26 (f) connector for connection to the *SENSOR* connector of the sensor box using a suitable sensor cable. Three sensor input lines. See p. 63 for pinout.

Operating elements of the sensor box

Name	Function
SENSOR	HD D-sub 26 (m) connector for connection to the *SENSOR* connector of the interface module using a suitable sensor cable. Three sensor output lines. See p. 63 for pinout.
 *PZT*	D-sub 15 (m) connector for connection to the *PIEZO* connector of the interface module using a suitable piezo cable. Four input voltage lines (-30 V to +135 V). See p. 63 for pinout.
-30V to +135 V *PZT & SENSOR* 	D-sub mixed 25W3 connector for piezo stages. Three capacitive sensor lines and four output voltage lines (-30 V to +135 V; E-711.AL4P must be present in the system). See "E-711.SC3H: Connector for Piezo Actuators and Capacitive Sensors" (p. 314) for pinout.

Specifications

	E-711.S3XC
Function	Set for digital sensor signal transmission, consists of: ▪ Interface module ▪ Sensor box with processing electronics
Sensor type	Capacitive dual-electrode
Sensor channels	3
Sensor bandwidth (-3dB)	10 kHz
Sensor resolution	18 bit (interpolated: 20 bit)
Ext. synchronization	Yes, via E-712.M1 or E-712.N1 digital processor module
Connection between interface module and sensor box	Via sensor cable (HD D-sub 26 (f/m), 1:1) and piezo cable (D-sub 15 (f/m), 1:1) Appropriate cables must be ordered separately. The maximum permissible cable length depends on the control loop sampling time, see p. 59 for more information.
Sensor connector	D-sub mixed 25W3, carries also the 4 piezo voltage lines of E-711.AL4P amplifier modules
Dimensions sensor box	198.5 x 102.9 x 38.3 mm (incl. mounting rail and ground stud); see also figure below
Mass sensor box	650 g

	E-711.S3XC
Dimensions interface module	4 TE
Mass interface module	150 g
Power consumption sensor box	8 W
Measurement category	II

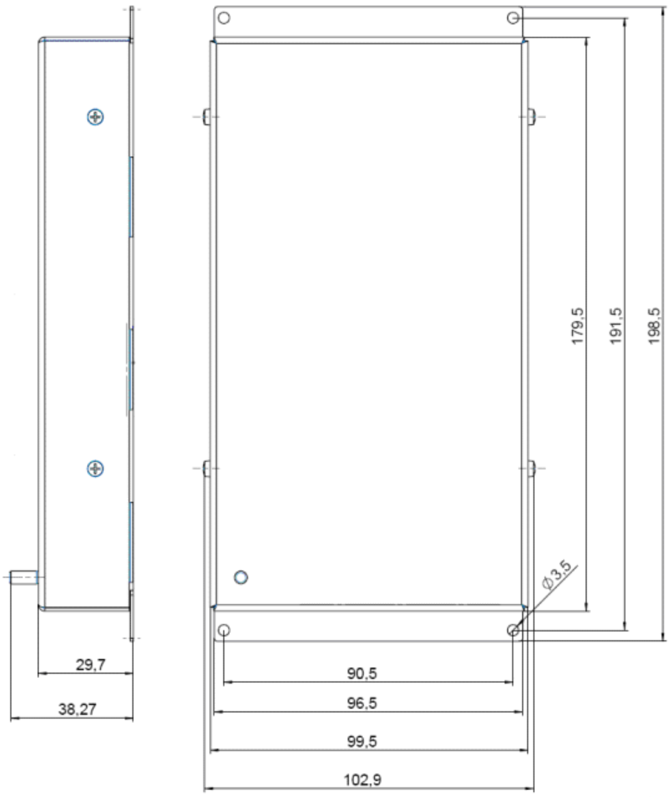


Figure 30: Dimensions of sensor box for E-711.S3XC digital sensor signal transmission; decimal places separated by commas

Piezo voltage connection: *PIEZO* D-sub 15 (f) on interface module, *PZT* D-sub 15 (m) on sensor box

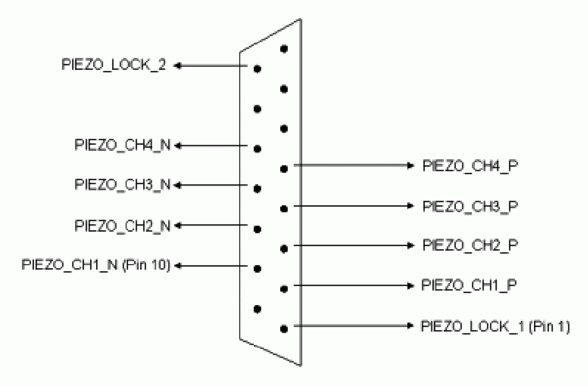


Figure 31: PZT *connector on on E-711.S3XC sensor box, front view*

Sensor data and power connection: *SENSOR* HD D-sub 26 (f) on interface module, HD D-sub 26 (m) on sensor box

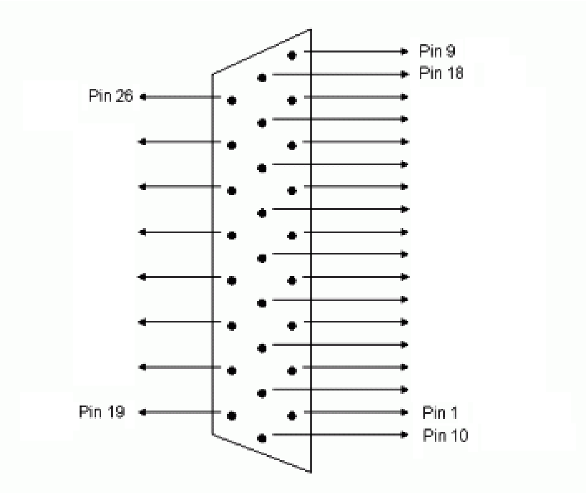


Figure 32: SENSOR *connector on E-711.S3XC sensor box, front view*

Pin	Name	Pin	Name	Pin	Name
1	CLK_OUT_N	10	CLK_OUT_P	19	GND_SENS
2	DATA_OUT_N	11	DATA_OUT_P	20	GND
3	AD_SYNC_N	12	AD_SYNC_P	21	GND
4	4800KHZ_N	13	4800KHZ_P	22	GND
5	CLK_IN_N	14	CLK_IN_P	23	GND
6	DATA_IN_N	15	DATA_IN_P	24	GND
7	GND	16	GND	25	GND
8	+24V	17	+24V	26	GND
9	+24V	18	+24V		

1.5.20 E-711.0ET, .0ET0 Digital Sensor Signal Transmission for PISeca Sensors

Digital transmission of sensor signals is required for applications where the distance between mechanics and electronics is greater than 2 m (in principle, max. 30 m are possible without repeater).

E-711.0ET and E-711.0ET0 can be used with E-712 digital piezo controllers and comprise the following components:

- 3-channel box with sensor processing electronics (**1**) ("sensor box"), for connection of PISeca sensors and piezo actuators, item number E711B0100. A banana plug (item number 3214) mating to the "SENSOR GND" socket is included in the scope of delivery.
- Interface module (**2**), comes usually installed in the E-712 modular digital controller, item number E711B0035
- With E-711.0ET only: Sensor cable HD D-sub 26f/m 1:1, 10 m (**3**), connects the sensors lines of the sensor box to the interface module, item number K030B0322

1 **2** **3**

Figure 33: E-711.0ET components, see above for component description

Cables for connection of sensor box and interface module **must be ordered separately** in the following cases:

- With E-711.0ET0: For greater flexibility in the distance between mechanics and electronics, E-711.0ET0 in contrast to E-711.0ET does not include the sensor cable. A sensor cable of a customized length must be ordered.
- If piezo actuators are to be connected to the D-sub mixed connector of the sensor box (E-711.AL4P amplifier module is present in the system): A piezo cable for the piezo voltage lines must be ordered.

Contact your PI sales engineer or our customer service department (info@pi.ws) to order or if you have any questions.

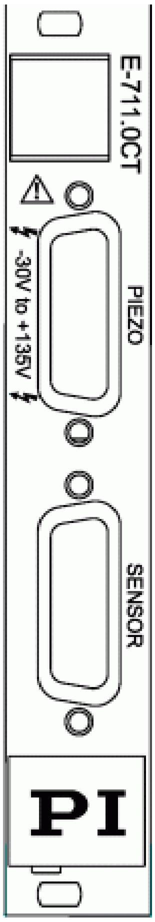
A PISeca sensor measures changes in capacitance between the sensor probe and a conductive, grounded target surface. The target or structure under test should provide a noise-free, low-impedance return path. To verify that a proper return path is present, connect a ground lead directly from the target to the “SENSOR GND” banana socket on the sensor box.

The surface structure of the target has a strong influence on linearity of the system. The target area size must be considerably larger than the sensor area (by at least 50%).

Motion of the connecting cable should be avoided. Thus, the sensor probe should always be the part at rest and the target the moving part.

Target and sensor surfaces must be clean and free from contaminants.

Measurement against a grounded semi-conductor is also possible.



INFORMATION

For greater flexibility in the distance between mechanics and electronics, E-711.0ET0 in contrast to E-711.0ET does not include a sensor cable.

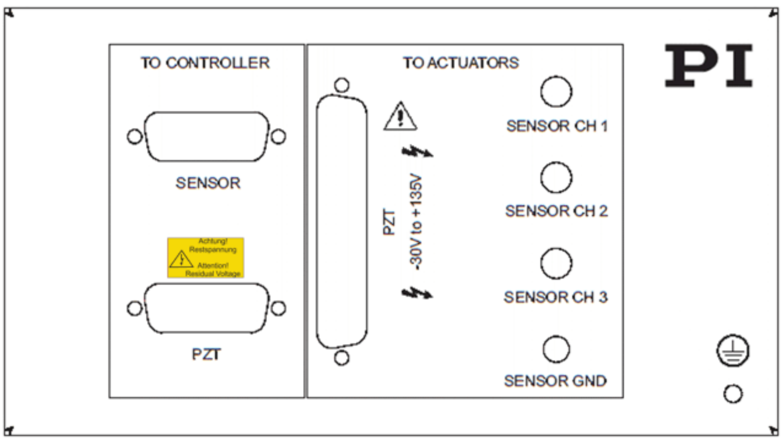


Figure 34: Front panels of E-711.0ET and .0ET0 digital sensor signal transmission for PISeca sensors: interface module (left) and sensor box (right)

Operating elements of the interface module

Name	Function
PIEZO *-30V to +135V* 	D-sub 15 (f) connector for connection to the *PZT* connector of the sensor box using a suitable piezo cable (not included). Four output voltage lines (-30 V to +135 V; E-711.AL4P must be present in the system). See p. 69 for pinout.
SENSOR	HD D-sub 26 (f) connector for connection to the *SENSOR* connector of the sensor box using a suitable sensor cable (with E-711.0ET, K030B0322 HD D-sub 26 f/m 1:1, 10 m is included). Three sensor input lines. See p. 68 for pinout.

Operating elements of the sensor box

Name	Function
SENSOR	HD D-sub 26 (m) connector for connection to the *SENSOR* connector of the interface module using a suitable sensor cable (with E-711.0ET, K030B0322 HD D-sub 26 f/m 1:1, 10 m is included). Three sensor output lines. See p. 68 for pinout.
 *PZT*	D-sub 15 (m) connector for connection to the *PIEZO* connector of the interface module using a suitable piezo cable (not included). Four input voltage lines (-30 V to +135 V). See p. 69 for pinout.
-30V to +135V *PZT* 	D-sub mixed 25W3 connector for piezo stages. Four output voltage lines (-30 V to +135 V; E-711.AL4P must be present in the system). See p. 315 for pinout.
SENSOR CH1 *SENSOR CH2* *SENSOR CH3*	Lemo triaxial, for input of three sensor probe signals (PISeca sensors). See p. 315 for details.
SENSOR GND	Banana socket for ground connection of the sensor target surface. See p. 65 and p. 315 for details.

Specifications

	E-711.0ET / .0ET0
Function	Set for digital sensor signal transmission, consists of: ▪ Interface module ▪ Sensor box with processing electronics ▪ E-711.0ET only: Sensor cable
Sensor type	Capacitive single-electrode
Sensor channels	3
Sensor bandwidth (-3dB)	max. 5 kHz
Static resolution*	0.0005 % of nominal measurement range
Dynamic resolution*	0.002 % of nominal measurement range
Ext. synchronization	Yes, via E-712.M1 or E-712.N1 digital processor module
Connection between interface module and sensor box	Sensor cable (included with E-711.0ET: HD D-sub 26 (f/m), 1:1, 10 m length; must be ordered separately with E-711.0ET0) If piezo actuators are to be connected to the D-sub mixed 25W3 connector of the sensor box (E-711.AL4P amplifier module present in the system): Piezo cable for the piezo voltage lines, must be ordered separately.
Sensor connector	3 x Lemo triaxial Banana socket for grounding of the target surfaces
Dimensions sensor box	See dimensional drawing
Mass sensor box	776 g
Dimensions interface module	4 TE
Mass interface module	150 g
Power consumption sensor box	10.8 W
Measurement category	II

*Static: bandwidth 10 Hz; dynamic: bandwidth 5 kHz; cable length 1 m

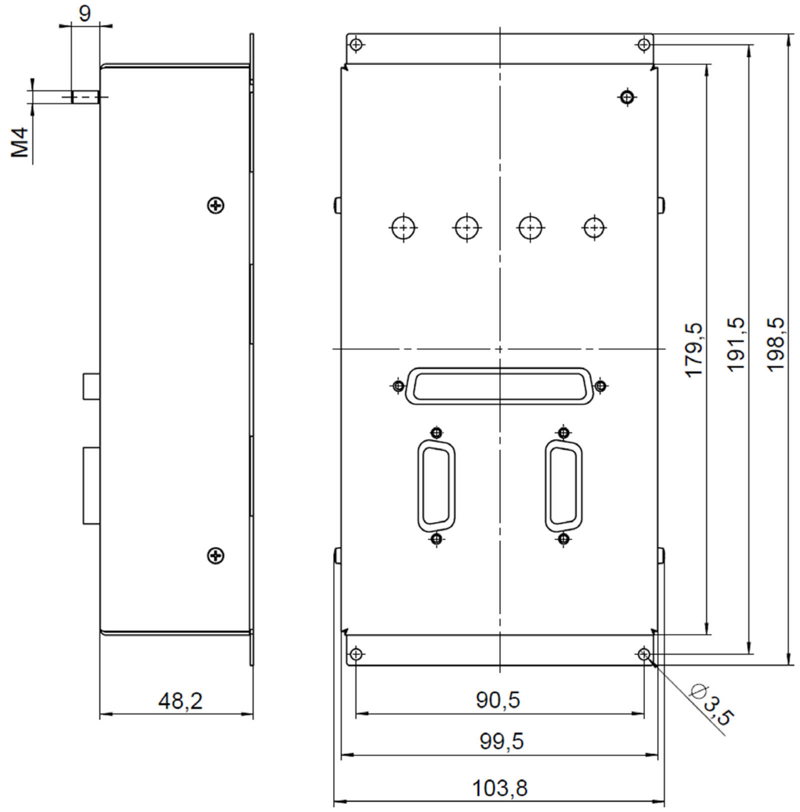


Figure 35: Dimensions of sensor box for E-711.0ET and .0ET0 digital sensor signal transmission; decimal places separated by commas

Sensor data and power connection between interface module and sensor box:

SENSOR HD D-sub 26 (f) on interface module, *SENSOR* HD D-sub 26 (m) on sensor box

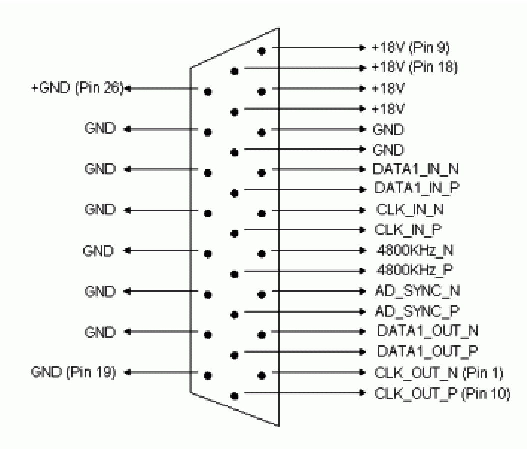


Figure 36: SENSOR *connector on E-711.0ET and .0ET0 sensor box, front view*

Piezo voltage connection between interface module and sensor box:

PIEZO D-sub 15 (f) on interface module, *PZT* D-sub 15 (m) on sensor box (in *the TO CONTROLLER* frame)

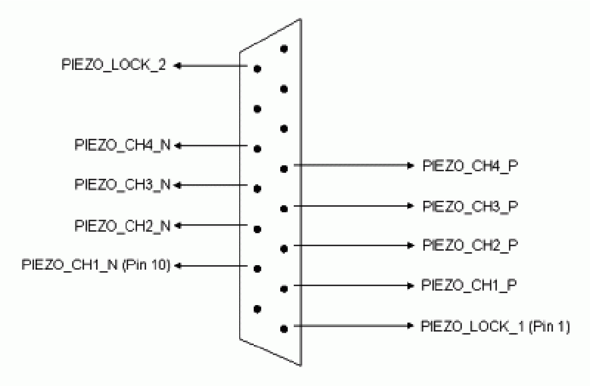


*Figure 37:*PZT *connector on E-711.0ET and .0ET0 sensor box, front view*

1.5.21 E-711.IA4 Analog Interface Module

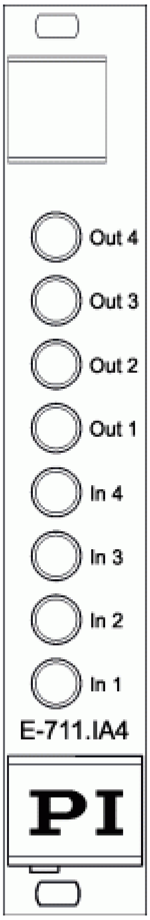


Figure 38: Front panel of E-711.IA4

Operating elements of E-711.IA4 analog interface module

Name	Function
Out 1 to *Out 4*	4 Lemo connectors for analog output lines; connect external amplifiers and/or measurement devices. See "How to Work with the Analog Output—Overview" (p. 123) for more information. See "Analog Output Connectors" (p. 333) for pinout and specifications.
In 1 to *In 4*	4 Lemo connectors for analog input lines; connect external sensors and/or signal sources for control value generation. See "How to Work with the Analog Input—Overview" (p. 123) for more information. See "Analog Input Connectors" (p. 332) for pinout and specifications.

Specifications

	E-711.IA4
Function	Analog interface module
Channels	4 inputs, 4 outputs
Resolution	Input: 18 bit Output: 16 bit
Voltage range	Input: ±10 V differential (|AIN+ - AIN-| ≤ 10 V in the range of -10 to +10 V) Output: ±12.775 V
Bandwidth	Input: max. 25 kHz Output: max. 12 kHz
Connector	8 x LEMO EPG.00.302.NLN
Supported	Input: control signal / sensor signal

	E-711.IA4
functionality	Output: axis position monitor / amplifier control signal
Dimensions	4 TE
Mass	162 g
Measurement category	II

1.5.22 E-711.iS3 and .iS6 SPI Interface Modules

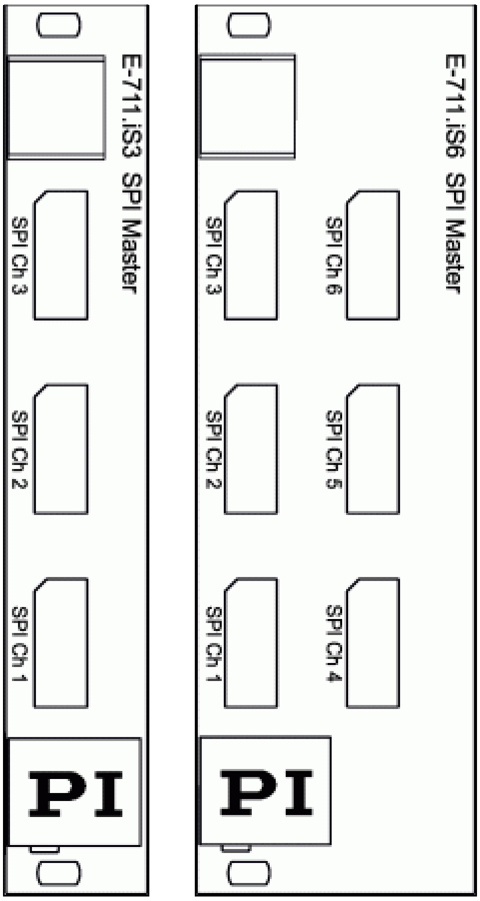


Figure 39: Front panels of E-711.iS3 (left) and E-711.iS6 (right)

Operating elements of E-711.iS3 and .iS6 SPI interface modules

Name	Function
SPI Ch 1 to *SPI Ch 3*	DisplayPort sockets for SPI interface. Each socket connects to one SPI slave unit.
SPI Ch 4 to *SPI Ch 6*	With E-711.iS6 only. DisplayPort sockets to connect three further SPI slave units.

See "E-711.iS3 and E-711.iS6: SPI Connector" (p. 334) for pinout.

INFORMATION

E-711.iS3 and E-711.iS6 SPI interface modules run in SPI master mode. The SPI slave unit connected to an E-711.iS3 or .iS6 SPI interface module can be, for example, a sensor box from PI.

Specifications

	E-711.iS3 / .iS6
Function	SPI master interface module
Channels	3 / 6
Connector type	DisplayPort
Dimensions	4 TE / 8 TE

	E-711.iS3 / .iS6
Mass	150 g / 170 g
Measurement category	II

1.5.23 E-711.IP PIO Interface Module

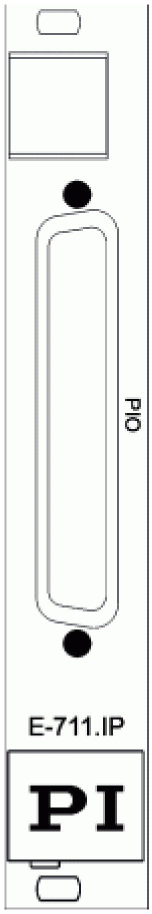


Figure 40: Front panel of E-711.IP

Operating elements of E-711.IP PIO interface module

Name	Function
PIO	HD D-sub 62 (f) connector for connection to a digital interface card in the PC via the included cable (K040B0121). See the E711T0001 technical note for pinout.

See the E711T0001 technical note for more information (data format, reading and writing data). See the PZ232E manual for the E-712.U3 PI RealTime system.

Specifications

	E-711.IP
Function	PIO interface module for high-speed data exchange
Channels	15
Resolution	32 bit
Operation timing	500 ns read / 1200 ns write

	E-711.IP
Connector	HD D-sub 62 (f) for connection to a digital interface card in the PC via the included cable (K040B0121)
Supported functionality	E-712.U3 PI RealTime system
Dimensions	4 TE
Mass	145 g

1.5.24 E-712.3CD, .3CDA, .6CD, .6CDA Predefinded System Configurations

Overview

The predefined system configurations for multi-axis piezo nanopositioning systems with dual-electrode capacitive sensors consist of the following components:

	E-712.M1	E-711.SC3H	E-711.AL4P	E-711.IA4	E-712.R1
E-712.3CD	1	1	1	0	1
E-712.3CDA	1	1	1	1	1
E-712.6CD	1	2	2	0	1
E-712.6CDA	1	2	2	1	1

Specifications

	E-712.3CD / E-712.3CDA / E-712.6CD / E-712.6CDA	Tolerance
Function	Modular digital controller for multi-axis piezo nanopositioning systems with dual-electrode capacitive sensors	
Axes	3 / 3 / 6 / 6	
Processor	PC-based	
Sampling rate, control loop	max. 50 kHz / 50 kHz / 20 kHz / 20 kHz	
Sampling rate, sensor	max. 50 kHz / 50 kHz / 20 kHz / 20 kHz	
Controller characteristics	PI, two notch filters	
Sensor		
Sensor type	Capacitive	
Sensor channels	3 / 3 / 6 / 6	

	E-712.3CD / E-712.3CDA / E-712.6CD / E-712.6CDA	Tolerance
Sensor bandwidth (-3dB)	10 kHz	max.
Sensor resolution	18 bit (interpolated: 20 bit)	
Ext. synchronization	Yes	
Amplifier		
Min. output voltage	-30 V	±3 V
Max. output voltage	+135 V	±3 V
Amplifier channels	4 / 4 / 8 / 8	
Peak output power per channel	25 W*	max.
Average output power per channel	8 W	max.
Current limitation	Short-circuit proof	
Resolution DAC	20 bit (effective)	
Overheat protection	Output voltage switch-off at 75 °C	
Interfaces and operation		
Communication interfaces	Ethernet, USB, RS-232, SPI	
Piezo connector	D-sub mixed 25W3 connector	
Sensor connector	D-sub mixed 25W3 connector	
Analog input	E-712.3CD and E-712.6CD: none E-712.3CDA and E-712.6CDA: 4 x ±10 V differential, bandwidth max. 25 kHz, resolution 18 bit, max. impedance 250 Ω, for control signal / sensor signal, Lemo connector	

	E-712.3CD / E-712.3CDA / E-712.6CD / E-712.6CDA	Tolerance
Analog output	E-712.3CD and E-712.6CD: none E-712.3CDA and E-712.6CDA: 4 x ±10 V differential, bandwidth max. 25 kHz, resolution 16 bit, for axis position monitor / amplifier control signal, Lemo connector	
Digital input	8 x TTL on MDR20	
Digital output	8 x TTL on MDR20	
Command set	PI General Command Set (GCS) 2.0	
User software	PIMikroMove	
Software drivers	Driver for NI LabVIEW software, shared libraries for Windows and Linux	
Supported functionality	Data recorder, wave generator, trigger I/O, macros	
Display and indicators	On-target LED, error LED, power LED, overtemperature LED	
Linearization	4th order polynomials, DDL option (Dynamic Digital Linearization)	
Miscellaneous		
Mass	5.35 kg / 5.53 kg / 5.78 kg / 5.96 kg	
Dimensions	9.5" housing, 236 x 132 x 296 mm + handles (47 mm length)	
Output power	100 W	max.
Line power fuses	2 x T1.6AH, 250 V**	
Power consumption	225 VA	max.
Operating voltage	100 V to 240 V AC, 50-60 Hz	

* The maximum output power is limited by the power supply of the housing and the number of modules present.

** Unless otherwise noted on the type plate on the rear panel of the housing.

1.5.25 E-712.6IDA Predefinded System Configuration

Overview

The E-712.6IDA is intended to control piezo nanopositioning systems that are designed as parallel kinematics for motion in six degrees of freedom, measured by incremental sensors, like, for example, the P-616.65I NanoCube®. As a predefined system configuration, the E-712.6IDA consists of the following components:

	E-712.M1	E-711.SA6	E-711.AL41	E-711.IA4	E-712.R1
E-712.6IDA	1	1	2	1	1

Specifications

	E-712.6IDA	Tolerance
Function	Modular digital controller for the P-616.65I NanoCube®	
Axes	6	
Processor	PC-based	
Sampling rate, control loop	typ. 10 kHz	
Sampling rate, sensor	typ. 10 kHz	
Controller characteristics	PI, two notch filters	
Sensor		
Sensor type	Incremental (analog sin/cos; 1 Vpp)	
Sensor channels	6	
Interpolation factor	512 to 524288	
Adjustment	Automatic adjustment, see p. 117	
Amplifier		
Min. output voltage	-30 V	±3 V
Max. output voltage	+135 V	±3 V
Amplifier channels	8	
Peak output power per channel	25 W	max.
Average output power per channel	8 W	max.
Current limitation	Short-circuit proof	
Resolution DAC	20 bit (effective)	

	E-712.6IDA	Tolerance
Overheat protection	Output voltage switch-off at 75 °C	
Interfaces and operation		
Communication interfaces	Ethernet, USB, RS-232, SPI	
Piezo connector	D-sub mixed 25W3 connector	
Sensor connector	HD D-sub 26 (m)	
Analog input	4 x ±10 V differential, bandwidth max. 25 kHz, resolution 18 bit, max. impedance 250 Ω, for control signal / sensor signal, Lemo connector	
Analog output	4 x ±10 V differential, bandwidth max. 25 kHz, resolution 16 bit, for axis position monitor / amplifier control signal, Lemo connector	
Digital input	8 x TTL on MDR20	
Digital output	8 x TTL on MDR20	
Command set	PI General Command Set (GCS) 2.0	
User software	PIMikroMove	
Software drivers	Driver for NI LabVIEW software, shared libraries for Windows and Linux	
Supported functionality	Data recorder, wave generator, trigger I/O, macros	
Display and indicators	On-target LED, error LED, power LED, overtemperature LED	
Linearization	4th order polynomials, DDL option (Dynamic Digital Linearization)	
Miscellaneous		
Mass	6.25 kg	
Dimensions	9.5" housing, 236 x 132 x 296 mm + handles (47 mm length)	
Output power	100 W	max.
Line power fuses	2 x T2.5AH, 250 V	
Power consumption	225 VA	max.
Operating voltage	100 V to 240 V AC, 50-60 Hz	

Operating notes

See the E712T0011 user manual for details on the support of parallel kinematics with six degrees of freedom (also referred to as “hexapods”) by the E-712.6IDA digital controller.

If a Hexdata.dat file for the piezo nanopositioning system has been saved on the controller by PI, the pivot point of the mechanics, i.e., the intersection of the three rotational axes, can be changed by the user via parameters. Note that if the pivot point is changed, the possible travel ranges for all axes change and thus the available workspace as well. It may therefore be necessary to adapt the workspace limits to the new pivot point coordinates. See the E712T0011 user manual for more information.

See the E712T0016 user manual for details on the Fast Alignment routines that are supported by the E-712.6IDA digital controller.

1.5.26 E-712.1AM Predefinded System Configuration

Overview

The E-712.1AM predefined system configuration for single-axis NEXLINE® systems with incremental encoder consists of the following components:

	E-712.N1	**E-711.AM5A**	**E-712.R4**
E-712.1AM	1	1	1

Specifications

	E-712.1AM
Function	Modular digital controller for NEXLINE® drives
Axes	1
Processor	PC-based
Sampling rate, control loop	50 kHz
Controller characteristics	PI, two notch filters
Sensor	
Sensor type	Incremental, analog signals (sin/cos)
Sensor resolution	16 bit
Ext. synchronization	Yes

	E-712.1AM
Amplifier	
Amplifier channels	4
Output voltage	-250 V to +250 V
Peak output power per channel	45 W
Average output power per channel	15 W
Peak output current per channel	180 mA
Average output current per channel	60 mA
Current limitation	Short-circuit proof
Resolution DAC	20 bit, interpolated
Overheat protection	Output voltage switch-off at 75 °C
Interfaces and operation	
Interface / communication	Ethernet, USB, RS-232, SPI
Piezo / sensor connection	D-sub 25 (f)
Digital input / output	MDR20; 8 × IN, 8 × OUT; TTL
Command set	PI General Command Set (GCS)
User software	PIMikroMove
Software drivers	Driver for NI LabVIEW software, shared libraries for Windows and Linux
Supported functionality	NEXLINE® firmware, data recorder, wave generator, trigger I/O, macros
Display and indicators	On-target LED, error LED, power LED, overtemperature LED
Linearization	4th order polynomials, DDL option (Dynamic Digital Linearization)
Miscellaneous	
Mass	5.35 kg
Dimensions	9.5" housing, 236 mm x 132 mm x 296 mm + handles (47 mm length)
Max. output power	100 W
Line power fuses	2 x T2.5AH, 250 V*
Max. power consumption	225 VA
Operating voltage	100 V to 240 V AC, 50-60 Hz

* Unless otherwise noted on the type plate on the rear panel of the housing.

1.5.27 E-712.xAN Predefinded System Configurations

E-712.xAN stands for the following predefined system configurations:

Digital controller for PICMAWalk drives with incremental sensors:		
E-712.1AN	1 Channel	PICMAWalk drives are a subset of the PiezoWalk® drives provided by PI.
E-712.2AN	2 Channels	
E-712.3AN	3 Channels	

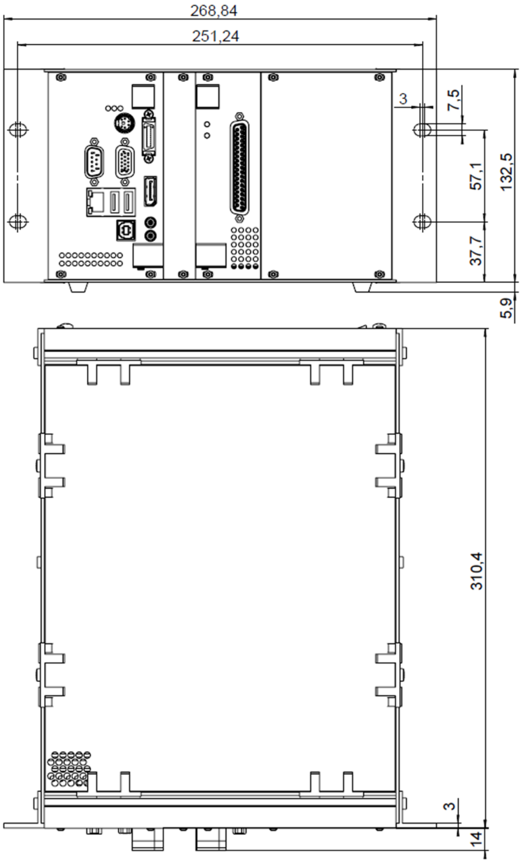


Figure 41: E-712.xAN dimensions in millimeters (here, E-712.1AN is shown as an example)

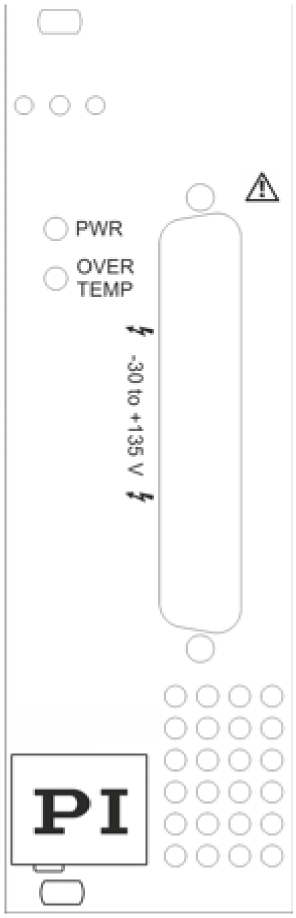


Figure 42: Front panel detail of E-712.xAN controllers

Operating elements of E-712.xAN digital controllers

Name	Function
PWR LED (green)	Switch-on and ready indicator.
OVER TEMP LED (red)	Deactivation indicator for the piezo voltage output; glows if the output is deactivated (e.g., during system initialization after switching on or rebooting, or due to internal overheating). See "Troubleshooting" (p. 305) for more information on overheating.
-30 to +135 V ⚠	D-sub 37 (f) connector for a PICMAWalk drive with incremental encoder; the output lines carry the piezo voltages for the PICMA® actuators in the PICMAWalk drive, in the range of -30 V to +135 V. See "E-712.xAN: Connector for PICMAWalk Drives with Encoder" (p. 325) for pinout.

See the description of the E-712.M1 and .N1 digital processor modules (p. 27) for all other operating elements on the front panel of an E-712.xAN digital controller.

Specifications

	E-712.1AN / E-712.2AN / E-712.3AN
Function	Digital controller for PICMAWalk drives with incremental sensors
Axes	1 / 2 / 3
Processor	PC-based, real-time operating system
Sampling rate, control loop	max. 50 kHz
Sampling rate, sensor	max. 50 kHz
Controller characteristics	PI, two notch filters

	E-712.1AN / E-712.2AN / E-712.3AN
Sensor	
Sensor type	Incremental, analog signals (sin/cos)
Sensor channels	1 / 2 / 3
Sensor resolution	16 bit
Ext. synchronization	Yes
Amplifier	
Amplifier channels	4 / 8 / 12
Output voltage	-30 V to +135 V
Peak output power per channel	25 W
Average output power per channel	8 W
Peak output current per channel	250 mA
Average output current per channel	150 mA
Current limitation	Short-circuit proof
Resolution DAC	20 bit effective
Overheat protection	Output voltage switch-off at 75 °C
Interfaces and operation	
Interface / communication	Ethernet, USB, RS-232, SPI
Piezo / sensor connection	D-sub 37 (f)
Digital input / output	MDR20; 8 × IN, 8 × OUT; TTL
Command set	PI General Command Set (GCS)
User software	PIMikroMove
Software drivers	Driver for NI LabVIEW software, shared libraries for Windows and Linux
Supported functionality	Data recorder, wave generator, trigger I/O, macros
Display and indicators	On-target LED, error LED, power LED, overtemperature LED
Linearization	4th order polynomials, DDL option (Dynamic Digital Linearization)
Miscellaneous	
Mass	4.1 kg / 4.62 kg / 5.13 kg
Line power fuses	2 x T2.5AH, 250 V*
Max. power consumption	225 VA
Operating voltage	100 V to 240 V AC, 50-60 Hz

* Unless otherwise noted on the type plate on the rear panel of the housing.

See the E712T0010 user manual for details on the support of PICMAWalk drives by E-712.xAN digital controllers.

1.6 Scope of Delivery

Unpack the E-711/E-712 modular digital multi-channel controller system with care. Compare the contents against the items covered by the contract and against the packing list.

With the E-712.3CD, .3CDA, .6CD, .6CDA, .6IDA, .1AM, .1AN, .2AN and .3AN predefined system configurations, the following components are included:

- E-711/E-712 system with power cord
- C-815.34 RS-232 cable for connecting controller and PC (null-modem cable)
- C-815.563 cross-over network cable, can be used to connect the E-712 to a network access point or to a PC with Ethernet socket
- 000011448 USB Type-A/Type-B cable
- C-990.CD1 data storage device with the PI Software Suite (see "Software Description" (p. 87))
- E-712 user manual in printed form (PZ195; this document)
- GCS commands manual in printed form (PZ233)
- Only with E-712.1AM, .1AN, .2AN, .3AN: E712T0010 user manual with PiezoWalk® description
- Only with E-712.6IDA: E712T0011 user manual with description of the Hexapod firmware

With customized hardware configurations, the following components are included:

- Configuration list (in printed form) with the codes of the individual modules, the housing and the external components (e.g., sensor boxes) of the system
- 3763 power cord
- C-815.34 RS-232 cable for connecting controller and PC (null-modem cable)
- C-815.563 cross-over network cable, can be used to connect the E-712 to a network access point or to a PC with Ethernet socket
- 000011448 USB Type-A/Type-B cable

- C-990.CD1 data storage device with the PI Software Suite (see "Software Description" (p. 87))
- E-712 user manual in printed form (PZ195; this document)
- GCS commands manual in printed form (PZ233)
- Only if E-712.N1 is present: E712T0010 user manual with PiezoWalk® description
- Only if E-711.0ET or E-711.0ET0 is present:
  - 3214 banana plug mating to the "SENSOR GND" socket, for ground connection of the sensor target surface
- Only if E-711.IP is present:
  - E711T0001 technical note for PIO interface
  - K040B0121 cable (HD D-sub 62 (m) / solderable end) for connection to digital interface card in the PC
- Optional: special documentation for customized configurations and additional components

Inspect the contents for signs of damage. If parts are missing or you notice signs of damage, contact PI immediately.

Save all packing materials in case the product needs to be shipped again.

If controller and mechanics were ordered together, make sure a label with the serial numbers of the mechanics is affixed to the controller housing.

1.7 Additional Components

Contact your PI sales engineer or write info@pi.ws, if you need one of the following options / accessories / modules:

E-710.SCN Dynamic Digital Linearization (DDL) option. The DDL makes it possible to achieve significantly better position accuracy for dynamic applications with periodic motion. It is used in conjunction with the wave generator output and in addition to the "normal" control algorithm in closed-loop operation. You can activate the DDL after purchase and without opening the device. See "Dynamic Digital Linearization (DDL)" (p. 235) for more information.

E-712.U1 Advanced Piezo Control option. Advanced Piezo Control (APC) is an alternative control algorithm for closed-loop operation of piezo actuator systems. You can activate the license after purchase and without opening the device. See the E712T0007 technical note for more information.

E-712.U4 firmware update Advanced Linearization option. Using the Advanced Linearization option, the crosstalk nonlinearity of axes can be minimized. To install the option, a firmware update is required. See the E712T0009 technical note for more information.

Analog cables **E-711.i1B** Lemo 2-pin/BNC and **E-711.i10** Lemo 2-pin/open end, 1.5 m. If the E-712 is equipped with an E-711.IA4 analog interface module, four analog input lines and four analog output lines are available. Use the cables to connect signals / external devices to these lines. See "Using the Analog Input" (p. 190) and "Using the Analog Output" (p. 202) for more information.

E-712.01 adapter cable for E-711.SC3H and E-711.AM4; 0.3 m. For connection of NEXLINE® PiezoWalk® systems which are equipped with capacitive sensors.

E-711.AS1 adapter cable from multi-axis piezo stage to digital controller (D-sub mixed) with external amplifier (LEMO); 1 m.

F-712.IRP1 logarithmic photodetector, 600 to 1700 nm wavelength range, 230 pW to 1.3 mW input power, 6 kHz signal bandwidth, 0.1 to 1.6 V logarithmic output voltage, single-channel benchtop device.

F-712.IRP2 logarithmic photodetector, 600 to 1700 nm wavelength range, 230 pW to1.3 mW input power, 6 kHz signal bandwidth, 0.1 to 1.6 V logarithmic output voltage, two-channel module for E-712 with E-711.IA4 analog interface module. 1.5 m cable for the E-711.IA4 included in the scope of delivery.

P-895.2DDC adapter cable for two channels, D-sub mixed 25W3 (m) to 2 x D-sub mixed 7W2 (f); 0.3 m.

P-895.3DDC adapter cable for three channels, D-sub mixed 25W3 (m) to 3 x D-sub mixed 7W2 (f); 0.3 m.

P-895.2D1DDC adapter cable for three channels, D-sub mixed 25W3 (m) to 1 x D-sub mixed 25W3 (f) and 1 x D-sub mixed 7W2 (f); 0.5 m.

P-895.3LDC adapter cable for three channels, D-sub mixed 25W3 (m) to 10 x Lemo (4 x piezo, 3 x sensor probe, 3 x sensor target); 0.3 m.

P-895.4LDS adapter cable for four channels, D-sub 37 (m) to 8 x Lemo (4 x piezo, 4 x sensor); 0.3 m.

K040B0107 synchronization cable. If multiple E-711/E-712 systems are used, their sensor signals can be synchronized. To synchronize *n+1* E-711/E-712 systems you need *n* synchronization cables. See "Synchronization of Multiple Controllers" (p. 124) for more information.

1.8 Motion System Requirements

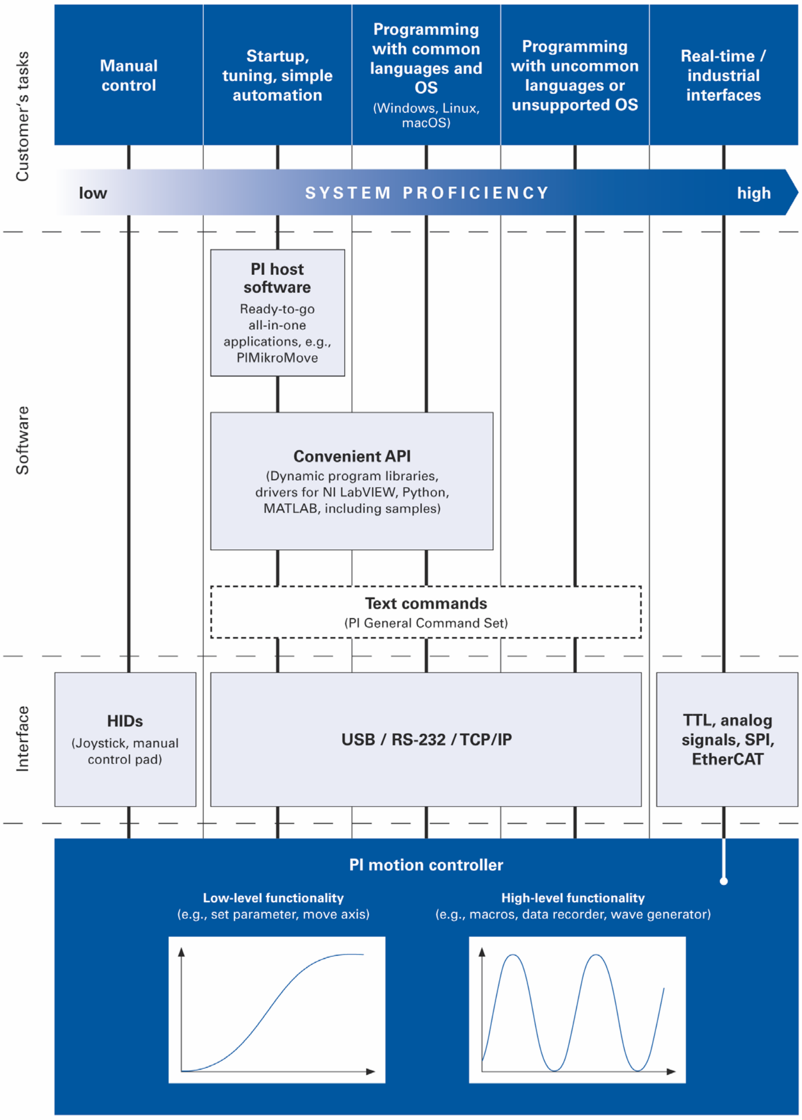
To start working with the E-711/E-712 system, your motion system must also include the following components:

- A PC with Windows operating system or Linux operating system. Note that not all software components are available for Linux operating systems. See the C-990.CD1 release news for the PI Software Suite for more information.
- Communication interface to the PC. Options:
  A free COM port on the PC
  A free USB port
  An Ethernet card in the PC
  A free access point on a network to which the PC is connected
- A suitable mechanics from PI. Mechanics equipped with capacitive sensors or strain gauge sensors must have been calibrated with the E-711/E-712 system or must contain an ID chip.

1.9 Software Description

1.9.1 Control of PI Systems

Basically, systems from PI can be controlled as follows:



1.9.2 PI Software Suite

A data storage device with the PI Software Suite is included in the scope of delivery of the E-711/E-712 system. Some components of the PI Software Suite are described in the table below. See the C-990.CD1 release news in the root directory of the data storage device for information on the compatibility of the software with PC operating systems.

Software Tool	Short Description	Recommended for
Dynamic program library for GCS	Allows program access to the E-711/E-712 system from languages like C++. The functions in the library are based on the PI General Command Set (GCS).	Recommended for customers who want to use a library for their applications. The library is needed by the driver set for NI LabVIEW software, and by PIMikroMove.
Drivers for use with NI LabVIEW software	NI LabVIEW is a software for data acquisition and process control (must be ordered separately from National Instruments). The driver library is a collection of virtual instrument drivers for PI electronics. The drivers support the PI General Command Set.	Users who want to use NI LabVIEW for programming their applications based on the GCS.
MATLAB drivers	MATLAB is a development environment and programming language for numerical calculations (must be ordered separately from MathWorks). The PI MATLAB driver consists of a MATLAB class that can be included in any MATLAB script. This class supports the PI General Command Set. The PI MATLAB driver does not require any additional MATLAB toolboxes.	For users who want to use MATLAB to program their application.
PIMikroMove	Graphic user interface with which the E-711/E-712 system and other controllers from PI can be used: • The system can be started without programming effort • Graph of motions in open-loop and closed-loop operation • Macro functionality for storing command sequences on the PC (host macros) • Support of HID devices • Complete environment for command entry, for trying out different commands • No command knowledge is necessary to operate PIMikroMove. PIMikroMove uses the dynamic program library to supply commands to the controller. To provide the *Device Parameter Configuration* window, PIMikroMove	For users who want to perform simple automation tasks or test their equipment before or instead of programming an application. A log window showing the commands sent makes it possible to learn how to use the commands.

Software Tool	Short Description	Recommended for
	requires the NI LabVIEW Run-Time Engine. See "Doing Initial Installation" (p. 90) for more information.	
PITerminal	PITerminal can be used as a simple terminal with almost all PI controllers.	Users who want to send the commands of the PI General Command Set (GCS) directly.
PIUpdateFinder	Checks the PI software installed on the PC. If more current versions of the PC software are available on the PI server, downloading is offered.	For users who want to update the PC software.
PIFirmware-Manager	The PIFirmwareManager guides you through the update of the firmware for the hardware modules of your E-711/E-712 system.	Users who want to update the firmware.
USB driver	Driver for the USB interface	For all users.

2 Installation

2.1 Installing the PC Software

2.1.1 Doing Initial Installation

Accessories

- PC with a Windows operating system or Linux operating system
- Data storage device with the PI Software Suite (included in the scope of delivery).

  See the C-990.CD1 release news in the root directory of the data storage device for information on the compatibility of the software with PC operating systems.

Installing the PC software in Windows

1. In the installation directory (root directory of the data storage device), start the setup program by double-clicking *PISoftwareSuite.exe*.

   The *InstallShield Wizard* window opens.

2. Follow the instructions on the screen.

   The PI Software Suite includes the following components:

   - Driver for use with NI LabVIEW software
   - Dynamic program library for GCS
   - PIMikroMove
   - PC software for updating the firmware of the E-711/E-712 system.
   - PIUpdateFinder for updating the PC software
   - USB driver

INFORMATION

PIMikroMove requires NI LabVIEW Run-Time Engine to provide the *Device Parameter Configuration* window. The setup program therefore prompts you to start the installation assistant for NI LabVIEW Run-Time Engine after the PI Software Suite has been installed (*Launch NI LabWindows-CVI-RTE 2010 SP1 Installer* checkbox).

Installing the PC software in Linux:

1 Unpack the tar archive from the /linux directory on the data storage device to a directory on your PC.

2 Open a terminal and go to the directory to which you have unpacked the tar archive.

3 Log on as a superuser (root privileges).

4 Enter ./INSTALL to start the installation. Pay attention to lower and upper case when entering commands.

5 Follow the instructions on the screen.

You can select individual components for installation.

2.1.2 Installing Updates

PI is constantly improving the PI Software Suite. Always install the latest version of the PI Software Suite.

Requirements

- Active connection to the Internet.
- If your PC uses a Windows operating system:
  - You have downloaded the PIUpdateFinder manual (A000T0028) from the PI website. The link is in the A000T0081 technical note "Downloading Manuals from PI" in the \Manuals directory on the data storage device with the PI Software Suite.

Updating the PC software on Windows

Use the PIUpdateFinder:

- Follow the instructions in the PIUpdateFinder manual (A000T0028).

Updating the PC software on Linux

1 Open the website https://www.physikinstrumente.com/en/products/software-suite.

2 Scroll down to ***Downloads***.

3 Select ***ADD TO LIST +*** for the PI Software Suite C-990.CD1.

4 Select ***REQUEST***.

5 Fill out the download request form and send the request.

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

6 Unpack the archive file on your PC to a separate installation directory.

7 Go to the *linux* subdirectory in the directory with the unpacked files.

8 Unpack the archive file in the *linux* directory by entering the command tar -xvpf <name of the archive file> on the console.

9 Log into the PC as superuser (root privileges).

10 Install the update.

INFORMATION

If software is missing in the ***Downloads*** area or problems occur with downloading: Contact our customer service department (p. 312).

2.2 Set Up the E-711/E-712 System

NOTICE

!

Place the system in a location with adequate ventilation to prevent internal heat build-up. Allow at least 15 cm clearance from the front and the rear of the housing and 1 cm from the bottom (ensured by the feet of the housing).

Never cover any ventilation openings as this will impede ventilation.

If the required space for ventilation is adhered to, the E-711/E-712 system can be installed on a desktop or in a cabinet in any orientation.

See "Ambient Conditions and Classifications" (p. 22) for more requirements concerning the place of installation.

When lifting or carrying the E-711/E-712 system use only the intended handles of the housing.

2.3 AC Power Connection

WARNING

The housing of the E-711/E-712 system requires a supply voltage of 100 to 240 VAC. The supply voltage may cause serious or even lethal injury. Strictly observe the following:

Use a standard mains supply socket with protective earth contacts (e.g., according to DIN VDE 0100-410) as power supply because the E-711/712 system is grounded via its mains supply line.

Install the E-711/E-712 system near the power supply so that the plug of the power cord can be quickly and easily disconnected from the mains supply socket.

Use the supplied power cord (p. 83) to connect the E-711/E-712 system to the power supply. If the supplied power cord must be replaced, use a sufficiently dimensioned power cord with protective earth contacts.

To disconnect the E-711/E-712 system from the power supply completely, remove the plug of the power cord from the mains supply socket, or remove the power cord from the housing of the E-711/E-712 system.

See "AC Power and Line Fuses" (p. 302) for how to replace the line power fuses.

The AC power connection and line fuses are located on the rear panel of the housing.

No settings need be changed when connecting an E-711/E-712 system to a different supply voltage.

If it ever should be necessary to change fuses, follow the instructions in "AC Power and Line Fuses" (p. 302).

2.4 How to Interconnect the System

WARNING

If stages with piezo actuators are used:

Temperature changes and compressive stresses can induce charges in piezo actuators. After being disconnected from the electronics, piezo actuators can also stay charged for several hours. Touching or short-circuiting the contacts in the connector of the piezo actuator can lead to minor injuries. In addition, piezo actuators can be destroyed by an abrupt contraction.

- Do **not** touch the contacts in the connector of the stage.
- Do **not** pull out the connector of the stage from the E-711/E-712 system during operation.
- Secure the connector of the stage with screws against accidental disconnection.

If a sensor box is used that also has connections for piezo actuators (digital sensor signal transmission with E-711.0CT, E-711.0CT0, E-711.0ET, E-711.0ET0, E-711.S3XC):

- Do **not** touch the contacts in the *PZT* D-sub 15 (m) connector of the sensor box when piezo actuators are connected to the sensor box.
- Before you connect the sensor box to the corresponding sensor or interface module, make sure that the E-711/E-712 system is switched off.
- During operation, do **not** disconnect the sensor box from the corresponding sensor or interface module.
- Secure the connections on the sensor box and on the corresponding sensor or interface module with screws against accidental disconnection.

NOTICE

Make sure that boxes for transmission or splitting of sensor signals are connected to the corresponding sensor or interface module before switching on the E-711/E-712 system. Connecting a box or removing it while the system is already powered on can cause damage to the electronics.

!

NOTICE

When interconnecting the system, respect any assignment of mechanics and electronics specified by the documentation accompanying the system or by labelings on the devices. Labelings may be attached to connectors, cables, front or rear panels of the devices.

1 Make sure that the On/Off switch of the E-711/E-712 system is in the OFF position (0).

2 **Connect the E-711/E-712 system either to the same TCP/IP network as the PC, or to the PC directly:**

• To connect directly to the PC, use a cross-over network cable or a USB Type-A/Type-B cable or a null-modem RS-232 cable (all cables come with the E-711/E-712 system).

• Use the included cross-over network cable or a straight-through network cable if connecting to a network access point (newer switches accept both cross-over and straight-through network cables). Note that many network administrators have set their networks to forbid unknown devices like the E-711/E-712 system to log on.

See "Communication" (p. 154) for more information.

3 **If you want to use the digital input and output lines of the E-711/E-712 system** to trigger external devices or to send start/stop signals to the integrated wave generator, connect the corresponding devices to the *DIGITAL I/O* connector (p. 335) on the E-712.M1 or .N1 module, whichever is present. See "External Triggering / Signaling" (p. 168) for more information.

4 **If an E-711.IA4 analog interface module is present:**

• If you want to use the analog input lines for external sensors and/or for control value generation, connect the appropriate input to the connectors *In 1* to *In 4* (p. 332) on the front panel of the E-711.IA4 module. See "How to Work with the Analog Input—Overview" (p. 123) for more information.

• If you want to use the analog output lines to monitor axis positions and/or to control external amplifiers, connect the appropriate devices to the connectors *Out 1* to *Out 4* (p. 333) on the front panel of the E-711.IA4 module. See "How to Work with the Analog Output—Overview" (p. 123) for more information.

5 **If an E-711.IP PIO interface module is present**:

For high-speed data exchange, connect to E-711.IP to a digital interface card in the PC via the included cable (K040B0121).

See the E711T0001 technical note for more information.

6 **Connect the stage to the E-711/E-712 system:**

- With **piezo nanopositioning systems** (i.e. mechanics with conventional piezo actuators and capacitive or strain gauge sensors):

  Mechanics with capacitive sensors: Connect the piezo stages to the connectors *CH 1 to 3* (p. 314) of the E-711.SC3H modules, possibly using an adapter.

  Mechanics with strain gauge sensors: Connect the piezo stages to the connectors *Ch 1 to Ch 4* (p. 318) of the E-711.SS3 modules, possibly using an adapter.

  A label on the case of the E-711/E-712 system indicates which piezo stage (axis) was calibrated with which controller (axis). Be sure to respect this assignment when connecting the stage to the controller. When you are using a piezo stage with ID chip together with the E-711/E-712 system, piezo stages can be easily exchanged because the calibration data is in the ID chip. See "ID Chip Support / Stage Replacement" (p. 260) for more information.

  Note: When you connect a stage to a switched-on controller, the ID chip of the stage is not read by the controller. To read the ID chip data, the controller must be switched off and on again or rebooted using the RBT command (p. 275) or the corresponding PC software functions.

- If **digital signal transmission** via E-711.0CT, .0CT0, .0ET, .0ET0, or .S3XC is required, i.e., when the **distance between the piezo nanopositioning system with capacitive sensors and the E-711/E-712 system is greater than 3 m**:

  Install the sensor box near the mechanics. If multiple sensor boxes are used for the same mechanics, mount them side by side.

  Connect the ground stud on the sensor box to a protective earth conductor (cross-sectional area of the cable ≥ 0.75 mm^2). The contact resistance must be < 0.1 Ω at 25 A at all connection points relevant to the protective earth conductor function. If multiple sensor boxes are used for the same mechanics, they must share a common protective earth conductor (min. 2 mm^2 conductor cross section).

  Only when the E-711/E-712 system is switched off: Connect all sensor boxes to the interface modules using the included piezo and sensor cables.

  Connect the piezo stages to the *PZT & SENSOR* connectors on the sensor boxes. See the above-mentioned notes on calibration and ID chip. With PISeca capacitive single-electrode sensors, see "How to Install PISeca Capacitive Single-Electrode Sensors" (p. 100).

- **With NEXLINE® PiezoWalk® drives**:

  Connect the drive to an E-711.AM4, .AM5, .AM5A or .AM5B amplifier module, or to the D-sub 50 (f) connector on the front panel of the housing, whichever is present.

- **With NEXACT® PiezoWalk® drives**:

  Connect the drive to an E-711.AN4 amplifier module, or to the D-sub 78 (f) connector on the front panel of the housing, whichever is present.

- **With PICMAWalk PiezoWalk® drives**:

  Connect the drive to a D-sub 37 (f) connector on the front panel of the housing.

- **With DC motor drives**:

  Connect the drive to an E-711.C82 DC motor driver module.

- **With sensor signal splitter boxes for incremental sensors**:

  Connect the sensor to a D-sub 15 connector on the E-711.SAP, .SAH or .SAN sensor signal splitter box, whichever is present. Make sure that the box type matches the sensor type.

  Connect the splitter box to the E-711.SA3 or .SA6 sensor module using an E-711.SAX, .SAX1, .SAX2 or .SAX5 cable.

  See Figure 43 (p. 99) for more information.

- **With PISeca capacitive single-electrode sensors**:

  See "How to Install PISeca Capacitive Single-Electrode Sensors" (p. 100).

7 **Connect the E-711/E-712 system to a wall socket** using the included power cord.

The E-711/E-712 system is equipped with a wide-range power supply and with fuses that are admissible for both 115 V and 230 V operation. See "AC Power Connection" (p. 93) and "AC Power and Line Fuses" (p. 302) for more information.

This section refers to a stand-alone E-711/E-712 system. Synchronization of multiple E-711/E-712 systems is described in "Synchronization of Multiple Controllers" (p. 124).

Incremental sensors via sensor signal splitter box:

How to interconnect sensor modules, splitter boxes and sensors:

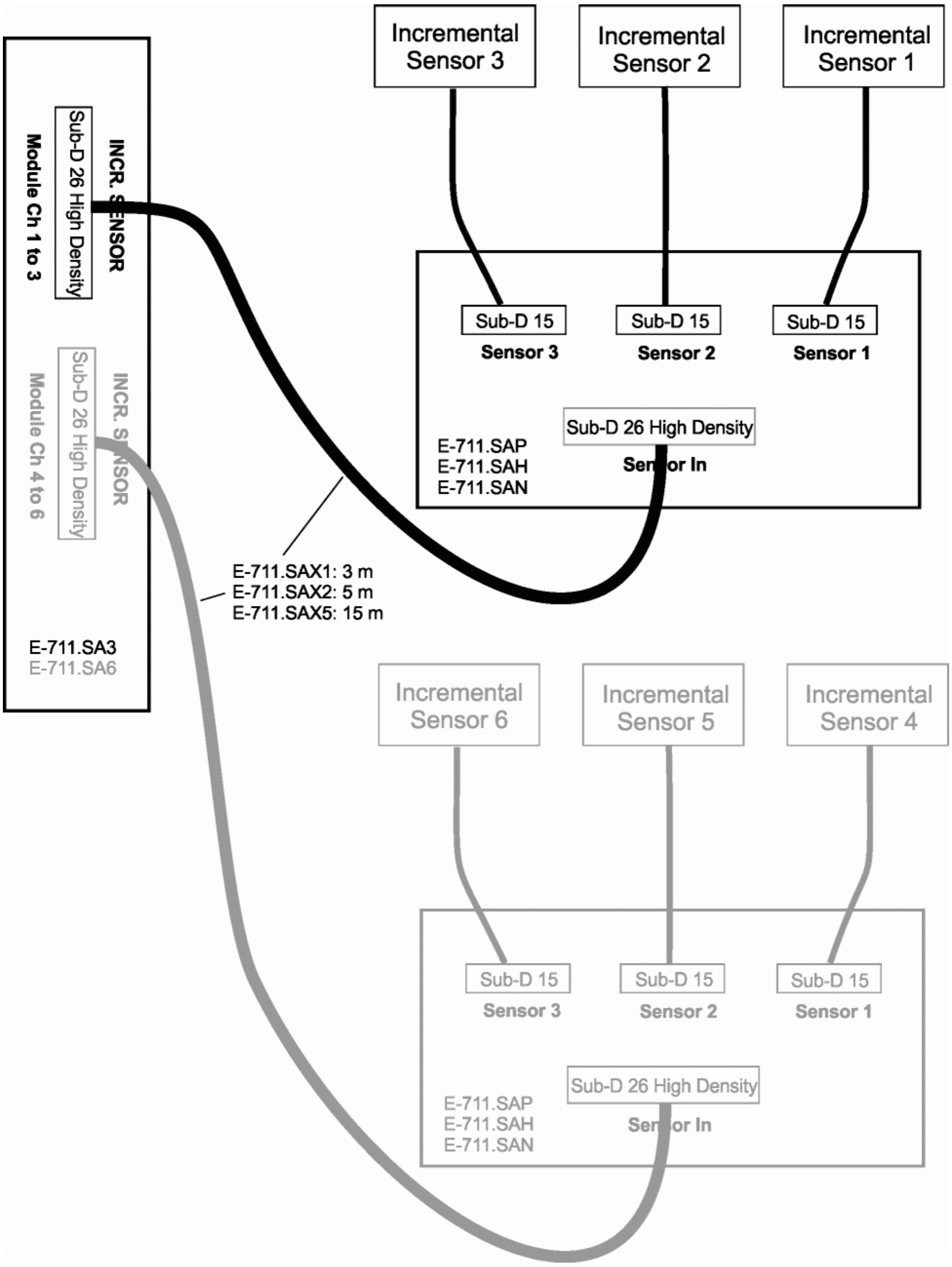


Figure 43: Interconnection of sensor module and sensor signal splitter box(es) for incremental sensors

2.5 How to Install PISeca Capacitive Single-Electrode Sensors

NOTICE

When interconnecting the system, respect any assignment of mechanics and electronics specified by the documentation accompanying the system or by labelings on the devices. Labelings may be attached to connectors, cables, front or rear panels of the devices.

NOTICE

Take care not to shift the sensor probe when connecting the cable!

INFORMATION

Motion of the connecting cable should be avoided because of capacitive influences. If possible, the application should be designed with sensor probe always at rest and the target the moving part of the system.

INFORMATION

In the firmware of the E-711/E-712 system, the Sensor Range parameter (ID 0x02000100) scales the measurement range (by changing the capacitance defined as the mid-position value). Example: The nominal measurement range of a sensor is 100 µm. With a factor of 2, the measurement range is enlarged to 200 µm, and with a factor of 5 enlarged to 500 µm. Possible parameter values for PISeca capacitive single-electrode sensors (parameter value = factor):

1 = 10x
2 = 5x
3 = 2x
4 = 1x (default)

This parameter also automatically selects the corresponding polynomial for electronics linearization.

With the E-711/E-712 system, all measurement ranges are calibrated by PI and therefore ready for use.

1 Mount the sensor probe in your intended application as described in the D510T0001 technical note. Note that the minimum allowable probe-to-target gap is 10 µm. A minimum gap of 15 µm is recommended.

2 Connect the sensor probe to a LEMO connector of the E-711.SE3 sensor module using the D-891.01E cable (comes with the sensor). If digital signal transmission via E-711.0ET or .0ET0 is required, connect the sensor probe to a LEMO connector of the sensor box.

Make sure that each sensor probe is connected to the channel with which it was calibrated (see label affixed to back of housing or to sensor box).

3 Connect the target surface to the *GND* ground stud of the E-711.SE3 module. If digital signal transmission via E-711.0ET or .0ET0 is required, connect the target surface to the *SENSOR GND* banana socket of the sensor box.

Up to three sensor probes can be connected. If they measure different target surfaces: Make sure that each target surface is connected to *GND*.

4 Perform steps 1 to 8 of "Starting the System in PIMikroMove" (p. 104).

5 Close the *Start Up Controller* window by selecting *Close*.

The PIMikroMove main window opens.

6 If you want to change the measurement range (the sensor range factor by default is 1):

a. In the PIMikroMove main window, open the *Device Parameter Configuration* window by selecting *E-712 > Parameter Configuration*.

b. Select the *Sensor Electronics* parameter group for the channel to which the PISeca sensor is connected.

c. In the *Edit Mask* field, select a new value for *Sensor Range factor*.

d. Copy the new parameter value from the *Edit Mask* field to the RAM (volatile memory) or nonvolatile memory of the E-711/E-712 system by selecting one of the three *Write selected edit values…* buttons in the upper-right corner of the window.

Note that changing the sensor range factor requires command level 1. If a corresponding dialog opens, switch to command level 1 by entering the password "advanced".

7 In the PIMikroMove main window, make sure that the axis to be measured by the PISeca sensor is in open-loop operation (the *Servo* checkbox must be cleared).

8 Adjust the sensor probe until the *Current Value / Position* column for the axis to be measured by the PISeca sensor shows the value 0. The *Current Value / Position* column is displayed on the *Axes* tab of the PIMikroMove main window.

The sensor is now adjusted. The gap between sensor probe and target is equal to the measurement range value. This means that the sensor probe is in the middle of the measurement range.

$$Measurement\ Range = Nom.\ Range * Sensor\ Range\ Factor$$

$$Upper\ Meas.\ Range\ Limit = Meas.\ Range + \frac{Meas.\ Range}{2}$$

$$Lower\ Meas.\ Range\ Limit = Meas.\ Range - \frac{Meas.\ Range}{2}$$

Example: The nominal measurement range of the sensor is 100 µm:

- With the default sensor range factor of 1, the gap between sensor probe and target is 100 µm after the adjustment, and the measurement range is 50 µm to 150 µm.
- With a sensor range factor of 5, the gap between sensor probe and target is 500 µm after the adjustment, and the measurement range is 250 µm to 750 µm.

9 Secure the sensor probe. See the D510T0001 technical note for mounting examples.

2.6 Synchronization of Multiple Controllers

If multiple E-711/E-712 systems are used, they can be synchronized.

To synchronize *n+1* E-711/E-712 systems, you need *n* special synchronization cables which can be obtained from PI (order number K040B0107, see "Additional Components" (p. 84)). Connect the *SYNC OUT* connector of the first device to the

SYNC IN connector of the second device, the *SYNC OUT* connector of the second device to the *SYNC IN* connector of the third device and so on. See "SYNC OUT Connector" (p. 337) and "SYNC IN Connector" (p. 337) for pinout and specifications.

Each connector of a synchronization cable matches to only one of the connectors on the E-711/E-712 system. Make sure that the connectors are assigned correctly.

INFORMATION

If you apply external synchronization signals to the *SYNC IN* connector, make sure that these signals match the following specifications:

The tolerance of the 100 kHz input signal is ±2 kHz.

The 4.8 MHz signal must be synchronized with the 100 kHz signal, and both signals must be in a fixed ratio to each other.

3 Quick Start

WARNING

If a sensor box is used that also has connections for piezo actuators (digital sensor signal transmission with E-711.0CT, E-711.0CT0, E-711.0ET, E-711.0ET0, E-711.S3XC):

If a protective earth conductor is not or not properly connected to the sensor box, dangerous contact voltages can occur on the sensor box in the case of malfunction or failure. If dangerous contact voltages exist, touching the sensor box can result in serious injury or death from electric shock.

- Connect the sensor box to a protective earth conductor before switching on the E-711/E-712 system (p. 94).
- Do not remove the protective earth conductor during operation.
- If the protective earth conductor must be removed temporarily (e.g., in the case of modifications or repair), reconnect the sensor box to the protective earth conductor before switching on the E-711/E-712 system again.

3.1 Starting the System in PIMikroMove

Proceed as follows to start the E-711/E-712 system with the mechanics in PIMikroMove:

1. Read "Safety Instructions" (p. 14) and the documentation of the mechanics.
2. Install the following on the PC:
   - PI Software Suite. See "Installing the PC Software" (p. 90) for more information.
   - Updates for PC software. See "Installing Updates" (p. 91) for more information.

3 Make sure that the On/Off switch of the E-711/E-712 system is in the OFF position (0).

4 Install the E-711/E-712 system:

- See "Set Up the E-711/E-712 System" (p. 92) for more information.

5 Connect the following to the E-711/E-712 system:

- The mechanics, the PC (direct or via network), and the power supply. See "How to Interconnect the System" (p. 94) for more information.
- If you want to synchronize multiple E-711/E-712 systems, see "Synchronization of Multiple Controllers" (p. 102).

6 Switch on the E-711/E-712 system. See "Sequence when Switching On and Rebooting" (p. 114) for more information.

7 Start PIMikroMove on the PC.

8 In PIMikroMove, establish communication between the E-711/E-712 system and the PC via RS-232 or USB or TCP/IP:

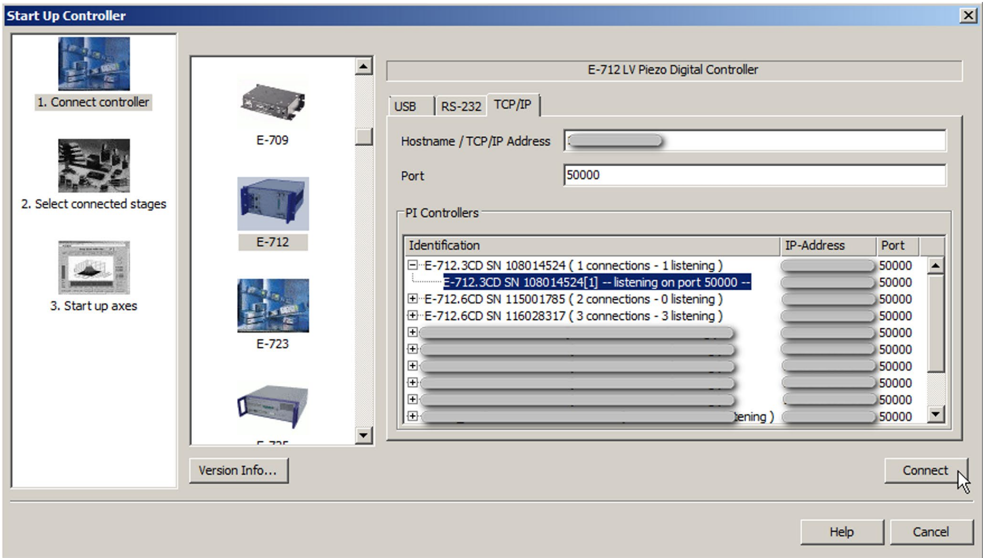
8.1 In the field for controller selection, select *E-712*.

8.2 Select the interface tab that matches the interface used (*TCP/IP* in the example shown below).

8.3 On the interface tab, select your controller (*TCP/IP*, *USB*) or select the interface settings (*RS-232*).

8.4 Select *Connect*.

See "Communication" (p. 154) for more information.



9 For systems with conventional piezo actuators and capacitive or strain gauge sensors:

In the *Set up axes* step of the *Start Up Controller* window, start the AutoZero procedure for all linear axes of the connected mechanics.

9.1 In the list, select the linear axes.

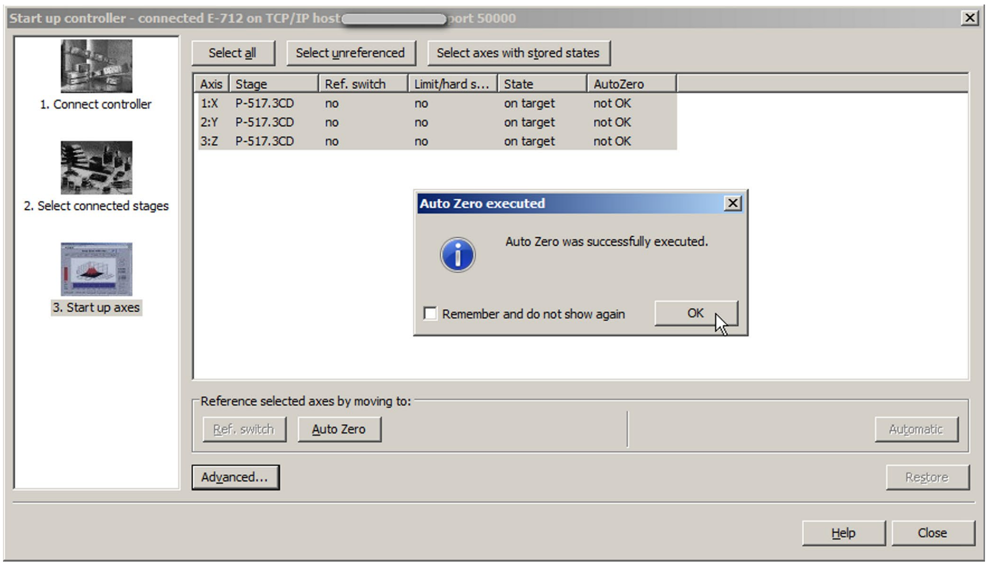
9.2 Select *Auto Zero*. The *Auto Zero* dialog opens.

9.3 In the *Auto Zero* dialog, start the AutoZero procedure by selecting *Start*.

9.4 In the *Auto Zero executed* dialog, select *OK*.

See "AutoZero Procedure" (p. 115) for more information.

Note: If the AutoZero procedure is started for rotation axes, error code 74 will be set.



10 If necessary, reference the axes whose position is measured by incremental sensors:

10.1 In the list, select the axes to be referenced.

10.2 Select the *Ref. switch* button or the *Automatic* button.

10.3 In the *Reference Axes* dialog, start the referencing move by selecting *Start*.

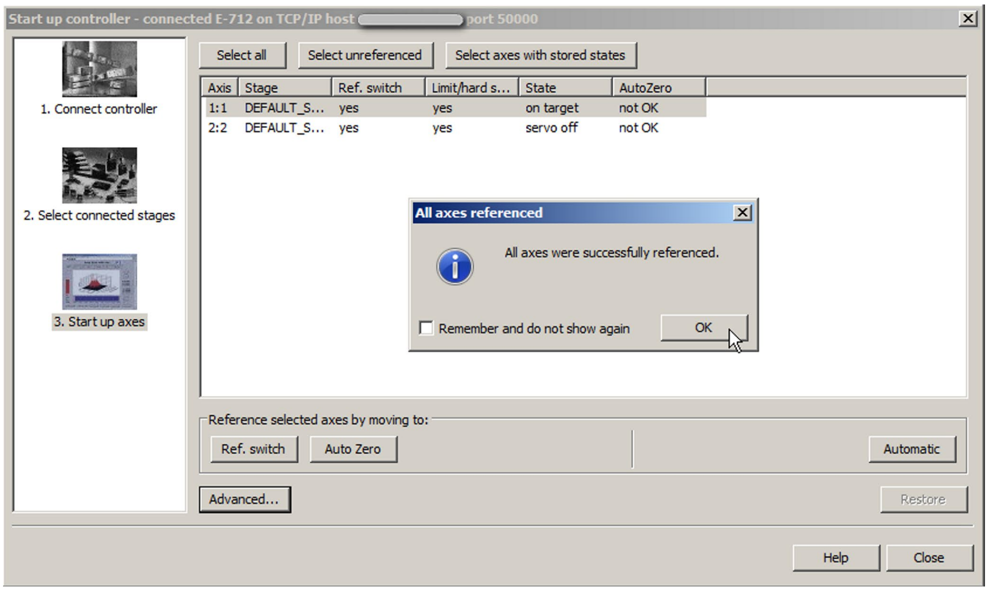
10.4 When the referencing move is successfully finished: In the *All axes referenced* dialog, select *OK*.

See "How to Reference an Axis" (p. 117) for more information.

Notes:

The referencing move is only possible in open-loop operation.

Axes measured by incremental sensors must be referenced before they can be switched to closed-loop operation.



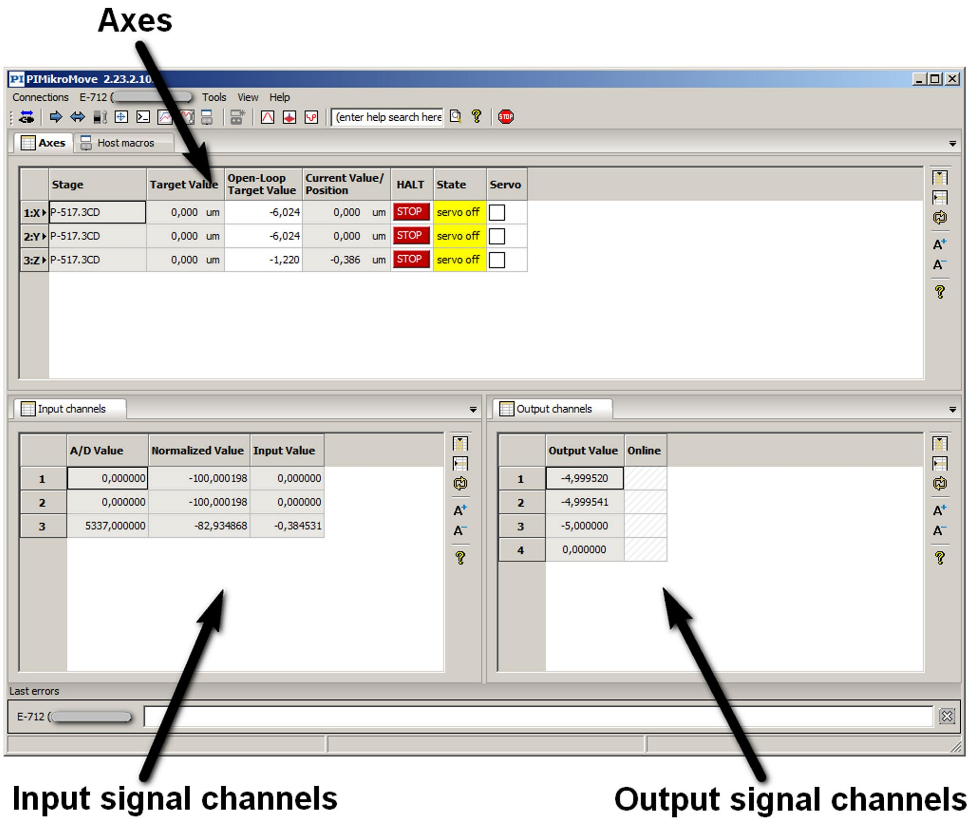
11 In the *Start Up Controller* window, select *Close*.

The main window of PIMikroMove opens.

12 Optionally: Configure the PIMikroMove main window.

It is recommended to show the tabs for axes, input signal channels and output signal channels (see figure below). You can arrange the tabs by dragging them with the left mouse button pressed.

On the *Axes* tab, you can start axis motion. The channel tabs show the current values of the input signal channels (sensors) and output signal channels (output voltages for piezo actuators).



Note that the input signal channels and output signal channels of the E-711/E-712 system are allocated to the logical axes via matrices. See "Processing Steps" (p. 132) for more information. Depending on the connected mechanics, an axis may be driven by more than one actuator or drive and measured by more than one sensor.

3.2 Creating Backups for Parameter Values

INFORMATION

The properties of the E-711/E-712 system and the connected mechanics are saved in the E-711/E-712 system as parameter values.

➔ Save a backup on the PC before changing the parameter values of the E-711/E-712 system. You can then restore the original settings at any time.

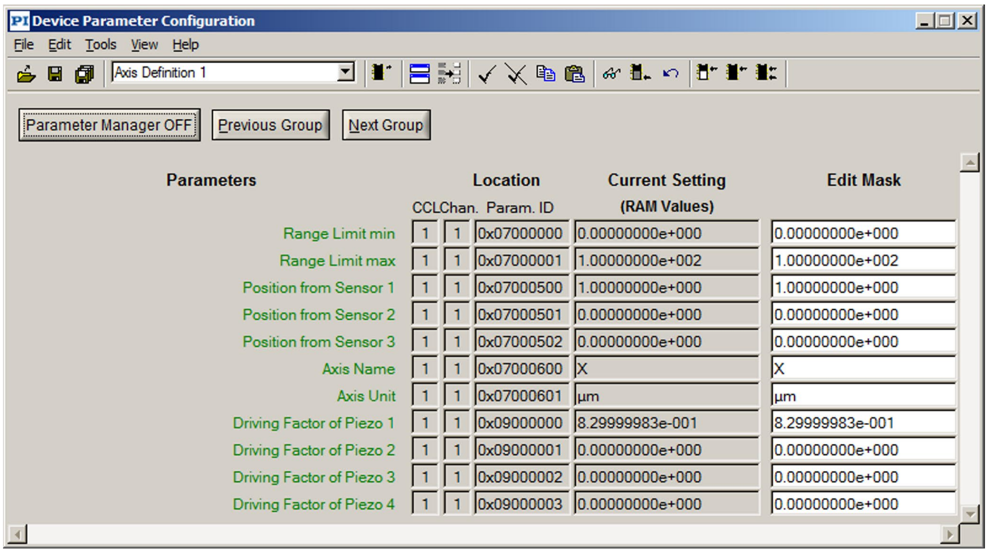
➔ Save an additional backup with a new file name every time you have optimized the parameter values.

To save the parameter values and to load them back to the E-711/E-712 system, use the *Device Parameter Configuration* window of PIMikroMove.

Proceed as follows to save a parameter file:

1 In the main window of PIMikroMove, open the *Device Parameter Configuration* window by selecting *E-712… > Parameter Configuration…*.

In the figure below, the *Device Parameter Configuration* window shows the *Axis Definition 1* parameter group (includes the parameters for the input matrix and output matrix for channel allocation).



2 Save the parameter values from the *Edit Mask* column of the *Device Parameter Configuration* window in a parameter file (file extension .pam) on your PC. Select one of the following options:

- *File > Save Edit Values* or *File > Save Edit Values As*
- (save) or (save as)

3.3 Executing Test Motions

3.3.1 Systems with Conventional Piezo Actuators and Capacitive Sensors or Strain Gauge Sensors

The first motions should be commanded in open-loop operation. With the factory default settings of the E-711/E-712 system, open-loop commanding means to specify open-loop control values which correspond approximately to axis positions.

1 In the main window of PIMikroMove, make some test motions with the individual axes using the controls on the *Axes* tab. During the test motions, observe the position display for the axes (in the *Current Value / Position* fields) and the current output voltages for the piezo actuators (in the *Output Value* fields of the *Output Channels* tab).

Proceed as follows for each linear axis (for rotation axes, the specified open-loop control values correspond approximately to positions in µrad, and the step size can be set to a larger value, e.g., 100 µrad):

1.1 Make sure that the *Servo* checkbox is cleared.

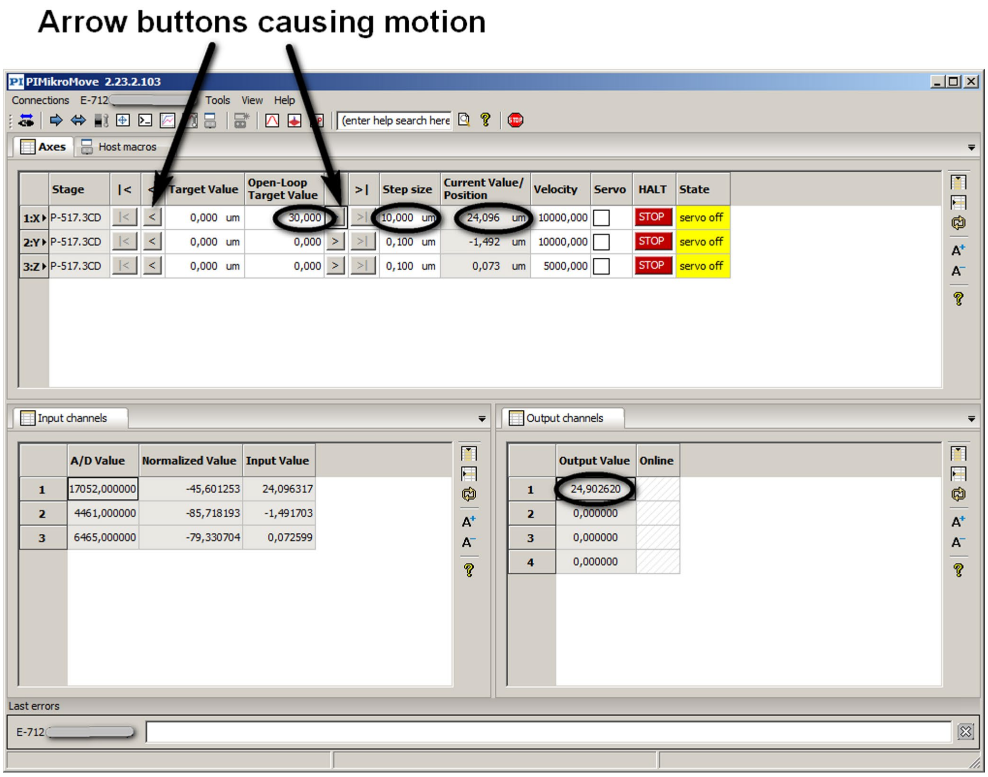
1.2 In the *Open-Loop Target Value* field of the axis, command an open-loop control value of 0 (µm) by entering 0 and pressing the *Enter* key or the return key on your keyboard.

1.3 In the *Step Size* field of the axis, enter the value 10 (µm) and press the *Enter* key or the return key.

1.4 Increment the commanded value by the value specified in the *Step Size* field (10) by selecting the > button next to the *Open-Loop Target Value* field. Increment the open-loop control value this way step by step up to the upper travel range limit of the axis.

1.5 Decrement the commanded value by the value specified in the *Step Size* field (10) by selecting the < button next to the *Open-Loop Target Value* field. Decrement the open-loop control value this way step by step back to zero.

The values for position and output voltage should follow the commanded open-loop control values: The axis position should always correspond approximately to the commanded value, and the output voltages should become noticeably different from 0 V and then go back to zero again during the procedure.



In the example shown in the figure above, the open-loop control value for axis 1 was increased to 30 by selecting the > button three times (step size value is 10). The current position approximately corresponds to the commanded open-loop control value (24.096 µm). Since axis 1 is driven by piezo actuator 1 in the example, the output voltage of the corresponding output signal channel 1 has changed to an appropriate value.

2 In the *Piezo Dynamic Tuner* window of PIMikroMove, determine the resonant frequencies of the axes by measuring the open-loop frequency response. If there are resonances which are intolerable in your application, adjust the notch filter settings for the axis before you switch to closed-loop operation for the first time. Furthermore, it might be necessary to readjust the preset control parameters for the axis. See "Optimization for Dynamic Operation" (p. 263) for more information.

3.3.2 Systems with PiezoWalk® Drives

After starting a system with PiezoWalk® drives (NEXLINE®, NEXACT® or PICMAWalk), you can proceed with test motions in open-loop or closed-loop operation.

- In the main window of PIMikroMove, make some test motions with the individual axes using the controls on the *Axes* tab (if necessary, select the columns to be displayed):
    - For motions in open-loop operation, make sure that the *Servo* checkbox is cleared and use the controls in the columns *OL Steps: <*, *OL Steps: >* and *Open-Loop Steps*.
    - For motions in closed-loop operation, make sure that the *Servo* checkbox is selected and use the controls in the columns *<*, *>*, *Target Value* and *Step Size*.
    - In the *Current Value / Position* fields, observe the position display for the axes during the test motions.

For optimum performance, it may be necessary to adapt parameter values of the E-711/E-712 system. See the E712T0010 user manual for more information.

3.3.3 Systems with DC Motors

After starting a system with DC motors, you can proceed with test motions in closed-loop operation.

- In the main window of PIMikroMove, make some test motions with the individual axes using the controls on the *Axes* tab (if necessary, select the columns to be displayed):
    - For motions in closed-loop operation, make sure that the *Servo* checkbox is selected and use the controls in the columns *|<*, *<*, *>*, *>|*, *Target Value* and *Step size*.
    - In the *Current Value / Position* fields, observe the position display for the axes during the test motions.

4 Operation

WARNING

If a sensor box is used that also has connections for piezo actuators (digital sensor signal transmission with E-711.0CT, E-711.0CT0, E-711.0ET, E-711.0ET0, E-711.S3XC):

If a protective earth conductor is not or not properly connected to the sensor box, dangerous contact voltages can occur on the sensor box in the case of malfunction or failure. If dangerous contact voltages exist, touching the sensor box can result in serious injury or death from electric shock.

- Connect the sensor box to a protective earth conductor before switching on the E-711/E-712 system (p. 94).
- Do **not** remove the protective earth conductor during operation.
- If the protective earth conductor must be removed temporarily (e.g., in the case of modifications or repair), reconnect the sensor box to the protective earth conductor before switching on the E-711/E-712 system again.

4.1 Sequence when Switching On and Rebooting

NOTICE

Thermally stable systems have the best performance. For a thermally stable system, switch on the E-711/E-712 system at least one hour before you start working with it.

Switch on the E-711/E-712 system using the On/Off switch of the housing. To reboot the E-711/E-712 system, use the RBT command.

When switching on or rebooting, the E-711/E-712 system verifies the firmware and copies information from nonvolatile memory to volatile memory. Switching on or rebooting takes about 40 seconds (the more hardware modules, the longer the duration). During this time, the *POWER* LED blinks with different intervals, and the *OVER TEMP* LEDs of amplifier modules glow red because the piezo voltage output is deactivated during switching on or rebooting. When the *POWER* LED glows permanently and the *OVER TEMP* LEDs are off, the controller has finished switching on or rebooting and is now ready for operation.

When a stage with ID chip is connected to the E-711/E-712 system for the first time, the parameter values from the ID chip will be written to nonvolatile and volatile memory when switching on or rebooting the E-711/E-712 system. See "ID Chip Support / Stage Replacement" (p. 260) for more information.

INFORMATION

Before communication between the E-711/E-712 system and the PC can be established, switching on or rebooting of the E-711/E-712 system must have finished successfully (takes approx. 40 s; the more modules, the longer the duration; when finished the *POWER* LED glows permanently). TCP/IP communication: If no DHCP server is available on the network or if a point-to-point connection between PC and controller is being used, it might take another period of about 30 seconds before communication is possible.

4.2 AutoZero Procedure

For systems with conventional piezo actuators and capacitive sensors or strain gauge sensors, the AutoZero procedure performs automatic zero-point adjustment of the sensors.

INFORMATION

During the AutoZero procedure, the axis will move, and the motion can cover the whole travel range.

The AutoZero procedure must be performed with linear axes only. If the AutoZero procedure is started for rotation axes, error code 74 will be set.

The AutoZero procedure changes the mechanical zero position of the piezo stage. If you need an absolute zero point that changes only within the limits of sensor accuracy during the life of the system:

➔ Perform the AutoZero procedure only once. Afterwards save the values of the parameters Sensor Mech. Correction 1 (ID 0x02000200) and Sensor Offset Factor (ID 0x02000102) to nonvolatile memory.

➔ Repeat the AutoZero procedure and the subsequent saving of the parameters only in case your system has been recalibrated.

The AutoZero procedure has the highest priority, i.e., it will overwrite the control values of all other sources. When the analog control input is enabled, it will be disabled automatically at the start of the AutoZero procedure and reenabled again when the AutoZero procedure is finished. See "Control Value Generation" (p. 139) for more information.

The AutoZero procedure works in open-loop operation only. If necessary, the AutoZero procedure switches to open-loop operation and back to closed-loop operation when it is finished.

4.2.1 Objective and Prerequisites of the AutoZero Procedure

Objective of the AutoZero procedure:

- Make the entire travel range available:

  Changes in temperature or changes in the mechanical load can cause small deviations of the sensor zero point. When the zero point of the sensor is set correctly, the complete output voltage range of the amplifier can be used in closed-loop operation.

- Prevent the piezo actuators from damage:

  In open-loop operation, the stage displacement with 0 V piezo voltage should already be about 10 % of the travel range. Then the average applied voltage is reduced which lengthens the lifetime of the piezo actuator in the stage without reducing the nominal travel range.

Requirements for the AutoZero procedure:

- *LowVoltage* < *HighVoltage*

  LowVoltage is specified by the value of the AutoZero Low Voltage parameter (ID 0x07000a00);

  HighVoltage is specified by the value of the AutoZero High Voltage parameter (ID 0x07000a01)

- The value of the AutoZero High Voltage parameter (ID 0x07000a01) should be identical with the piezo voltage that is required for maximum displacement of the axis.

4.2.2 Settings Changed by the AutoZero Procedure

The AutoZero procedure changes the values of the Sensor Mech. Correction 1 parameters (ID 0x02000200). With strain gauge sensors (E-711.SS3 sensor module is present in the system), the AutoZero procedure also changes the Sensor Offset Factor parameters (ID 0x02000102).

4.2.3 Starting the AutoZero Procedure via Command Entry

Via command entry, you have the following options to start the AutoZero procedure:

- Use the ATZ command to perform the AutoZero procedure once (see the PZ233 GCS commands manual for ATZ details). Afterwards save the values of the parameters Sensor Mech. Correction 1 (ID 0x02000200) and Sensor Offset Factor (ID 0x02000102) to nonvolatile memory.
- Send the ATZ command every time you have switched on or rebooted the E-711/E-712 system.
- Set the value of the Power Up AutoZero Enable parameter (ID 0x07000802) to 1 for all axes. The AutoZero procedure will then be performed automatically every time the E-711/E-712 system is switched on or rebooted.

4.2.4 Starting the AutoZero Procedure in PIMikroMove

See "Starting the System in PIMikroMove" (p. 104) for how to perform the AutoZero procedure in PIMikroMove.

4.3 How to Reference an Axis

4.3.1 Settings Relevant for Referencing

It depends on the type of sensor used for position feedback, if and how an axis needs to be referenced. With incremental sensors, the encoder signals used for position feedback provide only relative motion information. Hence the controller cannot know the absolute position of an axis after switching on or rebooting. Therefore referencing is required before absolute target positions can be commanded and reached.

Relevant settings of the E-711/E-712 system:

- Referencing mode of the sensors that are assigned to the axis via the input matrix (see "Input Signal Processing" (p. 134) for more information). The settings for the sensors are made via their Sensor Reference Mode parameter (ID 0x02000a00). Possible values:
  - 1 = no referencing (absolute sensors, no referencing required)
  - 2 = referencing on negative hardstop
  - 3 = referencing on positive hardstop
  - 4 = referencing on reference edge
  - 5 = referencing on reference pulse
- Referencing mode of the axis. The setting for the axis is made with the RON command. Possible values:
  - 1= Default; interpretation depends on the sensors used and hence on the corresponding setting of their Sensor Reference Mode parameter:
    - Absolute sensor (parameter value = 1): No referencing required; usage of POS is not allowed.
    - Incremental sensor (parameter value ≠ 1): A referencing move is required to reference the axis; usage of POS is not allowed.
  - 0= Referencing moves are not possible; an absolute position must be set with POS to reference the axis. Note that RON can only take the value 0 if the Sensor Reference Mode parameter has a value ≠ 1 for all sensors assigned to the axis.

INFORMATION

Axes measured by incremental sensors must be referenced before they can be switched to closed-loop operation.

INFORMATION

With E-711.SA3 and .SA6 modules for incremental sensors (p. 44), an automatic adjustment of the offset and gain for the sin/cos sensor signals is performed by the interpolation electronics. Using the adjustment, the absolute accuracy within one signal period is optimized for best performance. The adjustment requires a motion over at least 16 signal periods of the sensor.

If the referencing move comprises at least 16 signal periods, the adjustment is performed during the referencing move. If the referencing move is shorter than 16 signal periods, an additional motion over the whole travel range is recommended to make sure that the adjustment is performed. Like the referencing move, the adjustment must be repeated every time the E-711/E-712 system is switched on or rebooted.

4.3.2 Perform a Referencing Move

A referencing move is started with the FRF command.

INFORMATION

The velocity for the referencing move is set to the value of the Referencing Velocity parameter (ID 0x7030300).

Proceed as follows to perform a referencing move for an axis:

1. Make sure that the axis is in open-loop operation (SVO <AxisID> 0).
2. Only necessary if the current sensor settings do not match the connected hardware for the input signal channels which are assigned to the axis (via the input matrix; see "Input Signal Processing" (p. 134)):
    a. Select the type of referencing move supported by the sensors. This is done via the Sensor Reference Mode parameter (ID 0x02000a00) using the SPA command. See p. 117 for possible parameter values.
    b. Set the Sensor Mech. Correction 1 parameter (ID 0x02000200) to the value which is to be set as new sensor position after a referencing move.
3. Start the referencing move for the axis using the FRF command.
4. Check with FRF? if referencing was successful.

If referencing was not successful:

- Check the response to the SRG? command and value of the Lim, Ref Signals Detectable parameter (ID 0x02001900) (p. 152).
- See "Signals of Reference and Limit Switches" (p. 152) for more information.

See "Starting the System in PIMikroMove" (p. 104) for how to perform a referencing move in PIMikroMove.

4.3.3 Set Absolute Position

When the referencing mode of the axis is set to "0" with RON, referencing is done by entering an absolute position value using the POS command.

INFORMATION

The referencing mode can only be set to 0 for axes which are measured by incremental sensors only. This means that for all input signal channels involved in axis measurement, the value of the Sensor Reference Mode parameter (ID 0x02000a00) must be one of 2, 3, 4 or 5 (but not 1).

4.4 How to Command Axis Motion

The axes of the E-711/E-712 system can be used in open-loop or closed-loop operation. In closed-loop operation, sensor feedback participates in the control value generation, while it is not used in open-loop operation. The operating mode for the axes can be selected with the SVO command, and the axis motion can result from multiple control sources (see "Control Value Generation" (p. 139) for more information):

- Motion commands: SVA and SVR in open-loop operation, MOV and MVR in closed-loop operation, IMP and STE for both operating modes (see below for examples)
- Wave generator output for periodic motion in either operating mode (see "Wave Generator" (p. 210) for more information and examples)
- Analog control input for motion in either operating mode (see "Using the Analog Input" (p. 190) for more information and examples)

The sources are listed above according to their write priority, starting with the lowest priority. This means that, for example, the wave generator output will overwrite the control value specified by a motion command.

Furthermore, consider the following when working with PiezoWalk® drives:

- In closed-loop operation, target positions are commanded. Depending on the mode of driving that is selected with the PiezoWalk Driving Mode parameter and on the commanded target, motion is realized in full-step mode and/or analog mode or in nanostepping mode.

  The internal control value is a velocity and hence influenced by the settings for step size per cycle and minimum cycle time.

- In open-loop operation, the control sources described above will always cause motion in analog mode. Stepping motion must be started with the PiezoWalk-channel-related OSM command. See the E712T0010 user manual for more information on modes of driving.

To increase the lifetime of the PiezoWalk® drives, perform a relax procedure whenever there is no need for closed-loop positioning. See the E712T0010 user manual for more information.

Axis motion can also be commanded via SPI. Depending on the SPI data segment used, target values (with same write priority as analog control input) or motion commands can be sent from an SPI master. See "Control via SPI Master" (p. 210) for more information.

The following examples apply to a conventional nanopositioning system with piezo actuators and capacitive sensors. They can be used in a terminal, e.g., in the *Command entry* window of PIMikroMove or in the PI Terminal.

A first test that can be made after unpacking your new system: Install, interconnect and switch on the system as described in this manual. Then perform first open-loop motions and check the position values for the individual axes:

Command String to Send	Action Performed
SVO?	Check the operating mode. All axes should be in open-loop operation (response = 0 for all axes), i.e., there is no correction of drift or other effects.
SVA 1 0	Send this command to move axis 1 to an absolute open-loop value of 0. Note that with the factory default settings of the system, this value should correspond to 0 µm (approximately).
POS?	The current position value of axis 1 should be approximately 0 µm, but due to the calibration settings of the system, the axis position can differ from 0 by about 20% of the axis travel range.

Command String to Send	Action Performed
SVR 1 10	With this command, axis 1 moves relative by an open-loop value of 10 (corresponds approximately to 10 µm with the factory default settings of the system).
POS?	The current position value of axis 1 should be approximately 10 µm.

Perform the motion also for the other axes of the system. Note that for rotation axes, the position unit is µrad.

If no load is applied to the piezo stage or if the system was calibrated by PI with a load equal to the current one, you can perform first motions in closed-loop operation, in the example shown for axis 1:

Command String to Send	Action Performed
SVO 1 1	Switch to closed-loop operation for axis 1; this also sets the current axis position as the target position, to avoid jumps of the mechanics.
POS?	Get current position of axis 1. The current axis position value should be approximately 10 µm.
MOV 1 10	Axis 1 moves to an absolute position of 10 µm.
POS?	The current position of axis 1 should be exactly 10 µm.
MVR 1 4	Axis 1 moves relative by 4 µm.
POS?	The new position should be exactly 14 µm.

4.5 How to Customize the System

4.5.1 Set System Parameters

NOTICE

Incorrect parameter values may lead to improper operation or damage to your hardware. Be careful when changing parameters.

It is strongly recommended to save the parameter values of the E-711/E-712 system to a file on the PC before you make any changes. This way the original settings can be restored if the new parameter settings will not prove satisfactory. To save the parameter values and to load them back to the E-711/E-712 system, use the *Device Parameter Configuration* window of PIMikroMove. See "Creating Backups for Parameter Values" (p. 109) for more information.

To adapt the E-711/E-712 system to your application, you can modify parameter values. The parameters available depend on the controller firmware. See "Parameters" (p. 276) for more information.

4.5.2 Adjustment for Load Changes

If the controller and the attached stages are ordered together and if PI has sufficient knowledge of your application, then the parameters of notch filters and control algorithm (control parameters) will be set to suitable values by PI, and, if present, saved in the stage's ID chip (p. 260). For axes driven by conventional piezo actuators, modification of those parameters will, however, be necessary if the load applied to the stage is changed. See "Control Details" (p. 145) and "Optimization for Dynamic Operation" (p. 263) for more information.

5 System Description

5.1 Basic Elements

For successful operation of the E-711/E-712 system, you should familiarize yourself with the following features of the device.

Logical axes

Digital controllers from PI control logical axes. Multiple piezo amplifiers, DC motor drivers ("output signal channels") or PiezoWalk channels and multiple sensors ("input signal channels") can be involved in the motion of one logical axis, just as one amplifier/driver, one PiezoWalk channel or one sensor can participate in the motion of more than one logical axis.

See "Accessible Items and Their Identifiers" (p. 127) and "Processing Steps" (p. 132) for more information.

E-712.3CD, .3CDA and .3AN models can control up to 3 logical axes of a mechanics, E-712.6CD, .6CDA and E-712.6IDA models up to 6 axes, E-712.2AN models up to two axes, and the E-712.1AM and .1AN models control one axis.

Input and output signals

Most of the input and output signals provided by the E-711/E-712 system are used as interface to the connected mechanics (sensor signals and amplifier output). In addition, some signals can be used as control input / output, for external measurement devices or for trigger tasks. See "Accessible Items and Their Identifiers" (p. 127) for more information.

Communication interfaces

The E-711/E-712 system can be controlled from a PC (not included) with ASCII commands sent via:

- TCP/IP
- RS-232
- USB

In addition, the E-711/E-712 system can be controlled by an SPI master, see "Control via SPI Master" (p. 210) for more information.

All interfaces can be active simultaneously. The commands from the interfaces are queued in the order the completed command lines are received.

See "Communication" (p. 154) for more information.

Controller firmware

The firmware comprises the ASCII command set and the parameters and includes some special features. See "Firmware Updates" (p. 303) for version information and updates.

- ASCII commands:

  The E-711/E-712 system supports the PI General Command Set (GCS; version 2.0).

  The PI General Command Set (GCS) is supported by a wide range of PI systems. This command set is well-suited for positioning tasks with one or more axes. The command set itself is independent of the specific hardware (controller or attached stages).

  Commands are used, for example, to set operating modes, to initiate motion of the mechanics and to query system and motion values. See the PZ233 GCS commands manual for more information.

- Parameters:

  The key features of the E-711/E-712 system are mirrored in parameters. They represent the hardware basics and the calibration setup of the system. Some of the parameters are protected so that their values cannot be changed. Other parameters can be modified by the user to adapt the system to the individual application. See "Parameters" (p. 276) for more information.

  The stage which is connected to the E-711/E-712 system may contain an ID chip. The ID chip holds selected parameters which will be written to nonvolatile and volatile memory when the stage is connected for the first time. See "ID Chip Support / Stage Replacement" (p. 260) for more information.

  Note that PI records parameter files of every E-711/E-712 system during calibration.

- Command levels:

  "Command levels" determine the availability of commands and the write access to the parameters. Changing the current active command level may require a password and can be done with the CCL command.

- Special features:

  Wave generator: Each axis can be controlled by a "wave generator" which outputs so-called "waveforms". This feature is especially important in dynamic applications which require periodic, synchronous motion of the axes. See "Wave Generator" (p. 210) for more information.

  Data recorder: The E-711/E-712 system comprises a real-time data recorder. It can record several input and output signals (e.g., current position, sensor input, output voltage) from different data sources (e.g., logical axes or input and output signal channels). See "Data Recording" (p. 164) for more information.

  Macros: The E-711/E-712 system can save macros—command sequences can be defined and permanently saved in the nonvolatile memory of the device via the macro function. A startup macro can be defined that is executed every time the E-711/E-712 system is switched on or rebooted. This simplifies stand-alone operation (operation without a connection to the PC). See "Controller Macros" (p. 245) for more information.

- Control algorithm for closed-loop operation:

  For better position accuracy and performance, the E-711/E-712 system can be used in closed-loop operation. A control algorithm (with sensor feedback) will then apply corrections to the control value. See "Control Details" (p. 145), "Control Value Generation" (p. 139) and "Optimization for Dynamic Operation" (p. 263) for more information.

  In addition to the control algorithm, the Dynamic Digital Linearization (DDL) option can be used for dynamic applications with periodic motion (use of the wave generator). The Dynamic Digital Linearization (DDL) option must be expressly ordered. See "Dynamic Digital Linearization (DDL)" (p. 235) and "Wave Generator" (p. 210) for more information.

  The Advanced Piezo Control option (APC) is an alternative control algorithm for closed-loop operation of piezo actuator systems. You can activate the license after purchase (order number E-712.U1) and without opening the device. See the E712T0007 technical note for more information.

Software on the PC

Usually, a PC is used to operate or at least configure the E-711/E-712 system. Therefore, an ample array of software tools for installation on the PC comes with the E-711/E-712 system. See "Software Description" (p. 87) for a list of software contained in the PI Software Suite.

5.2 Accessible Items and Their Identifiers

The identifiers listed below are used to address the appropriate items with the commands of the PI General Command Set (GCS; supported by the firmware of the E-711/E-712 system). The identifiers are factory default settings and cannot be changed by the user.

See the E712T0016 Fast Alignment user manual for the identifiers of Fast Alignment routines and Fast Alignment input channels.

- **Logical axes**:

  A logical axis is an axis of a Cartesian coordinate system and represents a basic direction of motion in the firmware of the E-711/E-712 system (max. 16 axes). All closed-loop motion of the mechanics is commanded for logical axes (MOV, MVR commands). With PiezoWalk® systems, in open-loop operation an axis-related motion command is only available for motion in analog mode (SVA command) while stepping motion must be started with the PiezoWalk-channel-related OSM command.

  The number of axes is specified by the Number Of System Axes parameter (ID 0x0E000B02).

  See "Processing Steps" (p. 132) for more information regarding the interrelation of logical axes and input / output signal channels.

  E-712.3CD, .3CDA, .3AN: three axes, the identifiers are 1 to 3
  E-712.6CD, .6CDA, .6IDA: six axes, the identifiers are 1 to 6
  E-712.2AN: two axes, the identifiers are 1 and 2
  E-712.1AM, .1AN: one axis, the identifier is 1

- **PiezoWalk channels**:

  A PiezoWalk channel represents a PiezoWalk® drive (NEXLINE®, NEXACT® or PICMAWalk drive types) connected to the controller.

  Open-loop stepping motion must be started with a PiezoWalk-channel-related motion command (OSM).

The maximum possible number of PiezoWalk channels is specified by the Number Of PiezoWalk Channels parameter (ID 0x0E000B06). The number of PiezoWalk channels which are configured for use is specified by the Number Of Configured PiezoWalk Channels parameter (ID 0x0E000B07).

The piezo amplifier channels required for control of a PiezoWalk® drive are assigned to the corresponding PiezoWalk channel via parameters (ID 0x09000100, ID 0x09000101, ID 0x09000200, ID 0x09000201). Standard PiezoWalk® drives require four piezo amplifier channels. See the E712T0010 user manual for details and for the assignment of the PiezoWalk channels to the logical axes.

The identifiers of the PiezoWalk channels start with 1.

E-712.1AM, .1AN: one channel, the identifier is 1
E-712.2AN: two channels, the identifiers are 1 and 2
E-712.3AN: three channels, the identifiers are 1 to 3

- **Input signal channels**:

In the firmware of the E-711/E-712 system, the following input signals are represented by input signal channels (max. 32):

"Internal" sensors of the mechanics
Analog input lines
Input lines of the SPI slave interfaces

The counting of the channels always starts with the internal sensors, followed by the analog input lines, and ends with the SPI input lines.

Note that there is also the fast-alignment-input-channel concept which is only used with respect to Fast Alignment routines (see the E712T0016 Fast Alignment user manual for more information).

Internal sensors:

In the firmware of the E-711/E-712 system, the first input signal channels always represent the lines provided for the internal sensors which are integrated in the connected mechanics. These sensors are connected to sensor modules or sensor boxes.

Analog input lines:

If an E-711.IA4 analog interface module is present in the system, its four analog input lines (connectors *In 1* to *In 4* (p. 332)) are always represented by the input signal channels that follow the internal sensor channels. These lines can be used for external sensors and/or as signal sources for control value generation (see "Using the Analog Input" (p. 190) for more information).

Input lines of the SPI slave interface (on E-712.M1/.N1 digital processor module):

In the E-711/E-712 system, the input values received via the SPI slave interface are handled as additional input signal channels (i.e. as if it would be analog input). You can configure the number of additional input signal channels to be provided by the E-711/E-712 system for the SPI slave interface: Set the SPI Slave Number Of Inputs parameter (ID 0x0e001300) to the desired value (max. 15).

The total number of input signal channels is specified by the Number Of Input Channels parameter (ID 0x0E000B00).

The Number Of Sensor Channels parameter (ID 0x0E000B03) specifies the number of sensor channels and is always less than or equal to the number of input signal channels.

E-712.3CD: three channels, the identifiers are 1 to 3, all for capacitive sensors
E-712.3CDA: seven channels, the identifiers 1 to 3 are for capacitive sensors, 4 to 7 for analog input lines
E-712.6CD: six channels, the identifiers are 1 to 6, all for capacitive sensors
E-712.6CDA, .6IDA: ten channels, the identifiers 1 to 6 are for sensors (capacitive or incremental), 7 to 10 for analog input lines
E-712.1AM, .1AN / .2AN / .3AN: one / two / three channel/s, the identifier/s is/are 1 / 1, 2 / 1 to 3 (incremental encoder/s)

- **Output signal channels**:

In the firmware of the E-711/E-712 system, the following output signals are represented by output signal channels (max. 64):

"Internal" amplifiers and DC motor drivers for the mechanics
Analog output lines
Output lines of the SPI slave interface

The counting of the channels always starts with the internal amplifiers/drivers, followed by the analog output lines, and ends with the SPI output lines.

Internal amplifiers/drivers:

In the firmware of the E-711/E-712 system, the first output signal channels always represent the lines which carry the voltages for the actuators/motors in connected mechanics. These voltages are provided by the amplifier or DC motor driver modules.

Analog output lines:

If an E-711.IA4 analog interface module is present in the system, its four analog output lines (connectors *Out 1* to *Out 4* (p. 333)) are always represented by the output signal channels that follow the internal amplifier/driver channels. These lines can be used to control external amplifiers and/or to monitor axis positions (see "Using the Analog Output" (p. 123) for more information).

Output lines of the SPI slave interface (on E-712.M1/.N1 digital processor module):

In the E-711/E-712 system, the values output via the SPI slave interface are handled by the controller as additional output signal channels (i.e. as if it would be analog output). You can configure the number of additional output signal channels to be provided by the E-711/E-712 system for the SPI slave interface: Set the SPI Slave Number Of Outputs parameter (ID 0x0e001400) to the desired value (max. 15).

The total number of output signal channels is specified by the Number Of Output Channels parameter (ID 0x0E000B01). The Number Of Piezo Channels parameter (ID 0x0E000B04) specifies the number of piezo amplifier channels and is always less than or equal to the number of output signal channels.

E-712.3CD, .1AM, .1AN: four channels, the identifiers are 1 to 4, all for piezo amplifiers
E-712.3CDA: eight channels, the identifiers 1 to 4 are for piezo amplifiers, 5 to 8 for analog output lines
E-712.6CD, .2AN: eight channels, the identifiers are 1 to 8, all for piezo amplifiers
E-712.6CDA, .6IDA: twelve channels, the identifiers 1 to 8 are for piezo amplifiers, 9 to 12 for analog output lines
E-712.3AN: twelve channels, the identifiers are 1 to 12, all for piezo amplifiers

- **Digital output lines**: eight lines (*ServoTrigger* and *OUT1* to *OUT7*, see "Digital I/O Connector" (p. 335) for pinout), the identifiers for *OUT1* to *OUT7* are 1 to 7; the *ServoTrigger* output line is not accessible by commands.

  The number of digital output lines that are accessible by commands is specified by the Number Of Trigger Outputs parameter (ID 0x0E000B05).

  See "Configuring Trigger Output" (p. 168) for more information.

- **Digital input lines**: eight lines (*IN1* to *IN8*, see "Digital I/O Connector" (p. 335) for pinout), the identifiers are 1 to 8.

  See "Using Digital Input" (p. 168) for more information.

- **Wave generators**:

  The number of wave generators is the same as the number of logical axes, and each wave generator is fixed to one axis. See "Wave Generator" (p. 210) for more information.

  E-712.3CD, .3CDA, .3AN: three wave generators, the identifiers are 1 to 3
  E-712.6CD, .6CDA, .6IDA: six wave generators, the identifiers are 1 to 6
  E-712.2AN: two wave generators, the identifiers are 1 and 2
  E-712.1AM, .1AN: one wave generator, the identifier is 1

- **Wave tables** (memory tables for waveform data): 90 tables with a total of 2^{18} points, the identifiers are 1 to 90

  The number of wave tables is specified by the Number of Waves parameter (ID 0x1300010A). See "Wave Generator" (p. 210) for more information.

- **DDL tables** (memory tables for the data of the Dynamic Digital Linearization (DDL) option):

  The number of DDL tables is the same as the number of logical axes, and each DDL table is fixed to one axis. The total number of points provided for the DDL tables is 2^{18}, specified by the Max DDL Points parameter (ID 0x1400000B). See "Dynamic Digital Linearization (DDL)" (p. 235) for more information.

  E-712.3CD, .3CDA, .3AN: three DDL tables, the identifiers are 1 to 3
  E-712.6CD, .6CDA, .6IDA: six DDL tables, the identifiers are 1 to 6
  E-712.2AN: two DDL tables, the identifiers are 1 and 2
  E-712.1AM, .1AN: one DDL table, the identifier is 1

- **Data recorder tables** (memory tables for recorded data): up to 12 tables with a total of 2^{23} points, the identifiers start with 1 and continue sequentially up to the number of tables.

  The number of data recorder tables can be set via the Data Recorder Chan Number parameter (ID 0x16000300). The maximum number of tables is limited by the Max Number Of Data Recorder Channels parameter (ID 0x16000100).

  See "Data Recording" (p. 164) for more information.

- **Whole system**: the E-711/E-712 system, the identifier is 1

- **Hardware modules**: the slots available in the housing, the identifiers start with 1. Counting (front view): 1 = leftmost slot.

  The actual number of hardware modules present in the housing depends on the system configuration.

- **Firmware units**: the number of different firmware units present in the E-711/E-712 system, the identifiers start with 1 and continue sequentially up to the number of firmware units.

  E-712.M1 and .N1 digital processor modules have 2 different firmware units installed (CPU and FPGA firmware), and each of the other modules in the E-711/E-712 system has one firmware unit installed. All firmware units can be updated separately, see "Firmware Updates" (p. 303) for more information.

5.3 Processing Steps

The E-711/E-712 system controls the motion of the logical axes of the connected mechanics in open-loop or closed-loop operation. The block diagram below shows the signal path for an axis in closed-loop operation.

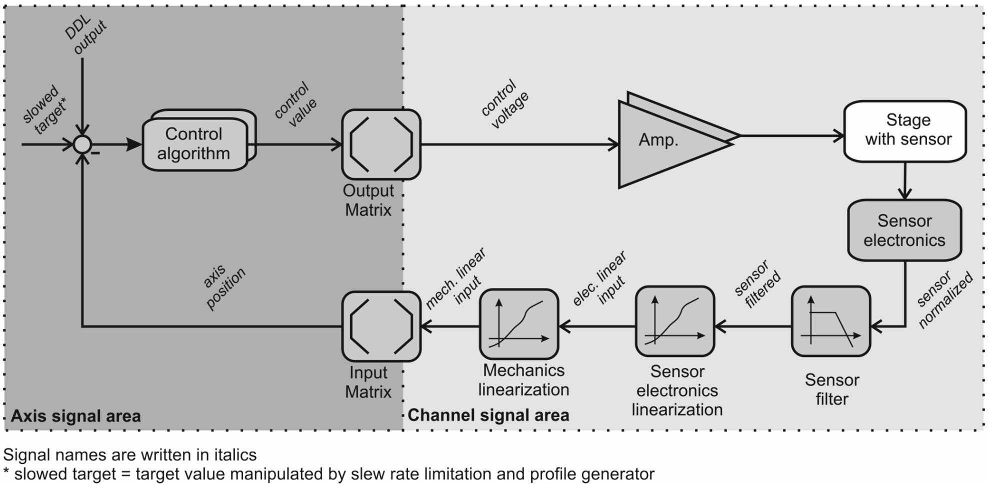


Figure 44: Block diagram of an axis in closed-loop operation

The individual processing steps and the corresponding parameters are described in the subsections below.

INFORMATION

It is strongly recommended to save the parameter values of the E-711/E-712 system to a file on the PC before you make any changes. This way the original settings can be restored if the new parameter settings will not prove satisfactory. To save the parameter values and to load them back to the E-711/E-712 system, use the *Device Parameter Configuration* window of PIMikroMove. See "Creating Backups for Parameter Values" (p. 109) for more information.

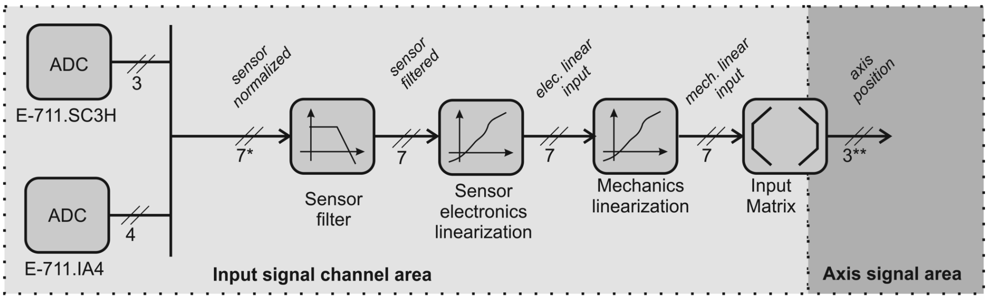
Wherever changing parameter values is mentioned, you can do this using SPA (volatile memory) or SEP (nonvolatile memory). Furthermore, you can use WPA to copy the current values from volatile memory to nonvolatile memory. To have write access to certain parameters, it might be necessary to switch to a higher command level using CCL. To read parameter values, query with the SPA? or SEP? commands.

The *Device Parameter Configuration* window of PIMikroMove gives access to parameter values in a more convenient way. Use this window to check/edit the individual parameters. See the PIMikroMove manual for more information.

5.3.1 Input Signal Processing

The following processing is applied to all input signal channels of the E-711/E-712 system (channels for internal sensors of the mechanics and for analog input lines):

- Analog-to-digital conversion
- Digital processing (filtering and linearization / scaling)
- Allocation of input signal channels to axes via the input matrix to calculate the axis positions from the input signals



Signal names are written in italics
* E-712.3CDA is shown as an example. It has a total of 7 input signal channels:
3 sensor channels (IDs 1 to 3) and 4 analog inputs (IDs 4 to 7)
** The positions of 3 axes are calculated from the 3 sensor channels via the input matrix.

Figure 45: Input signal processing for E-712.3CDA

Analog-to-digital conversion:

The results of the analog-to-digital conversion can be queried with the TAD? command for all channels.

For capacitive sensors: The following settings influence the analog sensor signal and can be selected by parameters:

- Sensor Range parameter (ID 0x02000100)

  Scales the measurement range (by changing the capacitance defined as the mid-position value). Example: The nominal measurement range of a sensor is 100 µm. With a factor of 1.27, the measurement range is enlarged to 127 µm, and with a factor of 3.26 enlarged to 326 µm. Possible parameter values for capacitive dual-electrode sensors (parameter value = factor):

  1 = 3.26x
  2 = 2.15x
  3 = 1.27x
  4 = 1.00x

This parameter also automatically selects the corresponding polynomial for electronics linearization (see "Digital processing").

- Sensor Cable Compensation parameter (ID 0x02000103)

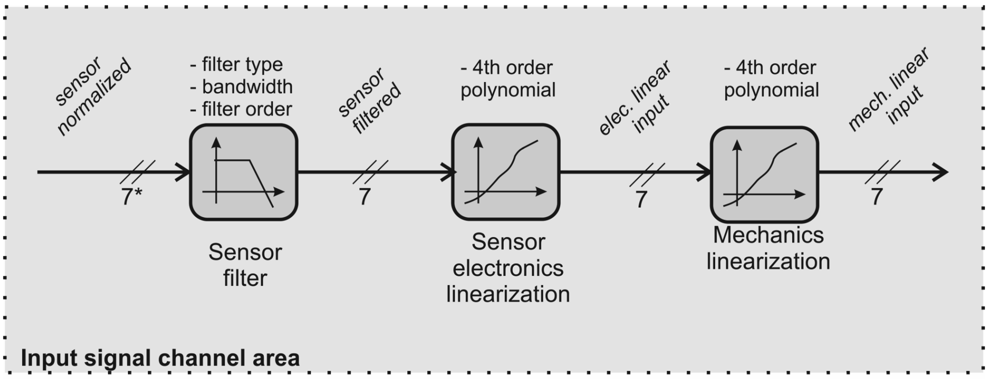
  When set to zero, cable compensation is disabled. Otherwise, the cable compensation is enabled and the electronics polynomial for cable compensation is selected. The value is determined by PI and should only be changed when an additional extension cable or adapter is used, or when the length of the stage cable is changed after PI has calibrated the E-711/E-712 system. In this case, contact your PI sales engineer or write info@pi.ws to obtain a suitable value.

Note that in PIMikroMove, the parameters are available in the *Sensor Electronics* parameter groups in the *Device Parameter Configuration* window.

Digital processing:

The digital processing of the input signals comprises the following steps:

- Digital filtering
- Electronics linearization
- Mechanics linearization



Signal names are written in italics
* E-712.3CDA is shown as an example. It has a total of 7 input signal channels:
3 sensor channels (IDs 1 to 3) and 4 analog inputs (IDs 4 to 7)

Figure 46: Digital processing of the input signals, shown for E-712.3CDA

The following parameters determine the digital filter settings:

- Digital Filter Type parameter (ID 0x05000000)

  0 = no filter
  1 = IIR low-pass filter, 2nd order
  2 = moving-average filter

- Digital Filter Bandwidth parameter (ID 0x05000001)

  Specifies the cut-off-frequency f_g of the IIR low-pass filter. Only used if "Digital Filter Type" is set to "IIR low-pass filter, 2nd order".

  Note that the duration of the signal processing for a capacitive sensor results from two portions:

  1) Duration of the analog sensor processing, which takes about 80 µs

  2) Duration of the digital filtering which depends on the f_g setting:
  for signal frequencies $f < f_g/2$, the duration of the filtering can be estimated as follows: $t \approx 0.216 / f_g$

- Digital Filter Order parameter (ID 0x05000002)

  Filter order of moving-average filter. Specifies the number of previous values used in determining the present output. Only used if the Digital Filter Type parameter is set to "moving-average filter" (for the IIR filter, the order is always 2).

In PIMikroMove, the digital filter parameters are available in the *Sensor Mechanics* parameter groups in the *Device Parameter Configuration* window.

Polynomial linearization is used to correct system performance. The basic form of the polynomials is as follows:

$$y = a_0 + a_1 \times x + a_2 \times x^2 + a_3 \times x^3 + a_4 \times x^4 + a_5 \times x^5$$
$$x - filtered\ sensor\ ADC\ value$$
$$y - linearized\ sensor\ value$$

To make the system components easily replaceable, sensor (i.e., mechanics) and electronics use separate polynomials. The coefficients of the polynomials are determined by PI. Some terms of the polynomials are provided for future application and presently set to zero. The following terms are currently in use:

- Electronics linearization: The coefficients of the polynomials are specified by the parameters 0x03000100 to 0x03000512. They are independent of the connected mechanics and may not be changed by the user. In

PIMikroMove, these parameters are available in the *Sensor Electronics* parameter groups in the *Device Parameter Configuration* window.

- Mechanics linearization: offset, gain, 2nd, 3rd and 4th order correction. The corresponding coefficients of the polynomial are specified by the parameters 0x02000200 to 0x02000600. They depend on the connected mechanics. In PIMikroMove, these parameters are available in the *Sensor Mechanics* parameter groups in the *Device Parameter Configuration* window.

  For the internal sensors in the mechanics, the parameters should not be changed by the user. For analog input lines (last four input signal channels if an E-711.IA4 analog interface module is present), changing the offset and gain values is required to scale the analog input to suitable position values (see "Using the Analog Input" (p. 190) for more information and examples).

  If the connected mechanics has an ID chip, the coefficients will be read in from the ID chip (see "ID Chip Support / Stage Replacement" (p. 260) for more information).

The TNS? command returns the result after the linearization for the electronics (normalized value, dimensionless), while the TSP? command returns the result after the linearization for the mechanics (scaled value, the unit is µm).

Allocation of input signal channels to axes:

Multiple sensors can be used to monitor the position of an axis, especially with rotation axes. The internal sensors in the mechanics are active by default, while additional, external sensors can optionally be connected to the analog input lines if an E-711.IA4 analog interface module is present in the E-711/E-712 system. The axis positions are calculated from the position values of the input signal channels using the input matrix. The number of rows and columns of the input matrix depends on the configuration of the E-711/E-712 system. The example below shows the matrix for an E-712.3CDA model which controls 3 axes and has 3 channels for internal sensors and 4 additional analog input lines (the last four input signal channels):

$$\begin{pmatrix} Axis1 \\ Axis2 \\ Axis3 \end{pmatrix} = \begin{pmatrix} a11 & a12 & a13 & a14 & a15 & a16 & a17 \\ a21 & a22 & a23 & a24 & a25 & a26 & a27 \\ a31 & a32 & a33 & a34 & a35 & a36 & a37 \end{pmatrix} * \begin{pmatrix} InputCh1 \\ InputCh2 \\ InputCh3 \\ InputCh4 \\ InputCh5 \\ InputCh6 \\ InputCh7 \end{pmatrix}$$

In equation form:

$Axis_1 = a_{11}InputCh_1 + a_{12}InputCh_2 + a_{13}InputCh_3 + a_{14}InputCh_4 + a_{15}InputCh_5 + a_{16}InputCh_6 + a_{17}InputCh_7$

$Axis_2 = a_{21}InputCh_1 + a_{22}InputCh_2 + a_{23}InputCh_3 + a_{24}InputCh_4 + a_{25}InputCh_5 + a_{26}InputCh_6 + a_{27}InputCh_7$

$Axis_3 = a_{31}InputCh_1 + a_{32}InputCh_2 + a_{33}InputCh_3 + a_{34}InputCh_4 + a_{35}InputCh_5 + a_{36}InputCh_6 + a_{37}InputCh_7$

The matrix coefficients are specified by the Position From Sensor *n* parameters (*n* depends on the number of input signal channels present in the E-711/E-712 system). With an E-712.3CDA, for example, the following parameters are used (with i = 1 to 3 for the three axes of the system, i.e., each parameter has a different value for each of the logical axes):

- a_{i1} = Position From Sensor 1 parameter (ID 0x07000500)

  a_{i2} = Position From Sensor 2 parameter (ID 0x07000501)

  a_{i3} = Position From Sensor 3 parameter (ID 0x07000502)

  These coefficients are for the internal sensors in the mechanics (sensor channels on the E-711.SC3H sensor module).

- a_{i4} = Position From Sensor 4 parameter (ID 0x07000503)

  a_{i5} = Position From Sensor 5 parameter (ID 0x07000504)

  a_{i6} = Position From Sensor 6 parameter (ID 0x07000505)

  a_{i7} = Position From Sensor 7 parameter (ID 0x07000506)

  These coefficients are for the analog input lines on the E-711.IA4 analog interface module (connectors *In 1* to *In 4*).

In PIMikroMove, these parameters are available in the *Axis Definition* parameter groups in the *Device Parameter Configuration* window.

INFORMATION

The coefficients of the input matrix are determined by PI during calibration. The preset values of the coefficients for the internal sensors should not be changed unless the internal sensors are to be excluded from the position feedback of the axes, e.g., if external sensors are connected to the analog input lines. The coefficients for the analog input lines on an E-711.IA4 analog interface module should be set to zero if no external sensors are connected to the analog input lines or when the analog input is used for control value generation (see "Using the Analog Input" (p. 190) for more information).

If the connected mechanics has an ID chip, the coefficients will be read in from the ID chip (see "ID Chip Support / Stage Replacement" (p. 260) for more information).

While TSP? returns the position values of the input signal channels, the POS? command returns the axis positions calculated via the input matrix (the unit is µm or µrad).

5.3.2 Control Value Generation

The control value for the motion of an axis can result from multiple sources (see below). Furthermore, the feedback from multiple sensors can be used to maintain the axis position, depending on the current operating mode. The interpretation of the control values depends on the settings of the output matrix (see "Output Generation" (p. 143) for more information). By default, the output matrix is set up so that control values correspond numerically to axis position values (see below for exceptions regarding PiezoWalk® systems).

The E-711/E-712 system supports the following operating modes:

- **Open-loop operation**: **No** control algorithm is used, and the sensor feedback does **not** participate in the control value generation.

- **Closed-loop operation**: Sensor feedback participates in the control value generation.

  For each logical axis, a control algorithm is used to generate corrections to the control value (default: PID algorithm). In addition, two notch filters are used for each axis (default: only active in closed-loop operation). The settings for control algorithm and notch filters are accessible as parameters. See "Control Details" (p. 145), "Optimization for Dynamic Operation" (p. 263) and "Parameters" (p. 276) for more information.

The operating mode can be selected with the SVO command for each axis. By default, open-loop operation is active after switching on or rebooting. Using the Power Up Servo On Enable parameter (ID 0x07000800), you can set up the individual axes to start with closed-loop operation. When switching from open-loop to closed-loop operation, the behaviour depends on the setting made with the Move To Last Commanded Position parameter (ID 0x0e002000). Default: The current axis position is set as the target position. See "Parameter Overview" (p. 279) for more information. Switching from closed-loop to open-loop operation sets the current closed-loop control value as the open-loop control value.

The E-711/E-712 system supports the following control sources:

- Motion commands, sent from the command line or from a macro:

  MOV and MVR in closed-loop operation
  SVA and SVR in open-loop operation
  IMP and STE for an impulse response or step response measurement

- Wave Generator: The wave generator is started with WGO.

  An offset value can be added to the wave generator output using the WOS command.

- Analog Input (only possible when an E-711.IA4 analog interface module is present in the E-711/E-712 system): The analog control input is enabled via parameter settings, see "How to Work with the Analog Input—Overview" (p. 190) for more information.

  An offset value can be added to the analog input scaled value using the AOS command.

- AutoZero procedure: this procedure is started with the ATZ command and performed in open-loop operation only (if necessary, the AutoZero procedure switches to open-loop operation and back to closed-loop operation when it is finished). The AutoZero procedure has the highest priority, i.e., it will overwrite the control values specified by all other sources. When the analog control input is enabled, it will be disabled automatically at the start of the AutoZero procedure and reenabled again when the AutoZero procedure is finished. See "AutoZero Procedure" (p. 115) for more information.

The E-711/E-712 system can also be commanded via SPI. Depending on the SPI data segment used, target values (with same write priority as analog control input) or GCS commands can be sent from an SPI master. See "Control via SPI Master" (p. 210) for more information.

Furthermore, consider the following when working with PiezoWalk® systems (i.e., systems driven by NEXLINE®, NEXACT® or PICMAWalk drives):

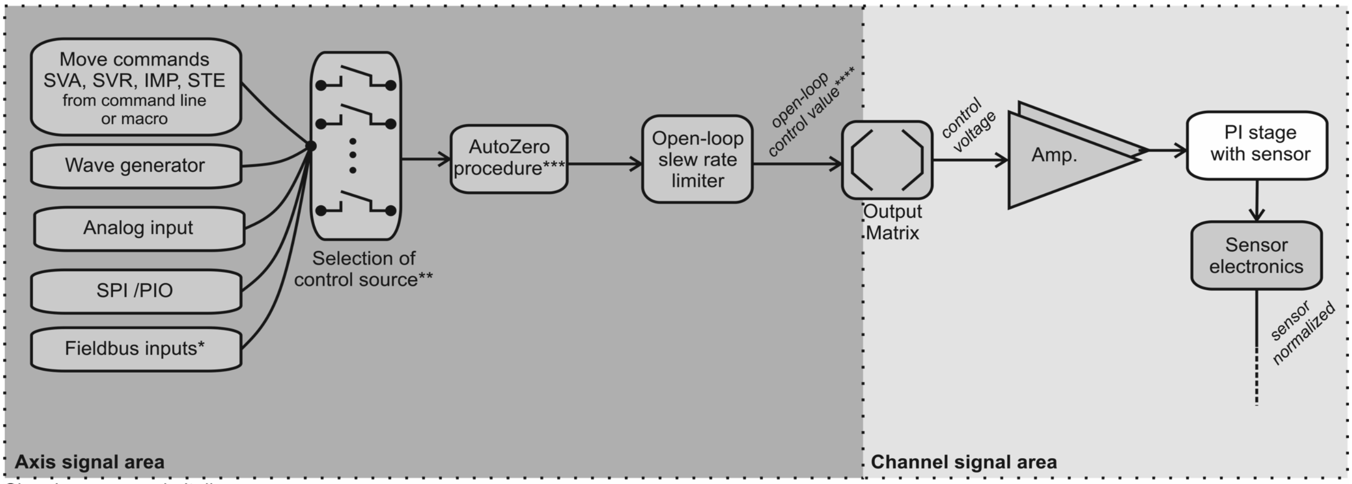
- In closed-loop operation, target positions are commanded. Depending on the mode of driving that is selected with the PiezoWalk Driving Mode parameter and on the commanded target, motion is realized in full-step mode and/or analog mode or in nanostepping mode.

  The internal control value is a velocity and hence influenced by the settings for step size per cycle and minimum cycle time.

- In open-loop operation, the control sources described above command voltage values and will always cause motion in analog mode. Stepping motion must be started with the PiezoWalk-channel-related OSM command.

See the E712T0010 manual for more information on PiezoWalk® modes of driving.

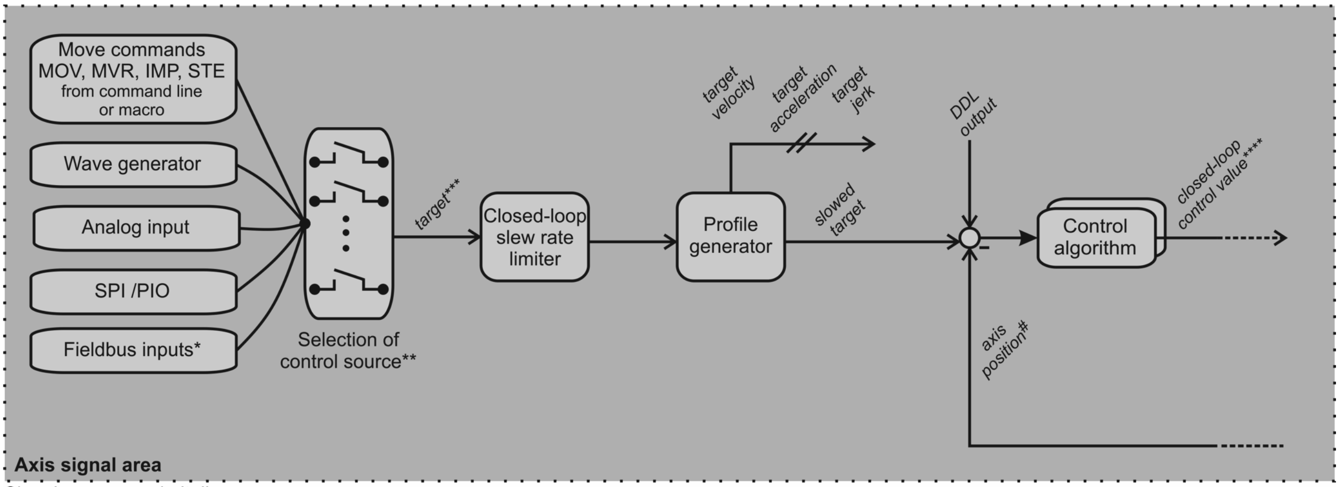
Open-Loop operation:



Signal names are in italics
* For future applications.
** Only one control source can be used at a time.
*** The AutoZero procedure is triggered with the ATZ command and has the highest priority for signal manipulation.
If the AutoZero procedure is not running, it is bypassed. For further details, see „AutoZero Procedure".
**** The open-loop control value is reported by the SVA? command.

Figure 47: Control sources for an axis of a conventional nanopositioning system in open-loop operation

Closed-Loop operation:



Signal names are in italics
* For future applications.
** Only one control source can be used at a time.
*** The target position is reported by the MOV? command.
**** The closed-loop control value is the input signal for the output matrix,
see block diagram of closed-loop operation for details.
The axis position is the output signal of the input matrix,
see block diagram of closed-loop operation for details.

Figure 48: Control sources for an axis of a conventional nanopositioning system in closed-loop operation

5.3.3 Output Generation

For PiezoWalk® systems (i.e., systems driven by NEXLINE®, NEXACT® or PICMAWalk drives): See the E712T0010 manual for the assignment of axes to output channels.

With conventional nanopositioning systems, multiple piezo actuators can be used to move an axis, i.e., multiple output signal channels (piezo amplifiers) can be involved. The control value for an axis is transformed to control voltage values for the output channels via the output matrix. After the digital-to-analog conversion, the resulting control voltage values are sent to the piezo amplifiers whose output drives the actuators in the mechanics.

If an E-711.IA4 analog interface module is present in the E-711/E-712 system, the control voltage values can also be output by the analog output lines to drive external amplifiers (see "Using the Analog Output" (p. 123) for more information).

The number of rows and columns of the output matrix depends on the configuration of the E-711/E-712 system. The example below shows the matrix for an E-712.3CDA model which controls 3 axes and has 4 piezo amplifier channels and 4 additional analog output lines (the last four output signal channels):

$$\begin{pmatrix} OutputCh1 \\ OutputCh2 \\ OutputCh3 \\ OutputCh4 \\ OutputCh5 \\ OutputCh6 \\ OutputCh7 \\ OutputCh8 \end{pmatrix} = \begin{pmatrix} p11 & p12 & p13 \\ p21 & p22 & p23 \\ p31 & p32 & p33 \\ p41 & p42 & p43 \\ p51 & p52 & p53 \\ p61 & p62 & p63 \\ p71 & p72 & p73 \\ p81 & p82 & p83 \end{pmatrix} * \begin{pmatrix} Axis1 \\ Axis2 \\ Axis3 \end{pmatrix}$$

In equation form:

$OutputCh_1 = p_{11}Axis_1 + p_{12}Axis_2 + p_{13}Axis_3$
$OutputCh_2 = p_{21}Axis_1 + p_{22}Axis_2 + p_{23}Axis_3$
$OutputCh_3 = p_{31}Axis_1 + p_{32}Axis_2 + p_{33}Axis_3$
$OutputCh_4 = p_{41}Axis_1 + p_{42}Axis_2 + p_{43}Axis_3$
$OutputCh_5 = p_{51}Axis_1 + p_{52}Axis_2 + p_{53}Axis_3$
$OutputCh_6 = p_{61}Axis_1 + p_{62}Axis_2 + p_{63}Axis_3$
$OutputCh_7 = p_{71}Axis_1 + p_{72}Axis_2 + p_{73}Axis_3$
$OutputCh_8 = p_{81}Axis_1 + p_{82}Axis_2 + p_{83}Axis_3$

The matrix coefficients are specified by the Driving Factor of Piezo *m* parameters (*m* depends on the number of output signal channels present in the E-711/E-712 system). With an E-712.3CDA, for example, the following parameters are used (with i = 1 to 3 for the three axes of the system, i.e., each parameter has a different value for each of the logical axes):

- p_{1i} = Driving Factor of Piezo 1 parameter (ID 0x09000000)

  p_{2i} = Driving Factor of Piezo 2 parameter (ID 0x09000001)
  p_{3i} = Driving Factor of Piezo 3 parameter (ID 0x09000002)
  p_{4i} = Driving Factor of Piezo 4 parameter (ID 0x09000003)
  These coefficients are for the piezo amplifiers in the E-711.AL4 amplifier module which drive the piezo actuators in the mechanics.

- p_{5i} = Driving Factor of Piezo 5 parameter (ID 0x09000004)

  p_{6i} = Driving Factor of Piezo 6 parameter (ID 0x09000005)
  p_{7i} = Driving Factor of Piezo 7 parameter (ID 0x09000006)
  p_{8i} = Driving Factor of Piezo 8 parameter (ID 0x09000007)
  These coefficients are for the analog output lines on the E-711.IA4 analog interface module (connectors *Out 1* to *Out 4*).

In PIMikroMove, these parameters are available in the *Axis Definition* parameter groups in the *Device Parameter Configuration* window.

INFORMATION

During calibration of conventional nanopositioning systems by PI, the coefficients of the output matrix are set numerically to the number of voltage units which are required by the attached piezo actuators per unit of length of the axis (i.e., the unit of the coefficients is V/µm). Thus, both the closed-loop control value and the open-loop control value correspond numerically to axis position values. This means that all control sources always command with axis position values, irrespective of the current operating mode. You should not change the coefficients for the piezo amplifier channels.

If the connected mechanics has an ID chip, the coefficients will be read in from the ID chip (see "ID Chip Support / Stage Replacement" (p. 260) for more information).

The VOL? command returns the current voltage output of the output signal channel (in volts).

With systems that support DC motors (E-711.C82 motor driver module is present), the output current can be limited for the output signal channels via the Max Output Current (A) parameter (ID 0x0B000900).

5.4 Control Details

5.4.1 Profile Generator

In closed-loop operation, a profile generator can be used to specify the target position, jerk and acceleration of the axis for any point in time (dynamics profile). Each axis has its own profile generator which can be enabled/disabled via the Target Generator Enable parameter (ID 0x06010300; 0 = off, 1 = on). The profile generator should only be enabled for axes driven by DC motors and disabled for all other axes.

INFORMATION

For axes with disabled profile generator, the target signal can be manipulated by a slew rate limitation (parameter with ID 0x07000200). For fastest possible settling, the slew rate limitation can be switched off with the VCO command.

The dynamics profile generated by the profile generator depends on the target position which is to be reached at the end of the motion and on the following motion parameters:

- Target Generator Maximum Acceleration parameter (ID 0x06010000)
- Target Generator Maximum Jerk parameter (ID 0x06010100)
- Target Generator Maximum Velocity parameter (ID 0x06010400; read-only and identical with the value of the Servo Loop Slew-Rate parameter (ID 0x07000200))

5.4.2 Control Algorithms for Closed-Loop Operation

The control algorithm to be used in closed-loop operation can be selected for each axis via the Closed-Loop Control Mode parameter (ID 0x07030100). Possible values of the parameter:

0 = Hardware, e.g., control via an external analog control module (position control)

1 = PID position control (a position sensor signal is used and the target is specified as position)

2 = Advanced Piezo Control (APC) algorithm, licence must be ordered separately; see "Additional Components" (p. 84)

6 = PID velocity control (a position sensor signal is used and the target is specified as velocity)

7 = PID position control with subordinate velocity control (a position sensor signal is used and the target is specified as position)

With the PID algorithms and all derived algorithms (see below), up to two notch filters (p. 151) and feedforward (p. 149) can be used.

A PID algorithm in principle has the following structure:

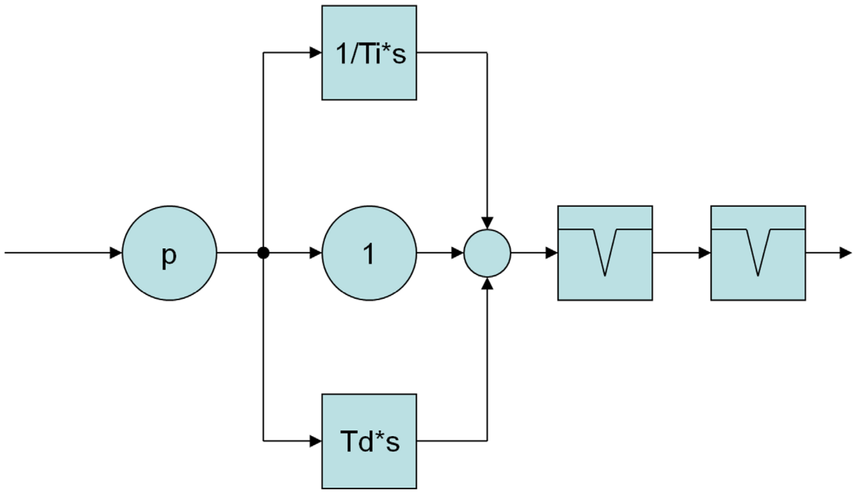


Figure 49: Structure of a PID algorithm; two notch filters are available; note that feedforward is not shown here

Other algorithms can be derived as follows from a PID algorithm:

- P algorithm: I term and D term are set to zero
- I algorithm: P term and D term are set to zero
- PI algorithm: The D term is set to zero

Axes driven by conventional piezo actuators, and PiezoWalk®-driven axes normally use the PID position control (algorithm 1); see the figure below. If you also want to use feedforward, see p. 149.

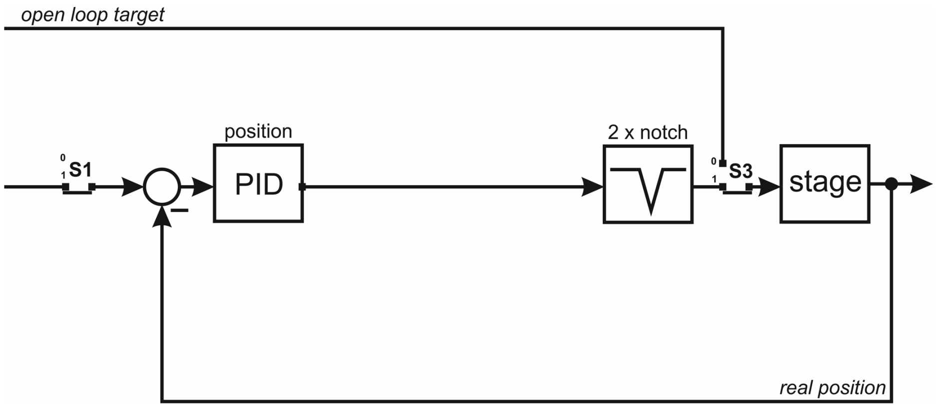


Figure 50: Control structure for PID position control (algorithm 1); note that feedforward is not shown here

Control algorithm	Operating mode	S1	S3
PID position control (algorithm 1)	Open-loop operation	0	0
	Closed-loop operation	1	1

Axes driven by DC motors normally use the PID position control with subordinate velocity control (algorithm 7); see the figure below. If you also want to use feedforward, see p. 149.

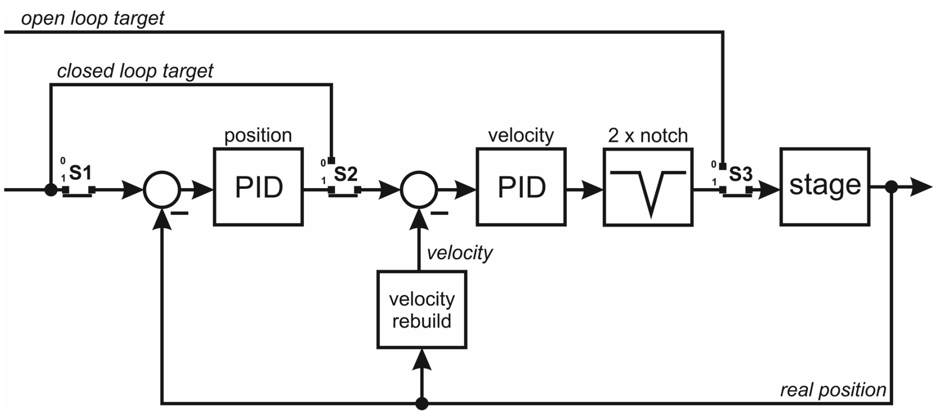


Figure 51: Control structure for PID position control with subordinate velocity control (algorithm 7) and for PID velocity control (algorithm 6); note that feedforward is not shown here

Control algorithm	Operating mode	S1	S2	S3
PID position control with subordinate velocity control (algorithm 7)	Open-loop operation	0	0	0
	Closed-loop operation	1	1	1
PID velocity control (algorithm 6)	Open-loop operation	0	0	0
	Closed-loop operation	0	0	1

The PID position control and PID velocity control can be configured with the following parameters:

Parameter	Notes
Servo-Loop P-Term ID 0x07000300	P constant for position control Must be > 0. See "Optimization for Dynamic Operation" (p. 263) for more information.
Servo-Loop I-Term ID 0x07000301	Integrator time constant Ti for position control output = Ts / Ti · ∑ input where Ts is the control loop sampling time (parameter with ID 0x0E000200). When the time constant Ti is zero, then the integrator is turned off. See "Optimization for Dynamic Operation" (p. 263) for more information.
Servo-Loop D-Term ID 0x07000302	Differentiator time constant Td for position control output = Td / Ts · Δinput where Ts is the control loop sampling time (parameter with ID 0x0E000200). Must be > 0. See "Optimization for Dynamic Operation" (p. 263) for more information.
Servo-Loop P-Term for Velocity ID 0x07000307	P constant for velocity control Must be > 0.
Servo-Loop I-Term for Velocity ID 0x07000308	Integrator time constant Ti for velocity control output = Ts / Ti · ∑ input where Ts is the control loop sampling time (parameter with ID 0x0E000200). When the time constant Ti is zero, then the integrator is turned off
Servo-Loop D-Term for Velocity ID 0x07000309	Differentiator time constant Td for velocity control output = Td / Ts · Δinput where Ts is the control loop sampling time (parameter with ID 0x0E000200). Must > 0.
On-Target Tolerance To Fix I-Term ID 0x07030a00	[µm] Specifies a position window which is centered around the target position. If the current position is in this window, the I term of the control algorithm is fixed to prevent a jitter of the axis. For axes driven by DC motors.

Parameter	Notes
Zeroing Control Value If I-Term Is Fixed ID 0x07030d00	Determines the control value when the I term is fixed (current position is in the window specified by the parameter with ID 0x07030a00; see above): 0 = The control value is fixed to the last valid value. 1 = The control value is set to zero. The purpose is to avoid heat generation in static operation. For axes driven by DC motors.

5.4.3 Feedforward

In closed-loop operation, the main component regarding the tracking error is the phase shift between the target value and the real value of the controlled variable (position and/or velocity). By adding a feedforward signal to the control algorithm the phase shift can be reduced.

The feedforward signal can be added to the output of the PID algorithms for position control and/or velocity control in the control modes 1, 6, and 7. See "Control Algorithms for Closed-Loop Operation" (p. 145) for more information on the control modes.

For every axis, an input signal channel of the controller can be selected as feedforward signal using the Input Channel For Feed Forward Signal parameter (ID 0x07030900; S1 in the figure below). This way, an external preshaping sequence can be used to compensate for a known error, for example. If no input signal channel is selected, the target signal is used as feedforward signal (the value of the parameter with ID 0x07030900 is zero).

For every axis, gain values can be applied to the feedforward signal. The gain is specified by the parameter with ID 0x07030600 for position feedforward and by the parameter with ID 0x07030601 for velocity feedforward. A gain value of 0 deactivates the corresponding feedforward.

The feedforward signal is fed in before the notch filters to avoid exciting the resonances of the system.

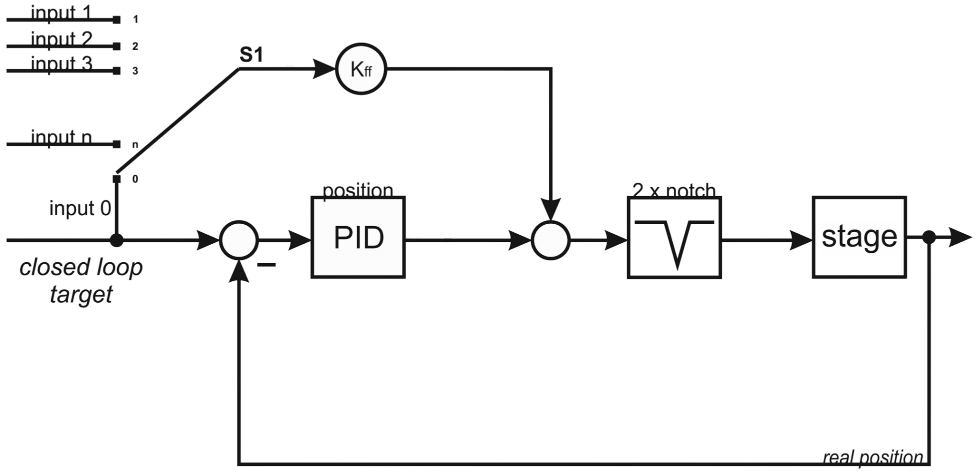


Figure 52: Control structure with feedforward signal using the example of PID position control (algorithm 1). K_{ff} is the feedforward signal multiplied by the gain specified by the parameter with ID 0x07030600.

Overview of the parameters for the configuration of position feedforward and velocity feedforward:

Parameter	Notes
Feed Forward in n-1th Derivative of Position n = 1 ID 0x07030600	Gain for position feedforward Must be ≥ 0 The gain value is multiplied with the feedforward signal. The resulting position feedforward is added to the output of the PID algorithm for position control; see K_{ff} in Figure 52. A gain value of 0 deactivates the position feedforward. Applied in control modes 1 and 7.
Feed Forward in n-1th Derivative of Position n = 2 ID 0x07030601	Gain for velocity feedforward Must be ≥ 0 The gain value is multiplied with the feedforward signal. The resulting velocity feedforward is added to the output of the PID algorithm for velocity control. A gain value of 0 deactivates the velocity feedforward. Applied in control modes 6 and 7.
Input Channel For Feed Forward Signal ID 0x07030900	Identifier of the input signal channel to be used as feedforward signal If 0, the target signal is used as feedforward signal. The feedforward signal is used in control modes 1, 6, and 7 according to the applied gain values. See "Accessible Items and Their Identifiers" (p. 127) for more information on available input signal channels and their identifiers.

5.4.4 Notch Filters

The E-711/E-712 system provides two notch filters per axis. The corrections by a notch filter only take place in closed-loop operation by default but can also be enabled for open-loop operation. The appropriate frequency component is reduced in the control value to compensate for undesired resonances in the mechanics.

The transfer function of a notch filter is as follows:

$$G(s) = k^2 \times \frac{s^2 + 2 \times \omega \times r \times s + \omega^2}{s^2 + 2 \times \omega \times k \times s + \omega^2 \times k^2}$$

Where

G(s) is the transfer function of the notch filter

k is the bandwidth of the notch filter

s is the input signal

ω is the angular frequency, with $\omega = 2*\pi*f_0$, where f_0 is the notch filter frequency in Hz

r is the notch rejection

The notch filters can be configured per axis using the following parameters:

Parameter	**Notes**
Notch Frequency 1 ID 0x08000100 Notch Frequency 2 ID 0x08000101	Frequency f_0 of notch filter 1 and notch filter 2, in Hz. The maximum value is: $f_{0max} = 0.45*f_{sample}$ where f_{sample} is the control rate in Hz (1/control loop sampling time (parameter with ID 0x0e000200)) Adjusting the notch filter frequency can be useful, particularly in the case of very high loads. See "Adjusting the Notch Filters in Open-Loop Operation" (p. 266) for more information.
Notch Rejection 1 ID 0x08000200 Notch Rejection 2 ID 0x08000201	Notch rejection value r for notch filter 1 and notch filter 2. 0 to 0.98 Recommended value is 0.05. A notch rejection value of 1 deactivates the notch filter. The notch rejection value determines the filter width of the notch filter, i.e., it scales the damping done by the notch filter: The greater the rejection value, the wider the frequency spectrum of the damping, but the smaller the damping effect.

Parameter	Notes
Notch Bandwidth 1 ID 0x08000300	Bandwidth k of notch filter 1 and notch filter 2 ≥ 0.1 The notch filter bandwidth determines the effect of the low-pass filtering: The smaller the bandwidth, the smaller the low-pass filter frequency.
Notch Bandwidth 2 ID 0x08000301	
Creep Factor T1/sec ID 0x08000400	Currently not used; provided for future applications.
Creep Factor T2/sec ID 0x08000401	
Enable Notch in Open Loop ID 0x08000500	Enables usage of notch filters in open-loop operation. In closed-loop operation, the notch filters are always enabled. 0 = disable notch filter in open-loop operation (default) 1 = enable notch filter in open-loop operation
Notch Filter Calculation Method ID 0x08000600	0 = bilinear 1 = zero-order hold 2 = frb (rejection rate is independent of bandwith)

5.5 Signals of Reference and Limit Switches

The signals of reference and limit switches can be fed into the E-711/E-712 system and evaluated only when one of the modules E-711.C82, .AM5A, .AM5B, .SA3 and/or .SA6 is present, and with predefined configurations for PiezoWalk® drives (E-712.1AM, .1AN, .2AN and .3AN). The activation state of the evaluation can be checked with the LIM? command or via the value of the Lim, Ref Signals Detectable parameter (ID 0x02001900).

While the reference switch signals are only used for referencing moves of the axes (see "How to Reference an Axis" (p. 117)), the limit switch signals can also be used for the safety shutdown functionality (see "Safety Shutdown" (p. 256)).

The current state of reference and limit switch signals can be queried using the SRG? command. The signal polarity can be inverted using the Sensor Lim, Ref Signal Inversion parameter (ID 0x02001000).

There are no separate channels for reference and limit switch signals in the firmware of the E-711/E-712 system, but each of the signals belongs to a certain input signal channel (i.e., to a sensor). For that reason, all parameters and commands for evaluation of reference and limit switch signals refer to input signal channels.

Overview of the parameters which are relevant for the reference and limit switch signals:

<table>
<tr><th>Parameter</th><th>Notes</th></tr>
<tr><td>Sensor Reference Mode
ID 0x02000a00</td><td>Determines how the sensor is to be referenced:
1 = no referencing (absolute sensors; no referencing required; RON cannot be set to 0)
2 = referencing on negative hardstop
3 = referencing on positive hardstop
4 = referencing on reference edge
5 = referencing on reference pulse</td></tr>
<tr><td>Sensor Lim, Ref Signal Inversion
ID 0x02001000</td><td>Determines if the E-711/E-712 system inverts the reference switch and limit switch signals.
The value is specified in hexadecimal format and is based on a combination of 4 bits:
<table>
<tr><td>bit 3</td><td>bit 2</td><td>bit 1</td><td>bit 0</td></tr>
<tr><td>[neg_lim]</td><td>[pos_lim]</td><td>[ref_sign]</td><td>[ref_slope]</td></tr>
</table>
bit is set (1) = the signal is inverted
bit is not set (0) = the signal is not inverted
Examples:
0xC (default) = 0b1100 = negative and positive limit switch signals are inverted (active low) to ensure normal operation for stages that have no limit switches.
0x8 = 0b1000 = the negative limit signal is inverted (active low), all other signals are not inverted
0x3 = 0b0011 = hardware is referencing on falling edge, the reference switch signal will be inverted</td></tr>
<tr><td>Lim, Ref Signals Detectable
ID 0x02001900</td><td>Flag that indicates if signals of limit and reference switches are evaluated by the firmware (does not indicate if switches are present)
0 = no evaluation of switch signals
1 = switch signals are evaluated
The parameter is read-only.</td></tr>
</table>

6 Communication

6.1 Interfaces Available

The E-711/E-712 system can be controlled from a PC (not included) with ASCII commands sent via:

- TCP/IP
- RS-232
- USB

All interfaces can be active simultaneously. The commands from the interfaces are queued in the order the completed command lines are received.

INFORMATION

Before communication between the E-711/E-712 system and the PC can be established, the switch-on sequence of the controller must have finished successfully (takes approx. 40 s; the more modules, the longer the duration; when finished the *POWER* LED glows permanently). TCP/IP communication: If no DHCP server is available on the network or if a point-to-point connection between PC and controller is being used, it might take another period of about 30 seconds before communication is possible.

Up to 8 command streams can be connected to the E-711/E-712 system via TCP/IP (default: 1). The maximum number of connections can be configured via the Max. TCP/IP Connections parameter (ID 0x11000c00).

With TCP/IP and USB interfaces, communication cannot be maintained when the E-711/E-712 system is switched off or rebooted.

Using multiple interfaces simultaneously may cause problems with the PC software.

It is also possible to set up the E-711/E-712 system so that it can be commanded directly by an analog input signal. See "Using the Analog Input" (p. 190) for more information.

The E-711/E-712 system can also be commanded via SPI. Depending on the SPI data segment used, target values (with same write priority as analog control input) or ASCII commands (GCS) can be sent from an SPI master. See "Control via SPI Master" (p. 210) for more information.

With PIMikroMove, it is possible to connect to multiple controllers in one program instance. With PITerminal, you need a new program instance for each E-711/E-712 system you want to connect to.

6.2 Default and Current Settings

The default communication parameters are saved on the E-711/E-712 system. You can read the default settings using the IFS? command and change them with IFS. New default settings become active the next time the E-711/E-712 system is switched on or rebooted.

The currently active baud rate for RS-232 interface can be temporarily changed with IFC. The new setting becomes active immediately and the PC interface configuration may need to be changed to maintain communication. When the controller is switched off or rebooted, the baud rate setting made with IFC is lost if it was not saved with WPA.

To read all current active communication parameters use the IFC? command.

INFORMATION

The IFS, IFS?, IFC and IFC? commands affect the controller side only.

It is also possible to change the default settings with SEP and to read them with the SEP? command, but do **not** activate them with RPA and do **not** change the current settings with SPA—except the baud rate—because it will not be possible to maintain communication afterwards. The appropriate parameters are listed below.

The **factory default settings** of the communication parameters are as follows (response to IFS?):

- RSBAUD: specifies the baud rate to be used for RS-232 communication

  default is 115200
  also accessible as Uart Baudrate parameter (ID 0x11000400)

- IPADR: the first four portions specify the default IP address for TCP/IP communication, the last portion specifies the default port to be used

  default is 192.168.168.10:50000
  also accessible as IP Address parameter (ID 0x11000600)
  Note: While the IP address can be changed, the port must always be 50000!

- IPSTART: defines the startup behavior for configuration of the IP address for TCP/IP communication

  default is 1 = "use DHCP to obtain IP address, if this fails, use IPADR"
  also accessible as IP Configuration parameter (ID 0x11000800)

- IPMASK: specifies the IP mask to be used for TCP/IP communication

  default is 255.255.255.0
  also accessible as IP Mask parameter (ID 0x11000700)

- MACADR: is the unique address of the network hardware in the E-711/E-712 system, read-only, example:

  0-d0-c9-a7-1f-86
  also accessible as MAC Address parameter (ID 0x11000B00)

- IPMAXCONN: specifies the maximum number of allowed connections for TCP/IP communication

  default is 1 (maximum is 8)
  also accessible as Max. TCP/IP Connections parameter (ID 0x11000C00)

INFORMATION

When communication is established via TCP/IP and the IP address is obtained from a DHCP server, this address will automatically be written to the IP Address parameter (ID 0x11000600) in the E-711/E-712 systems volatile memory. Provided that the current command level is 1 (see the CCL command) and you send WPA 100, the new address setting will be saved to nonvolatile memory as the new default value (together with all other current valid parameter values with level-1 write access).

6.3 TCP/IP Interface

The TCP/IP interface is available on the front panel of the controller (E-712.M1 or E-712.N1 digital processor module) via the RJ 45 socket with the network icon. The access differs depending on the network availability, which can be as follows:

- Network with DHCP server

- PC equipped with an Ethernet interface or network without DHCP server

See "Default and Current Settings" (p. 155) for the default IP address, IP mask and startup behaviour settings of the TCP/IP interface.

!

NOTICE

If the communication between PC and E-711/E-712 system is done via TCP/IP, do not use RPA after you have changed the parameters of the TCP/IP communication with IFS or SEP in nonvolatile memory, because it will not be possible to maintain communication afterwards.

With TCP/IP and USB interfaces, communication cannot be maintained after the E-711/E-712 system is switched off or rebooted.

INFORMATION

Make sure that your network administrator has not set the network to forbid unknown devices like the E-711/E-712 system from logging on.

The maximum number of TCP/IP connections can be configured via the Max. TCP/IP Connections parameter (ID 0x11000c00; default value: 1; maximum value: 8).

The default port setting (50000) cannot be changed.

6.3.1 Network with DHCP Server

INFORMATION

The correct startup behaviour for the IP address configuration must be selected. The default selection is "Use DHCP to obtain IP address", so that nothing must be changed.

If you want to check the startup behaviour setting, establish communication via USB or RS-232 interface, and query with the IFS? command. In the response, IPSTART must be 1. If the IPSTART value differs from 1, send IFS 100 IPSTART 1

If a network with DHCP server is available, connect the controller to a network access point and switch it off and on again (newer switches accept both cross-over and straight-through network cables). Factory default setting: The controller will automatically obtain an IP address over DHCP. If this should not be successful within 30 seconds, the default IP address of the controller will automatically be used (see "Default and Current Settings" (p. 155)).

In the PC software (e.g., PIMikroMove, PITerminal or drivers for use with NI LabView software), all available E-711/E-712 systems with their IP address and available connections are listed. In PIMikroMove you have, for example, to select the controller type (1). Then select the *TCP/IP* tab (2). On the interface tab, select the E-711/E-712 system to which you want to connect (3). To establish communication, select *Connect* (4).

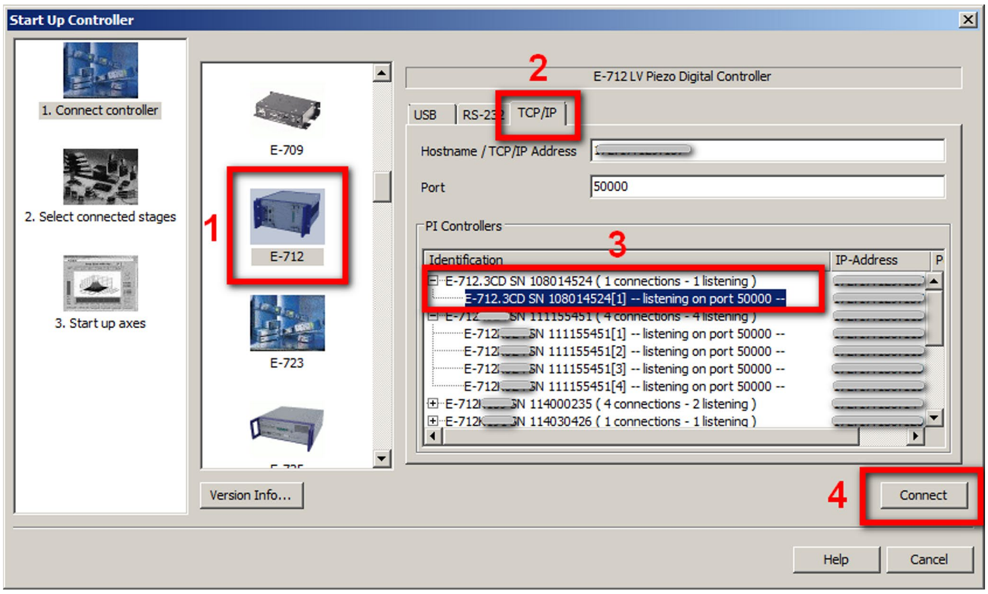


Figure 53: TCP/IP *tab in PIMikroMove*

INFORMATION

In the controller selection list, you can identify the controllers which are currently connected via TCP/IP.

6.3.2 PC with Ethernet Interface or Network without DHCP Server

The IP address and IP mask settings of PC and controller must be compatible with each other in the following cases:

- The E-711/E-712 system is directly connected to an Ethernet interface of the PC.
- E-711/E-712 system and the PC both are connected to the same network where no DHCP server is available (in this case, the settings must also be compatible with those of any other devices in the same network).

Otherwise, communication cannot be established. You can configure either the PC or the controller settings to be compatible. If you have a network with multiple E-711/E-712 systems, the settings of the individual controllers must be changed to have unique IP addresses for all devices in the network. See below for how to proceed.

INFORMATION

Switching on or rebooting the E-711/E-712 system may take about 40 seconds. You might have to wait for another period of about 30 seconds before communication is possible.

If you want to change the PC settings:

Configure the PC according to the IP address and IP mask settings of the controller (see "Default and Current Settings" (p. 155) for the default controller settings). Note that the following steps may vary in some details depending on the version of your Windows operating system:

1. On your PC, open the window in which the properties of the TCP/IP Internet protocol are displayed and set, in a suitable way. The necessary steps depend on the operating system used.

   If your operating system distinguishes between Internet protocol version 4 (TCP/IPv4) and version 6 (TCP/IPv6), open the window for version 4.

2. In the *Internet Protocol (TCP/IP) Properties* window, activate *Use the following IP address.* Make a note of the current *IP address* and *Subnet mask* settings, if any, in case they need to be restored later. Then adapt the *IP address* and *Subnet mask* settings to make them compatible with the settings of your E-711/E-712 system:

   Set the first three portions of *IP address* identical to those of the IP address of the E-711/E-712 system, while the last portion must be different. One possible *IP address* setting would be, for example, 192.168.168.2 (the default IP address of the E-711/E-712 system is 192.168.168.10). Do not use "255" for the last portion.

   Set *Subnet mask* to 255.255.255.0 (if the IP mask of the E-711/E-712 system is 255.255.255.0).

   Confirm with *OK*. An example is shown in the figure below.

3 Connect the E-711/E-712 system to the Ethernet socket of the PC using the included, special, cross-over cable ("point-to-point" connection). If you connect the E-711/E-712 system to a free access point (e.g., to a hub) on a network to which the PC is connected, it might be necessary to use a straight-through network cable.

4 Switch on the E-711/E-712 system.

5 Establish communication between PC and the E-711/E-712 system as described in "Network with DHCP Server" (p. 157).

INFORMATION

If communication cannot be established, change the last portion of the *IP address* setting on the PC and try again to connect.

Adapt *IP address* and *Subnet mask*; do not change the *Default gateway* setting

Press *OK*

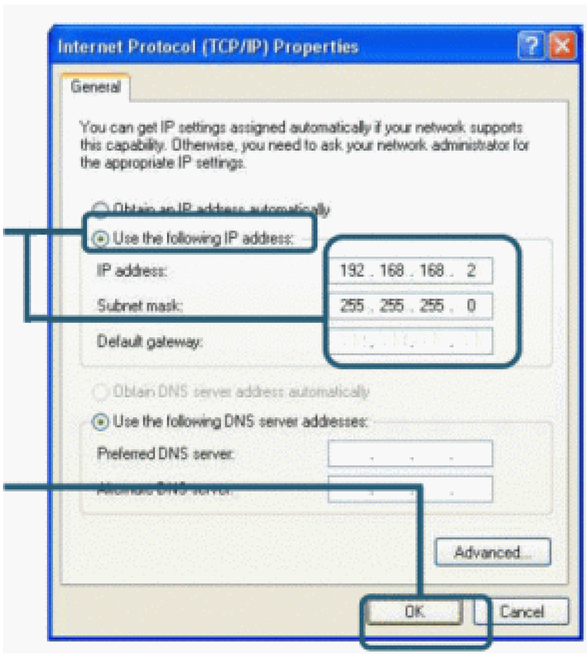


Figure 54: Internet Protocol (TCP/IP) Properties *window. The settings shown are only examples, maybe they do not match that of your controller.*

If you want to change the controller settings:

1 Establish communication between PC and E-711/E-712 system as described in "RS-232 Interface" (p. 161).

2 Use the IFS command to adapt the IP address and IP mask settings of the E-711/E-712 system to those of the PC (to check the PC settings, you can open the *Internet Protocol (TCP/IP) Properties* window as described above):

   To change the IP mask (subnet mask), send:
   IFS 100 IPMASK *mask*
   mask must be identical to the Subnet mask setting of the PC.

   To change the IP address, send:
   IFS 100 IPADR *address*

   At least the last portion of the IP address must be different from that of the PC and any other device in the same network (the applicable address settings depend on the IP mask setting). If, for example, the PC has the IP address 172.21.0.1, send:
   IFS 100 IPADR 172.21.0.2:50000
   Do not use "255", and do not change the port setting (must always be 50000).

3 Close the connection.

4 Connect the E-711/E-712 system to the Ethernet socket of the PC using the included, special, cross-over cable ("point-to-point" connection). If you connect the E-711/E-712 system to a free access point (e.g., to a hub) on a network to which the PC is connected, it might be necessary to use a straight-through network cable.

5 Switch the E-711/E-712 system off and on again.

6 Establish communication between PC and the E-711/E-712 system as described in "Network with DHCP Server" (p. 157).

6.4 RS-232 Interface

The RS-232 interface is accessed via the D-sub 9 (m) *RS-232* connector (p. 336) on the front panel of the controller (E-712.M1 or E-712.N1 digital processor and interface module). Use the included null-modem cable to connect the controller to the PC; if the PC has only one COM port, it is probably COM 1.

The serial port on the E-711/E-712 system is preset as follows:

115,200 baud, 8 bits, no parity, RTS/CTS.

In the connection dialog of the PC software (e.g., PIMikroMove, PITerminal or drivers for use with NI LabView software), you make the settings on the PC side. In PIMikroMove you have, for example, to select the controller type (1). Then select the *RS-232* tab (2). On the interface tab, select the correct COM port and baud rate of the PC (3). To establish communication, select *Connect* (4).

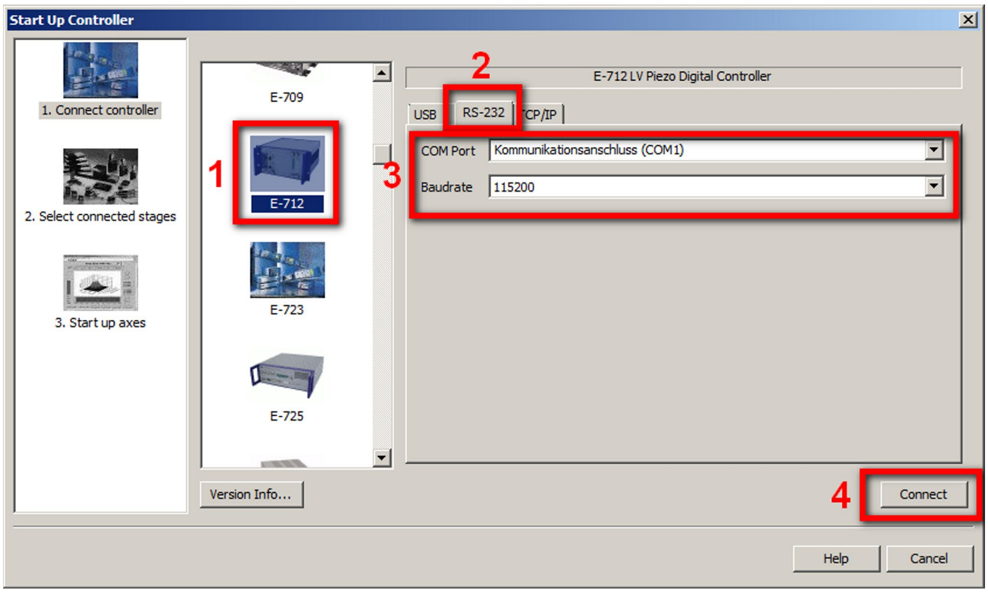


Figure 55: RS-232 *tab in PIMikroMove*

If you have established communication and want to change the currently active baud rate, proceed as follows:

1 In the command entry facility of the program, use the IFC command, e.g., by sending IFC RSBAUD 57600.

2 Close the connection.

3 Establish communication again with the baud rate you just set with IFC (in the example 57600).

6.5 USB Interface

The USB interface is available on the front panel of the controller (E-712.M1 or E-712.N1 digital processor and interface module) via the USB Type-B socket. Use the included USB Type-A/Type-B cable to connect the controller to the PC.

In the PC software (e.g., PIMikroMove, PITerminal or drivers for use with NI LabView software) all E-711/E-712 system which are connected to the USB sockets of the PC are listed. In PIMikroMove you have, for example, to select the controller type (1). Then select the *USB* tab (2). On the interface tab, select the E-711/E-712 system to which you want to connect (3). To establish communication, select *Connect* (4).

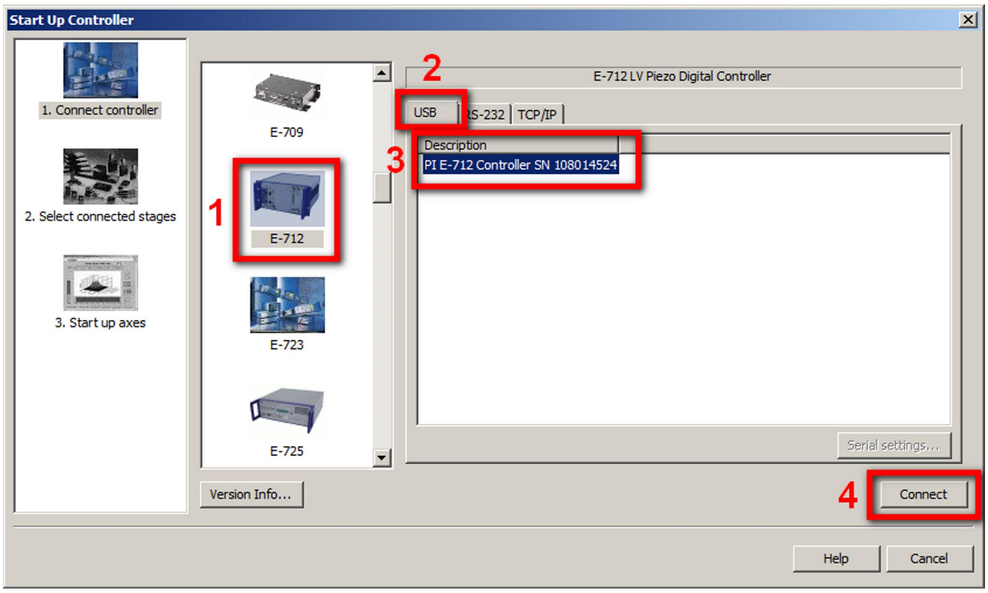


Figure 56: USB *tab in PIMikroMove*

INFORMATION

With TCP/IP and USB interfaces, communication cannot be maintained after the E-711/E-712 system is switched off or rebooted.

PI

7 Data Recording

7.1 How to Use the Data Recorder

The E-711/E-712 system includes a real-time data recorder. It can record several input and output signals (e.g., current position, sensor input, output voltage) from different data sources (e.g., controller axes or input and output channels). The gathered data is saved (temporarily) in "data recorder tables"—each table contains the signal from one data source. You can configure the data recorder flexibly, e.g., select the type of data and the data source. Furthermore, you can choose the number of data recorder tables and hence influence their size.

For general information regarding the data recording, you can send HDR?, which lists available options, and gives information about additional parameters and commands concerned with data recording.

How to Define What to Record—Set Record Options

The data recorder configuration, i.e., the assignment of data sources and record options to the data recorder tables, can be read with the DRC? command. The response contains the values of the parameters DRC Data Source (ID 0x16000700) and DRC Record Option (ID 0x16000701). Use the DRC command or change the parameter values directly in volatile memory. The default setting is that the current positions of the axes are recorded.

How to Start Data Recording—Set Trigger Options

Data recording can be triggered in several ways. Query the current trigger option with DRT? and use DRT to change it. Irrespective of the DRT settings, data recording is always triggered by the following four commands:

- STE (step response measurement),
- IMP (impulse response measurement),
- WGO (wave generator start)
- WGR (restarts data recording when the wave generator is running).

Data recording always takes place for all data recorder tables and ends when the data recorder tables are filled.

If digital input lines are used to trigger data recording (configuration with DRT): For reliable triggering, the pulse width of the digital input signal must be at least 2 x the control loop sampling time of the E-711/E-712 system. The control loop sampling time is specified in seconds by the parameter with ID 0x0E000200.

How to Read Recorded Data

The last recorded data can be read with the DRR? command. The data is returned in GCS data format. See the SM146E manual for more information on the GCS data format.

Reading recorded data can take some time, depending on the number of points to be read! It is possible to read the data while data recording is still in progress.

The number of points comprised by the last data recording can be read with the DRL? command. This can be useful, for example, if you restart data recording with WGR and want to read data while recording is still in progress.

How to Configure Number of Tables and Sampling Rate

The number of available data recorder tables can be read with the TNR? command. The response contains the value of the Data Recorder Chan Number parameter (ID 0x16000300). You can change the parameter value to increase or decrease the number of data recorder tables. For the E-711/E-712 system, the number of tables must be in the range of 1 to 12.

The total number of points available for data recording is specified by the Data Recorder Max Points parameter (ID 0x16000200). The controller allocates these points in equal shares to the available tables (i.e., to the number of tables specified in the TNR? response). For the E-711/E-712 system, the total number of points is 2^{23}. If, for example, TNR? replies 8, each table is comprised of 1,048,576 points.

The data recorder sampling rate can be read with the RTR? command. The response contains the value of the Data Recorder Table Rate parameter (ID 0x16000000) whose default value is one control loop cycle. You can cover longer periods by increasing this value. Use the RTR command or change the parameter value directly in volatile memory.

How to Save Settings to Nonvolatile Memory

Wherever changing parameter values is mentioned, you can do this using SPA (volatile memory) or SEP (nonvolatile memory). Furthermore, you can use WPA to copy the current values from volatile memory to nonvolatile memory. To have write access to certain parameters, it might be necessary to switch to a higher command level using CCL. To read parameter values, query with the SPA? or SEP? commands.

When the controller is switched off or rebooted, the content of the data recorder tables and all settings which were only made in volatile memory are lost. When switching on or rebooting, all settings are reset to their defaults.

7.2 Data-Recorder Related Commands and Parameters

Command	Description	Notes
DRC	Set Data Recorder Configuration	Assigns data sources and record options to data recorder tables in volatile memory (parameters DRC Data Source (ID 0x16000700) and DRC Record Option (ID 0x16000701))
DRC?	Get Data Recorder Configuration	Reads current data recorder settings
DRR?	Get Recorded Data Values	Reading can take some time, depending on the number of points.
DRT	Set Data Recorder Trigger Source	Determines how data recording is to be triggered. Settings will be lost when switching off or rebooting the E-711/E-712 system.
DRT?	Get Data Recorder Trigger Source	Reads current trigger option
HDR?	Get All Data Recorder Options	Lists available record options, gives information about additional parameters and commands concerned with data recording
IMP	Start Impulse and Response Measurement	Triggers data recording
RTR	Set Record Table Rate	Changes the record table rate in volatile memory (Data Recorder Table Rate parameter (ID 0x16000000))
RTR?	Get Record Table Rate	Reads the current setting of the record table rate (Data Recorder Table Rate parameter (ID 0x16000000))

Command	Description	Notes
STE	Start Step and Response Measurement	Triggers data recording
TNR?	Get Number of Record Tables	Reads the number of available data recorder tables (Data Recorder Chan Number parameter (ID 0x16000300))
WGO	Set Wave Generator Start/Stop Mode	Triggers data recording
WGR	Start Recording Synchronous to Wave Generator	Triggers data recording

See "How to Use the Data Recorder" (p. 164) for more information. For detailed command descriptions see the PZ233 GCS commands manual. See "Accessible Items and Their Identifiers" (p. 127) for the identifiers of the items which can be addressed with the commands.

Parameter ID	Com-mand Level	Item Type	Max. No. of Items	Data Type	Parameter Description
0x16000000	1	System	1	INT	Data Recorder Table Rate
0x16000100	3	System	1	INT	Max Number of Data Recorder Channels
0x16000200	3	System	1	INT	Data Recorder Max Points
0x16000300	1	System	1	INT	Data Recorder Chan Number; the available data recorder points are allocated in equal shares to the number of tables specified by this parameter
0x16000700	1	Data recorder table	12	INT	DRC Data Source
0x16000701	1	Data recorder table	12	INT	DRC Record Option

See "Parameters" (p. 276) for more information regarding the parameters and their handling.

8 External Triggering / Signaling

The digital input and output lines of the E-711/E-712 system are available on the "Digital I/O Connector" (see p. 335 for the lines and pinout).

8.1 Using Digital Input

The values of the digital input lines *IN1* to *IN8* can be recorded, see the DRC command for details.

The input lines *IN1* to *IN8* can be used to start data recording, see the DRT command and "Data Recording" (p. 164) for more information.

The input lines *IN1* and *IN2* can be used in conjunction with the WGO command to trigger the wave generator output (*IN1* and *IN2*) and to stop it (*IN2*). See "Wave Generator Started by Trigger Input" (p. 230) for an example.

The input lines *IN1* to *IN8* can be used for safety shutdown of the E-711/E-712 system. Configure the lines via parameters. It is not recommended to define lines which are used to start the data recorder or to start/stop the wave generators. See "Safety Shutdown" (p. 256) for more information.

8.2 Configuring Trigger Output

8.2.1 Overview of Trigger Options, Commands and Parameters

The values of the digital output lines *OUT1* to *OUT7* can be recorded, see the DRC command for more information.

You can program the digital output lines *OUT1* to *OUT7* of the E-711/E-712 system to trigger other devices using the CTO command. The *ServoTrigger* output line carries the control loop cycle and is not accessible by command.

The general format of the CTO command is as follows, i.e., all trigger-related settings for a digital output line can normally be made with one command line (the number of arguments following a command mnemonic is limited to 32):

CTO {<TrigOutID> <CTOPam> <Value>}

The following trigger modes are supported by the E-711/E-712 system:

- 0 = *Position Distance*; a trigger pulse is written whenever the axis has covered a specified distance. Optionally, values for *StartThreshold* and *StopThreshold* can be defined to enable the trigger output for a limited position range and a certain direction of motion only (negative or positive). When *StartThreshold* and *StopThreshold* are set to the same value, they will not be used. Further options which cannot be configured with CTO but only via parameters: The length of the trigger pulses can be set to a constant value, and filters can be applied to the axis position to reduce false triggers caused by position noise. See "Example—"Position Distance" Trigger Mode" (p. 171).

- 2 = *OnTarget*; the on-target state of the selected axis is written to the selected digital output line (this state can also be read with the ONT? command). See "Example—"OnTarget" Trigger Mode" (p. 183).

- 3 = *MinMaxThreshold*; values for *MinThreshold* and *MaxThreshold* must be defined. When the axis position of the selected axis is inside the band specified by the *MinThreshold* and *MaxThreshold* values, the selected digital output line is set *high*, otherwise it is set *low*. See "Example—"MinMaxThreshold" Trigger Mode" (p. 184).

- 4 = *Generator Level Trigger*; the trigger action must be defined with TWS. The trigger output will be synchronized with the wave generator output. The length of a single trigger pulse corresponds to the control loop sampling time. If the state of the digital output line is set to *high* with TWS for consecutive points of a wave table, the state therefore does not change back to *low* between the points. See "Example—"Generator Level Trigger" Mode" (p. 185) and "Trigger Output Synchronized with Wave Generator" (p. 228).

- 9 = *Generator Pulse Trigger*; the trigger action must be defined with TWS. The trigger output will be synchronized with the wave generator output. The length of a single trigger pulse is shorter than the control loop sampling time. If the state of the digital output line is set to *high* with TWS for consecutive points of a wave table, the state therefore changes back to *low* after each point. See "Example—"Generator Pulse Trigger" Mode" (p. 187).

- 14 = *TriggerOutAND*; the digital output line *TrigOutID* outputs the state of the digital output lines selected with *TriggerOutMask* (<CTOPam> ID 16). The states of the selected digital output lines are combined via AND bit operation. See "Examples—"TriggerOutAND" and "TriggerOutOR" Modes" (p. 188).

- 15 = *TriggerOutOR*; the digital output line *TrigOutID* outputs the state of the digital output lines selected with *TriggerOutMask* (<CTOPam> ID 16). The states of the selected digital output lines are combined via OR bit operation. See "Examples—"TriggerOutAND" and "TriggerOutOR" Modes" (p. 188).

To select the mode, set <CTOPam> = 3 and <Value> to the code of the mode; default selection is *OnTarget* (2).

Furthermore, it is possible to select the signal polarity for the digital output line (active *high* / active *low*). See "Example—Polarity Setting" (p. 188).

CTO changes the values of the parameters listed below in volatile memory. The current values in volatile memory can be read with the CTO? command. You can also change these parameters using SPA (volatile memory) or SEP (nonvolatile memory). Furthermore, you can use WPA to copy the current values from volatile memory to nonvolatile memory. When using SPA, SEP or WPA, it is necessary to switch to command level 1 with CCL to have write access to the parameters. To read the parameter values, you can also query with the SPA? or SEP? commands.

Parameter ID	**Com-mand Level**	**Item Type**	**Max. No. of Items**	**Data Type**	**Parameter Description**
0x18000201	1	Digital Output Line	7	FLOAT	CTO Trigger Step (<CTOPam> = 1)
0x18000202	1	Digital Output Line	7	INT	CTO Axis (<CTOPam> = 2)
0x18000203	1	Digital Output Line	7	INT	CTO Trigger Mode (<CTOPam> = 3)
0x18000205	1	Digital Output Line	7	FLOAT	CTO Min.Threshold (<CTOPam> = 5)
0x18000206	1	Digital Output Line	7	FLOAT	CTO Max.Threshold (<CTOPam> = 6)
0x18000207	1	Digital Output Line	7	INT	CTO Polarity (<CTOPam> = 7)
0x18000208	1	Digital Output Line	7	FLOAT	CTO Start Threshold (<CTOPam> = 8)
0x18000209	1	Digital Output Line	7	FLOAT	CTO Stop Threshold (<CTOPam> = 9)

Parameter ID	Com-mand Level	Item Type	Max. No. of Items	Data Type	Parameter Description
0x18000210	1	Digital Output Line	7	INT	CTO Trigger Out Mask (<CTOPam> = 16)

The following examples can be reproduced using the command entry facilities of PIMikroMove or PI Terminal.

8.2.2 Example—"Position Distance" Trigger Mode

The *Position Distance* trigger mode is designed for scanning applications. A trigger pulse is written whenever the axis has covered the *TriggerStep* distance. The unit of *TriggerStep* is the physical unit of the axes (query with the PUN? command).

In addition to the basic configuration, the *Position Distance* trigger mode provides several options:

- Definition of pulse length, p. 172: variable (depending on velocity) or constant
- Definition of thresholds for trigger limitation to a certain position range and direction of motion, p. 175
- Filter definition for reduction of false triggers, p. 178

Basic trigger configuration

The following parameters must be set for the digital output line which is to be used for trigger output (*TrigOutID*):

- *Axis* (<CTOPam> = 2)
- *TriggerMode* (<CTOPam> = 3)
- *TriggerStep* (<CTOPam> = 1)

General notation of the CTO command for this mode (in fact, the command arguments can be divided in three "portions", each starting with the *TrigOutID* declaration):

Command mnemonic	Axis selection	Trigger mode selection	Step size setting
CTO	<TrigOutID> 2 *Axis*	<TrigOutID> 3 0	<TrigOutID> 1 *Stepsize*

Instead of using the CTO command, you can also set the values of the corresponding parameters with SPA or SEP. See "Configuring Trigger Output" (p. 168) for a parameter list.

INFORMATION

Possible values for *TriggerStep* depend on the axis velocity.

→With high velocities, the minimum *TriggerStep* value is limited as follows:
TriggerStep > 4 * velocity * control loop sampling time

The control loop sampling time is specified in seconds by the parameter with ID 0x0E000200.
In the following examples, the control loop sampling time of the E-711/E-712 system is 20 µs:
With a velocity of 1000 µm/s, the minimum *TriggerStep* value is 80 nm.
With a *TriggerStep* value of 100 nm, the maximum velocity is 1250 µm/s.

→With very small velocities, the minimum *TriggerStep* value is limited by the noise of the position sensor. For reliable triggering, the *TriggerStep* setting must be at least 5 times larger than the peak-to-peak level of the sensor noise. The sensor noise level can be reduced by digital filtering of the signal (p. 134). To detect the noise, you can record, for example, the position error of the axis using the data recorder.

Example 1: A pulse on the digital output line 1 is to be generated whenever axis 1 of the stage has covered 0.1 µm. Send:

CTO 1 2 1 1 3 0 1 1 0.1

Pulse length definition

The value of the Pos. Distance Trig. High Time Definition parameter (ID 0x18000400) determines how the trigger pulse length is set (i.e., the time the digital output line is set to *high*):

- Parameter value = 0 (default setting): The trigger pulse length varies depending on the distance set with *TriggerStep* and on the current velocity of the axis. The digital output line changes its state every time the axis has covered half the *TriggerStep* distance.
- Parameter value = 1: The trigger pulse length is constant. The trigger *high* time is adjustable using the Position Distance Trigger High Time parameter (ID 0x18000401)

Switch to command level 1 with CCL to have write access to the parameters. To set the parameters, use SPA or SEP. Furthermore, you can use WPA to copy the current values from volatile memory to nonvolatile memory. To read the parameter values, you can query with the SPA? or SEP? commands.

Variable pulse length depending on *TriggerStep* setting and current axis velocity:

The Pos. Distance Trig. High Time Definition parameter has the value 0.

Example: If *TriggerStep* is 100 nm, a rising edge of the digital output line (*low* -> *high*) will be followed by a falling edge (*high* -> *low*) when the axis has covered 50 nm. The next rising edge follows when the axis has covered another distance of 50 nm, and so on.

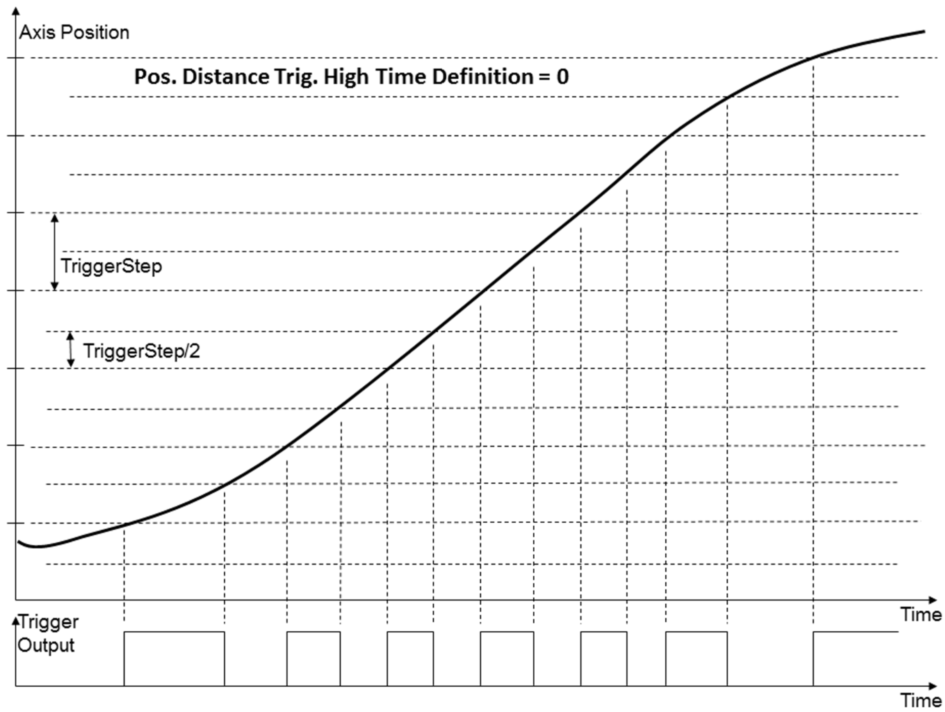


Figure 57: Position Distance *trigger mode, trigger pulse length depends on the axis velocity*

Constant pulse length:

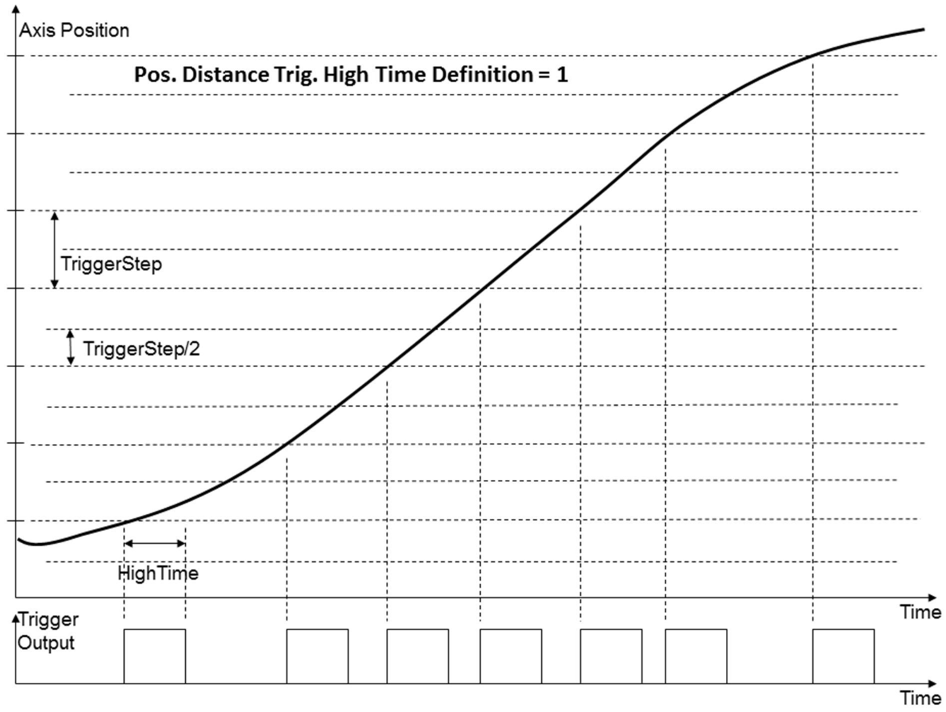


Figure 58: Position Distance *trigger mode, constant trigger pulse length*

The Pos. Distance Trig. High Time Definition parameter has the value 1.

The trigger pulse length is constant. The trigger *high* time is adjustable using the Position Distance Trigger High Time parameter (ID 0x18000401). The parameter value is specified in seconds. If the parameter value is set to 0 (default setting), the length of a trigger pulse is one control loop cycle.

Possible values for the Position Distance Trigger High Time parameter (ID 0x18000401) depend on the axis velocity and the *TriggerStep* value. Pulses can get lost if the pulse length and/or *TriggerStep* values are not suitable for the current axis velocity, see the figure below for an example.

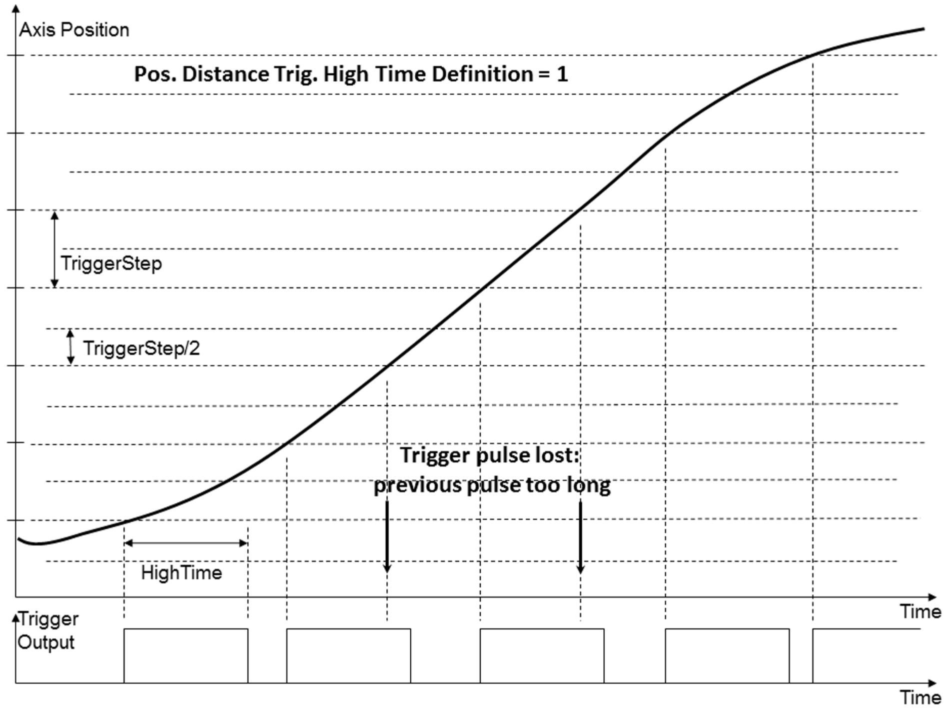


Figure 59: Position Distance *trigger mode, constant trigger pulse length; pulse length and/or step size not suitable for the axis velocity*

Configuration of threshold values

Optionally, start and stop values can be set with CTO (*StartThreshold* and *StopThreshold*) to enable the trigger output for a limited position range and a certain direction of motion only (positive or negative). Should the direction of motion be reversed when the axis position is still between the start and stop values, the trigger output depends on the value of the Pos. Distance Trig. Single Direction parameter (ID 0x18000300). Default: Trigger pulses will continue to be generated. See "Filtering for reduction of false triggers" (p. 178) for more information.

When *StartThreshold* and *StopThreshold* are set to the same value, they will not be used.

The following parameters must then be set for the digital output line which is to be used for trigger output (*TrigOutID*):

- *Axis* (<CTOPam> = 2)
- *TriggerMode* (<CTOPam> = 3)
- *TriggerStep* (<CTOPam> = 1)

- *StartThreshold* (<CTOPam> = 8)
- *StopThreshold* (<CTOPam> = 9)

General notation of the CTO command for this option (in fact, the command arguments can be divided in five "portions", each starting with the *TrigOutID* declaration):

Command mnemonic	Axis selection	Trigger mode selection	Step size setting	Start threshold setting	Stop threshold setting
CTO	<TrigOutID> 2 Axis	<TrigOutID> 3 0	<TrigOutID> 1 *Stepsize*	<TrigOutID> 8 *Startpos*.	<TrigOutID> 9 *Stoppos*.

Instead of using the CTO command, you can also set the values of the corresponding parameters with SPA or SEP. See "Configuring Trigger Output" (p. 168) for a parameter list.

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For reliable activation of the trigger output, the axis must move through the "Trigger ready, not active" position range, or the motion must start in this range (see Figure 60 and Figure 61).

For reliable deactivation of the trigger output, the axis must move through the "Trigger stopped" position range, or the motion must end in this range (see Figure 60 and Figure 61). Of course, the trigger output is also deactivated when the axis leaves the trigger range via the *StartThreshold*.

The distance between the start position of the axis and the *StartThreshold* setting must be at least 3 times larger than the noise of the axis position (peak-to-peak value), as well as the distance between the end position of the axis and the *StopThreshold* setting. In addition, the distance between the start position of the axis and the *StartThreshold* must be at least *TriggerStep*/4.

See the examples 2 and 3 below for more information.

Example 2: A pulse on the digital output line 1 is to be generated whenever axis 1 of the stage has covered 0.1 µm, if axis 1 moves in positive direction in the range of 0.2 µm to 0.55 µm (start threshold < stop threshold). For reliable activation and deactivation of the trigger output, the axis motion should start at 0.15 µm and end at 0.6 µm. Send:

CTO 1 2 1 1 3 0 1 1 0.1 1 8 0.2 1 9 0.55

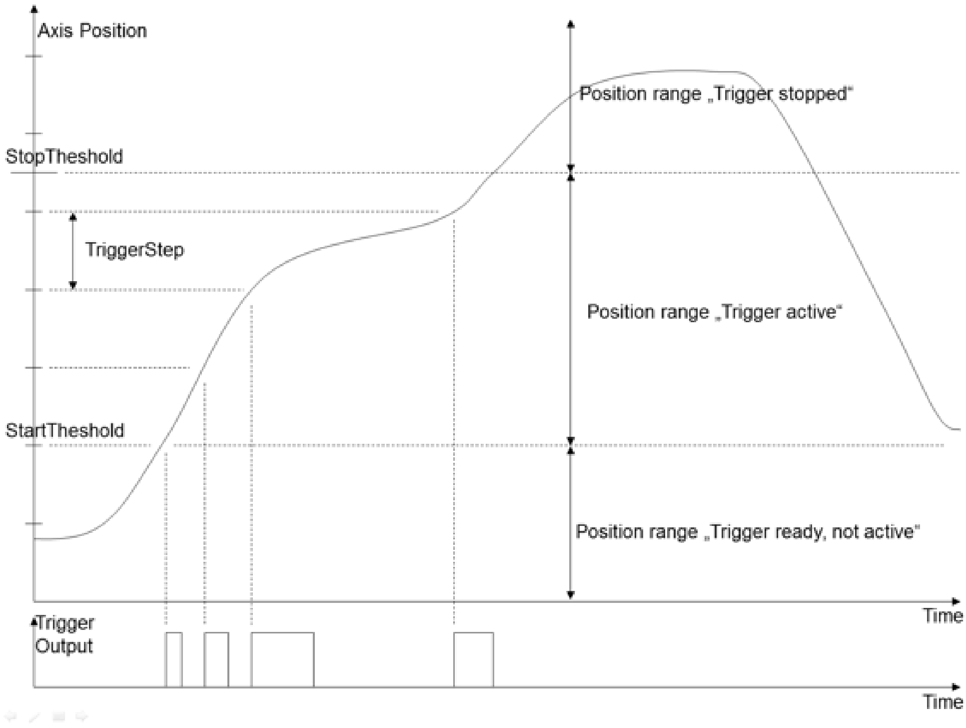

Figure 60: Position Distance *trigger mode with threshold settings for positive direction of motion; variable pulse length (the Pos. Distance Trig. High Time Definition parameter has the value 0)*

Example 3: A pulse on the digital output line 1 is to be generated whenever axis 1 of the stage has covered 0.1 µm, if axis 1 moves in negative direction in the range of 0.55 µm to 0.2 µm (start threshold > stop threshold). For reliable activation and deactivation of the trigger output, the axis motion should start at 0.6 µm and end at 0.15 µm. Send:

CTO 1 2 1 1 3 0 1 1 0.1 1 8 0.55 1 9 0.2

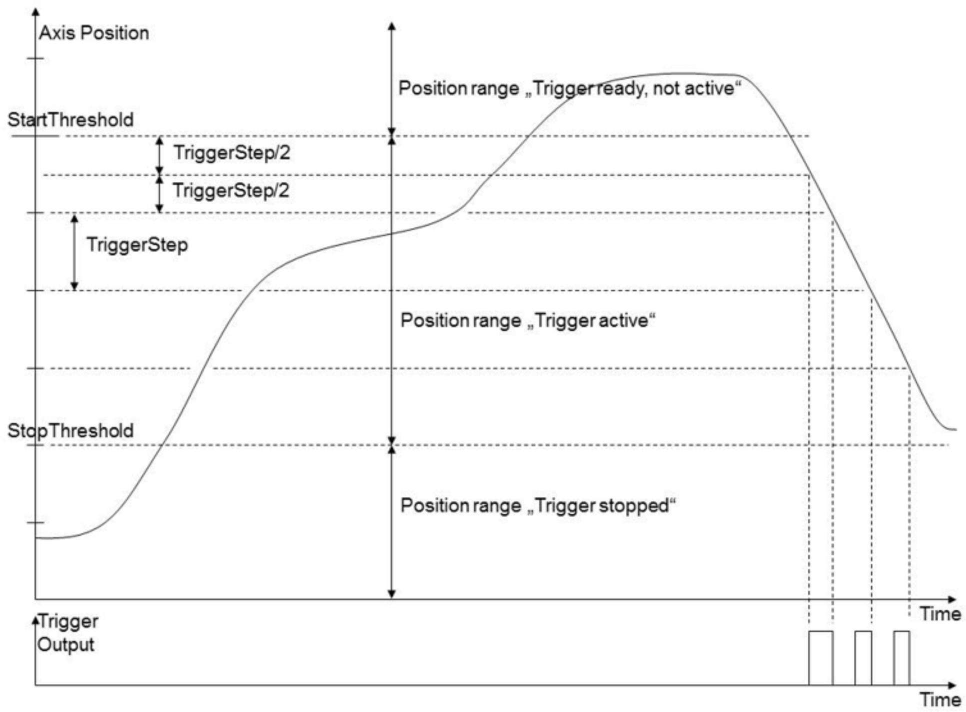

Figure 61: Position Distance *trigger mode with threshold settings for negative direction of motion; here, the trigger output is not yet disabled reliably at the end of the curve*

Filtering for reduction of false triggers

If the peak-to-peak level of the sensor position noise is greater than one fifth of the *TriggerStep* value set, this can lead to unwanted generation of multiple trigger pulses at the same position in *Position Distance* trigger mode. The occurrence of these false triggers can be reduced with the following parameters:

- Only allow the trigger output in one direction within the start/stop threshold values: Pos. Distance Trig. Single Direction parameter (ID 0x18000300)

- To prevent false triggering within the start threshold range also:
  Pos. Distance Trig. Filter Time parameter (ID 0x18000301)
  or
  Pos. Distance Trig. Filter Level parameter (ID 0x18000302)

However, the position precision cannot be retrieved by using the parameters to reduce the trigger impact of the sensor position noise.

Switch to command level 1 with CCL to have write access to the parameters. To set the parameters, use SPA or SEP. Furthermore, you can use WPA to copy the current values from volatile memory to nonvolatile memory. To read the parameter values, you can query with the SPA? or SEP? commands.

Direction of motion for trigger output:

If the start and stop thresholds are active in *Position Distance* trigger mode (start threshold ≠ stop threshold), the value of the Pos. Distance Trig. Single Direction parameter (ID 0x18000300) determines the direction of motion for trigger output:

- 0 (default setting) = Trigger is generated whenever the position is within the range defined by the start/stop thresholds. Trigger output is independent of the current direction of motion, i.e., continues when the motion direction is reversed before the axis position has reached the stop threshold (Figure 62).

- 1 = Trigger is generated only when the position is within the range defined by the start/stop thresholds **and** when the axis moves in the direction determined by the start/stop thresholds (Figure 63)

If start and stop thresholds are not active (start threshold = stop threshold), the Pos. Distance Trig. Single Direction parameter has no effect.

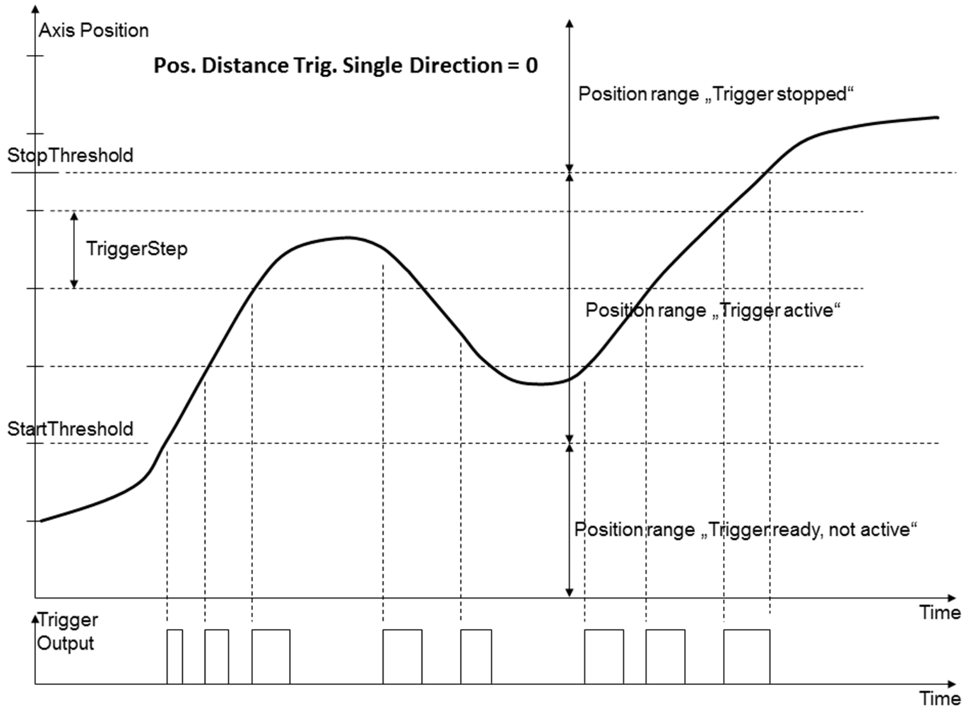

Figure 62: Position Distance *trigger mode with threshold settings, trigger output continues when the motion direction is reversed*

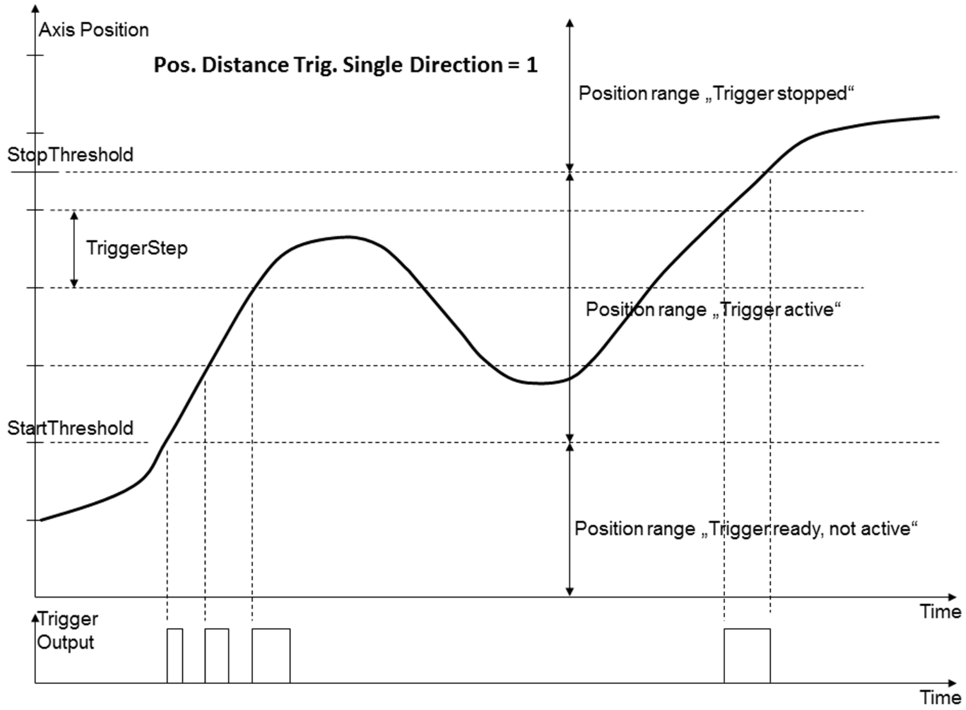

Figure 63: Position Distance *trigger mode with threshold settings, trigger output only for positive direction of motion*

Filter settings for start threshold range:

If the *Position Distance* trigger mode is selected and the start and stop thresholds are active (start threshold ≠ stop threshold), a filter can reduce the influence of noise around the start threshold. In combination with the Pos. Distance Trig. Single Direction parameter (ID 0x18000300) the filter setting can be used to avoid multiple triggers at the same position in cases where the noise is too high. Filter options:

- The Pos. Distance Trig. Filter Time parameter (ID 0x18000301) specifies a time filter. The time filter is used to delay the trigger deactivation when the axis position falls below the start threshold due to noise (Figure 65). The time value is specified in seconds. Recommended minimum value: period of the noise signal. Default value: 0 (= filter deactivated)

- The Pos. Distance Trig. Filter Level parameter (ID 0x18000302) specifies a position level filter. The position level filter is used to delay the trigger deactivation when the axis position falls below the start threshold due to noise (Figure 66). The filter level value is specified in axis units. Recommended minimum value: amplitude of the noise signal. Default value: 0 (= filter deactivated)

Note: Although the activation of multiple triggers at the same position can be avoided by the filter setting, the precision of the position trigger is lost if the trigger step value is not at least 5 times higher than the peak-to-peak level of the sensor position noise.

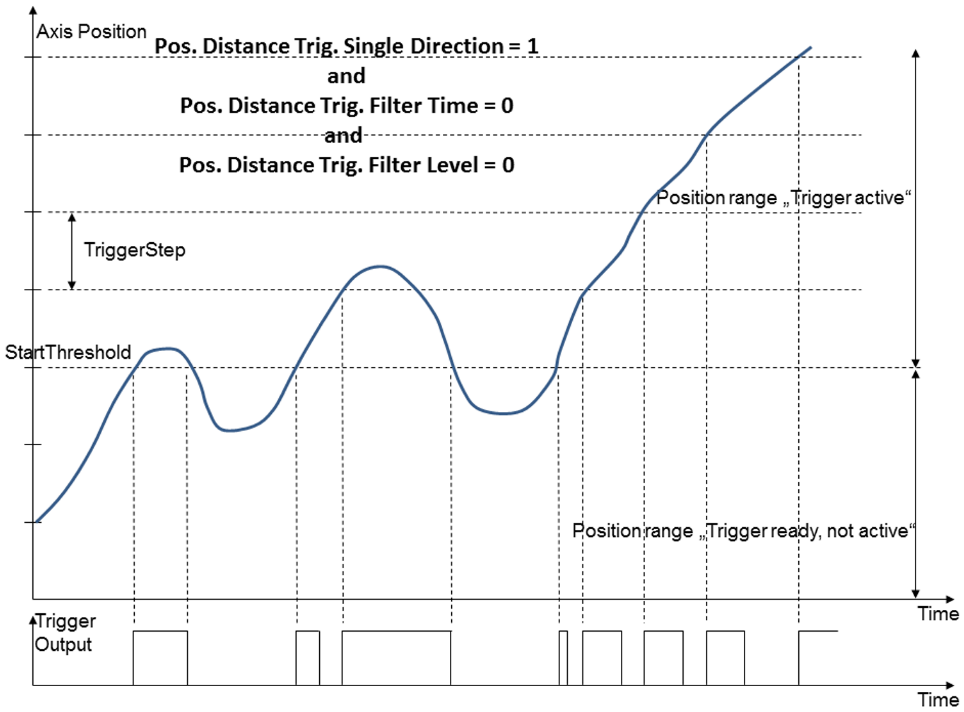

Figure 64: Position Distance *trigger mode with threshold settings, without any filter settings*

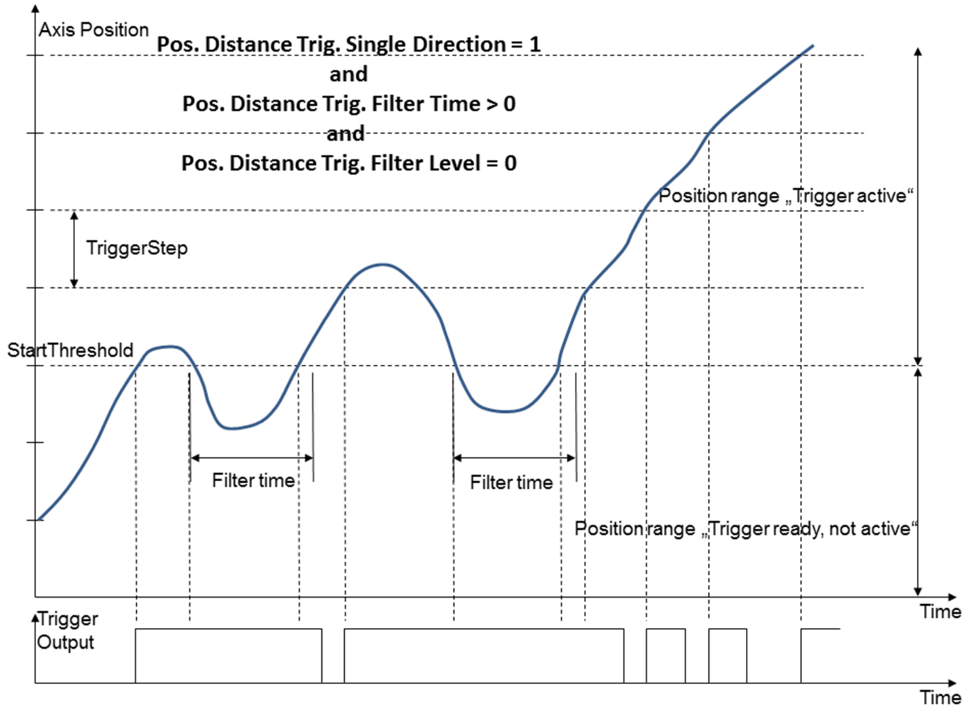

Figure 65: Position Distance *trigger mode with threshold settings, with time filter*

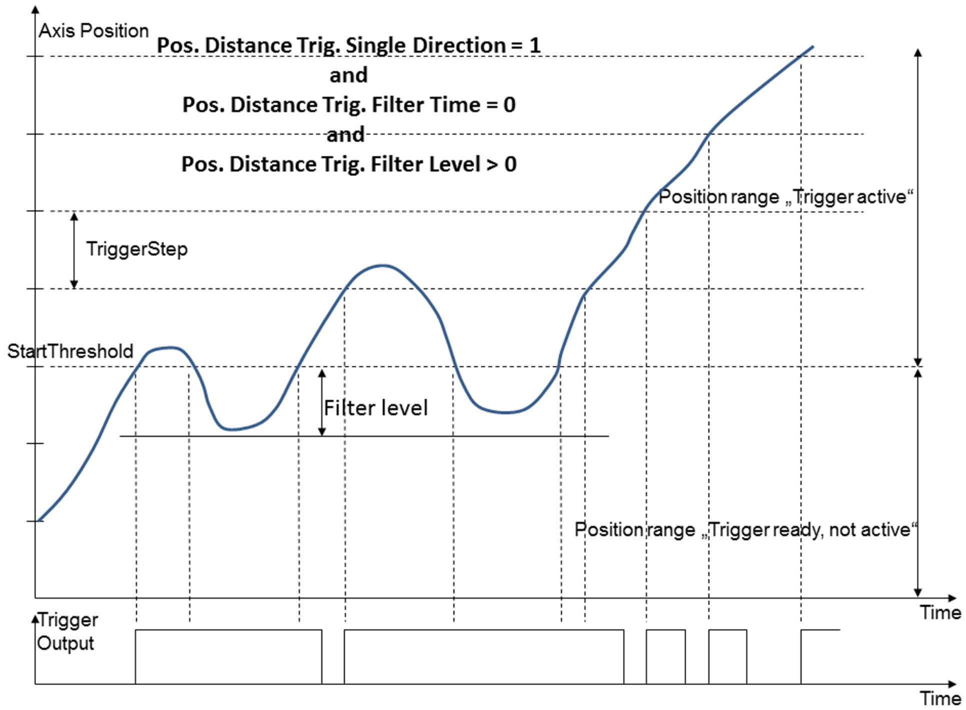

Figure 66: Position Distance *trigger mode with threshold settings, with position level filter*

8.2.3 Example—"OnTarget" Trigger Mode

With the *OnTarget* trigger mode, the on-target state of the selected axis is written to the selected digital output line.

The on-target state is influenced by the settling window (On Target Tolerance parameter (ID 0x07000900)) and delay time (Settling Time parameter (ID 0x07000901)). The on-target state is true when the current position is inside the settling window and stays there for at least for the duration of the delay time. The settling window is centered around the target position. The on-target state can also be read with the ONT? command.

The following parameters must be set for the digital output line which is to be used for trigger output (*TrigOutID*):

- *Axis* (<CTOPam> = 2)
- *TriggerMode* (<CTOPam> = 3)

General notation of the CTO command for this mode (in fact, the command arguments can be divided in two "portions", each starting with the *TrigOutID* declaration):

Command mnemonic	Axis selection	Trigger mode selection
CTO	<TrigOutID> 2 *Axis*	<TrigOutID> 3 2

Instead of using the CTO command, you can also set the values of the corresponding parameters with SPA or SEP. See "Configuring Trigger Output" (p. 168) for a parameter list.

Example: The on-target state of axis 1 is to be written to the digital output line 1. Send:

CTO 1 2 1 1 3 2

8.2.4 Example—"MinMaxThreshold" Trigger Mode

With the *MinMaxThreshold* trigger mode, a band is specified with *MinThreshold* and *MaxThreshold* (<CTOPam> ID 5 and ID 6). When the axis position is inside the specified band then the digital output line is set *high*, otherwise it is set *low*.

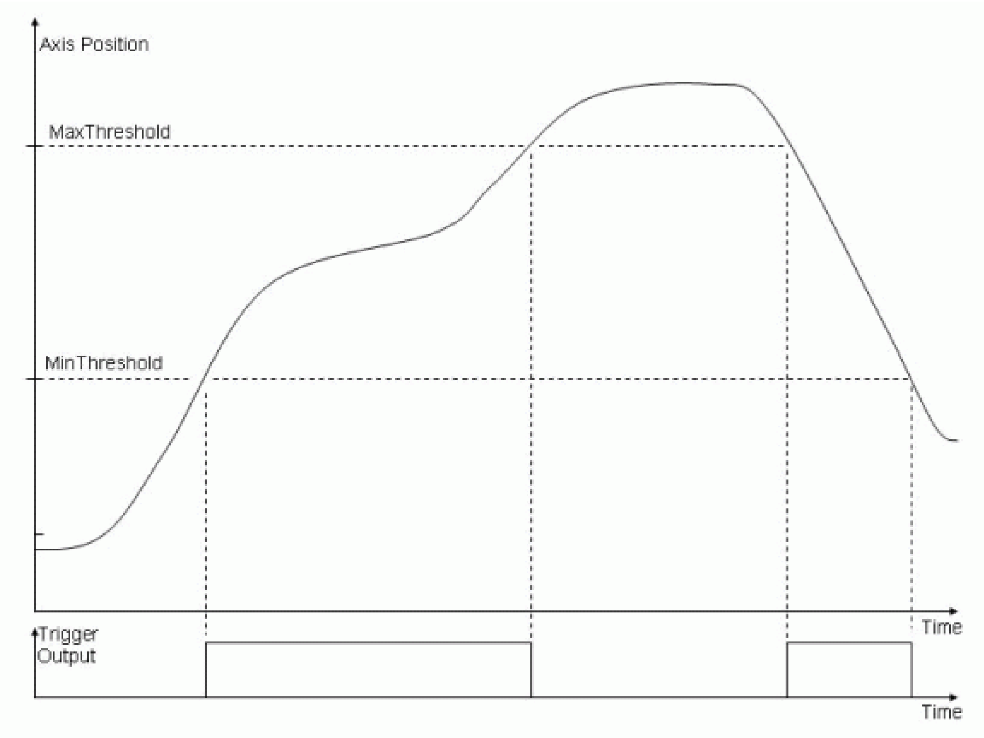

Figure 67: MinMaxThreshold *trigger mode*

The following parameters must be set for the digital output line which is to be used for trigger output (*TrigOutID*):

- *Axis* (<CTOPam> = 2)
- *TriggerMode* (<CTOPam> = 3)
- *MinThreshold* (<CTOPam> = 5)
- *MaxThreshold* (<CTOPam> = 6)

General notation of the CTO command for this mode (in fact, the command arguments can be divided in four "portions", each starting with the *TrigOutID* declaration):

Command mnemonic	Axis selection	Trigger mode selection	Min threshold setting	Max threshold setting
CTO	<TrigOutID> 2 *Axis*	<TrigOutID> 3 3	<TrigOutID> 5 *min.pos.*	<TrigOutID> 6 *max.pos.*

Instead of using the CTO command, you can also set the values of the corresponding parameters with SPA or SEP. See "Configuring Trigger Output" (p. 168) for a parameter list.

Example: The digital output line 1 is to be set *high* whenever the axis position of axis 1 is higher than 0.3 µm and lower than 0.6 µm. Send:

CTO 1 2 1 1 3 3 1 5 0.3 1 6 0.6

8.2.5 Example—"Generator Level Trigger" Mode

With the *Generator Level Trigger* mode, the trigger output will be synchronized with the wave generator output, and CTO must be used in combination with TWS.

The length of a single trigger pulse corresponds to the control loop sampling time. If the state of the digital output line is set to *high* with TWS for consecutive points of a wave table, the state therefore does **not** change back to *low* between the points.

The following parameter must be set for the digital output line which is to be used for trigger output (*TrigOutID*):

- *TriggerMode* (<CTOPam> = 3)

General notation of the CTO command for this mode:

Command mnemonic	Trigger mode selection
CTO	<TrigOutID> 3 4

Instead of using the CTO command, you can also set the value of the corresponding parameter with SPA or SEP. See "Configuring Trigger Output" (p. 168) for a parameter list.

Example 1: Generate single trigger pulses synchronized with the wave generator in *Generator Level Trigger* mode.

Command String to Send	Action Performed
WAV 2 X SIN_P 2000 20 10 2000 0 1000	Define a sine waveform for wave table 2, the segment length and hence the number of points in the wave table is 2000
TWC	Clears all trigger output settings for the wave generators by setting the state of all digital output lines for all points to *low* (for all points, the default state of the digital output line is also *low*). It is recommended to use TWC before new trigger actions are defined.
TWS 1 500 1 1 1500 1 1 1900 1 1 2000 1	Set trigger actions for the digital output line *OUT1* (identifier is 1): at the waveform points 500, 1500, 1900 and 2000 it is set *high*; at all other points the state of the digital output line is *low* (due to the TWC usage).
CTO 1 3 4	The digital output line *OUT1* is set to *Generator Level Trigger* mode.
WSL 1 2	Connect wave generator 1 (axis 1) to wave table 2
WGO 1 1	Start output of wave generator 1 immediately (synchronized by control loop cycle). Now the trigger output will take place as specified.
WGO 1 0	Stop output of wave generator 1 and hence also the trigger output.

Example 2: Use *Generator Level Trigger* mode to switch the digital output line to a certain state for a certain range of the waveform.

Command String to Send	Action Performed
WAV 2 X SIN_P 2000 20 10 2000 0 1000	Define a sine waveform for wave table 2, the segment length and hence the number of points in the wave table is 2000
CTO 1 3 4	The digital output line *OUT1* is set to *Generator Level Trigger* mode.

Command String to Send	Action Performed
TWS 1 1 3 1 750 2 1 1150 3	For all waveform points from point 1 to point 749, the digital output line is set *low*. At point 750, there is a rising edge on the digital output line. Therefore, the digital output line is set *high* from point 751 to point 1149. At point 1150, there is a falling edge on the digital output line, and for all subsequent points the line will therefore be set *low*.
WSL 1 2	Connect wave generator 1 (axis 1) to wave table 2
WGO 1 1	Start output of wave generator 1 immediately (synchronized by control loop cycle). Now the trigger output will take place as specified.
WGO 1 0	Stop output of wave generator 1 and hence also the trigger output.

8.2.6 Example—"Generator Pulse Trigger" Mode

With the *Generator Pulse Trigger* mode, the trigger output will be synchronized with the wave generator output, and CTO must be used in combination with TWS.

The length of a single trigger pulse is shorter than the control loop sampling time. If the state of the digital output line is set to *high* with TWS for consecutive points of a wave table, the state therefore changes back to *low* after each point. This way, the trigger output can be used, for example, to count the waveform points that are output by the wave generator.

The following parameter must be set for the digital output line which is to be used for trigger output (*TrigOutID*):

- *TriggerMode* (<CTOPam> = 3)

General notation of the CTO command for this mode:

Command mnemonic	Trigger mode selection
CTO	<TrigOutID> 3 9

Instead of using the CTO command, you can also set the value of the corresponding parameter with SPA or SEP. See "Configuring Trigger Output" (p. 168) for a parameter list.

The examples for the *Generator Level Trigger* mode (p. 185) can also be used in *Generator Pulse Trigger* mode. Note: If example 2 is used in *Generator Pulse Trigger* mode, the digital output line will toggle between *high* and *low* with each waveform point from point 751 to point 1149.

8.2.7 Example—Polarity Setting

It is possible to select the signal polarity (active *high* = 1, default / active *low* = 0) for the digital output line which is to be used for trigger output.

The following parameter must be set for the digital output line (*TrigOutID*):

- *Polarity* (<CTOPam> = 7)

General notation of the CTO command for polarity selection:

Command mnemonic	Trigger mode selection
CTO	<TrigOutID> 7 *pol.code*

Instead of using the CTO command, you can also set the value of the corresponding parameter with SPA or SEP. See "Configuring Trigger Output" (p. 168) for a parameter list.

Example: The signal polarity for the digital output line 1 is to be set to active *low*. Send:

CTO 1 7 0

8.2.8 Examples—"TriggerOutAND" and "TriggerOutOR" Modes

With the *TriggerOutAND* and *TriggerOutOR* trigger modes, the states of multiple digital output lines are combined by a logical operation, and the result is written to another digital output line. A bit-mapped mask selects the digital output lines whose states are to be logically combined. The mask can be specified in hex or decimal format.

Bit-mapped mask values of the digital output lines:

Digital output line	Bit	Value in hex format	Value in decimal format
OUT1	0	0x1	1
OUT2	1	0x2	2
OUT3	2	0x4	4
OUT4	3	0x8	8
OUT5	4	0x10	16
OUT6	5	0x20	32
OUT7	6	0x40	64

The following parameters must be set for the digital output line (*TrigOutID*):

- *TriggerMode* (<CTOPam> = 3)
- *TriggerOutMask* (<CTOPam> = 16)

General notation of the CTO command for the *TriggerOutAND* mode:

Command mnemonic	Trigger mode selection	Mask specification
CTO	<TrigOutID> 3 14	<TrigOutID> 16 *TriggerOutMask*

General notation of the CTO command for the *TriggerOutOR* mode:

Command mnemonic	Trigger mode selection	Mask specification
CTO	<TrigOutID> 3 15	<TrigOutID> 16 *TriggerOutMask*

Instead of using the CTO command, you can also set the values of the corresponding parameters with SPA or SEP. See "Configuring Trigger Output" (p. 168) for a parameter list.

Example 1: The states of the digital output lines 1 and 3 are to be combined by a logical AND operation. The result is to be written to the digital output line 2. The mask for selection of the digital output lines to be combined is specified in hex format. Send:

CTO 2 3 14 2 16 0x5

Example 2: The states of the digital output lines 2 and 3 are to be combined by a logical OR operation. The result is to be written to the digital output line 1. The mask for selection of the digital output lines to be combined is specified in decimal format. Send:

CTO 1 3 15 1 16 6

9 Using the Analog Input

9.1 How to Work with the Analog Input—Overview

The E-711.IA4 analog interface module provides four analog input lines on its front panel, labeled as *In 1* to *In 4* (e.g., present in E-712.3CDA, E-712.6CDA, and E-712.6IDA models). See "Analog Input Connectors" (p. 332) for pinout and specifications. For highest resolution, it is recommended to use the full range of ±10 V.

You can use an analog input line as follows:

- Connect an external sensor
- Connect a signal source for control value generation

Irrespective of the intended usage, the analog input values must first be scaled to suitable position values (see "Scaling the Analog Input" (p. 192)). Then, to set the usage of the analog input, it is furthermore necessary to change certain parameters. See "Use as Signal Source for Control Value Generation" (p. 196) and "Use as External Sensor Input" (p. 197) for more information. Analog input lines which are not used should be deactivated to avoid interferences. See "Deactivation of Unused Analog Input Lines" (p. 198) for more information.

The analog input lines are a subset of the E-711/E-712 systems input signal channels (Number Of Input Channels parameter (ID 0x0E000B00)) which comprise also the sensor channels for the internal sensors in the mechanics (Number Of Sensor Channels parameter (ID 0x0E000B03)). In the firmware of the E-711/E-712 system, the internal sensor channels are always represented by the first input signal channels, while the analog input lines are always represented by the last input signal channels. Examples:

- If the E-711/E-712 system is equipped with three internal sensor channels, they are accessible as input signal channels 1 to 3, while the analog input lines *In 1* to *In 4* have the channel identifiers 4 to 7.
- If the E-711/E-712 system is equipped with six internal sensor channels, they are accessible as input signal channels 1 to 6, while the analog input lines *In 1* to *In 4* have the identifiers 7 to 10.

See "Accessible Items and Their Identifiers" (p. 127) for more information.

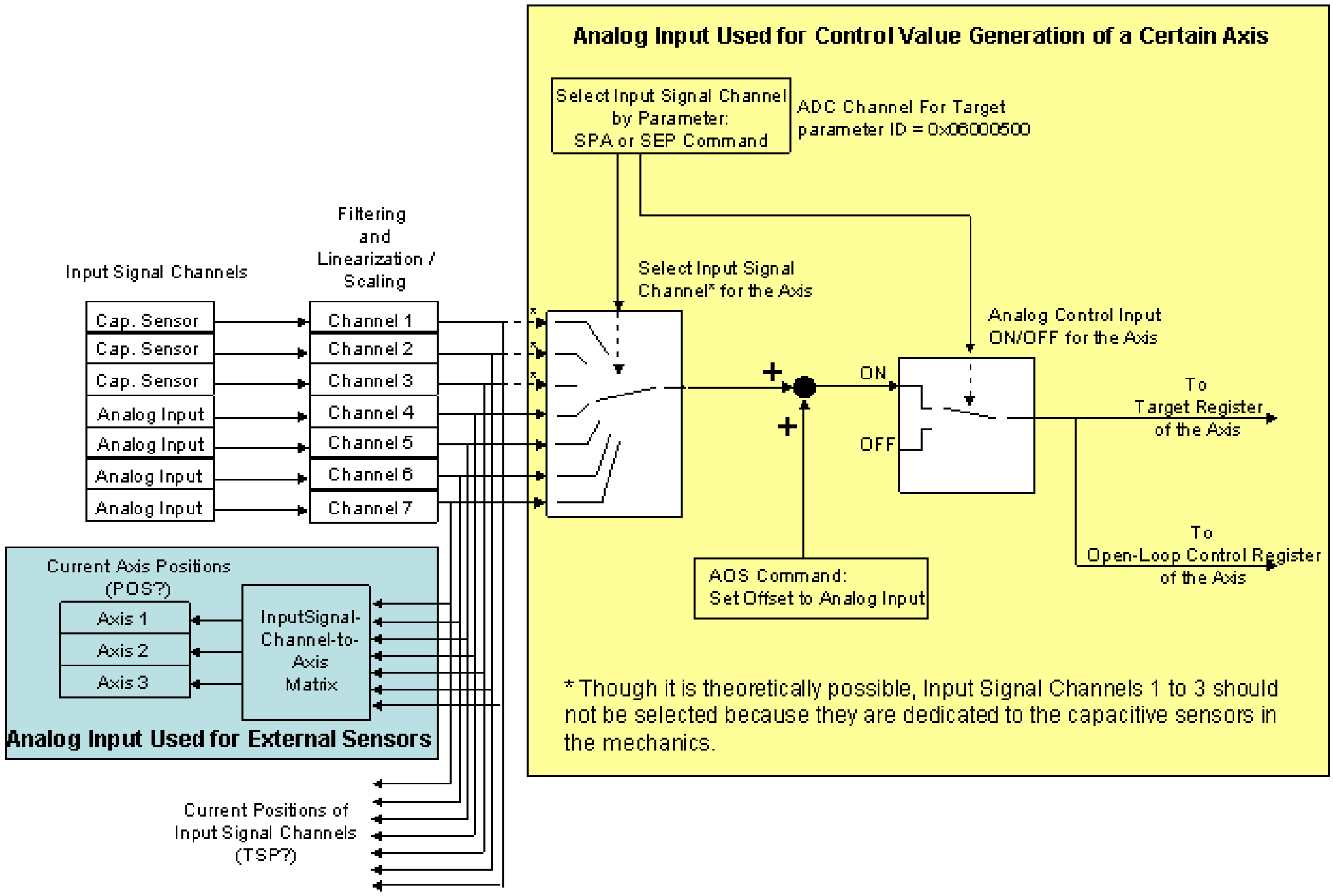

Figure 68: Overview over the usage of the analog input lines, exemplified by E-712.3CDA

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It is strongly recommended to save the parameter values of the E-711/E-712 system to a file on the PC before you make any changes. This way the original settings can be restored if the new parameter settings will not prove satisfactory. To save the parameter values and to load them back to the E-711/E-712 system, use the *Device Parameter Configuration* window or PIMikroMove. See "Creating Backups for Parameter Values" (p. 109) for more information.

Wherever changing parameter values is mentioned, you can do this using SPA (volatile memory) or SEP (nonvolatile memory). Furthermore, you can use WPA to copy the current values from volatile memory to nonvolatile memory. To have write access to certain parameters, it might be necessary to switch to a higher command level using CCL. To read parameter values, query with the SPA? or SEP? commands.

The *Device Parameter Configuration* window of PIMikroMove gives access to parameter values in a more convenient way. Use this window to check/edit the individual parameters. See the PIMikroMove manual for more information.

9.2 Scaling the Analog Input

Before the analog input line can be used with an external sensor or with a signal source for control value generation, the input levels must be associated with suitable position values. To do this, adjust the OFFSET (parameter with ID 0x02000200) and the GAIN (parameter with ID 0x02000300) of the mechanics linearization polynomial according to the travel range of the axis and the input signal range. See below for more information. The TSP? command returns the analog input values after the scaling as position values in µm.

In addition, the digital filter parameters can be adjusted. See "Digital processing" (p. 135) for more information.

How to adjust *OFFSET* and *GAIN* to map the analog input voltage to a suitably scaled position value for a certain axis:

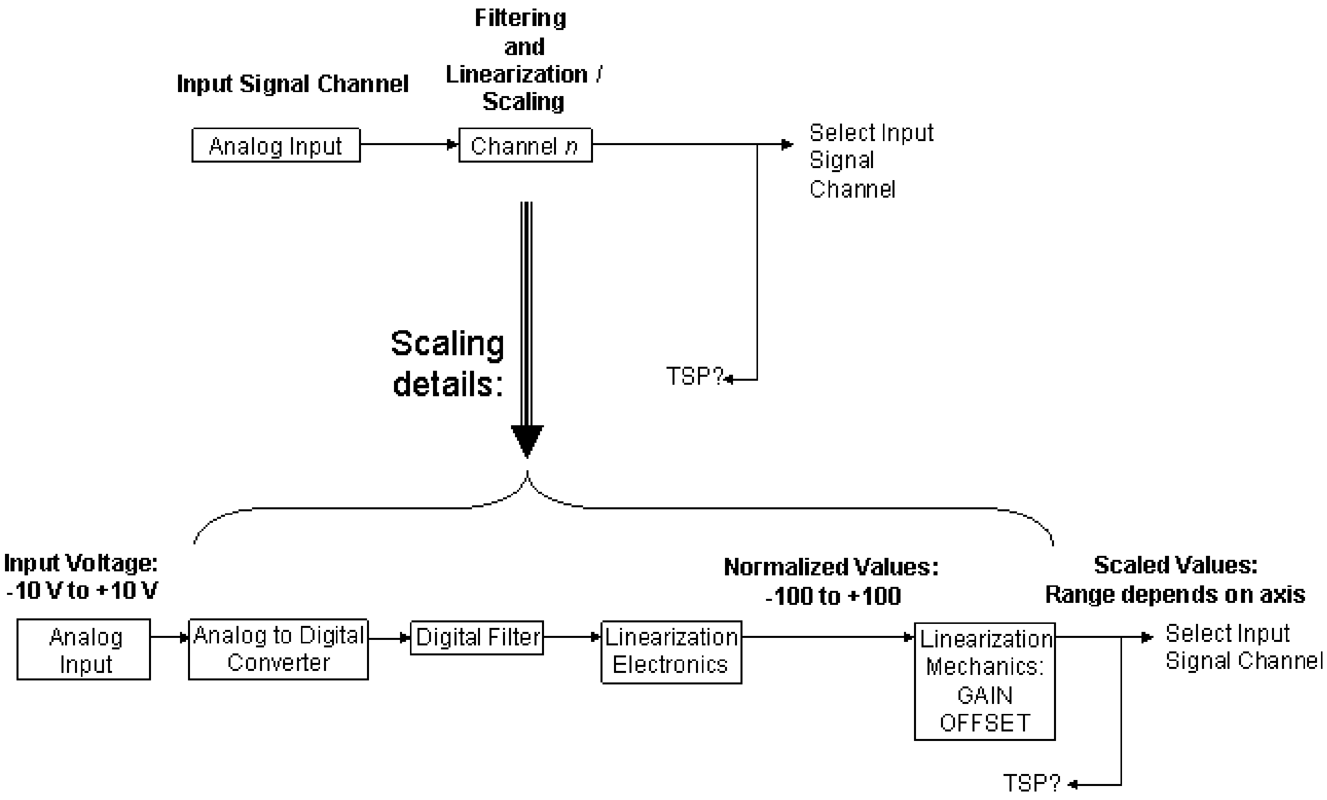


Figure 69: Processing of an analog input signal, detail from the overview figure above

Input voltage: the maximum range is -10 V to +10 V

Normalized value: The polynomial used for electronics linearization (see "Digital processing" for more information) converts the analog input voltage to a number in the range of -100 to +100. An input voltage value of -10 V always corresponds to -100, and +10 V corresponds to +100 respectively.

Scaled value: The range depends on the axis and can be set by the coefficients of the polynomial used for mechanics linearization (see "Digital processing" for more information):

*ScaledValue = OFFSET + GAIN * NormalizedValue*

where

OFFSET corresponds to the Sensor Mech. Correction 1 parameter (ID 0x02000200)
GAIN corresponds to the Sensor Mech. Correction 2 parameter (ID 0x02000300)

If no linearization is necessary, the other coefficients of the mechanics linearization polynomial can be set to zero (parameters with ID 0x02000400, ID 0x02000500, ID 0x02000600).

Note that in PIMikroMove, these parameters are available in the *Sensor Mechanics* parameter groups in the *Device Parameter Configuration* window (E-712.3CDA: *Sensor Mechanics 4* to *Sensor Mechanics 7*; E-712.6CDA, .6IDA: *Sensor Mechanics 7* to *Sensor Mechanics 10*).

How to calculate the values to set for *OFFSET* and *GAIN*:

GAIN = (MaxScaledValue - MinScaledValue) / (MaxNormalizedValue - MinNormalizedValue)

*OFFSET = MaxScaledValue - GAIN * MaxNormalizedValue*

The values of *MinScaledValue* and *MaxScaledValue* depend on the travel range of the axis with which the analog input line is to be used:

MinScaledValue is contained in the TMN? response (is defined by the Range Limit Min parameter (ID 0x07000000)), and *MaxScaledValue* is contained in the TMX? response (is defined by the Range Limit Max parameter (ID 0x07000001)).

The values of *MinNormalizedValue* and *MaxNormalizedValue* depend on the range of the external signal applied to the analog input line. See the examples below. For all examples, it is assumed that you have an E-712.3CDA, and the *In 1* analog input line (input signal channel 4) is to be used with axis 1 which has the following travel range:

MinScaledValue = -20 µm

MaxScaledValue = +120 µm

Example 1:

The full range of -10 V to +10 V is to be used (this is recommended for highest resolution).

MinNormalizedValue = -100

MaxNormalizedValue = +100

GAIN = (120 - (-20)) / (100 - (-100)) = 0.7

OFFSET = 120 - 0.7 * 100 = 50

ScaledValue = 50 + 0.7 * *NormalizedValue*

So, to adjust the *GAIN* and *OFFSET* parameters for input signal channel 4 (= *In 1* analog input line) in the E-712.3CDA, you must send:

SPA 4 0x02000200 50

SPA 4 0x02000300 0.7

Example 2:

Only positive input voltages are to be used, i.e., the range is 0 V to +10 V.

MinNormalizedValue = 0

MaxNormalizedValue = +100

GAIN = (120 - (-20)) / (100 - 0) = 1.4

OFFSET = 120 - 1.4 * 100 = -20

ScaledValue = -20 + 1.4 * *NormalizedValue*

Send:

SPA 4 0x02000200 -20

SPA 4 0x02000300 1.4

Example 3:

Positions with positive sign shall correspond to positive input voltages, and positions with negative sign shall correspond to negative input voltages.

The positive input voltage ranges to +10 V.

Then, the following is valid provided that the absolute value of the negative positions will never be greater than the positive positions.

MinNormalizedValue = 0

MaxNormalizedValue = +100

GAIN = (120 - 0)) / (100 - 0) = 1.2

OFFSET = 120 - 1.2 * 100 = 0

ScaledValue = 1.2 * *NormalizedValue*

Send:

SPA 4 0x02000200 0

SPA 4 0x02000300 1.2

Note that these *OFFSET* and *GAIN* values would also be valid if axis 1 had a travel range of 0 µm to 120 µm and if there were only positive input voltages to +10 V.

Example 4:

The same conditions as in example 3 are valid, but the positive input voltages range to +5 V.

MinNormalizedValue = 0

MaxNormalizedValue = +50

GAIN = (120 - 0)) / (50 - 0) = 2.4

OFFSET = 120 - 2.4 * 50 = 0

ScaledValue = 2.4 * *NormalizedValue*

Send:

SPA 4 0x02000200 0

SPA 4 0x02000300 2.4

9.3 Use as Signal Source for Control Value Generation

To enable the analog control input for an axis, an input signal channel must be connected to that axis. The connection is done with the ADC Channel For Target parameter (ID 0x06000500). If the connection of axis and input signal channel is saved in nonvolatile memory, the axis can be commanded via analog input immediately after switching on or rebooting the E-711/E-712 system, and no PC is required. Example: With an E-712.3CDA, the *In 1* analog input line input signal channel 4) is to be used to command axis 1. To enable the connection in volatile memory, send:

SPA 1 0x06000500 4

Note that in PIMikroMove, this parameter is available in the *Target Manipulation 1* parameter group in the *Device Parameter Configuration* window.

When the analog control input is enabled for an axis, then it overwrites the values of all other control sources for that axis except those from the AutoZero procedure. The AutoZero procedure has the highest priority, i.e., it will overwrite the control values specified by all other sources. When the analog control input is enabled, it will be disabled automatically at the start of the AutoZero procedure and reenabled again when the AutoZero procedure is finished. See "Control Value Generation" (p. 139) for more information.

An offset value can be added to the analog input scaled value for an axis using the AOS command.

When no input signal channel is connected to an axis (i.e., the value of the ADC Channel For Target parameter is 0), the analog control input is disabled for that axis (including the offset set with AOS).

When the analog input is used as control source and the axis motion is stopped with STP or #24, the behaviour depends on the value of the Disconnect Analog Target Input When Stopping parameter (ID 0x0E001E00): 1 = the analog input channel is disconnected from the axis; 0 = the analog input channel remains connected to the axis. If the analog input channel is disconnected from the axis: To recommence commanding the axis via the analog input, the corresponding input signal channel must be reconnected to the axis. See the description above.

When the analog input is being used as control source and the operating mode is switched to open-loop operation, the axis motion will continue in open-loop operation.

INFORMATION

The analog input values must be scaled to suitable position values. See "Scaling the Analog Input" (p. 192) for more information.

Make sure that the analog input line which is used to control an axis is not used as external sensor for the same axis. This means that in the input matrix, the coefficient of the appropriate analog input line must be set to zero for that axis. With an E-712.3CDA, the coefficients of the analog input lines are represented by the values of the Position From Sensor 4 to Position From Sensor 7 parameters (ID 0x07000503 to ID 0x07000506); E-712.6CDA, .6IDA: Position From Sensor 7 to Position From Sensor 10 parameters (ID 0x07000506 to ID 0x07000509). In PIMikroMove, these parameters are available in the *Axis Definition* parameter groups in the *Device Parameter Configuration* window.

9.4 Use as External Sensor Input

To include the sensor on the analog input line in the position signal of an axis, set the corresponding coefficient in the input matrix to 1 for that axis. Example: With an E-712.3CDA, the *In 1* analog input line (input signal channel 4) is to be used to measure the position of axis 1, i.e., the Position From Sensor 4 parameter (ID 0x07000503) must be set to 1 for axis 1. To change the coefficient in volatile memory, send:

SPA 1 0x07000503 1

In PIMikroMove, this parameter is available in the *Axis Definition 1* parameter group in the *Device Parameter Configuration* window.

If only the external sensor on the analog input line is to be used for position control of an axis, the signals of all other sensors must be excluded from the position monitoring of that axis, especially the signals of the internal sensors integrated in the mechanics. To do this, set the corresponding coefficients in the input matrix to zero for that axis (with the E-712.3CDA, the internal sensors are represented by the Position From Sensor 1 to Position From Sensor 3 parameters; E-712.6CDA, .6IDA: Position From Sensor 1 to Position From Sensor 6 parameters). Example: To deactivate the first internal sensor for axis 1, send:

SPA 1 0x07000500 0

The position of the axis (i.e. the POS? response) will then be based on the external sensor only, but it is still possible to read the signals of all sensors using the TSP? command.

INFORMATION

The analog input values must be scaled to suitable position values. See "Scaling the Analog Input" (p. 192) for more information.

Make sure that internally, the analog input line used to monitor the position of an axis is not connected to the same axis for control value generation. This means that the value of the ADC Channel For Target parameter (ID 0x06000500) for an axis must be different from the identifier of the analog input line which is used as external sensor for that axis. In PIMikroMove, you can check this in the *Target Manipulation* parameter groups in the *Device Parameter Configuration* window.

9.5 Deactivation of Unused Analog Input Lines

Analog input lines which are not used should be deactivated to avoid interferences. To deactivate an unused analog input line, the following settings must be done:

1. Exclude the analog input line from the calculation of axis positions by setting its coefficients for all axes to zero in the input matrix (Position From Sensor *n* parameters).

2. Make sure that the analog input line is not connected to an axis for control value generation. This means that the value of the ADC Channel

For Target parameter (ID 0x06000500) for all axes must be different from the ID of the analog input line.

Example: The *In 4* analog input line of an E-712.3CDA model is to be deactivated temporarily (i.e. in volatile memory). Because the E-712.3CDA has three internal sensor channels, the *In 4* analog input line is the 7th input signal channel and its input matrix coefficients corresponds to the Position From Sensor 7 parameters (ID 0x07000506) for axis 1 to axis 3.

To exclude the analog input line from the axis position calculation, send:

SPA 1 0x07000506 0 2 0x07000506 0 3 0x07000506 0

Then check the RAM settings for the axis control value generation. Send:

SPA? 1 0x06000500 2 0x06000500 3 0x06000500

The response must be different from 7 for all axes. I.e., the *In 4* analog input line is still connected to axis 1 if the E-711/E-712 system replies

1 0x06000500=7

2 0x06000500=3

3 0x06000500=0

To disconnect *In 4*, you must send:

SPA 1 0x06000500 0

9.6 Analog-Input-Related Commands and Parameters

Command	Description	Notes
AOS	Set Analog Input Offset	Adds an offset value to the analog input scaled value (Analog Target Offset parameter (ID 0x06000501)). This offset is active if the analog input is enabled as control source for this axis.
AOS?	Get Analog Input Offset	Reads the current value of the Analog Target Offset parameter (ID 0x06000501) from volatile memory
SEP	Set Nonvolatile Memory Parameters	Can be used to set the default configuration for analog input usage.
SEP?	Get Nonvolatile Memory Parameters	Reads the current parameter values from nonvolatile memory

Command	Description	Notes
SPA	Set Temporary Memory Parameters	Can be used to set a temporary configuration for analog input usage.
SPA?	Get Temporary Memory Parameters	Reads the current parameter values from volatile memory (RAM)
TAD?	Get ADC Value Of Input Signal	Returns the current ADC value of the analog input, dimensionless
TNS?	Get Normalized Input Signal Value	Returns the resulting value for the analog input after the electronics linearization, dimensionless
TSP?	Get Input Signal Position Value	Returns the resulting value for the analog input after the mechanics linearization (scaling), the unit is µm
WPA	Save Parameters To Nonvolatile Memory	Can be used to save the currently active configuration (including analog input usage) to nonvolatile memory.

See "How to Work with the Analog Input—Overview" (p. 190) for more information. See the PZ233 GCS commands manual for detailed command descriptions. See "Accessible Items and Their Identifiers" (p. 127) for the identifiers of the items which can be addressed with the commands.

Parameter ID	Com-mand Level	Item Type	Max. No. Of Items	Data Type	Parameter Description
0x02000200	1	Input Signal Channel	E-712.3CDA: 7 E-712.6CDA: 10 E-712.6IDA: 10	FLOAT	Sensor Mech. Correction 1 (Offset)
0x02000300	1	Input Signal Channel	E-712.3CDA: 7 E-712.6CDA: 10 E-712.6IDA: 10	FLOAT	Sensor Mech. Correction 2 (Gain)
0x05000000	1	Input Signal Channel	E-712.3CDA: 7 E-712.6CDA: 10 E-712.6IDA: 10	INT	Digital Filter Type
0x05000001	1	Input Signal Channel	E-712.3CDA: 7 E-712.6CDA: 10 E-712.6IDA: 10	FLOAT	Digital Filter Bandwidth
0x05000002	1	Input Signal Channel	E-712.3CDA: 7 E-712.6CDA: 10 E-712.6IDA: 10	INT	Digital Filter Order

Parameter ID	Com-mand Level	Item Type	Max. No. Of Items	Data Type	Parameter Description
0x06000500	1	Logical Axis	E-712.3CDA: 3 E-712.6CDA: 6 E-712.6IDA: 6	INT	ADC Channel for Target; if 0, then the analog control input is disabled for the axis
0x06000501	1	Logical Axis	E-712.3CDA: 3 E-712.6CDA: 6 E-712.6IDA: 6	FLOAT	Analog Target Offset
0x07000500	1	Logical Axis	E-712.3CDA: 3 E-712.6CDA: 6 E-712.6IDA: 6	FLOAT	Position from Sensor 1
0x07000501	1	Logical Axis	E-712.3CDA: 3 E-712.6CDA: 6 E-712.6IDA: 6	FLOAT	Position From Sensor 2
0x07000502	1	Logical Axis	E-712.3CDA: 3 E-712.6CDA: 6 E-712.6IDA: 6	FLOAT	Position From Sensor 3
0x07000503	1	Logical Axis	E-712.3CDA: 3 E-712.6CDA: 6 E-712.6IDA: 6	FLOAT	Position From Sensor 4
0x07000504	1	Logical Axis	E-712.3CDA: 3 E-712.6CDA: 6 E-712.6IDA: 6	FLOAT	Position From Sensor 5
0x07000505	1	Logical Axis	E-712.3CDA: 3 E-712.6CDA: 6 E-712.6IDA: 6	FLOAT	Position From Sensor 6
0x07000506	1	Logical Axis	E-712.3CDA: 3 E-712.6CDA: 6 E-712.6IDA: 6	FLOAT	Position From Sensor 7
0x07000507	1	Logical Axis	E-712.3CDA: 3 E-712.6CDA: 6 E-712.6IDA: 6	FLOAT	Position From Sensor 8
0x07000508	1	Logical Axis	E-712.3CDA: 3 E-712.6CDA: 6 E-712.6IDA: 6	FLOAT	Position From Sensor 9
0x07000509	1	Logical Axis	E-712.3CDA: 3 E-712.6CDA: 6 E-712.6IDA: 6	FLOAT	Position From Sensor 10
0x0e000b00	3	System	1	INT	Number Of Input Channels
0x0e000b03	3	System	1	INT	Number Of Sensor Channels

See "Parameters" (p. 276) for more information regarding the parameters and their handling.

10 Using the Analog Output

10.1 How to Work with the Analog Output—Overview

The E-711.IA4 analog interface module provides four analog output lines on its front panel, labeled as *Out 1* to *Out 4* (e.g., present with E-712.3CDA, E-712.6CDA, and E-712.6IDA models). The output range is ±12.775 V, see "Analog Output Connectors" (p. 333) for pinout and more specifications.

You can use an analog output line as follows:

- Control an external amplifier
- Monitor an axis position

The usage of the analog output is set via the parameters Select Output Type (ID 0x0a000003) and Select Output Index (ID 0x0a000004). See "Use Analog Output to Control External Amplifier" (p. 204) and "Use Analog Output to Monitor Axis Position" (p. 205) for more information. If the analog output is set up to control an external amplifier, the VOL? command returns the output voltage.

The analog output lines are a subset of the E-712.3CDA's, .6CDA's and .6IDA's output signal channels (Number Of Output Channels parameter (ID 0x0E000B01)) which comprise also the piezo amplifier channels for the piezo actuators in the mechanics (Number Of Piezo Channels parameter (ID 0x0E000B04)). In the firmware of the E-711/E-712 system, the piezo amplifier channels are always represented by the first output signal channels, while the analog output lines are always represented by the last output signal channels. Examples for counting of the output signal channels:

- The E-712.3CDA is equipped with four piezo amplifier channels, they are accessible as output signal channels 1 to 4, while the analog output lines *Out 1* to *Out 4* have the channel identifiers 5 to 8.
- The E-712.6CDA is equipped with eight piezo amplifier channels, they are accessible as output signal channels 1 to 8, while the analog output lines *Out 1* to *Out 4* have the identifiers 9 to 12.

See "Accessible Items and Their Identifiers" (p. 127) for more information.

The parameters Select Output Type and Select Output Index can only be changed for analog output lines. For piezo amplifier channels, they are read-only: the Select Output Type parameter is fixed to "control voltage of output signal channel", and the Select Output Index parameter is fixed to a certain output signal channel.

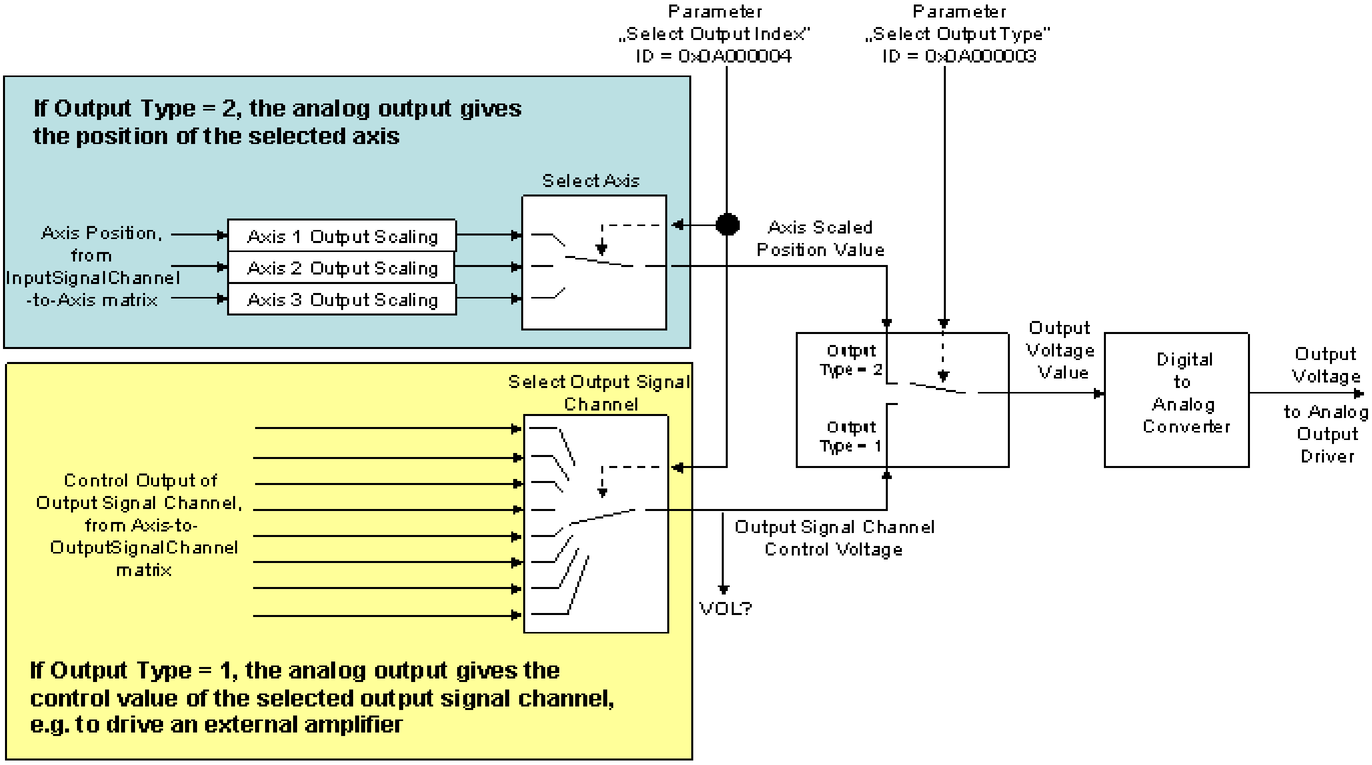


Figure 70: Overview over the usage of an analog output line, exemplified by E-712.3CDA

INFORMATION

It is strongly recommended to save the parameter values of the E-711/E-712 system to a file on the PC before you make any changes. This way the original settings can be restored if the new parameter settings will not prove satisfactory. To save the parameter values and to load them back to the E-711/E-712 system, use the *Device Parameter Configuration* window of PIMikroMove. See "Creating Backups for Parameter Values" (p. 109) for more information.

Wherever changing parameter values is mentioned, you can do this using SPA (volatile memory) or SEP (nonvolatile memory). Furthermore, you can use WPA to copy the current values from volatile memory to nonvolatile memory. To have write access to certain parameters, it might be necessary to switch to a higher command level using CCL. To read parameter values, query with the SPA? or SEP? commands.

The *Device Parameter Configuration* window of PIMikroMove gives access to parameter values in a more convenient way. Use this window to check/edit the individual parameters. See the PIMikroMove manual for more information.

10.2 Use Analog Output to Control External Amplifier

Proceed as follows if you want to control an external amplifier via an analog output line:

1. Select output type 1 = "control voltage of output signal channel" for the analog output line using the Select Output Type parameter (ID 0x0A000003).

   Example: With an E-712.6CDA, the *Out 2* analog output line (output signal channel 10) is to be used to control an external amplifier. To select the corresponding output type in volatile memory, send:

   SPA 10 0x0A000003 1

   Note that in PIMikroMove, this parameter is available in the *DAC 10* parameter group in the *Device Parameter Configuration* window.

2 Connect the output signal channel whose control value is to be output to the analog output line using the Select Output Index parameter (ID 0x0A000004.)

Note:

The control value of an output signal channel results from the output matrix, see "Output Generation" (p. 143) for more information.

In the example, the control value of output signal channel 1 (which is the first internal piezo amplifier of the E-712.6CDA) is to be connected to the *Out 2* line (output signal channel 10). Send

SPA 10 0x0A000004 1

In PIMikroMove, this parameter is also available in the *DAC 10* parameter group in the *Device Parameter Configuration* window. Note that for piezo amplifier channels, the Select Output Index parameter is fixed to a certain output signal channel.

3 Check the output matrix (Driving Factor of Piezo *n* parameters (ID 0x09000000 to 0x0900000*n-1*)) for feasible settings. In PIMikroMove, the parameters are available in the *Axis Definition* parameter groups in the *Device Parameter Configuration* window.

10.3 Use Analog Output to Monitor Axis Position

Proceed as follows if you want to output axis position values on an analog output line:

1 Select output type 2 = "current position of axis" for the analog output line using the Select Output Type parameter (ID 0x0A000003).

Example: With an E-712.6CDA, the *Out 1* analog output line (output signal channel 9) is to be used to monitor the position of axis 3. To select the corresponding output type in volatile memory, send:

SPA 9 0x0A000003 2

In PIMikroMove, this parameter is available in the *DAC 9* parameter group in the *Device Parameter Configuration* window. Note that for piezo amplifier channels, the output type is fixed to "control voltage of output signal channel" (1).

2 Connect the desired axis to the analog output line using the Select Output Index parameter (ID 0x0A000004).

Note:

An axis position results from the input matrix, see "Input Signal Processing" (p. 134) for more information.

In the example, to connect the axis 3 position to the *Out 1* analog output line (output signal channel 9), send:

SPA 9 0x0A000004 3

In PIMikroMove, this parameter is also available in the *DAC 9* parameter group in the *Device Parameter Configuration* window.

3 Scale the output value, i.e. associate the axis position values with suitable output levels (= scaled position values). To do this, set the Position Report Scaling parameter (ID 0x07001005) and the Position Report Offset parameter (ID 0x07001006) to suitable values for the appropriate axis. See also the figure below.

*ScaledPositionValue = PositionReportScaling * (PositionReportOffset + PositionValue)*

Example:

The position range of axis 3 with which the *Out 1* analog output line is to be used is contained in the TMN? response (is defined by the Range Limit Min parameter (ID 0x07000000)) and in the TMX? response (is defined by the Range Limit Max parameter (ID 0x07000001)). The range is -20 µm to +120 µm in the example. Furthermore, the output range to be used is -10 V to +10 V. The resulting parameter values for the axis position scaling are as follows:

The value of the Position Report Scaling parameter is 0.143.

The value of the Position Report Offset parameter is -50.

You must send:

SPA 3 0x07001005 0.143

SPA 3 0x07001006 -50

In PIMikroMove, these parameters for axis 3 are available in the *Servo 3* parameter group in the *Device Parameter Configuration* window.

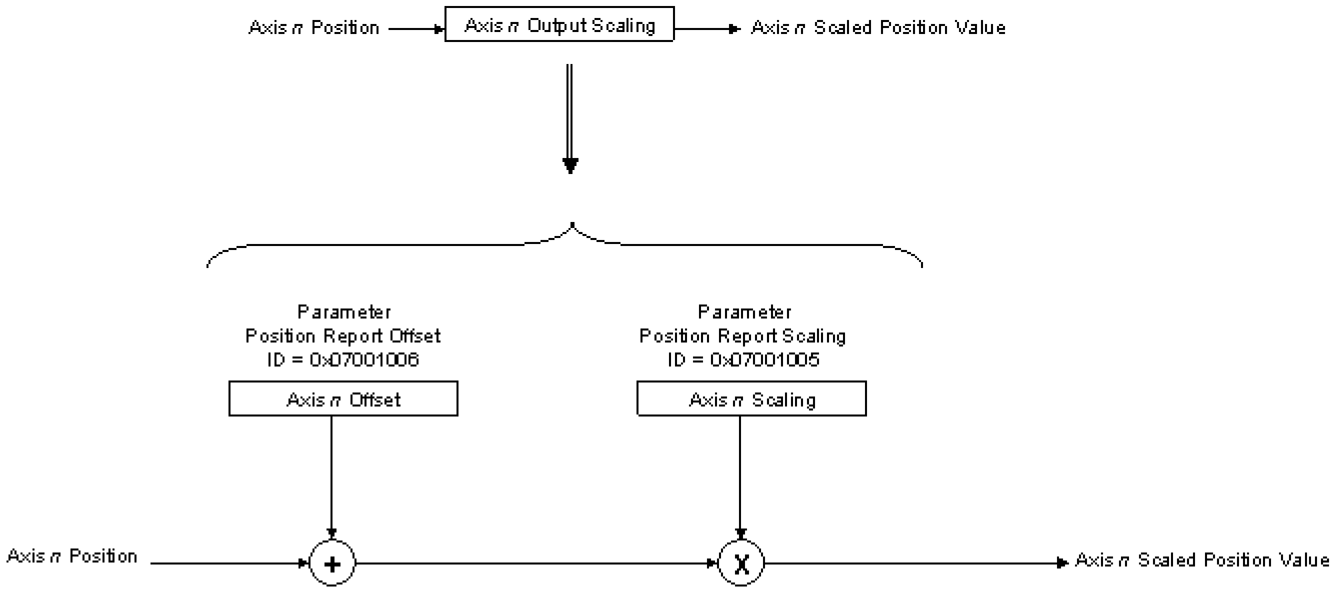


Figure 71: Processing of axis position output, detail from the overview figure

10.4 Analog-Output-Related Commands and Parameters

Command	**Description**	**Notes**
SEP	Set Nonvolatile Memory Parameters	Can be used to set the default configuration for analog output usage.
SEP?	Get Nonvolatile Memory Parameters	Reads the current parameter values from nonvolatile memory
SPA	Set Temporary Memory Parameters	Can be used to set a temporary configuration for analog output usage.
SPA?	Get Temporary Memory Parameters	Reads the current parameter values from volatile memory (RAM)
VOL?	Get Voltage Of Output Signal Channel	Reads output voltage value of the specified output signal channel, if the output type is set to "control voltage of output signal channel"
WPA	Save Parameters To Nonvolatile Memory	Can be used to save the currently active configuration (including analog output usage) to nonvolatile memory.

See "How to Work with the Analog Output—Overview" (p. 202) for more information. See the PZ233 GCS commands manual for detailed command descriptions. See "Accessible Items and Their Identifiers" (p. 127) for the identifiers of the items which can be addressed with the commands.

Parameter ID	Com-mand Level	Item Type	Max. No. Of Items	Data Type	Parameter Description
0x07001005	1	Logical Axis	E-712.3CDA: 3 E-712.6CDA: 6 E-712.6IDA: 6	FLOAT	Position Report Scaling Required if the axis position is to be output (output type = 2)
0x07001006	1	Logical Axis	E-712.3CDA: 3 E-712.6CDA: 6 E-712.6IDA: 6	FLOAT	Position Report Offset Required if the axis position is to be output (output type = 2)
0x09000000 to 0x0900000d	1	Logical Axis	E-712.3CDA: 3 E-712.6CDA: 6 E-712.6IDA: 6	FLOAT	Driving Factor of Piezo 1 to Driving Factor of Piezo 14 Specify the output matrix
0x0A000003	1	Output Signal Channel	E-712.3CDA: 8 (ch. 1 to 4 read-only) E-712.6CDA, .6IDA: 12 (ch. 1 to 8 read-only)	INT	Select Output Type 1 = control voltage of output signal channel 2 = current position of axis
0x0A000004	1	Output Signal Channel	E-712.3CDA: 8 (ch. 1 to 4 read-only) E-712.6CDA, .6IDA: 12 (ch. 1 to 8 read-only)	INT	Select Output Index The selected object can be an output signal channel or an axis (depends on the selected output type).
0x0e000b01	3	System	1	INT	Number Of Output Channels
0x0e000b04	3	System	1	INT	Number Of Piezo Channels

See "Parameters" (p. 276) for more information regarding the parameters and their handling.

11 Control via SPI Master

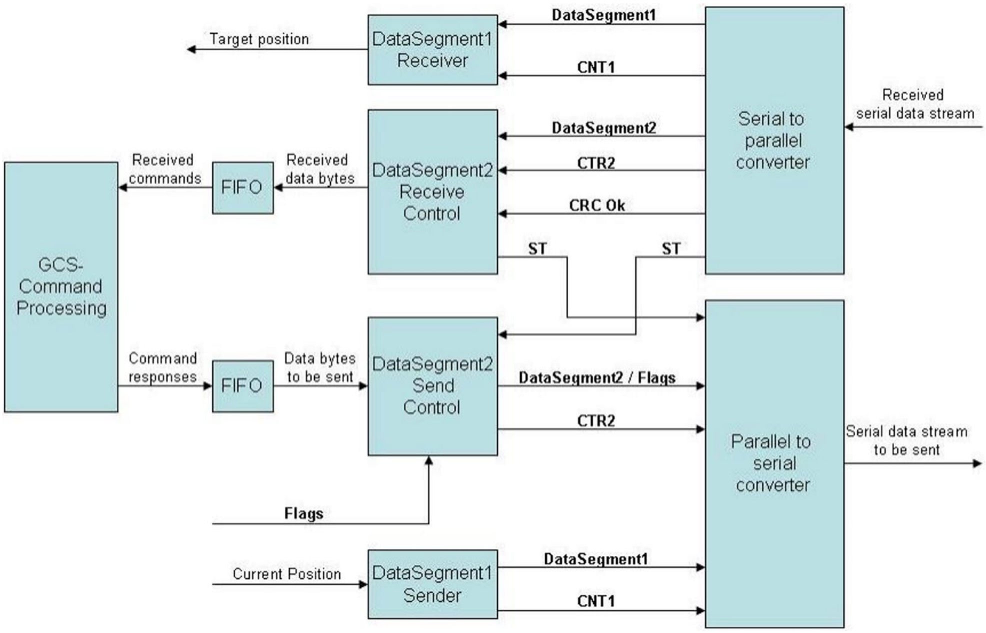
11.1 Definition of Terms

PI-controller: E-711/E-712 system, the SPI slave.

Host: SPI master unit which sends commands to the PI-controller.

11.2 Overview

The following block diagram shows the protocol architecture on PI-controller side. The signals shown in this diagram are described in the SPIST0001 user manual.



Data segment 1 is used here for fast transfer of target position and current position of the axes.

Data segment 2 is used here for slow transfer of GCS commands and command responses.

If no responses to GCS commands are sent the PI-controller can send flags, for example for the on-target state.

All transfers are initiated by the host.

11.3 Preparing the E-711/E-712 System as an SPI Slave

The input lines and output lines of the SPI slave interface are located on the E-712.M1 and E-712.N1 digital processor module of the E-711/E-712 system (p. 27).

In the E-711/E-712 system, the input values received via the SPI slave interface are handled as additional input signal channels (i.e. as if it would be analog input). This means that these inputs could be used for external sensors and/or as signal sources for control value generation (see "Using the Analog Input" (p. 190) for more information). **In this document, it is assumed that the inputs are used for control value generation, i.e. to transfer the target positions or open-loop control values for the axes**.

The values output via the SPI slave interface are handled by the E-711/E-712 system as additional output signal channels (i.e. as if it would be analog output). This means that these outputs could be used to control external amplifiers and/or to monitor axis positions (see "Using the Analog Output" (p. 202) for more information). **In this document, it is assumed that the outputs are used for axis position monitoring, i.e. to transfer the current positions of the axes.**

If the inputs and outputs have not already been configured by PI, the user can configure them via parameters of the E-711/E-712 system.

INFORMATION

It is strongly recommended to save the parameter values of the E-711/E-712 system to a file on the PC before you make any changes. This way the original settings can be restored if the new parameter settings will not prove satisfactory. To save the parameter values and to load them back to the E-711/E-712 system, use the *Device Parameter Configuration* window or PIMikroMove. See "Creating Backups for Parameter Values" (p. 109) for more information.

Wherever changing parameter values is mentioned, you can do this using SPA (volatile memory) or SEP (nonvolatile memory). Furthermore, you can use WPA to copy the current values from volatile memory to nonvolatile memory. To have write access to certain parameters, it might be necessary to switch to a higher command level using CCL. To read parameter values, query with the SPA? or SEP? commands.

The *Device Parameter Configuration* window of PIMikroMove gives access to parameter values in a more convenient way. Use this window to check/edit the individual parameters. See the PIMikroMove manual for more information.

You can configure the SPI slave interface of the E-711/E-712 system as follows:

1 Configure the number of additional input signal channels and output signal channels via the parameters SPI Slave Number Of Inputs (ID 0x0e001300) and SPI Slave Number Of Outputs (ID 0x0e001400). The maximum number of channels is 15 in each case.

   Device Parameter Configuration window: *System Global* parameter group

2 Configure each input signal channel that is to be used for the SPI slave interface:

   2.1 Scale the input channel to the minimum and maximum values to be transmitted in your application using the parameters Sensor Mech. Correction 1 (*OFFSET*; ID 0x02000200) and Sensor Mech. Correction 2 (*GAIN*; ID 0x02000300).

   Device Parameter Configuration window: *Sensor Mechanics* parameter groups

   2.2 Configure the numerical format of the data for the input signal channel via the Input Numerical Format parameter (ID 0x03003400).

   Device Parameter Configuration window: *Sensor Electronics* parameter groups

   2.3 Connect the input channel to the axis via the ADC Channel For Target parameter (ID 0x06000500).

   Device Parameter Configuration window: *Target Manipulation* parameter groups

3 Configure each output signal channel that is to be used for the SPI slave interface:

   3.1 Select the output type 2 = "current position of axis" via the Select Output Type parameter (ID 0x0a000003).

   Device Parameter Configuration window: *DAC* parameter groups

   3.2 Connect the output channel to the axis via the Select Output Index parameter (ID 0x0a000004).

Device Parameter Configuration window: *DAC* parameter groups

3.3 Scale the output channel to the minimum and maximum values to be transmitted in your application using the parameters Min Output Voltage of Amplifier (minimum value; ID 0x0b000007) and Max Output Voltage of Amplifier (maximum value; ID 0x0b000008).

Device Parameter Configuration window: *Driver* parameter groups

3.4 Configure the numerical format of the data for the output signal channel via the Output Numerical Format parameter (ID 0x0b000500).

Device Parameter Configuration window: *Driver* parameter groups

11.4 Using the SPI Interface

See the SPIST0001 user manual for the SPI protocol description.

12 Wave Generator

Each axis can be controlled by a "wave generator" which outputs so-called "waveforms". This feature is especially important in dynamic applications which require periodic, synchronous motion of the axes. The waveforms to be output are saved in "wave tables" in the controller’s volatile memory—one waveform per wave table. Waveforms can be defined based on predefined "curve" types. This can be sine, ramp or single scan line curves. In addition, a curve type for user-defined curves can be selected. Programmable trigger inputs and outputs facilitate synchronization of external events.

In "How to Work with the Wave Generator" (p. 214) and "Wave Generator Examples" (p. 221) you will learn how to use the wave generator. "Wave-Generator-Related Commands and Parameters" (p. 232) gives an overview.

The Dynamic Digital Linearization (DDL) option can be used in conjunction with the wave generator output in addition to the "normal" control algorithm. See "Dynamic Digital Linearization (DDL)" (p. 235) for more information.

During the wave generator output, data is recorded in "data recorder tables" on the controller. See "Data Recording" (p. 164) for more information.

12.1 How to Work with the Wave Generator

The following subsections describe the wave generator handling. See "Wave Generator Examples" (p. 221) for more information.

12.1.1 Basic Data

The number of wave tables can be queried as the value of the parameter with ID 0x1300010A using the SPA? command. The E-711/E-712 system has 90 wave tables for defining and (temporarily) storing arbitrary waveforms (identifiers are 1 to 90).

To query the number of wave generators, use the TWG? command. The assignment of wave generators and axes to each other is fixed: wave generator 1 is connected to axis 1, wave generator 2 to axis 2, ..., wave generator *n* to axis *n*.

The available wave tables can be flexibly assigned to the wave generators and hence to the axes using the WSL command. A wave table can be used by multiple wave generators at the same time.

A certain amount of the controller's memory space is reserved for the waveform data (ask with the SPA? command for the value of the parameter with ID 0x13000004). The E-711/E-712 system provides 2^{18} data points for waveform definition. This memory space is (temporarily) allocated to the individual wave tables during the waveform definition.

12.1.2 Basic Operation

1. Define the waveform segment-by-segment using the WAV command. The waveform will be written to the selected wave table.

2. Connect the wave generator to the wave table using the WSL command.

3. Start the wave generator output and hence the motion of the axis using the WGO command. You can choose several start options (e.g., start/stop by external trigger, initialization/usage of the Dynamic Digital Linearization (DDL) option; see the description of the WGO command and "Dynamic Digital Linearization (DDL)" (p. 235) for more information).

   When starting the wave generator, data recording is started automatically.

4. Stop the wave generator output with WGO or #24 or STP.

A simple example for your first steps (using the command entry facilities of PIMikroMove or PITerminal):

Command String to Send	Action Performed
WAV 4 X SIN_P 2000 20 10 2000 0 1000	Define a sine waveform for wave table 4; see the WAV description for more information
WSL 1 4	Connect the wave generator 1 (axis 1) to wave table 4
WGO 1 1	Start output of wave generator 1 immediately (synchronized by control loop cycles)
WGO 1 0	Stop output of wave generator 1

12.1.3 Additional Steps and Settings

You can calculate the memory space remaining if you query the current wave table length with WAV?. To release memory space, delete the content of selected wave tables with the WCL command.

After you send the waveform definition to the wave table (with WAV), it is always a good idea to check it by reading back the waveform from the controller before outputting it. This can be done by the GWD? command. Note that the response to GWD? does not contain any offset set with WOS to the wave generator output.

You can add an offset to the output of a wave generator using the WOS command. Thereafter, the output of the specified wave generator is the sum of the offset value and the wave value:

Wave generator output = offset + current wave value

If the wave generator is started with the option "start at the endpoint of the last cycle", the E-711/E-712 system at the end of each output cycle equates the WOS offset value with the current wave generator output.

WOS sets the value of the Wave Offset parameter (ID 0x1300010b) in volatile memory. You can also change this parameter with SPA or SEP and save the value to nonvolatile memory with WPA (switch to command level 1 before with the CCL command).

Deleting wave table content with WCL has no effect on the WOS settings.

For trigger tasks, the wave generator output can be coupled with the digital output lines *OUT1* to *OUT7* of the controller (see "Digital I/O Connector" (p. 335)). You should first use TWC to set the state of the digital output lines to *low* for all waveform points (*low* is also the default). Then use the TWS command to define the trigger actions by setting the states (*high* or *low*) of selected digital output lines for selected waveform points. At last, use the CTO command to activate the *Generator Level Trigger* mode or *Generator Pulse Trigger* mode for the selected digital output lines.

The single-character command #9 can be used to query the current activation state of the wave generators. The response shows if a wave generator is running or not but does not contain any information about the wave generator start mode (e.g., with DDL). With WGO? you can query the last commanded wave generator start options (WGO settings).

You can limit the duration of the wave generator output by setting the number of output cycles with WGC. The waveform itself remains unchanged.

Using the WTR command, you can lengthen the individual output cycles of the waveform. The duration of one output cycle for the waveform can be calculated as follows:

Output duration = control loop sampling time * WTR value * number of points

where

The control loop sampling time is specified in seconds by the parameter with ID 0x0E000200.

The WTR value specifies the number of control loop cycles the output of a waveform point lasts; default is 1.

The number of points is the length of the waveform (i.e. the length of the wave table).

WTR sets the value of the Wave Generator Table Rate parameter (ID 0x13000109) in volatile memory. You can change this parameter also with SPA or SEP and save the value to nonvolatile memory with WPA (switch to command level 1 before with the CCL command). The value is always valid for the whole system and cannot be set separately for individual wave generators. The value of the parameter in volatile memory can be read with the WTR? command.

WTR also sets the type of interpolation to use for the wave generator output. If the Wave Generator Table Rate is larger than 1, interpolation helps to avoid sudden position jumps of an axis controlled by the wave generator.

With WGR you can restart data recording while the wave generator is running. The recorded data can be read with the DRR? command. See "Data Recording" (p. 164) for more information.

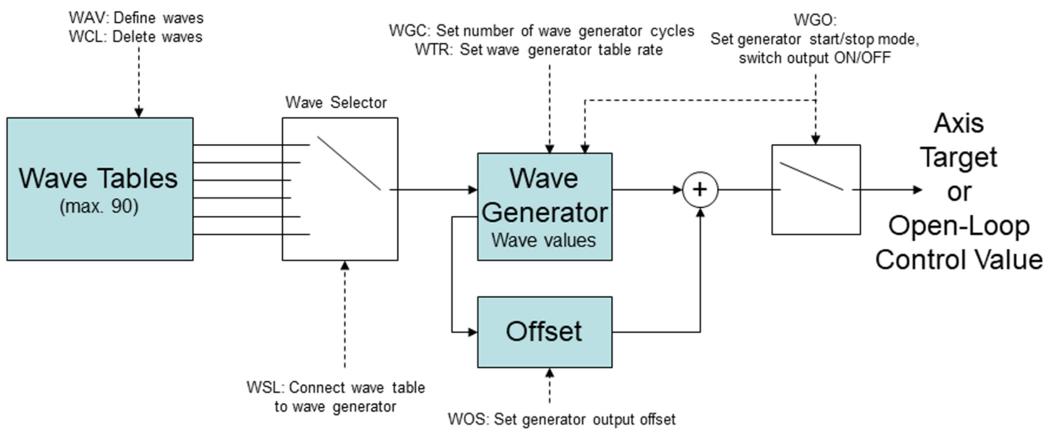


Figure 72: Block diagram of one wave generator

12.1.4 Application Notes

All wave generators can run simultaneously. All waveform output is synchronized because there is a common pulse generator used by all wave generators. For that reasons, wave tables which are supposed to run at the same time (each with one wave generator) should have the same length. If the wave tables have different lengths, an output cycle will comprise only the number of points contained in the shortest table. This means that all waveform output is cut to the length of the shortest waveform currently output.

Waveforms cannot be changed while they are being output by a wave generator. If you want to modify a waveform with WAV, first stop any wave generator output from the associated wave table.

The frequency of the wave generator output depends, among other factors, on the wave table length. When you define waveforms, keep in mind that the usable frequency is limited by the available amplifier power. Example: with a capacitive load of 6.6 µF, the frequency should not exceed 15 Hz if three amplifiers are involved in the motion or 50 Hz if only one amplifier is involved. If the frequency is too high, overheating of the amplifiers can occur, and the piezo voltage output will be deactivated automatically. If that occurs, the piezo stage will not move although communication with the controller is still possible.

When you use the wave generator to create white noise for a measurement (WAV command with <WaveType> = "NOISE"), make sure that the wave table segment is at least as long as the duration of the measurement. Otherwise, the noise sequence will be repeated during the measurement and will no longer be white noise.

Wave generator output and analog control input: It is possible to configure an axis for control by an analog input line while the wave generator output is active for that axis. In that case, the wave generator will continue running, but its output will no longer be used for control value generation. If the corresponding axis is set up to be commanded by analog control input, you can stop the wave generator output, but not restart it.

Wave generator output and motion commands: When the wave generator output is active, motion commands like MOV or SVA are not allowed for the associated axis.

See "Control Value Generation" (p. 139) for more information.

When the wave generator is to be started by an external trigger signal (WGO bit 1 is set): For reliable triggering, the pulse width of the digital input signal must be at least 2 x the control loop sampling time of the E-711/E-712 system (the control loop sampling time is specified in seconds by the parameter with ID 0x0E000200). The value of the Wave Multi Start By Trigger parameter (ID 0x13000202) determines if the trigger is enabled for only one wave generator start or for multiple starts. See "Wave Generator Started by Trigger Input" (p. 230) for more information and an example.

In closed-loop operation, the wave generator output is interpreted as target positions in either case. In open-loop operation, the interpretation of the wave generator output depends on the settings of the output matrix (see "Output Generation" (p. 143) for more information). By default, the matrix is set up so that commanded open-loop control values numerically correspond to axis position values.

The operating mode cannot be switched to open-loop operation (SVO) while a wave generator is running for the axis.

If a wave generator is running, it is not possible to change (WSL) or to delete (WCL) the connected wave table (i.e. the waveform). The wave generator table rate (WTR), the number of output cycles (WGC), the wave offset (WOS) and the trigger output settings (TWS) can be modified while a wave generator is running.

When a wave generator finishes by running through a specified number of cycles completely, the final position will be the first point of the waveform, unless the option "start at the endpoint of the last cycle" was selected. In that case, the final position is the sum of the endpoint of the last output cycle and any offset defined with WAV for the waveform.

When the wave generator is stopped within an output cycle by command, the axis will remain at the last output position until a new position is commanded. If the wave generator is then restarted, it will normally continue with the first point of the waveform, unless started with the option "start wave generator output triggered by external signal", and the digital input line *IN2* (see "Digital I/O Connector" (p. 335)) is used for triggering. In that case, the wave generator starts with the first rising edge which is detected on this input line, and it will be stopped when a falling edge is detected on this line. With the next rising edge, the wave generator output will continue at the waveform point where it was stopped.

Wave generator output will continue even if the terminal or the program from which it was started is quit or if the piezo voltage output is deactivated.

See the WGO command for more information.

The following data is always lost when the controller is switched off or rebooted:

- Wave table content (WAV)
- Assignment of wave tables to wave generators (WSL)

- Trigger output settings (TWS)
- Number of cycles for wave generator output (WGC)

The following settings can be saved with WPA to nonvolatile memory (switch to command level 1 before with the CCL command):

- Wave offset (WOS)
- Wave generator table rate (WTR)

INFORMATION

You can permanently save the settings of the wave generator in the E-711/E-712 system with the macro functionality (p. 245). You can also use a startup macro to configure the wave generator and start the output every time the E-711/E-712 system is switched on or rebooted.

The different software interfaces provided for the controller also support use of the wave generator. Waveforms can be defined, saved and displayed in and by the software in a more convenient way than in a terminal using WAV and WGO. If using the wave generator with the PC software from PI, read the descriptions in the associated software manual first.

INFORMATION

It is recommended to use the *Frequency Generator* window or the *Wave Generator* window of PIMikroMove.

No command knowledge is necessary to work with PIMikroMove. See the PIMikroMove manual (SM148E) for more information.

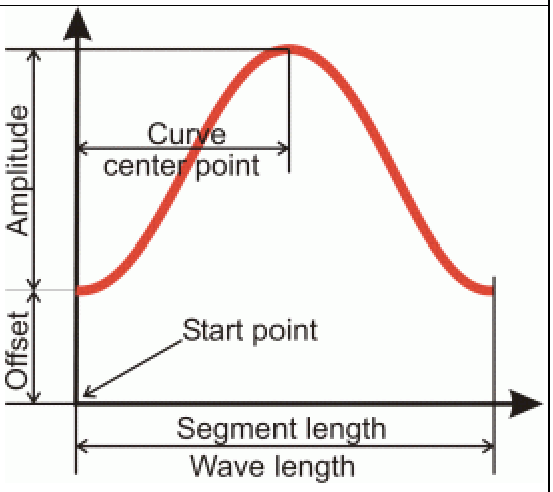
12.2 Wave Generator Examples

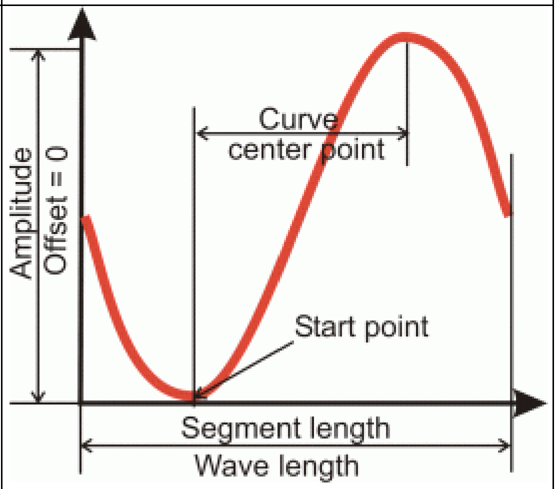
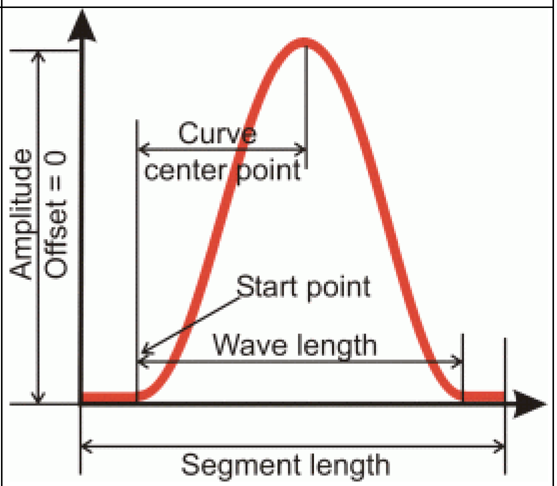
The following examples can be reproduced using the command entry facilities of PIMikroMove or PI Terminal. Note that it might be necessary to adapt them to your hardware configuration.

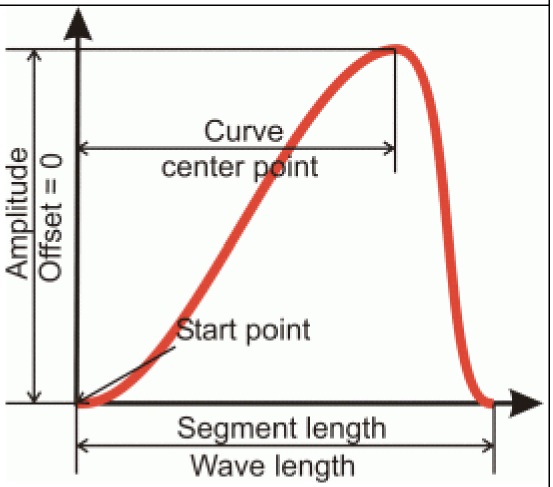
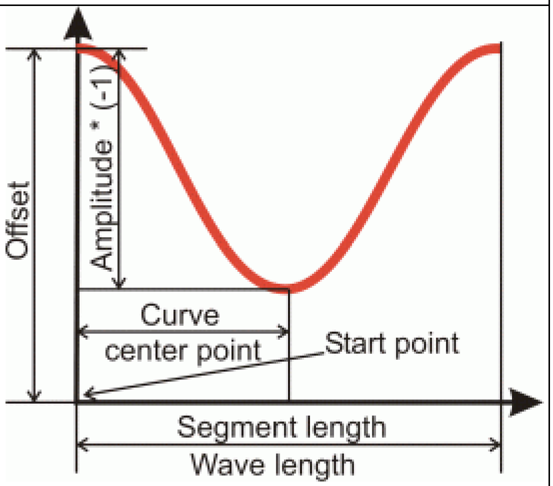
12.2.1 Defining Waveforms

Examples for how to define waveform segments for the wave tables, based on predefined curve types (each WAV command defines a waveform segment which either replaces or is appended to the waveform in the specified wave table):

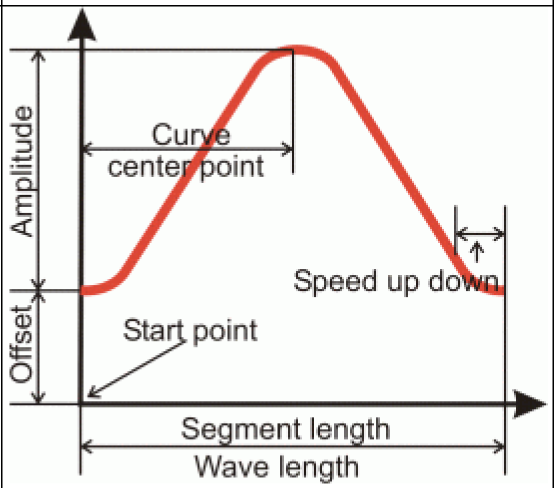
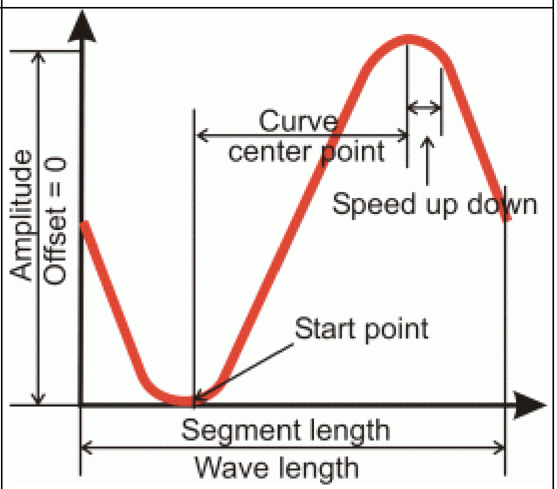
Sine Curves

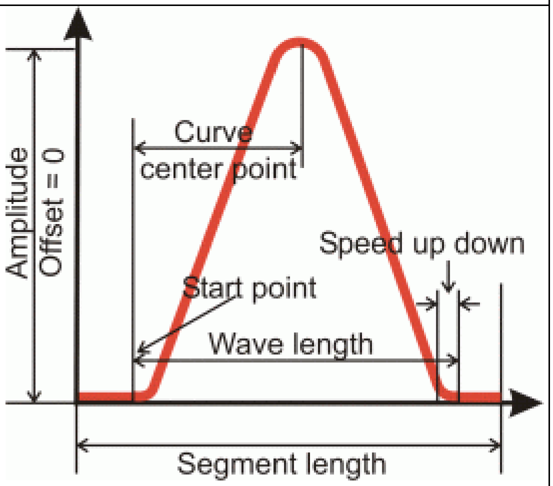
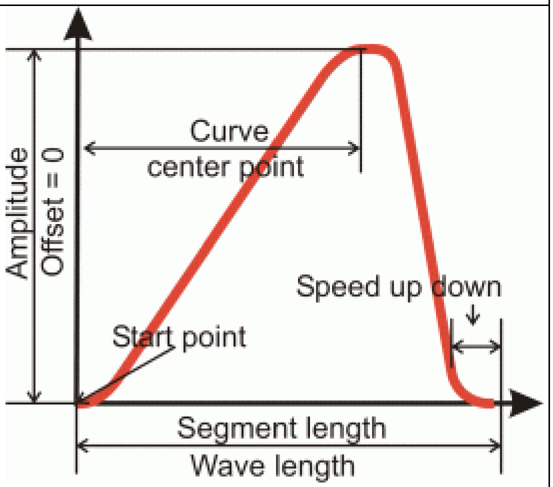
WAV command	Comments	Waveform Segment
WAV 2 X SIN_P 2000 20 10 2000 0 1000 <WaveTableID> = 2 <AppendWave> = X <WaveType> = SIN_P <SegLength> = 2000 <Amp> = 20 <Offset> = 10 <WaveLength> = 2000 <StartPoint> = 0 <CurveCenterPoint> = 1000	The previous content of the wave table is overwritten by the new segment. Waveform offset = 10 Do not confuse with the wave generator output offset set with WOS! Symmetric curve	

WAV command	Comments	Waveform Segment
WAV 2 X SIN_P 2000 30 0 2000 499 1000 <WaveTableID> = 2 <AppendWave> = X <WaveType> = SIN_P <SegLength> = 2000 <Amp> = 30 <Offset> = 0 <WaveLength> = 2000 <StartPoint> = 499 <CurveCenterPoint> = 1000	The previous content of the wave table is overwritten by the new segment. Symmetric curve	
WAV 2 & SIN_P 2000 25 0 1800 100 900 <WaveTableID> = 2 <AppendWave> = & <WaveType> = SIN_P <SegLength> = 2000 <Amp> = 25 <Offset> = 0 <WaveLength> = 1800 <StartPoint> = 100 <CurveCenterPoint> = 900	The defined segment will be appended to the existing wave table content. Symmetric curve	

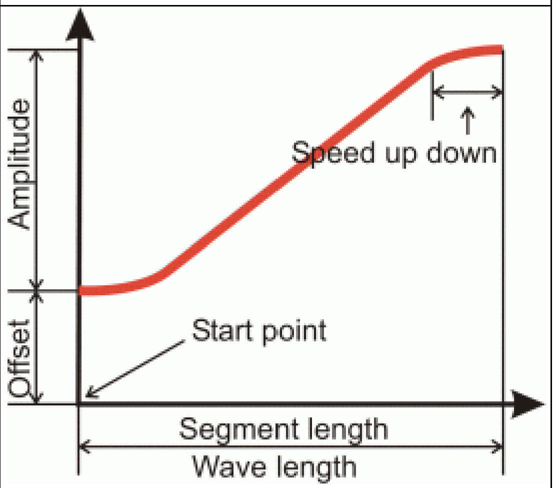
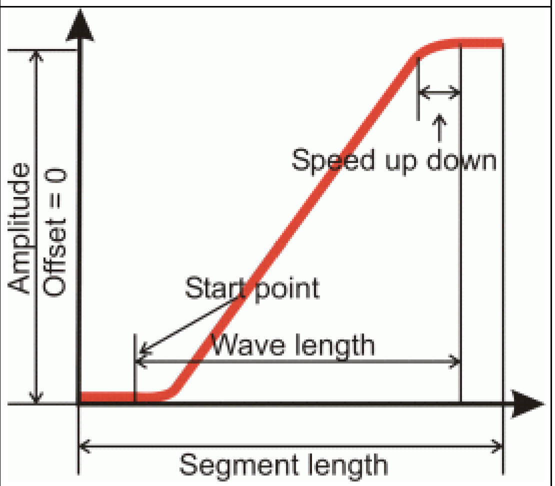
WAV command	Comments	Waveform Segment
WAV 3 X SIN_P 4000 20 0 4000 0 3100 <WaveTableID> = 3 <AppendWave> = X <WaveType> = SIN_P <SegLength> = 4000 <Amp> = 20 <Offset> = 0 <WaveLength> = 4000 <StartPoint> = 0 <CurveCenterPoint> = 3100	The previous content of the wave table is overwritten by the new segment. Asymmetric curve	
WAV 2 X SIN_P 1000 -30 45 1000 0 500 <WaveTableID> = 2 <AppendWave> = X <WaveType> = SIN_P <SegLength> = 1000 <Amp> = -30 <Offset> = 45 <WaveLength> = 1000 <StartPoint> = 0 <CurveCenterPoint> = 500	The previous content of the wave table is overwritten by the new segment. Negative-amplitude curve Symmetric curve	

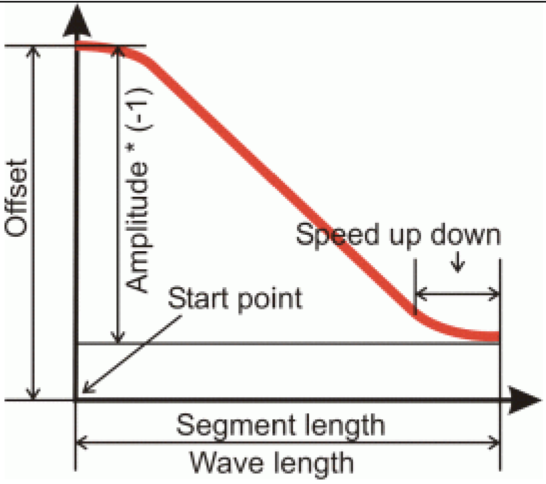
Ramp Curves

WAV command	Comments	Waveform Segment
WAV 4 X RAMP 2000 20 10 2000 0 300 1000 <WaveTableID> = 4 <AppendWave> = X <WaveType> = RAMP <SegLength> = 2000 <Amp> = 20 <Offset> = 10 <WaveLength> = 2000 <StartPoint> = 0 <SpeedUpDown> = 300 <CurveCenterPoint> = 1000	The previous content of the wave table is overwritten by the new segment. Waveform offset = 10 Do not confuse with the wave generator output offset set with WOS! Symmetric curve	
WAV 4 X RAMP 2000 35 0 2000 499 300 1000 <WaveTableID> = 4 <AppendWave> = X <WaveType> = RAMP <SegLength> = 2000 <Amp> = 35 <Offset> = 0 <WaveLength> = 2000 <StartPoint> = 499 <SpeedUpDown> = 300 <CurveCenterPoint> = 1000	The previous content of the wave table is overwritten by the new segment. Symmetric curve	

WAV command	**Comments**	**Waveform Segment**
WAV 5 X RAMP 2000 15 0 1800 120 150 900 <WaveTableID> = 5 <AppendWave> = X <WaveType> = RAMP <SegLength> = 2000 <Amp> = 15 <Offset> = 0 <WaveLength> = 1800 <StartPoint> = 120 <SpeedUpDown> = 150 <CurveCenterPoint> = 900	The previous content of the wave table is overwritten by the new segment. Symmetric curve	
WAV 5 & RAMP 3000 35 0 3000 0 200 2250 <WaveTableID> = 5 <AppendWave> = & <WaveType> = RAMP <SegLength> = 3000 <Amp> = 35 <Offset> = 0 <WaveLength> = 3000 <StartPoint> = 0 <SpeedUpDown> = 200 <CurveCenterPoint> = 2250	The defined segment will be appended to the existing wave table content. Asymmetric curve	

Single Scan Line Curves

WAV command	Comments	Waveform Segment
WAV 1 X LIN 1500 30 15 1500 0 370 <WaveTableID> = 1 <AppendWave> = X <WaveType> = LIN <SegLength> = 1500 <Amp> = 30 <Offset> = 15 <WaveLength> = 1500 <StartPoint> = 0 <SpeedUpDown> = 370	The previous content of the wave table is overwritten by the new segment. Waveform offset = 15 Do not confuse with the wave generator output offset set with WOS!	
WAV 2 X LIN 1500 40 0 1100 210 180 <WaveTableID> = 2 <AppendWave> = X <WaveType> = LIN <SegLength> = 1500 <Amp> = 40 <Offset> = 0 <WaveLength> = 1100 <StartPoint> = 210 <SpeedUpDown> = 180	The previous content of the wave table is overwritten by the new segment.	

WAV command	Comments	Waveform Segment
WAV 2 & LIN 3000 -40 50 3000 0 650 <WaveTableID> = 2 <AppendWave> = & <WaveType> = LIN <SegLength> = 3000 <Amp> = -40 <Offset> = 50 <WaveLength> = 3000 <StartPoint> = 0 <SpeedUpDown> = 650	The defined segment will be appended to the existing wave table content. Negative-amplitude curve	

12.2.2 Modifying the Wave Generator Table Rate

An example for how to modify the duration of the wave generator output using the wave generator table rate:

Command String to Send	Action Performed
WAV 2 X SIN_P 2000 20 10 2000 0 1000	Define a sine waveform for wave table 2, the segment length and hence the number of points in the wave table is 2000
SPA? 1 0x0E000200	Ask for the E-711/E-712 system’s control loop sampling time (reading the wave table for wave generator output is clocked by control loop cycles). An E-712.3CD, for example, has a control loop sampling time of 20 µs.

Command String to Send	Action Performed
WTR?	Ask for the current wave generator table rate and interpolation settings, default is wave generator table rate = 1 (i.e. the output of one wave table point takes one control loop cycle). The duration of of one output cycle for the waveform will be: Control loop sampling time (in s) * WTR value * number of points = output duration (in s) 0.000020 s * 1 * 2000 = 0.04 s
WTR 0 3 1	Set the wave generator table rate to 3, tripling the duration of one output cycle for the waveform, with linear interpolation (the output of one wave table point now takes three control loop cycles, with linear interpolation to smooth the output). Duration of one output cycle will now be: 0.000020 s * 3 * 2000 = 0.12 s Note that the WTR command must always specify all wave generators in the system (<WaveGenID> must be 0).

12.2.3 Trigger Output Synchronized with Wave Generator

Using the digital output lines *OUT1* to *OUT7* of the E-711/E-712 system, it is possible to trigger external devices. See "Digital I/O Connector" (p. 335) for the availability of the lines (pinout) and "Configuring Trigger Output" (p. 168) for more information.

An example for how to generate trigger pulses synchronized with the wave generator in *Generator Level Trigger* mode:

Command String to Send	Action Performed
WAV 2 X SIN_P 2000 20 10 2000 0 1000	Define a sine waveform for wave table 2, the segment length and hence the number of points in the wave table is 2000
TWC	Clears all trigger output settings for the wave generators by setting the state of all digital output lines for all points to *low* (for all points, the default state of the digital output line is also *low*). It is recommended to use TWC before new trigger actions are defined.
TWS 1 500 1 1 1500 1 1 1900 1 1 2000 1	Set trigger actions for the digital output line *OUT1* (identifier is 1): at the waveform points 500, 1500, 1900 and 2000 it is set *high*; at all other points the state of the line is *low* (due to the TWC usage).
CTO 1 3 4	The digital output line *OUT1* is set to *Generator Level Trigger* mode.
WSL 1 2	Connect wave generator 1 (axis 1) to wave table 2
WGO 1 1	Start output of wave generator 1 immediately (synchronized by control loop cycle). Now the trigger output will take place as specified.
WGO 1 0	Stop output of wave generator 1 and hence also the trigger output.

INFORMATION

If a phase shift between the trigger output and the actual position is observed when the wave generator is running with the "Use DDL" or "Use and reinitialize DDL" options (actual position measured with external device is ahead of the trigger output), check the cut-off-frequency f_g of the IIR low-pass filter used for digital filtering and increase it to shorten the duration of the digital filtering. See below for more information.

The duration of the signal processing for an internal sensor results from two portions:

- Duration of the analog sensor processing, which takes about 80 µs for the E-711/E-712 system

- Duration of the digital filtering. If the Digital Filter Type parameter (ID 0x05000000) is set to "IIR low-pass filter, 2nd order", the required time depends on the cut-off-frequency f_g of the IIR low-pass filter which is specified by the Digital Filter Bandwidth parameter (ID 0x05000001). For signal frequencies $f < f_g/2$, the duration of the filtering can be estimated as follows:

  $t \approx 0.216 / f_g$

  If required, increase f_g. Examples:

  f_g = 300 Hz: t = 0.72 ms

  f_g = 1000 Hz: t = 0.216 ms

12.2.4 Wave Generator Started by Trigger Input

Using the digital input lines of the E-711/E-712 system, it is possible to apply start/stop signals for the wave generator output. See the pinout description of the *Digital I/O* connector (p. 335) for the availability of the lines and "Using Digital Input" (p. 168) for an overview.

INFORMATION

For reliable triggering, the pulse width of the digital input signal must be at least 2 x the control loop sampling time of the E-711/E-712 system. The control loop sampling time is specified in seconds by the parameter with ID 0x0E000200.

An example for how to start and stop the wave generator by external trigger signals:

Command String to Send	Action Performed
WAV 2 X SIN_P 2000 20 10 2000 0 1000	Define a sine waveform for wave table 2, the segment length and hence the number of points in the wave table is 2000
WSL 1 2	Connect wave generator 1 (axis 1) to wave table 2

Command String to Send	Action Performed
WGO 1 2	Start output of wave generator 1 triggered by external signal. To provide the external signal, the digital input lines *IN1* or *IN2* can be used. If *IN1* is used: The wave generator output starts with the first rising edge which is detected on this input line. If *IN2* is used: The wave generator output starts with the first rising edge which is detected on this input line, and it will be stopped when a falling edge is detected on this line. With the next rising edge, the wave generator output will continue at the waveform point where it was stopped. Starting and stopping the wave generator this way can be repeated indefinitely. If output cycle limitations were made with WGC: with each wave generator restart the counting of the output cycles continues, and the wave generator will be stopped when the specified number of cycles are completed, irrespective of any further trigger pulses. It is possible to mix the usage of both digital input lines.
WGO 1 0	Stop output of wave generator 1 (any further trigger pulses will be ignored). You can also use #24 or STP.

INFORMATION

When the wave generator is to be started by an external trigger signal (WGO bit 1 is set), the value of the Wave Multi Start By Trigger parameter (ID 0x13000202) determines if the trigger is enabled for only one wave generator start or for multiple starts:

0 = Trigger is enabled for only one wave generator start. Trigger becomes disabled after the wave generator has been started. To enable the trigger again, WGO must be sent again with start mode bit 1 set. Default setting.

1 = If WGO bit 1 is set, the trigger stays enabled for an unlimited number of wave generator starts. To disable the trigger, the wave generator output must be stopped with WGO, STP or #24.

12.3 Wave-Generator-Related Commands and Parameters

Command	Description	Notes
CTO	Set Configuration Of Trigger Output	Activates the *Generator Level Trigger* mode or *Generator Pulse Trigger* mode which is required for the trigger actions set with TWS.
DDL?	Get DDL Table Values	Reads the current content of the DDL tables. DDL initialization and usage are started by the wave generator start command (WGO).
DRR?	Get Recorded Data Values	Reads the last recorded data. Data recording is triggered by the WGO and WGR commands (among others).
GWD?	Get Wave Table Data	Should be used to check the waveform before the wave generator output is started.
TWC	Clear All Wave Related Triggers	Clears only the TWS settings, but not the CTO settings.
TWG?	Get Number Of Wave Generators	Number of wave generators = number of axes
TWS	Set TriggerLine Action To Waveform Point	In addition, the CTO command must be used to activate the *Generator Level Trigger* mode or *Generator Pulse Trigger* mode for the desired digital output line.
WAV	Set Waveform Definition	A waveform must be defined before the wave generator output can be started.
WAV?	Get Waveform Definition	Reads the current wave table length.
WCL	Clear Wave Table Data	Clears the wave table content, but not the WSL and WOS settings.
WGC	Set Number Of Wave Generator Cycles	If WGC is not used, the wave generator must be stopped with WGO, #24 or STP.
WGC?	Get Number Of Wave Generator Cycles	
WGO	Set Wave Generator Start/Stop Mode	The WGO command starts the wave generator output. It provides several start options, e.g., "Start wave generator output triggered by external signal", "Use and reinitialize DDL" or "Use DDL".

Command	Description	Notes
WGO?	Get Wave Generator Start/Stop Mode	Gets the last commanded start options, but not the activation state (use #9 instead)
WGR	Starts Recording in Sync with Wave Generator	Restarts data recording if a wave generator is running.
WOS	Set Wave Generator Output Offset	Sets the value of the Wave Offset parameter (ID 0x1300010b) in volatile memory.
WOS?	Get Wave Generator Output Offset	Gets the value of the Wave Offset parameter (ID 0x1300010b) from volatile memory.
WSL	Set Connection Of Wave Table To Wave Generator	Must be set before the wave generator can be started.
WSL?	Get Connection Of Wave Table To Wave Generator	
WTR	Set Wave Generator Table Rate	Sets the value of the Wave Generator Table Rate parameter (ID 0x13000109) in volatile memory; determines the interpolation type for wave generator table rate values > 1.
WTR?	Get Wave Generator Table Rate	Gets the value of the Wave Generator Table Rate parameter (ID 0x13000109) from volatile memory and the current interpolation type.
#9	Get Wave Generator State	Gets the current activation state of the wave generator, but not the start options (use WGO? instead)

See "How to Work with the Wave Generator" (p. 214) for more information. See the PZ233 GCS commands manual for detailed command descriptions. See "Accessible Items and Their Identifiers" (p. 127) for the identifiers of the items which can be addressed with the commands.

Parameter ID	Com-mand Level	Item Type	Max. No. of Items	Data Type	Parameter Description
0x13000004	3	System	1	INT	Max Wave Points
0x13000109	1	System	1	INT	Wave Generator Table Rate
0x1300010a	3	System	1	INT	Number of Waves

Parameter ID	Com-mand Level	Item Type	Max. No. of Items	Data Type	Parameter Description
0x1300010b	1	Logical Axis	E-712.3CD, .3CDA: 3 E-712.6CD, .6CDA, .6IDA: 6	FLOAT	Wave Offset
0x13000202	1	System	1	INT	Wave Multi Start By Trigger

See "Parameters" (p. 276) for more information regarding the parameters and their handling.

13 Dynamic Digital Linearization (DDL)

Dynamic Digital Linearization (DDL) makes it possible to achieve significantly better position accuracy in dynamic applications with periodic motion. It is used in conjunction with the wave generator output and in addition to the "normal" control algorithm in closed-loop operation of an axis. DDL "observes" axis motion over one or more wave generator output cycles (DDL initialization). The information gathered is written to "DDL tables" and can then be used to refine the control output signals.

"Working Principle" (p. 235) describes the DDL basics, "How to Activate the DDL License" (p. 238) gives information on how to get the DDL started the first time, in "How to Work with the DDL" (p. 240) you will learn how to use the DDL option, and "DDL-Related Commands and Parameters" (p. 243) gives a summary.

See "Wave Generator" (p. 210) for more information.

13.1 Working Principle

For periodic motion it is possible to record the tracking error for an axis during one or more DDL initialization cycles and then compensate for the error in all subsequent cycles. The principle of DDL is thus the inclusion of a regulating error-feedback loop in addition to the PID control algorithm.

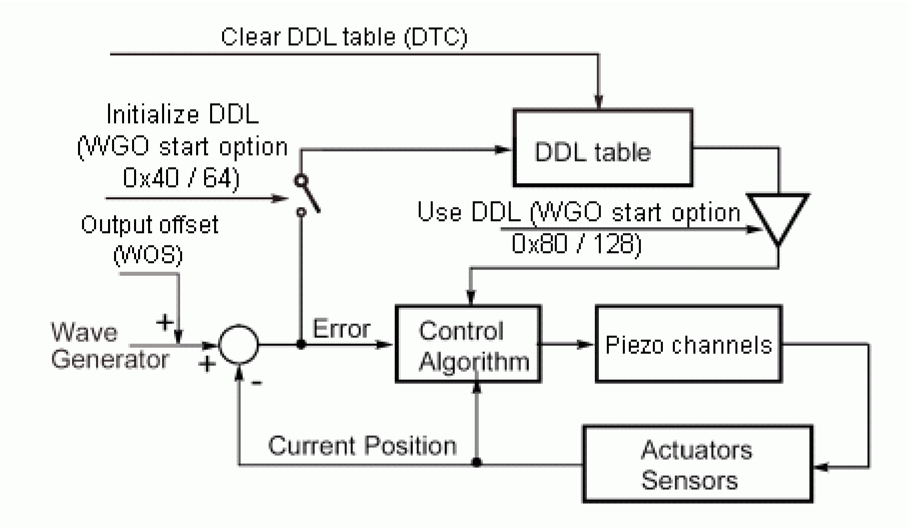


Figure 73: DDL block diagram, for one axis

Example:

A simple 400 µm forward and backward scan at 2.5 Hz.

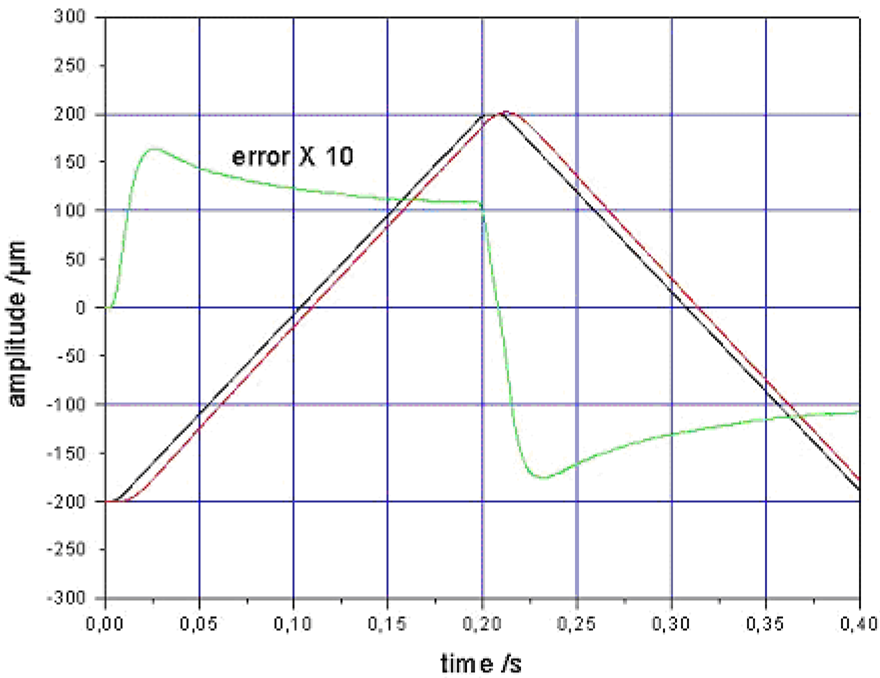


Figure 74: Without DDL

With DDL, after only one initialization cycle the tracking error can be considerably reduced.

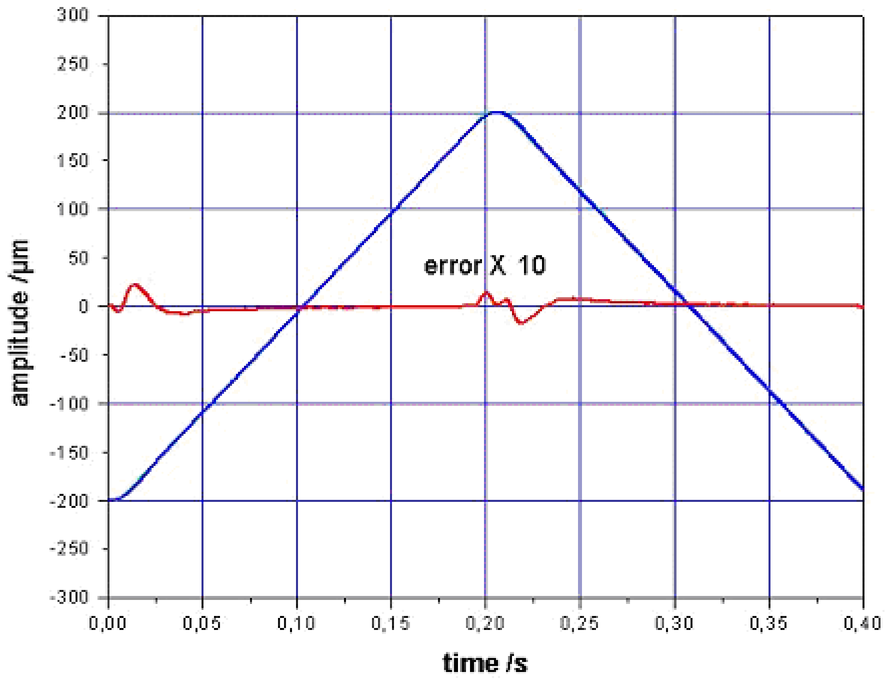


Figure 75: With DDL, one initialization cycle

With more DDL initialization cycles, the tracking error can be further reduced.

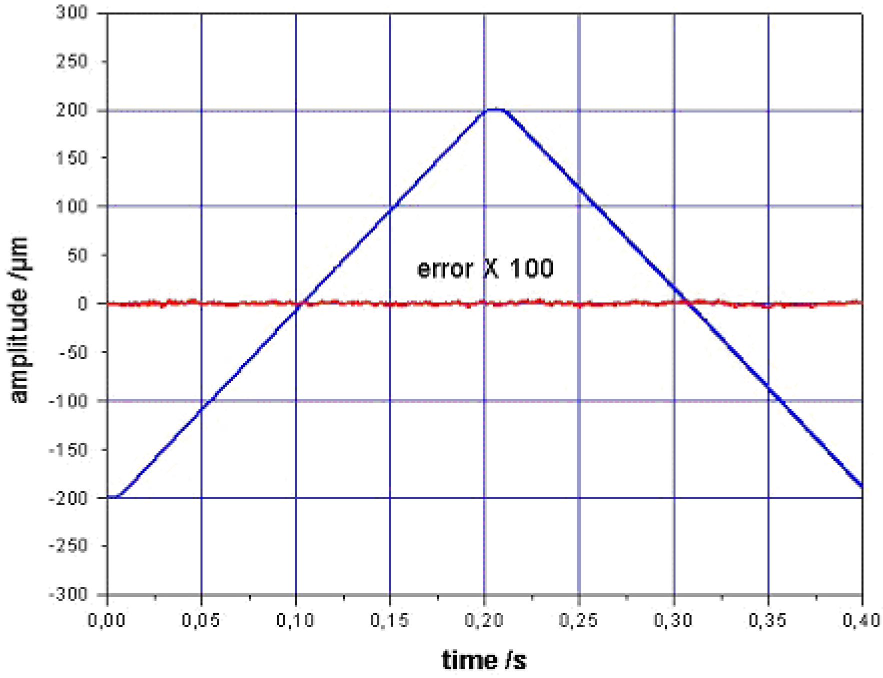


Figure 76: With DDL, after several DDL initialization cycles

13.2 How to Activate the DDL License

The Dynamic Digital Linearization (DDL) option must be expressly ordered (order number E-710.SCN). You can activate DDL after purchase and without opening the device.

To activate the DDL license, proceed as follows:

1. Order DDL for your controller and inform PI of the controller serial number. PI generates your DDL license number based on this information.

   The serial number is saved in the controller as the Device S/N parameter (ID 0x0D000000).

   You can read it in PIMikroMove or using the commands SPA? or SEP?:

   Send: SPA? 1 0x0D000000 (reads the value from volatile memory)
   or
   Send: SEP? 1 0x0D000000 (reads the value from nonvolatile memory)

2 PI will provide you with the DDL license number.

3 Switch to command level 1 using the CCL command:

Send: CCL 1 advanced

4 Write the DDL license number to the nonvolatile memory of your controller using the DDL License parameter (ID 0x0E000400).

You can do this in PIMikroMove or using the SEP command:

Send: SEP 100 1 0x0E000400 *licensenumber*

5 Switch the controller off and on again.

6 Check if the DDL activation was successful. To do this, read the value of the DDL License Valid parameter (ID 0x0E000401) in PIMikroMove or using SPA? or SEP?.

Send: SPA? 1 0x0E000401
or
Send: SEP? 1 0x0E000401

DDL activation was successful if the parameter value is 1. Otherwise the DDL option is still deactivated.

If the DDL activation fails:

- Check if the correct serial number was used for license number generation.
- Check whether the correct license number was entered into controller memory:

  Send: SEP? 1 0x0E000400

- Make sure that command level 1 is active during license activation.

13.3 How to Work with the DDL

INFORMATION

The Dynamic Digital Linearization (DDL) option must be expressly ordered (order number E-710.SCN). You can activate it after purchase. See "How to Activate the DDL License" (p. 238) for more information.

If you are not sure if the DDL option is activated on your controller, use the SPA? command to check the value of the DDL License Valid parameter (ID 0x0E000401). If the parameter value is 1, the DDL option is activated, otherwise it is deactivated.

DDL related commands will not provoke an error when the DDL option is deactivated.

NOTICE

Before you work with Dynamic Digital Linearization (DDL), eliminate any residual oscillations by adjusting the notch filters and the control parameters (Servo-Loop P-Term, Servo-Loop I-Term; see "Optimization for Dynamic Operation" (p. 263)). Using DDL could be critical if there are any residual oscillations in the system; DDL will then cause the oscillations to build up—the more wave generator cycles are used for DDL initialization, the stronger the effect.

The number of DDL tables can be queried using the TLT? command. The number of DDL tables present in the E-711/E-712 system is the same as the number of logical axes, and each DDL table is fixed to one axis.

A certain amount of memory space is reserved for the DDL data (ask with the SPA? command for the value of the parameter with ID 0x1400000B). 2^{18} memory points are available. The individual DDL tables may use different portions of the complete memory space—the number of points in a DDL table corresponds to the length of the waveform which was output during the DDL initialization. You can query the current DDL table length using the DTL? command.

DDL tables are automatically filled with data when a wave generator is started with the "Use and reinitialize DDL" option activated. It is also possible to write data "manually" with the DDL command—in this case, make sure that the DDL table length is correct (see the DDL command description for more information).

INFORMATION

The DDL initialization must be repeated when a new stage is connected, the control parameters are changed (e.g., due to load changes) or the waveform is changed.

It is recommended to start the DDL initialization for all axes at the same time. Each new initialization will stop all running initialization processes. The initialization process is also stopped by the DDL command.

How to initialize DDL for an axis:

1. Define a waveform using the WAV command.
2. Optionally: Set the number of wave generator output cycles to use for DDL initialization. This can be done using the SPA or SEP command with the DDL Repeat Number parameter (ID 0x14000001). The factory default setting is 35. (To have write access to the parameter, it might be necessary to switch to command level 1 using CCL).
3. Not essential but recommended: Delete DDL table content which is no longer used. This can be done using the DTC command.
4. When the control parameters (notch filter frequency, Servo-Loop P-Term, Servo-Loop I-Term and Servo Loop Slew-Rate) have changed: Recalculate the internal DDL processing parameters using the DPO command.
5. Assign the waveform to the axis using the WSL command.
6. Switch to closed-loop operation for the axis using the SVO command.
7. Start the wave generator output with the WGO command, with the "Use and reinitialize DDL" option activated.
8. Optionally: Check the content of the DDL table using the DDL? command.

How to use DDL for an axis:

If your application does not change, you can use the current DDL table content without new initialization. In this case, start the wave generator output with WGO and the "Use DDL" option activated.

INFORMATION

If the DDL performance does not prove satisfactory or if errors occur during DDL use:

- Recalculate the internal DDL processing parameters using DPO.
- Reduce the frequency of the wave generator output to make sure that the axis can follow the target values. To do this, define a new, optimized waveform with the WAV command. You can also use the WTR command, which sets the wave generator table rate, to optimize the output frequency.

After such changes DDL initialization must be repeated.

INFORMATION

If a phase shift between the trigger output and the actual position is observed when the wave generator output is running with the "Use DDL" or "Use and reinitialize DDL" options (actual position measured with external device is ahead of the trigger output), check the cut-off-frequency f_g of the IIR low-pass filter used for digital filtering and increase it to shorten the duration of the digital filtering. See below for more information.

The duration of the signal processing for a capacitive sensor results from two portions:

- Duration of the analog sensor processing, which takes about 80 µs for the E-711/E-712 system
- Duration of the digital filtering. If the Digital Filter Type parameter (ID 0x05000000) is set to "IIR low-pass filter, 2nd order", the required time depends on the cut-off-frequency f_g of the IIR low-pass filter which is specified by the Digital Filter Bandwidth parameter (ID 0x05000001). For signal frequencies $f < f_g/2$, the duration of the filtering can be estimated as follows:

  $t \approx 0.216 / f_g$
  If required, increase f_g. Examples:
  f_g = 300 Hz: t = 0.72 ms
  f_g = 1000 Hz: t = 0.216 ms

INFORMATION

The DDL table content and the calculated processing parameters will be lost when the controller is switched off or rebooted.

13.4 DDL-Related Commands and Parameters

Command	Description	Notes
DDL	Set DDL Table Values	Can be used to fill the DDL tables "manually" with data
DDL?	Get DDL Table Values	Reads the current content of the DDL tables
DPO	DDL Parameter Optimization	Recalculates the DDL processing parameters (Time Delay Max (ID 0x14000006) and Time Delay Min (ID 0x14000007)), required if the control parameters have changed
DTC	Clear DDL Table Data	It is recommended that the content of DDL tables which are not used be deleted. This avoids errors due to unsufficient memory space during the DDL initialization. When the controller is switched off or rebooted, the content of the DDL tables will be cleared automatically.
DTL?	Get DDL Table Length	Returns the value of the Max DDL Points parameter (ID 0x1400000B)
TLT?	Get Number of DDL Tables	The returned value corresponds to the number of axes available on the controller
WAV	Set Waveform Definition	Since DDL works only in conjunction with the wave generator output, the waveform must first be defined
WGO	Set Wave Generator Start/Stop Mode	The WGO command starts the wave generator output and provides two modes for the DDL: "Use and reinitialize DDL" and "Use DDL"

See "How to Work with the DDL" (p. 240) for more information. See the PZ233 GCS commands manual for detailed command descriptions. See "Accessible Items and Their Identifiers" (p. 127) for the identifiers of the items which can be addressed with the commands.

Parameter ID	**Com-mand Level**	**Item Type**	**Max. No. of Items**	**Data Type**	**Parameter Description**
0x0e000400	1	System	1	INT	DDL License
0x0e000401	3	System	1	INT	DDL License Valid
0x14000001	1	Logical Axis	E-712.3CD, .3CDA: 3 E-712.6CD, .6CDA, .6IDA: 6	INT	DDL Repeat Number
0x14000006	1	Logical Axis	E-712.3CD, .3CDA: 3 E-712.6CD, .6CDA, .6IDA: 6	FLOAT	Time Delay Max
0x14000007	1	Logical Axis	E-712.3CD, .3CDA: 3 E-712.6CD, .6CDA, .6IDA: 6	FLOAT	Time Delay Min
0x14000008	1	Logical Axis	E-712.3CD, .3CDA: 3 E-712.6CD, .6CDA, .6IDA: 6	INT	Time Delay Change Rule
0x1400000a	1	Logical Axis	E-712.3CD, .3CDA: 3 E-712.6CD, .6CDA, .6IDA: 6	INT	DDL Zero Gain Number
0x1400000b	3	System	1	INT	Max DDL Points

See "Parameters" (p. 276) for more information regarding the parameters and their handling.

14 Controller Macros

The E-711/E-712 system can save and process command sequences as macros.

The following functionalities make macros an important tool in many application areas:

- Several macros can be saved at the same time.
- Any macro can be defined as the startup macro. The startup macro is executed every time the E-711/E-712 system is switched on or rebooted.
- Processing a macro and stopping macro execution can be linked to conditions. In this way, loops can be realized as well.
- Macros can call up themselves or other macros in max. 5 nesting levels.
- Variables (p. 254) can be set for the macro and in the macro itself and used in different operations.
- Input signals can be evaluated for conditions and variables.

14.1 Commands for Macros

The following commands are specially available for handling macros or for use in macros:

Command	Syntax	Function
ADD	ADD <Variable> <FLOAT1> <FLOAT2>	Adds two values and saves the result to a variable (p. 254). Can only be used for local variables in macros.
CPY	CPY <Variable> <CMD?>	Copies a command response to a variable (p. 254). Can only be used for local variables in macros.
DEL	DEL <uint>	Can only be used in macros. Delays <uint> milliseconds.
JRC	JRC <Jump> <CMD?> <OP> <Value>	Can only be used in macros. Triggers a relative jump of the macro execution pointer depending on a condition.

Command	Syntax	Function
MAC	MAC BEG <macroname>	Starts the recording of a macro with the name macroname on the controller. macroname can consist of up to 15 characters.
	MAC DEF <macroname>	Defines the specified macro as the startup macro.
	MAC DEF?	Gets the startup macro.
	MAC DEL <macroname>	Deletes the specified macro.
	MAC END	Ends the macro recording.
	MAC ERR?	Returns the last error which occurred during macro execution.
	MAC FREE?	Gets the free memory space for macro recording (unit: number of characters).
	MAC NSTART <macroname> <uint> [<String1> [<String2>]]	Starts the specified macro n times in succession (n = number of macro executions). The values of local variables can be set for the macro with <String1> and <String2>.
	MAC START <macroname> [<String1> [<String2>]]	Starts one execution of the specified macro. The values of local variables can be set for the macro with <String1> and <String2>.
MAC?	MAC? [<macroname>]	Lists all macros or the content of a specified macro.
MEX	MEX <CMD?> <OP> <Value>	Can only be used in macros. Stops the macro execution depending on a condition.
RMC?	RMC?	Lists macros which are currently running.
VAR	VAR <Variable> <String>	Sets a variable (p. 254) to a certain value or deletes it. Can only be used for local variables in macros.
VAR?	VAR? [{<Variable>}]	Gets variable values.

Command	Syntax	Function
WAC	WAC <CMD?> <OP> <Value>	Can only be used in macros. Waits until a condition is met.
#8	-	Tests if a macro is running on the controller.

14.2 Working with Macros

Work with macros comprises the following:

- Recording of macros (p. 247)
- Starting macro execution (p. 249)
- Stopping macro execution (p. 252)
- Setting up a startup macro (p. 252)
- Deleting of macros (p. 253)

INFORMATION

For working with controller macros, it is recommended to use the *Controller macros* tab in PIMikroMove. There you can conveniently record, start and manage controller macros. Details are found in the PIMikroMove manual.

14.2.1 Recording a Macro

INFORMATION

A maximum of 5 nesting levels are possible in macros.

Basically all GCS commands can be included in a macro. Exceptions:
RBT for rebooting the E-711/E-712 system
MAC BEG and MAC END for macro recording
MAC DEL for deleting a macro

Query commands can be used in macros in combination with the CPY, JRC, MEX and WAC commands. Otherwise they have no effect since macros do not send any responses to interfaces.

To make the use of macros more flexible, you can use local and global variables in macros. See "Variables" (p. 254) for more information.

The number of write cycles in the nonvolatile memory is restricted by the limited lifetime of the memory chip.
→ Only record macros when it is necessary.
→ Use variables (p. 254) in macros to make macros more flexible. Specify the corresponding variable values when starting macro execution.
→ Contact our customer service department (p. 312) if the E-711/E-712 system shows unexpected behavior.

A macro must be deleted before a macro with the same name can be re-recorded.

---

1. Start the macro recording.

   - If you are working with PITerminal or in the *Command entry* window of PIMikroMove: Send the MAC BEG *macroname* command, where *macroname* indicates the name of the macro.
   - If you are working in PIMikroMove on the *Controller macros* tab: Select the *Create new empty macro* icon to create a tab for entering a new macro. Do **not** enter the MAC BEG *macroname* command.

2. Enter the commands to be included in the macroname macro line by line, using the normal command syntax.

   Macros can call up themselves or other macros in several nesting levels.

3. End the macro recording.

   - If you are working with PITerminal or in the *Command entry window* of PIMikroMove: Send the MAC END command.
   - If you are working in PIMikroMove on the *Controller macros* tab: Do **not** enter the MAC END command. Select the *Send macro to controller* icon and enter the name of the macro in a dialog.

   The macro has been saved in the nonvolatile memory of the E-711/E712 system.

4. If you want to check whether the macro has been correctly recorded:

   If you are working with PITerminal or in the *Command entry* window of PIMikroMove:

   - Get which macros are saved in the E-711/E-712 system by sending the MAC? command.

- Get the contents of the macroname macro by sending the MAC? macroname command.

If you are working in PIMikroMove on the *Controller macros* tab:

- Select the *Read list of macros from controller* icon.
- In the list on the left side, select the macro to be checked and select the *Load selected macro from controller* icon.

14.2.2 Starting a Macro Execution

INFORMATION

Any commands can be sent from the command line when a macro is running on the controller. The macro content and motion commands received from the command line can overwrite each other.

Simultaneous execution of multiple macros is not possible. Only one macro can be executed at a time.

You can link the macro execution to conditions with the JRC and WAC commands. The commands must be included in the macro.

In the following, PITerminal or the *Command entry* window of PIMikroMove is used to enter commands. Details on working with the *Controller macros* tab in PIMikroMove are found in the PIMikroMove manual.

1. Start the macro execution:

   - If the macro is to be executed once, send the MAC START *macroname string* command, whereby *macroname* indicates the name of the macro.
   - If the macro is to be executed n times, send the MAC NSTART *macroname n string* command, whereby *macroname* indicates the name of the macro and *n* indicates the number of macro executions.

   string stands for the values of local variables. The values only must be specified when the macro contains corresponding local variables. The sequence of the values in the input must correspond to the numbering of the appropriate local variables, starting with the value of the local variable 1. The individual values must be separated from each other with spaces.

2. If you want to check the macro execution:

   - Get whether a macro is being executed on the controller by sending the #8 command.

   - Get the name of the macro that is currently being executed on the controller by sending the RMC? command.

Example: Moving an axis with a variable travel distance back and forth

---

INFORMATION

When macros are recorded on the *Controller macros* tab in PIMikroMove, the MAC BEG and MAC END commands must be omitted.

The axis 1 is to move back and forth. The travel to the left and to the right is to be variably adjustable without having to change the used macros. Local and global variables are therefore used.

1. Create the global variables LEFT and RIGHT by sending:

   VAR LEFT 5
   VAR RIGHT 15

   LEFT thus has the value 5, and RIGHT has the value 15. These values can be changed at any time, e.g., by sending the VAR command again.

   - Create the global variables again every time the E-711/E-712 system is switched on or rebooted, since they are only written to the volatile memory of the E-711/E-712 system.

2. Record the MOVLR macro by sending:

   MAC BEG movlr
   MAC START movwai ${LEFT}
   MAC START movwai ${RIGHT}
   MAC END

   MOVLR successively starts the MOVWAI macro (which is still to be recorded) for both directions of motion. The values of the global variables LEFT and RIGHT are used when MOVWAI is started, to set the value of the local variable 1 contained in MOVWAI (dollar signs and braces are necessary for the local variable 1 in the macro to be replaced by the value of the global variable and not by its name).

3. Record the MOVWAI macro by sending:

   MAC BEG movwai
   MOV 1 $1

```
WAC ONT? 1 = 1
MAC END
```

MOVWAI moves axis 1 to the target position which is specified by the value of the local variable 1 and waits until the axis has reached the target position.

4. Start the execution of the MOVLR macro by sending:

   ```
   MAC NSTART movlr 5
   ```

   The MOVLR macro is executed five times in succession, i.e., axis 1 alternately moves to the positions 5 and 15 five times. You can also select any other value for the number of macro executions.

Example: Implementing multiple calls of a macro via a loop

INFORMATION

When macros are recorded on the *Controller macros* tab in PIMikroMove, the MAC BEG and MAC END commands must be omitted.

The TESTDION macro checks the state of the digital input lines on the *Digital I/O* connector. It uses a local variable to identify the digital input line (1 to 4). So that the TESTDION macro does not have to be called separately for each input line, another macro with a loop is recorded.

- Record the LOOPDION macro by sending:

  ```
  MAC BEG loopdion
  VAR COUNTER 1
  MAC START TESTDION ${COUNTER}
  ADD COUNTER ${COUNTER} 1
  JRC -2 VAR? COUNTER < 5
  MAC END
  ```

The COUNTER variable is created with the value 1. After this, the TESTDION macro is started for the input line whose identifier is specified via the COUNTER variable. Then the value of the COUNTER is increased by 1. If the value of the COUNTER is less than 5, the macro execution pointer subsequently jumps two lines back, so that the TESTDION is now started for the next digital input line.

14.2.3 Stopping a Macro Execution

INFORMATION

You can link the stopping of the macro execution to a condition with the MEX command. The command must be included in the macro.

In the following, PITerminal or the *Command entry* window of PIMikroMove is used to enter commands. Details on working with the *Controller macros* tab in PIMikroMove are found in the PIMikroMove manual.

- Stop the macro execution with the #24 or STP commands.
- If you want to check whether an error has occurred during the macro execution, send the MAC ERR? command. The response shows the last error that has occurred.

14.2.4 Setting up a Startup Macro

Any macro can be defined as the startup macro. The startup macro is executed every time the E-711/E-712 system is switched on or rebooted.

INFORMATION

Deleting a macro does not delete its selection as the startup macro.

In the following, PITerminal or the *Command entry* window of PIMikroMove is used to enter commands. Details on working with the *Controller macros* tab in PIMikroMove are found in the PIMikroMove manual.

- Define a macro as the startup macro with the MAC DEF *macroname* command, whereby *macroname* indicates the name of the macro.
- If you want to cancel the selection of the startup macro and do not want to define another macro as the startup macro, only send MAC DEF.
- Get the name of the currently defined startup macro by sending the MAC DEF? command.

Example: Moving an axis via a startup macro to a certain position in closed-loop operation

INFORMATION

When macros are recorded on the *Controller macros* tab in PIMikroMove, the MAC BEG and MAC END commands must be omitted.

Setting the operating mode via a startup macro is not necessary because this can be done via the value of the Power Up Servo ON Enable parameter (ID 0x07000800; 0 = no automatic switching to closed-loop operation; 1 = automatic switching to closed-loop operation). Furthermore, the AutoZero procedure can be performed automatically according to the value of the Power Up AutoZero Enable parameter (ID 0x07000802; 0 = AutoZero procedure is not automatically performed; 1 = AutoZero procedure is automatically performed). For that reason, the STARTCL macro only starts the motion to the desired position which is 10 in this example.

- Send:

```
CCL 1 advanced
SEP 100 1 0x07000800 1
SEP 100 1 0x07000802 1
MAC BEG startcl
MOV 1 10
MAC END
MAC DEF startcl
```

14.2.5 Deleting a Macro

INFORMATION

A running macro may not be deleted.

In the following, PITerminal or the *Command entry* window of PIMikroMove is used to enter commands. Details on working with the *Controller macros* tab in PIMikroMove are found in the PIMikroMove manual.

- Delete a macro with the MAC DEL *macroname* command, whereby *macroname* indicates the name of the macro.

15 Variables

For more flexible programming, the E-711/E-712 system supports variables. While global variables are always available, local variables are only valid for a specified macro. Typically, variables are used when working with macros.

Variables are present in volatile memory (RAM) only. The variable values are of the STRING data type.

The following conventions apply to variable names:

- Variable names must not contain special characters (especially no "$").
- The maximum number of characters is 8.
- Names of global variables can consist of characters A to Z and 0 to 9. They must start with an alphabetic character.
- Names of local variables must not contain alphabetic characters. Possible characters are 0 to 9.
- The variable name can also be specified via the value of another variable.

If the value of a variable is to be used, the notation must be as follows:

- The variable name must be preceded by the dollar sign ($).
- Variable names consisting of multiple characters must be put in curly brackets.

If the variable name consists of a single character, the curly brackets can be omitted.

Note that if the curly brackets are omitted with variable names consisting of multiple characters, the first character after the "$" is interpreted as the variable name.

Local variables:

- Local variables can only be used in macros.
- At present, the controller firmware supports three local variables: 0, 1 and 2.
- The values of the local variables 1 and 2 are specified as arguments of the MAC START or MAC NSTART command when starting the macro.

The command formats are:
MAC START <macroname> [<String1> [<String2>]]
MAC NSTART <macroname> <uint> [<String1> [<String2>]]
<STRING1> and <STRING2> indicate the values for the local variables 1 and 2 used in the macro. <STRING1> and <STRING2> can be specified directly or via the values of variables. <uint> defines the number of times the macro is to be run. See the MAC command description for more information.

- The local variable 0 is read-only. Its value specifies the number of arguments (i.e. values of local variables) set when starting the macro.

- Inside a macro, the values of local variables can be modified using ADD, CPY or VAR, and can be deleted with VAR (except the local variable 0).

- If the macro is running, the values of the local variables can be queried with:
  VAR? 0
  VAR? 1
  VAR? 2
  The queries can be sent inside or outside of the macro.

Global variables:

- Global variables can be used inside and outside of macros.

- The maximum number of global variables is 10.

- Global variables are created and modified using ADD, CPY or VAR. They can be deleted with VAR.

- The variable values can be queried with VAR?.

16 Protective Functions

16.1 Safety Shutdown

The firmware of the E-711/E-712 system provides a safety shutdown functionality: The E-711/E-712 system observes several items and compares their current states with abort criteria defined by parameters (see the table below for more information).

The safety shutdown functionality is enabled/disabled for the individual axes using the value of the Safety Shutdown Activation Register parameter (ID 0x1a000600). The parameter value is the hexadecimal sum of bits for up to 32 axes (bit 0: axis 1, bit 1: axis 2, … bit 31: axis 32). The safety shutdown functionality is enabled for an axis if the corresponding bit ist set. Default value: 0xFFFFFFFF (safety shutdown functionality is enabled for axes 1 to 32).

If any of the abort criteria is true, for all axes with enabled safety shutdown functionality the E-711/E-712 system will

- Stop all motion
- Set all piezo/drive voltages to zero
- Switch to open-loop operation
- Activate all brakes (if present)
- Set the error code to a non-zero value

INFORMATION

The error code can be read and reset with the ERR? command. But if any of the abort criteria is true, every ERR? command will return a non-zero value.

To get back to normal operation, proceed as follows:

1. Send ERR? to check the error code.
2. Via the corresponding parameter, disable the criterion which caused the system abort.
3. Eliminate the condition which caused the system abort.
4. Send ERR? to clear the error code.
5. Enable the criterion again.

6. Switch to closed-loop operation for the axes in question.

   When switching to closed-loop operation, the target position is set to the current axis position and the brakes are deactivated (if present).

Item	Abort Criterion	Parameters
Position error of axis	Position error for the axis is out of specified range of tolerance.	Maximum Position Error parameters (ID 0x1A000000 to 0x1A00000*n*): Specify the range of tolerance for axes 1 to *n+1*. The parameter values are floating-point numbers ("float", the range of tolerance is –float to +float), float must be > 0; the unit is the axis position unit. Use Position Error to Stop parameters (ID 0x1A000400 to 0x1A00040*n*): Enable/disable the usage of the criterion for axes 1 to *n+1*; parameter values can be: 0 = position error criterion not used 1 = position error criterion used Example: To use the position error criterion with the axis 3, you must set the parameters with ID 0x1A000002 and ID 0x1A000402 to appropriate values.
Digital input lines	Digital input signal is *high*.	Trigger to Stop parameter (ID 0x1A000100): Specifies the digital input line which is to be observed (one of the lines on the *Digital I/O* connector). Active *high*. The digital input signal must be *high* for as long as the safety shutdown is to be effective. Notes: If the parameter value is 0, the criterion is disabled. The digital inputs are pulled to *high* by internal pullup resistors when nothing is connected to the *Digital I/O* connector. It is not recommended to define lines which are used to start the data recorder or to start/stop the wave generators.
Analog input lines	Analog input signal is out of specified range of tolerance.	Maximum Value of Input parameters (ID 0x1A000200 to 0x1A00020*n*): Specify the range of tolerance for input signal channels 1 to *n+1*. The parameter values are floating-point numbers ("float", the range of tolerance is –float to +float), must not be negative. If the parameter value is 0, the criterion is disabled for the input signal channel.

Item	Abort Criterion	Parameters
		Notes: This criterion should only be enabled with input signal channels provided by an E-711.IA4 analog interface module. These input lines can be used, for example, with external force sensors. This criterion is used irrespective of the settings which determine the usage of the analog input as sensor or for control value generation. Nevertheless, make sure that the analog input is scaled to suitable values (see p. 192 for more information). Example: To use the analog input criterion with the input signal channel 4, you must set the parameter with ID 0x1A000203 to an appropriate value.
Limit switches of input signal channel	Limit switch tripped.	Use Limit Switch of Input parameters (ID 0x1A000300 to 0x1A00030*n*): Enable/disable the usage of the criterion for input signal channel 1 to *n+1*; parameter values can be: 0 = limit switch criterion not used 1 = limit switch criterion used Notes: This criterion should only be enabled for sensors which support limit switches. This criterion can be used to detect if the system is connected properly: If a connector is not connected, both negative and positive limit switch will be active. Example: During axis motion the limit switch lines are observed. The axis trips a limit switch, and the system is aborted. Now you must identify the limit switch which caused the system abort. Disable the abort criterion for the corresponding input signal channel (using the corresponding parameter) and move the axis away from the limit switch (e.g., using motion commands; probably you must switch to closed-loop operation before). Enable the abort criterion again for the input signal channel.
Sensor signal (input signal channel)	Sensor signal invalid.	Observe Sensor Signal parameter (ID 0x1a000500): Enable/disable the usage of the criterion for input signal channel 1 to *n+1*; parameter values can be: 0 = sensor signal criterion not used 1 = sensor signal criterion used Notes: The E-711/E-712 system validates the sensor signal based on internal criteria which are not accessible to the user.

16.2 Plausibility Check of Sensor Position

A plausibility check of the sensor position is necessary if the position of multiple axes is measured by the same sensors. If the plausibility check is enabled, the E-711/E-712 system checks if the sensor components resulting from specified axis target positions will be inside the permitted sensor ranges. If the sensor ranges will be exceeded by the axis targets, the motion will not be executed, and error code 7 ("Position out of limits") will be set.

Example: A tip/tilt stage provides motion in axes Z, rotX and rotY. The motion is realized by three actuators, here, referred to as Z1, Z2, and Z3. In addition, the stage is equipped with three position sensors, and each sensor belongs to one of the three actuators. Due to this design, the motion of an axis always results from the motion of multiple actuators, and the axis position value always results from the values of multiple sensors (via matrix calculations; see "Input Signal Processing" (p. 134) and "Output Generation" (p. 143) for more information). The range limits of the sensors could be exceeded when motion is commanded for multiple axes, i.e., as a combination of Z-motion, rotX-motion and/or rotY-motion. Exceeding the sensor range could cause sensor overflow or even sensor damage by internal collisions.

To configure the plausibility check, proceed as follows:

1. Enable the plausibility check for the E-711/E-712 system:

   Set the Check Sensor Position Plausibility parameter (ID 0x0e001f00) to value 1 (= plausibility check in enabled) with the SEP command.

   Value 0 means that the plausibility check is disabled for the E-711/E-712 system.

2. Reboot the E-711/E-712 system. The parameters with ID 0x02001B00, ID 0x2001C00 and ID 0x02001D00 are now available for the individual input signal channels.

3. Set the range limits for every input signal channel which represents a sensor that is to be checked:

   Set the Maximum Position Of Sensor parameter (ID 0x02001B00) to the maximum permissible sensor position.

   Set the Minimum Position Of Sensor parameter (ID 0x02001C00) to the minimum permissible sensor position.

4. Enable the plausibility check for every input signal channel which represents a sensor that is to be checked:

   Set the Validate Sensor Position Range parameter (ID 0x02001D00) to value 1 (= plausibility check is enabled) for the sensor.

   Value 0 means that the plausibility check is disabled for the sensor.

17 Adjustment Procedures

17.1 ID Chip Support / Stage Replacement

The stage which is connected to the E-711/E-712 system may contain an ID chip. The following data is saved in the ID chip and cannot be modified there by the customer:

- Stage type
- Serial number of the stage
- Calibration data
- Control parameters (load dependent)

The parameters which are usually saved in ID chips are marked in the table in "Parameter Overview" (p. 279), but the list can differ slightly among the different mechanics provided by PI.

When a stage with ID chip is connected to the E-711/E-712 system for the first time, the parameter values from the ID chip will be written to nonvolatile and volatile memory when switching on or rebooting the E-711/E-712 system. The next time the E-711/E-712 system is switched on or rebooted, the complete set of ID chip parameters will be written only if the *Power Up Read ID-Chip* option is enabled. By default, this option is disabled to facilitate maintaining optimized parameter settings in the E-711/E-712 system.

INFORMATION

When the complete set of ID chip parameters of the stage is read by the E-711/E-712 system, the axes of the stage are assigned to the logical axes in the firmware of the E-711/E-712 system. The assignment depends on the value of the ID-Chip Chan. to Axis Map Ctrl parameter (ID 0x07030c00). Possible values:

0 = The first axis of the stage is assigned to the first logical axis of the E-711/E-712 system which is free, i.e. not assigned to another stage with ID chip that is currently connected.

2 (default) = The first axis of the stage is assigned to the logical axis of the E-711/E-712 system that has the same ID as the first input signal channel

that is occupied by the stage. Example: A stage is connected to input signal channels 4 to 6. The first axis of the stage therefore is assigned to axis 4 in the E-711/E-712 system.

INFORMATION

When you connect a stage to a switched-on E-711/E-712 system, the ID chip of the stage is not read by the E-711/E-712 system. To read the ID chip data, the E-711/E-712 system must be switched off and on again or rebooted using the RBT command or the corresponding PC software functions.

A stage can be easily exchanged due to the functionality of the ID chip.

Consider the following when replacing stages with ID chips.

"Simple" replacement

Normally, when you replace a stage and you are using factory default settings for all parameters, you do not have to adjust anything. The ID chip holds all information needed. When switching on or rebooting the E-711/E-712 system, the firmware reads the stage type and serial number saved in the ID chip and compares this data to the data from the last connected stage, saved in the E-711/E-712 system:

- If there is a new stage type connected to the E-711/E-712 system, all the data in the ID chip will be read and the corresponding parameters in the E-711/E-712 system overwritten.

- If there is a stage of the same type but with a different serial number connected to the E-711/E-712 system, the calibration data from the ID chip will be read and only the corresponding parameters overwritten. The control parameters will not be read, so those parameters will remain unchanged in the E-711/E-712 system.

If you have optimized some parameters for your application, PI recommends that you repeat your optimization routine with any new stage, because there are variations of stages, e.g., in the stiffness and natural frequency.

Upgrade or repair of stages

If you send your stage to PI, e.g., for upgrade or repair, the calibration data saved in the ID chip might be changed in the process. However, when you reconnect this stage to the E-711/E-712 system to which it was connected before, the firmware will detect that the type and serial number are unchanged and will not read the new ID chip data.

To force the E-711/E-712 system to read the complete data of the ID chip of the connected stage when the E-711/E-712 system is switched on, you can enable the *Power Up Read ID-Chip* option (parameter with ID 0X0F000000). This must be done for each input signal channel separately. Note that it might be necessary to switch to a higher command level to have write access to that parameter (use CCL or the appropriate facilities of PIMikroMove). Proceed as follows:

1. In the PIMikroMove main window, open the *Device Parameter Configuration* window (*E-712* > *Parameter Configuration*) and select the *System Mechanics* groups.

2. In the *System Mechanics* groups, enable the *Power Up Read ID-Chip* option for all input signal channels associated with the stage.

3. In the icon bar of the *Device Parameter Configuration* window, select the "Write selected edit values to default settings" button.

   Alternatively you can enter the following commands in a terminal to enable the option:

SEP 100 1 0X0F000000 1	for input signal channel 1
SEP 100 2 0X0F000000 1	for input signal channel 2, etc.

4. Reboot the E-711/E-712 system by entering the RBT command in the terminal. Alternatively you can switch the E-711/E-712 system off and on again. This time all data is read from the ID chip and saved in the E-711/E-712 system.

5. Disable the *Power Up Read ID-Chip* option for each input signal channel to ensure that the E-711/E-712 system will not read all data again the next time it is switched on or rebooted.

   In PIMikroMove, proceed as described above in steps 1 to 3 but make sure that the parameter now has the value "disabled".

   Alternatively you can enter the following commands in a terminal to disable the option:

SEP 100 1 0X0F000000 0 for input signal channel 1

SEP 100 2 0X0F000000 0 for input signal channel 2, etc.

If you had optimized parameters before the repair or upgrade, PI recommends you repeat your optimization routine when the stage is returned.

17.2 Optimization for Dynamic Operation

If the E-711/E-712 system and the attached stages are ordered together and if PI has sufficient knowledge of your application, then the parameters of notch filters and control algorithm (control parameters) will be set to suitable values by PI, and, if present, saved in the stage's ID chip (p. 260). For axes driven by conventional piezo actuators, modifications of those parameters may, however, be necessary if the load applied to the stage is changed.

17.2.1 Parameters to be Modified

The following parameters may need to be modified in the E-711/E-712 system:

- Settings for notch filters 1 and 2:

  Notch Frequency 1 parameter (ID 0x08000100), Notch Frequency 2 parameter (ID 0x08000101)

  To determine the resonant frequencies and set the notch filters properly, observe the system response to an impulse in open-loop operation (p. 266).

  Note that by default, the notch filters are enabled only in closed-loop operation.

- Control parameters:

  Servo-Loop P-Term parameter (ID 0x07000300), Servo-Loop I-Term parameter (ID 0x07000301):

  The optimum settings for Servo-Loop P-Term and Servo-Loop I-Term are found by observing the response of the axis to an abrupt change of the control value (step response) in closed-loop operation (p. 270).

17.2.2 General Notes on Optimization for Dynamic Operation

NOTICE

If the stage starts oscillating (humming noise):

Immediately switch to open-loop operation or stop the motion. Switch to closed-loop operation only after you have adjusted the notch filters and the control parameters (Servo-Loop P-Term, Servo-Loop I-Term).

Otherwise, the stage could be damaged.

- Before you change parameter values of the E-711/E-712 system, save a backup. See "Creating Backups for Parameter Values" (p. 109) for more information.
- Enter the password "advanced" when prompted to switch to command level 1.
- For stages with ID chip, to make the optimized settings available in the future, the *Power Up Read ID-Chip* option must have "disabled" as its default (the value of the parameter with ID 0x0F000000 is 0 in nonvolatile memory). See "ID Chip Support / Stage Replacement" (p. 260) for more information.
- The settling behavior of the axis in closed-loop operation is influenced by the notch filter settings. Set the notch filters **before** you optimize the control parameters (p. 270).
- If you work with the *Piezo Dynamic Tuner* window of PIMikroMove:
  - If you change a parameter value of the E-711/E-712 system by entering a corresponding value: The value is displayed in a blue font until you press the *Enter* key or the return key on your keyboard. Pressing the *Enter* key or the return key sends the value to the E-711/E-712 system 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-711/E-712 system differ.
  - When the *Notch Frequency 1* value is set in the *Parameter Settings* panel of the *Piezo Dynamic Tuner* window, the *Servo-Loop I-Term* value can be adjusted automatically in accordance. The

adjustment depends on the selection in the *Automatic I-Term calculation* dropdown menu.

Default: The I term is set to a conservative value which is calculated with the following formula:

$$I\ term_{conservative} = \frac{P\ term}{0.05\ \times 4\ \times \pi\ \times \text{Notch Frequency 1}}$$

Further options:

Dynamic I term value, calculated with the following formula:

$$I\ term_{dynamic} = \frac{0.8\ \times P\ term}{0.05\ \times 4\ \times \pi\ \times \text{Notch Frequency 1}}$$

Off, i.e. no automatic I term calculation.

- The settings for slew rate (*Slew Rate / Velocity* field) and record table rate (*Record Rate* field) can be changed in the *Piezo Dynamic Tuner* window. Entering new values in these fields changes the values of the corresponding parameters in volatile memory: Servo Loop Slew-Rate (ID 0x07000200) or Open Loop Slew-Rate (ID 0x07000201), depending on the current operating mode (open-loop operation or closed-loop operation); Data Recorder Table Rate (ID 0x16000000). The values are **not** saved or reset when you use the *Save …* and *Reset …* buttons in the *Parameter Settings* panel of the *Piezo Dynamic Tuner* window.

17.2.3 Adjusting the Notch Filters in Open-Loop Operation

The corrections by a notch filter only take place in closed-loop operation by default but can also be enabled for open-loop operation. The appropriate frequency component is reduced in the control value to compensate for undesired resonances in the mechanical system. Adjusting the notch filter frequency can be useful, particularly in the case of very high loads.

See "Notch Filters" (p. 151) for more information.

INFORMATION

The notch rejection value, which scales the damping done by the notch filter, should always be 0.05. A notch rejection value of 1 deactivates the notch filter.

Before you measure the resonant frequencies as described below, make sure that the notch filters 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 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.

In addition to the measurement described below, you can create a Bode plot: In the PIMikroMove main window, open the *Data Recorder* window by selecting *E-712… > Show data recorder …*. In the *Data Recorder* window, enter the *Amplitude* value and select *Estimate* to start the frequency response measurement.

To measure the resonant frequency and adjust the notch filters, a frequency response (axis response to an impulse) is recorded in open-loop operation.

Proceed as follows for each axis:

1 Read the "General Notes on Optimization for Dynamic Operation" (p. 264).

2 Make sure the stage is mounted in the same way as in the application. The load on the stage is especially important.

3 In the main window of PIMikroMove, open the *Piezo Dynamic Tuner* window by selecting *E-712… > Dynamic Tuner …*.

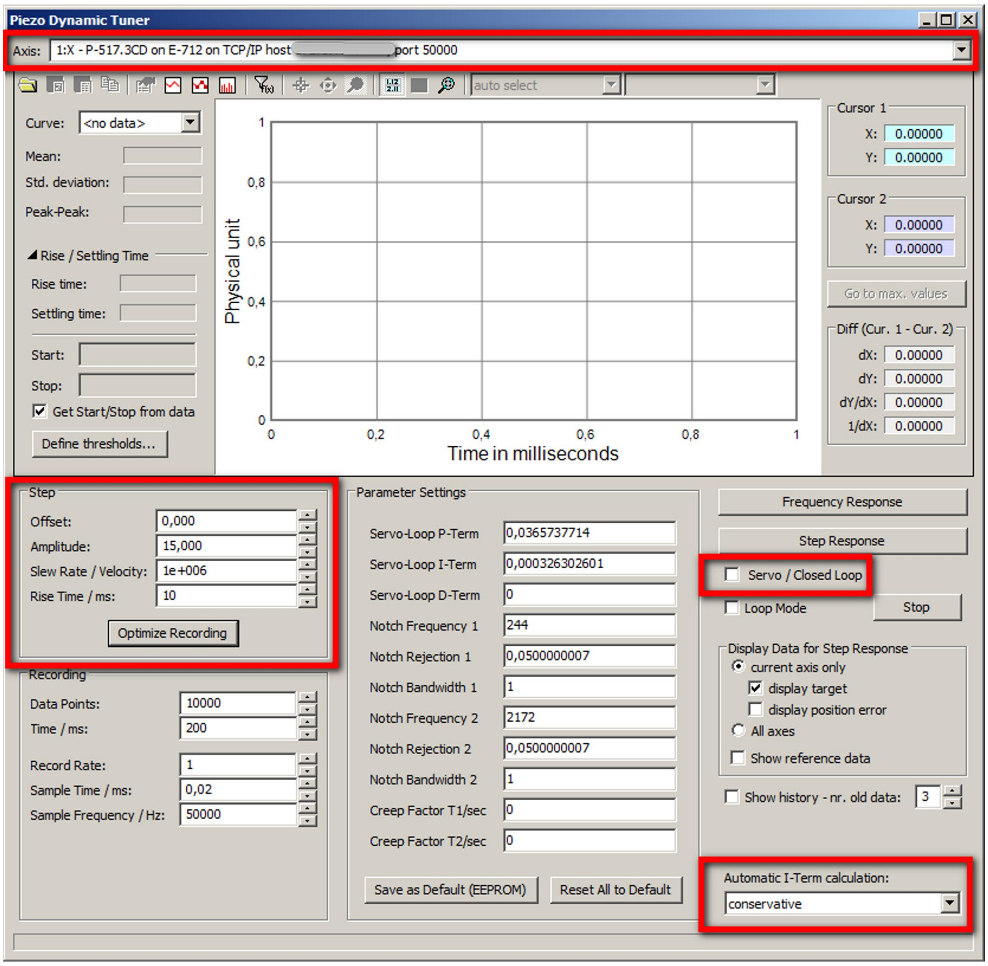
4 In the *Piezo Dynamic Tuner* window, configure the frequency response measurement:

4.1 Make sure that the correct axis is selected (*Axis* dropdown list).

4.2 In the *Step* panel, enter suitable values for the start value (*Offset*:) and the amplitude (*Amplitude*:) of the impulse. The start value should be 0, and the amplitude should be about 10 % of the axis travel range.

4.3 Make sure that the axis is in open-loop operation (the *Servo / Closed Loop* checkbox is cleared).

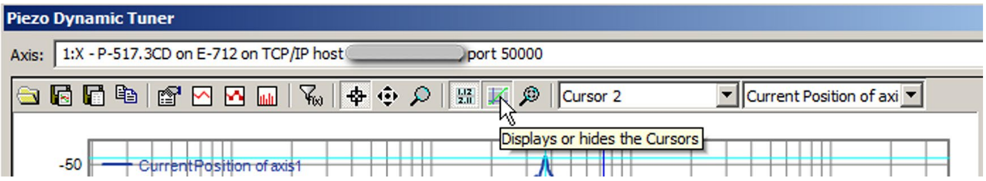
4.4 Select if and how the *Servo-Loop I-Term* is to be adjusted automatically when *Notch Frequency 1* is changed (*Automatic I-Term calculation*).

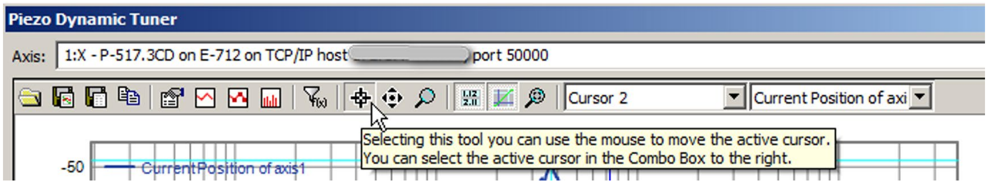


5 Perform the frequency response measurement by selecting the *Frequency Response* button.

6 Identify the resonant frequency:

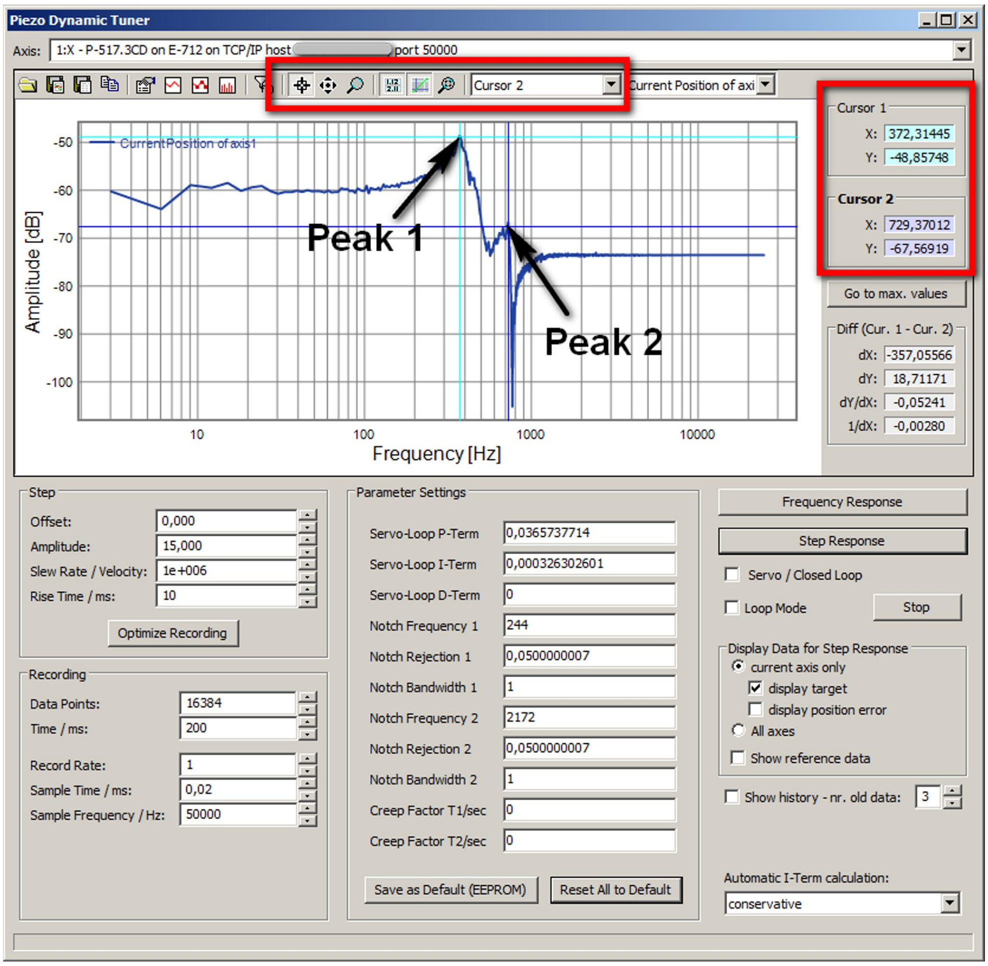
6.1 Show cursors and enable cursor motion using the buttons shown in the figures below.





6.2 Identify the resonance peaks 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.

In the figure below, cursor 1 is at the first resonance peak (372.31445 Hz), and cursor 2 is at the second (next higher) resonance peak (729.37012 Hz).

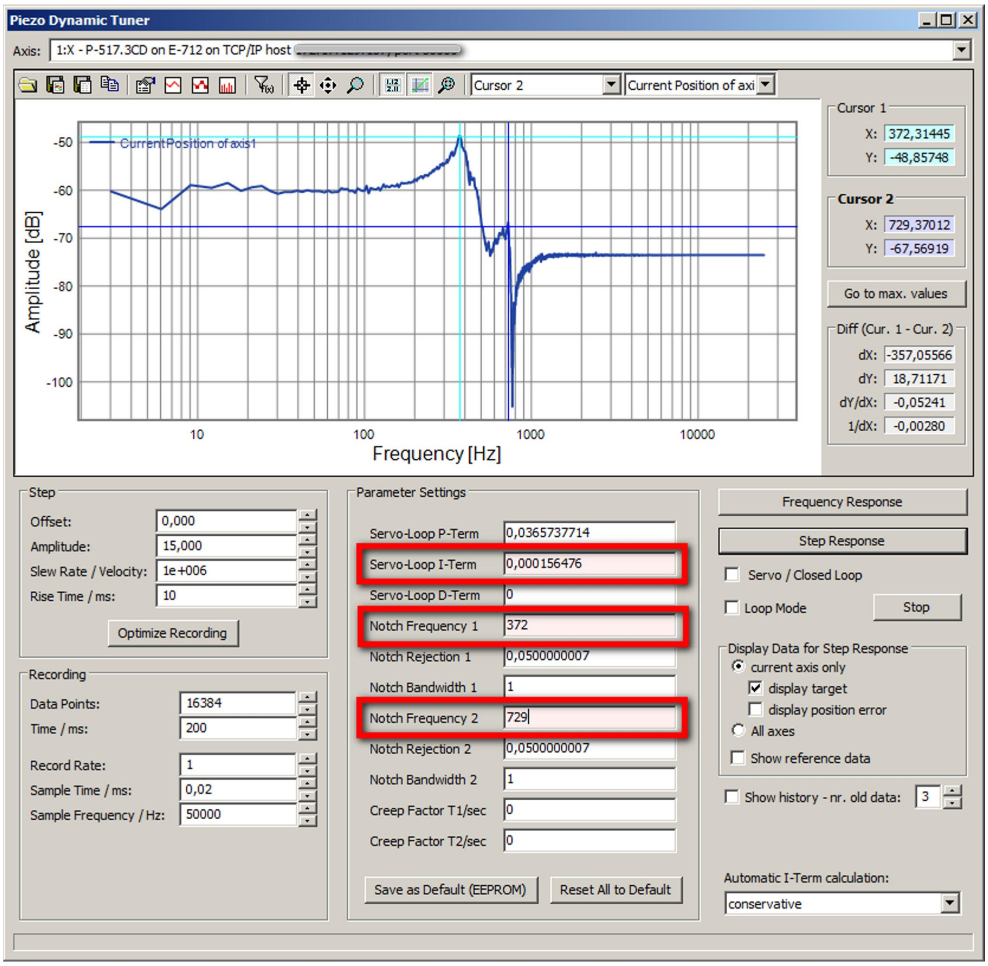


7 If necessary, adjust the notch filter settings in the *Parameter Settings* panel to the measured resonant frequencies (adjustment is necessary if the values significantly differ).

7.1 In the *Notch Frequency 1* field, enter the frequency value of the first resonance peak (in Hz). You can either right-click the field with the mouse and select the value from a menu or enter the value in the field.

Note that depending on the selection for *Automatic I-Term calculation*, the *Servo-Loop I-Term* value is changed too automatically when you change the *Notch Frequency 1* value (see p. 264 for more information).

7.2 If you have measured a second resonance peak: In the *Notch Frequency 2* field, enter the frequency value of the second resonance peak (in Hz). If the second notch filter is deactivated (rejection value = 1), change the rejection value to 0.05 in the *Notch Rejection 2* field.



8 In the *Parameter Settings* panel, save or discard the new settings:

- If you want to keep the new settings, save them to the nonvolatile memory of the E-711/E-712 system by selecting the *Save as Default (EEPROM)* button.
- If you want to discard the new settings and reset the parameter values to their defaults (i.e. to their values from nonvolatile memory), select the *Reset All to Default* button.

17.2.4 Checking and Optimizing the Control Parameters

Adjusting the control parameters (Servo-Loop P-Term, Servo-Loop I-Term) optimizes the dynamic properties of the system (overshoot and settling time). The optimum settings depend on your application and your requirements.

See "Control Algorithms for Closed-Loop Operation" (p. 145) for more information regarding the PID algorithm.

The optimization of the control parameters is typically done empirically: The response of the axes to a step ("step response") is analyzed under various values in closed-loop operation.

Proceed as follows for each axis:

1 Read "General Notes on Optimization for Dynamic Operation" (p. 264).

2 Make sure the stage is mounted in the same way as in the application. The load on the stage is especially important.

3 Make sure that the notch filters are properly adjusted. See "Adjusting the Notch Filters in Open-Loop Operation" (p. 266) for more information.

4 In the main window of PIMikroMove, open the *Piezo Dynamic Tuner* window by selecting *E-712…* > *Dynamic Tuner …*.

5 In the *Piezo Dynamic Tuner* window, configure the step response measurement:

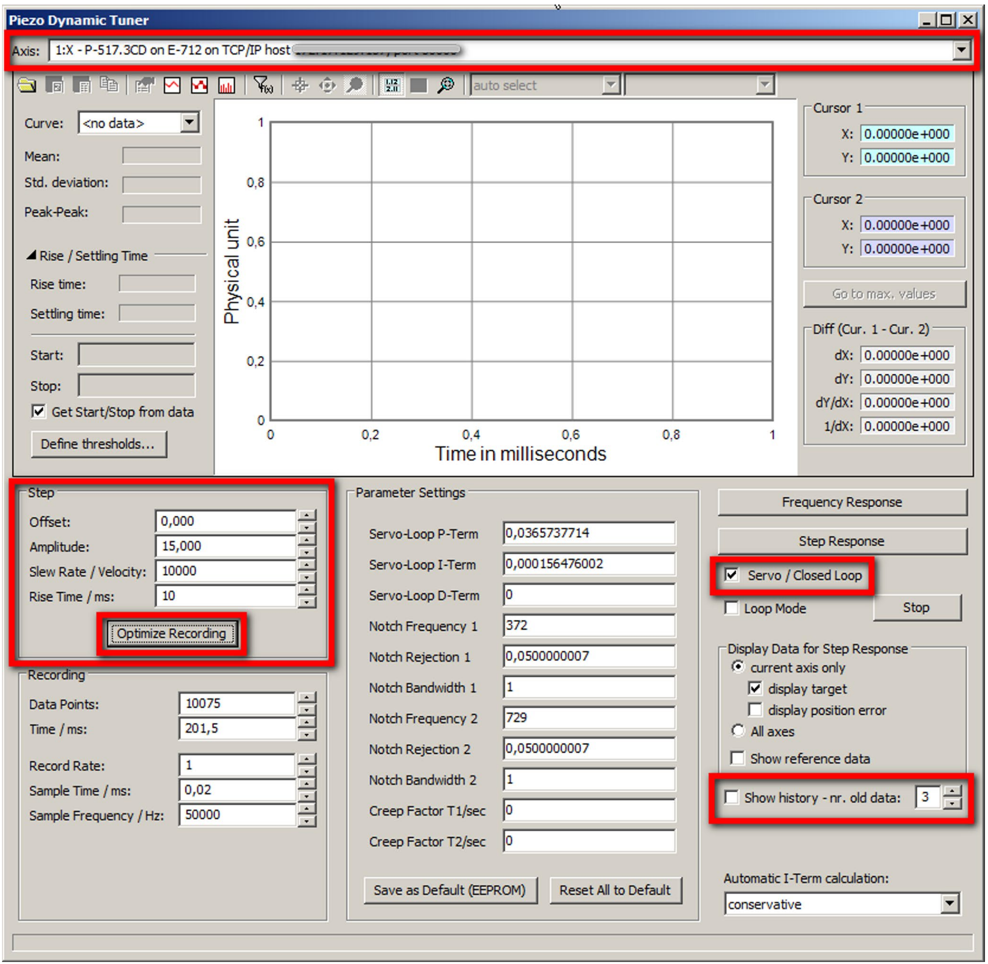
5.1 Make sure that the correct axis is selected (*Axis* dropdown list).

5.2 Make sure that the axis is in closed-loop operation (the *Servo / Closed Loop* checkbox is selected).

5.3 In the *Step* panel, enter suitable values for the start value (*Offset*:) and the amplitude (*Amplitude*:) of the step. The start value should be 0, and the amplitude should be about 10 % of the axis travel range.

5.4 In the *Step* panel, select the *Optimize Recording* button to optimize the number of data recorder points that will be read from the controller when the step response measurement has been performed.

5.5 If you want to compare the results of multiple step resonse measurements, select the *Show history* checkbox and select the number of old recordings to be displayed.

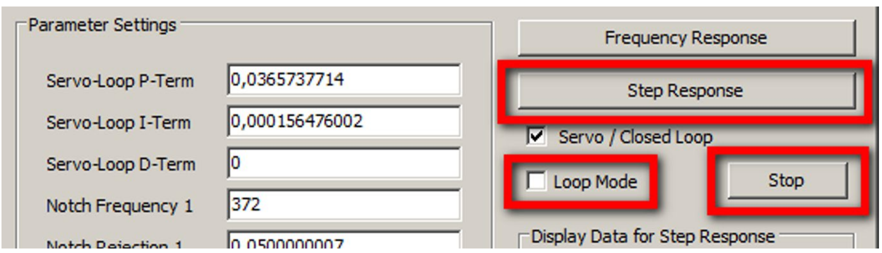


6 Perform and analyze the step response measurement:

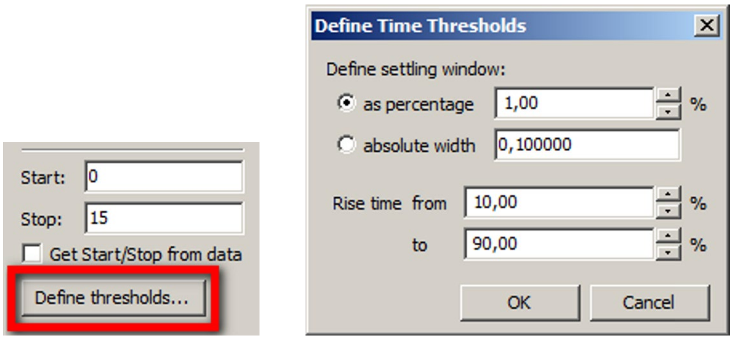
6.1 Optional: Select the *Loop Mode* checkbox to move the axis in a permanent loop.

The loop mode is useful if you want to do the adjustment of the control parameters during the motion. The loop motion can be stopped at any time by selecting the *Stop* button.

6.2 Start the step response measurement by selecting the *Step Response* button.

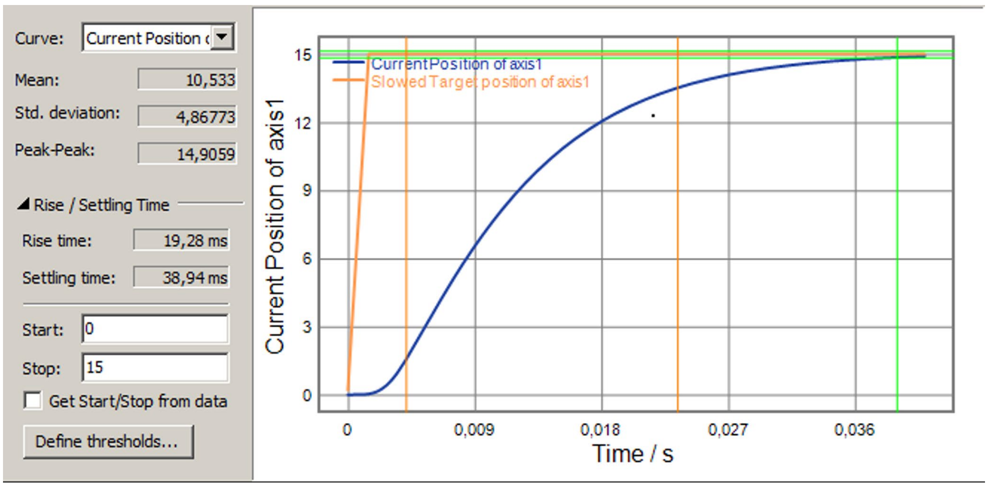


6.3 Optional: Select the *Define thresholds...* button to open the *Define Time Thresholds* window. In the *Define Time Thresholds* window, you can adjust the thresholds which are used by the *Piezo Dynamic Tuner* window to calculate and display the rise time and settling time of the axis, based on the recorded step response measurement.

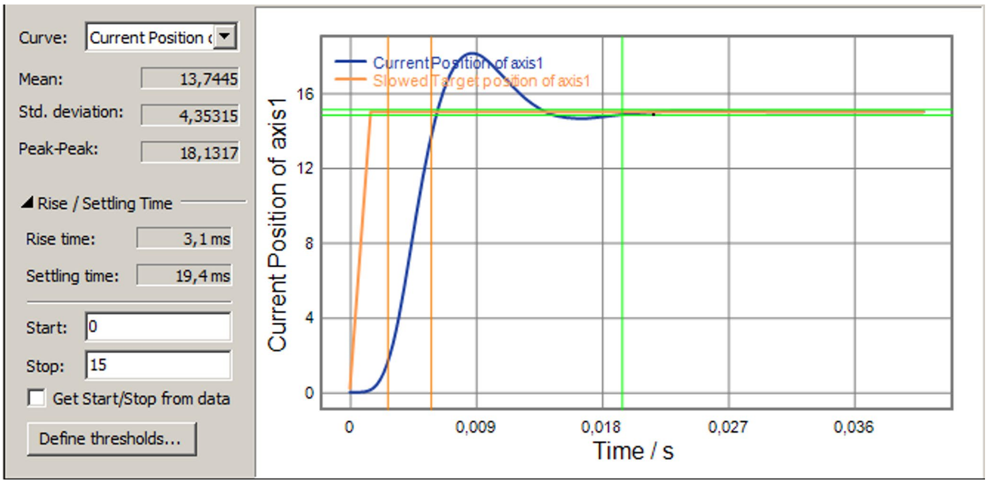


6.4 Check the result of the step response measurement and compare it with the examples shown in the figures below.

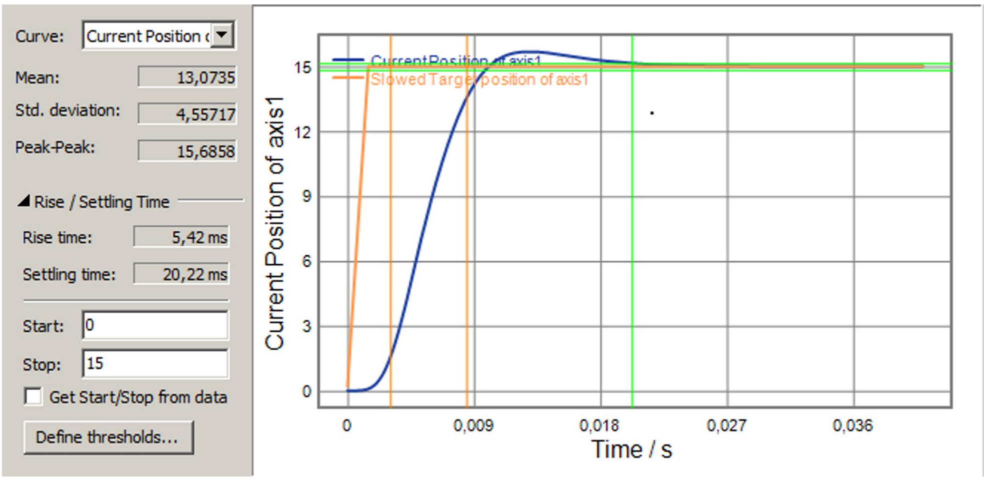
The rise rate of the step response is very low in the figure below. This means that the P term is too low and must be increased.



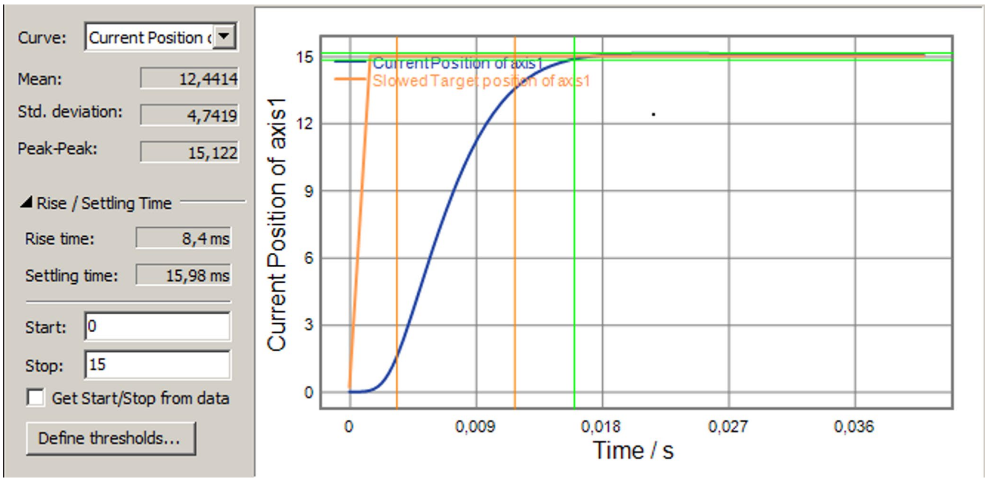
The figure below shows a step response with a high overshoot which means that the P term is too high and must be decreased.



The figure below shows a step response with a small overshoot which means that the P term is still too high and must be decreased.



The result of the step response is satisfactory when there is minimum overshoot, and the settling time is not too long, as in the figure below. No changes are required for the control parameters.



7 In the *Parameter Settings* panel, save or discard the new settings:

- If you want to keep the new settings, save them to the nonvolatile memory of the E-711/E-712 system by selecting the *Save as Default (EEPROM)* button.
- If you want to discard the new settings and reset the parameter values to their defaults (i.e. to their values from nonvolatile memory), select the *Reset All to Default* button.

18 Parameters

NOTICE

Incorrect parameter values may lead to improper operation or damage to your hardware. Be careful when changing parameters.

It is strongly recommended to save the parameter values of the E-711/E-712 system to a file on the PC before you make any changes. This way the original settings can be restored if the new parameter settings will not prove satisfactory. To save the parameter values and to load them back to the E-711/E-712 system, use the *Device Parameter Configuration* window of PIMikroMove. See "Creating Backups for Parameter Values" (p. 109) for more information.

18.1 Parameter Handling

The key features of the E-712/E-712 system are mirrored in parameters. They represent the hardware basics and the calibration data of the system. Some of the parameters are protected so that their factory default settings cannot be changed. Other parameters can be modified by the user to adapt the system to the individual application.

Each parameter is in the volatile and nonvolatile memory of the E-711/E-712 system. The values in the nonvolatile memory are loaded to the volatile memory as default values when switching on or rebooting the E-711/E-712 system. The values in the volatile memory determine the current behavior of the system.

In the PC software from PI, the parameter values in the volatile memory are also referred to as "current settings" or "active values" while the parameter values in the nonvolatile memory are also referred to as "default settings" or "startup values".

Note that PI records parameter files of every E-711/E-712 system during calibration.

The stage which is connected to the E-711/E-712 system may contain an ID chip. The ID chip holds selected parameters whose values will be written to nonvolatile and volatile memory when the stage is connected for the first time. See "ID Chip Support / Stage Replacement" (p. 260) for more information. The parameters saved in the ID chip are marked in the "Notes" column in the parameter table (p. 279).

The available parameters depend on the controller firmware. With HPA? you can obtain a list of all available parameters with information about each (e.g., short descriptions).

The parameter values in volatile memory and nonvolatile memory can be read with the SPA? or SEP? commands, respectively.

The "Command Level" column in the parameter table (p. 279) shows the command level for write access and thus indicates whether a parameter is "protected". By switching to command level 1 using the CCL command, it is possible to change level-1 parameters. Parameters with level 2 or higher are reserved for PI service personnel.

Using the "general" modification commands SPA, RPA, SEP and WPA, all parameters can be changed in volatile memory (SPA, RPA) or in nonvolatile memory (SEP, WPA), provided that write access is allowed in the current command level. It is recommended that any modifications be first made with SPA, and when the E-711/E-712 system runs well, saved using WPA. Do **not** change the current interface settings with SPA—except the baud rate—because it will not be possible to maintain communication afterwards.

In addition to the "general" modification commands, there are commands which change certain specific parameters. All the commands listed below, except IFS, change the parameter value only in volatile memory, and WPA must be used to save the value to nonvolatile memory. IFS changes and saves the interface parameters directly in nonvolatile memory only.

AOS (analog input offset)
ATZ (the result of the AutoZero procedure, see p. 117 for more information)
CTO (trigger output configuration)
DRC (data source and record option)
DPO (internal DDL processing parameters)
FDG (defines a Fast Alignment gradient search routine)
FDR (defines a Fast Alignment area scan routine)
IFC (baud rate for the RS-232 interface)
RTR (record table rate)
SIC (defines calculation settings for an analog input channel)
VEL (*Servo Loop Slew-Rate*)
WOS (wave generator output offset)
WTR (wave generator table rate)

IFS (interface parameters in nonvolatile memory)

In addition, certain specific parameters can be changed by Fast Alignment commands. See the E712T0016 Fast Alignment user manual for more information on these commands and the corresponding parameters.

When communication is established via TCP/IP and the IP address is obtained from a DHCP server, this address will automatically be written to the IP Address parameter (ID 0x11000600) in the E-711/E-712 system's volatile memory. Provided that the current command level is 1 (see the CCL command) and you send WPA 100, the new address setting will be saved to nonvolatile memory as the new default value (together with all other current valid parameter values with level-1 write access).

INFORMATION

The *Device Parameter Configuration* window of PIMikroMove gives access to parameter values in a more convenient way. Use this window to check or edit the individual parameters. See the PIMikroMove manual for more information.

Each parameter refers to one of the following items (see the "Item Type" column in the parameter table (p. 279)):

- Whole system (controller)
- Hardware modules of the controller
- Firmware units
- Logical axes
- PiezoWalk channels
- Input or output signal channels
- Digital output lines
- Data recorder tables
- External axes, i.e. axes of an SPI slave connected to the E-711/E-712 system. An E-711.iS3 or E-711.iS6 SPI master interface must be present in the E-711/E-712 system.

In addition, an item can be a Fast Alignment routine or a Fast Alignment input channel. See the E712T0016 Fast Alignment user manual for more information on these items.

The "Max. No. of Items" column in the parameter table (p. 279) shows the maximum number of items for which the parameter is used. Example: With an

E-712.6CD, for the parameter with ID 0x02000200 the number of items is "6" which means that this parameter has different values for each of the 6 input signal channels. For parameters which refer to the whole system the maximum number of items is always 1. See "Accessible Items and Their Identifiers" (p. 127) for the item identifiers to use with SPA, SEP or WPA when changing or saving parameter values or when querying parameter values with the SPA? or SEP? commands.

18.2 Parameter Overview

See "Parameter Handling" (p. 276) for the meaning of the individual columns.

The table below does not contain the parameters for Fast Alignment routines and Fast Alignment input channels. See the E712T0016 Fast Alignment user manual for descriptions of these parameters.

The content of the "Max. No. of Items" column is to be interpreted as follows:

- For "Item Type" = "Input Signal Channel", it shows the number of channels for:

  E-712.3CD, .3AN / E-712.3CDA
  E-712.6CD / E-712.6CDA, .6IDA
  E-712.1AM, .1AN / E-712.2AN

- For "Item Type" = "Output Signal Channel", it shows the number of channels for:

  E-712.3CD, .1AM, .1AN / E-712.3CDA, .6CD, .2AN
  E-712.6CDA, .6IDA, .3AN

- For "Item Type" = "Logical Axis", it shows the number of axes for:

  E-712.3CD, .3CDA, .3AN / E-712.6CD, .6CDA, .6IDA
  E-712.1AM, .1AN / E-712.2AN

- For "Item Type" = "PiezoWalk Channel", it shows the number of PiezoWalk channels for:

  E-712.1AM, E-712.1AN / E-712.2AN / E-712.3AN / any other system with PiezoWalk channels, "*" means that the number depends on the configuration of the E-711/E-712 system (no PiezoWalk channels with E-712.3CD, E-712.3CDA, E-712.6CD, E-712.6CDA, E-712.6IDA). A PiezoWalk channel represents a NEXLINE®, NEXACT® or PICMAWalk drive connected to the controller.

- For "Item Type" = "Hardware Module", it shows the number of slots available in the E-712.R1 housing. Counting (front view): 1 = leftmost slot , 8 = rightmost slot. The actual number of hardware modules present in the housing depends on the system configuration. See "Model Survey" (p. 18) for more information.

- For "Item Type" = "Firmware Unit", it shows the number of different firmware units present in:

E-712.3CD, .2AN / E-712.3CDA, .3AN
E-712.6CD, .6IDA / E-712.6CDA
E-712.1AM, .1AN

An E-712.M1 or .N1 digital processor module has 2 different firmware units installed (CPU and FPGA firmware), and all other modules have one firmware unit installed. All firmware units can be updated separately. See "Firmware Updates" (p. 303) for more information.

Parameter ID (hexa-decimal)	**Command Level for Write Access**	**Item Type**	**Max. No. of Items**	**Data Type**	**Parameter Description**	**Notes**
0x02000001	1	Input Signal Channel	3 / 7 6 / 10 1 / 2	INT	Sensor Type	0 = reserved 1 = absolute (e.g., analog sensor) 2 = incremental sin/cos (analog) 3 = incremental A/B (digital) 4 = absolute BiSS/C 5 = absolute ENDAT
0x02000100	1	Input Signal Channel	3 / 7 6 / 10 1 / 2	INT	Sensor Range Factor	ID chip The available factors depend on the type of sensor module.
0x02000101	1	Input Signal Channel	3 / 7 6 / 10 1 / 2	INT	Sensor Board Gain	Gain of the input board's PGA (Programmable Gain Amplifier)
0x02000102	1	Input Signal Channel	3 / 7 6 / 10 1 / 2	INT	Sensor Offset Factor	ID chip
0x02000103	1	Input Signal Channel	3 / 7 6 / 10 1 / 2	INT	Sensor Cable Compensation	ID chip

Parameter ID (hexa-decimal)	Command Level for Write Access	Item Type	Max. No. of Items	Data Type	Parameter Description	Notes
0x02000200	1	Input Signal Channel	3 / 7 6 / 10 1 / 2	FLOAT	Sensor Mech. Correction 1	ID chip This value is set as new sensor position after a referencing move started with FRF.
0x02000300	1	Input Signal Channel	3 / 7 6 / 10 1 / 2	FLOAT	Sensor Mech. Correction 2	ID chip
0x02000400	1	Input Signal Channel	3 / 7 6 / 10 1 / 2	FLOAT	Sensor Mech. Correction 3	ID chip
0x02000500	1	Input Signal Channel	3 / 7 6 / 10 1 / 2	FLOAT	Sensor Mech. Correction 4	ID chip
0x02000600	1	Input Signal Channel	3 / 7 6 / 10 1 / 2	FLOAT	Sensor Mech. Correction 5	ID chip
0x02000a00	1	Input Signal Channel	3 / 7 6 / 10 1 / 2	INT	Sensor Reference Mode	Determines how the sensor is to be referenced: 1 = no referencing (absolute sensors, no referencing required, RON cannot be set to 0) 2 = referencing on negative hardstop 3 = referencing on positive hardstop 4 = referencing on reference edge 5 = referencing on reference pulse
0x02001000	1	Input Signal Channel	3 / 7 6 / 10 1 / 2	INT	Sensor Lim, Ref Signal Inversion	Determines if the E-711/E-712 system inverts the reference switch and limit switch signals. See "Signals of Reference and Limit Switches" (p. 152).
0x02001800	1	Input Signal Channel	3 / 7 6 / 10 1 / 2	INT	Configuration of Serial Sensor Interface	For Renishaw sensors with BiSS C protocol

Parameter ID (hexa-decimal)	Command Level for Write Access	Item Type	Max. No. of Items	Data Type	Parameter Description	Notes
0x02001900	3	Input Signal Channel	3 / 7 6 / 10 1 / 2	INT	Lim, Ref Signals Detectable	Flag that indicates if signals of limit and reference switches are evaluated by the firmware (does not indicate if switches are present) 0 = no evaluation of switch signals 1 = switch signals are evaluated
0x02001B00	1	Input Signal Channel	3 / 7 6 / 10 1 / 2	FLOAT	Maximum Position Of Sensor	The parameters are only available if the plausibility check is enabled with the Check Sensor Position Plausibility parameter (ID 0x0e001f00) See “Plausibility Check of Sensor Position” (p. 259).
0x02001C00	1	Input Signal Channel	3 / 7 6 / 10 1 / 2	FLOAT	Minimum Position Of Sensor	
0x02001D00	1	Input Signal Channel	3 / 7 6 / 10 1 / 2	INT	Validate Sensor Position Range	
0x030001*i*	2	Input Signal Channel	3 / 7 6 / 10 1 / 2	FLOAT	Sensor Elec. Correction *j* 1	Coefficients of the polynomials for electronics linearization; independent of the connected mechanics *i* = 00, 01, 02, 03, 04, 05, 06, 07, 08, 09, 0a, 0b, 0c, 0d, 0e, 0f, 11, 12 *j* = 1 to 19
0x030002*i*	2	Input Signal Channel	3 / 7 6 / 10 1 / 2	FLOAT	Sensor Elec. Correction *j* 2	
0x030003*i*	2	Input Signal Channel	3 / 7 6 / 10 1 / 2	FLOAT	Sensor Elec. Correction *j* 3	
0x030004*i*	2	Input Signal Channel	3 / 7 6 / 10 1 / 2	FLOAT	Sensor Elec. Correction *j* 4	
0x030005*i*	2	Input Signal Channel	3 / 7 6 / 10 1 / 2	FLOAT	Sensor Elec. Correction *j* 5	
0x03001*i*00	2	Input Signal Channel	3 / 7 6 / 10 1 / 2	FLOAT	Sensor Offset Correction *j*	Coefficients of the polynomial for sensor offset correction *i* = 0, 1, 2, 3, 4, 5 *j* = 1 to 6
0x03003400	1	Input Signal Channel	3 / 7 6 / 10 1 / 2	INT	Input Numerical Format	0 = IEEE 32 bit float format 1 = unsigned integer 16 bit 2 = unsigned integer 24 bit 3 = unsigned integer 32 bit 4 = signed integer 16 bit 5 = signed integer 24 bit 6 = signed integer 32 bit

Parameter ID (hexa-decimal)	Command Level for Write Access	Item Type	Max. No. of Items	Data Type	Parameter Description	Notes
0x0400000*i*	2	Input Signal Channel	3 / 7 6 / 10 1 / 2	FLOAT	PGA Correction of Gain *j*	Amplification factors for the gain settings of the input board's PGA *i* = 0, 1, 2, 3, 4, 5, ... (gains specified by parameter 0x02000101) *j* = 1 to *i*+1
0x05000000	1	Input Signal Channel	3 / 7 6 / 10 1 / 2	INT	Digital Filter Type	ID chip
0x05000001	1	Input Signal Channel	3 / 7 6 / 10 1 / 2	FLOAT	Digital Filter Bandwidth	ID chip
0x05000002	1	Input Signal Channel	3 / 7 6 / 10 1 / 2	INT	Digital Filter Order	ID chip
0x05000101	1	Input Signal Channel	3 / 7 6 / 10 1 / 2	FLOAT	User Filter Param. 1	
0x05000102	1	Input Signal Channel	3 / 7 6 / 10 1 / 2	FLOAT	User Filter Param. 2	
0x05000103	1	Input Signal Channel	3 / 7 6 / 10 1 / 2	FLOAT	User Filter Param. 3	
0x05000104	1	Input Signal Channel	3 / 7 6 / 10 1 / 2	FLOAT	User Filter Param. 4	
0x05000105	1	Input Signal Channel	3 / 7 6 / 10 1 / 2	FLOAT	User Filter Param. 5	
0x06000500	1	Logical Axis	3 / 6 1 / 2	INT	ADC Channel for Target	
0x06000501	1	Logical Axis	3 / 6 1 / 2	FLOAT	Analog Target Offset	
0x06010000	1	Logical Axis	3 / 6 1 / 2	FLOAT	Target Generator Maximum Acceleration	
0x06010100	1	Logical Axis	3 / 6 1 / 2	FLOAT	Target Generator Maximum Jerk	See "Profile Generator" (p. 145).
0x06010200	1	Logical Axis	3 / 6 1 / 2	FLOAT	Time Constant Of Target Generator	

Parameter ID (hexa-decimal)	Command Level for Write Access	Item Type	Max. No. of Items	Data Type	Parameter Description	Notes
0x06010300	1	Logical Axis	3 / 6 1 / 2	INT	Target Generator Enable	
0x06010400	3	Logical Axis	3 / 6 1 / 2	FLOAT	Target Generator Maximum Velocity	
0x07000000	1	Logical Axis	3 / 6 1 / 2	FLOAT	Range Limit min	ID chip
0x07000001	1	Logical Axis	3 / 6 1 / 2	FLOAT	Range Limit max	ID chip
0x07000200	1	Logical Axis	3 / 6 1 / 2	FLOAT	Servo Loop Slew-Rate	ID chip
0x07000201	1	Logical Axis	3 / 6 1 / 2	FLOAT	Open Loop Slew-Rate	
0x07000204	1	PiezoWalk Channel	1 / 2 3 / *	FLOAT	PiezoWalk Open-Loop Velocity	[µm/s] Used to calculate the piezo voltage slew rate, affects the duration of the relax procedures for PiezoWalk channels
0x07000300	1	Logical Axis	3 / 6 1 / 2	FLOAT	Servo-Loop P-Term	ID chip See "Control Algorithms for Closed-Loop Operation" (p. 145).
0x07000301	1	Logical Axis	3 / 6 1 / 2	FLOAT	Servo-Loop I-Term	ID chip
0x07000302	1	Logical Axis	3 / 6 1 / 2	FLOAT	Servo-Loop D-Term	ID chip
0x07000307	1	Logical Axis	3 / 6 1 / 2	FLOAT	Servo-Loop P-Term for Velocity	See "Control Algorithms for Closed-Loop Operation" (p. 145).
0x07000308	1	Logical Axis	3 / 6 1 / 2	FLOAT	Servo-Loop I-Term for Velocity	
0x07000309	1	Logical Axis	3 / 6 1 / 2	FLOAT	Servo-Loop D-Term for Velocity	
0x07000500	1	Logical Axis	3 / 6 1 / 2	FLOAT	Position from Sensor 1	ID chip
0x07000501	1	Logical Axis	3 / 6 1 / 2	FLOAT	Position From Sensor 2	ID chip
0x07000502	1	Logical Axis	3 / 6 1 / 2	FLOAT	Position From Sensor 3	ID chip
0x07000503	1	Logical Axis	3 / 6 1 / 2	FLOAT	Position From Sensor 4	ID chip
0x07000504	1	Logical Axis	3 / 6 1 / 2	FLOAT	Position From Sensor 5	ID chip

Parameter ID (hexa-decimal)	Command Level for Write Access	Item Type	Max. No. of Items	Data Type	Parameter Description	Notes
0x07000505	1	Logical Axis	3 / 6 1 / 2	FLOAT	Position From Sensor 6	ID chip
0x07000506	1	Logical Axis	3 / 6 1 / 2	FLOAT	Position From Sensor 7	
0x07000507	1	Logical Axis	3 / 6 1 / 2	FLOAT	Position From Sensor 8	
0x07000508	1	Logical Axis	3 / 6 1 / 2	FLOAT	Position From Sensor 9	
0x07000509	1	Logical Axis	3 / 6 1 / 2	FLOAT	Position From Sensor 10	
0x0700050a	1	Logical Axis	3 / 6 1 / 2	FLOAT	Position From Sensor 11	
0x0700050b	1	Logical Axis	3 / 6 1 / 2	FLOAT	Position From Sensor 12	
0x0700050c	1	Logical Axis	3 / 6 1 / 2	FLOAT	Position From Sensor 13	
0x0700050d	1	Logical Axis	3 / 6 1 / 2	FLOAT	Position From Sensor 14	
0x07000600	1	Logical Axis	3 / 6 1 / 2	CHAR	Axis Name	ID chip
0x07000601	2	Logical Axis	3 / 6 1 / 2	CHAR	Axis Unit	ID chip
0x07000800	1	Logical Axis	3 / 6 1 / 2	INT	Power Up Servo ON Enable	
0x07000802	1	Logical Axis	3 / 6 1 / 2	INT	Power Up AutoZero Enable	
0x07000900	1	Logical Axis	3 / 6 1 / 2	FLOAT	ON Target Tolerance	ID chip [µm] Specifies the settling window. The settling window is centered around the axis target position. The on-target state of an axis is true when the current axis position is inside the settling window and stays there for at least the duration of the delay time (Settling Time parameter, ID 0x07000901). See the E712T0010 user manual for the special functionality of this parameter with PiezoWalk systems.

Parameter ID (hexa-decimal)	Command Level for Write Access	Item Type	Max. No. of Items	Data Type	Parameter Description	Notes
0x07000901	1	Logical Axis	3 / 6 1 / 2	FLOAT	Settling Time	[s]
0x07000a00	1	Logical Axis	3 / 6 1 / 2	FLOAT	AutoZero Low Voltage	ID chip
0x07000a01	1	Logical Axis	3 / 6 1 / 2	FLOAT	AutoZero High Voltage	ID chip
0x07000c01	1	Logical Axis	3 / 6 1 / 2	FLOAT	Default voltage	ID chip
0x07001005	1	Logical Axis	3 / 6 1 / 2	FLOAT	Position Report Scaling	See "Using the Analog Output" (p. 202).
0x07001006	1	Logical Axis	3 / 6 1 / 2	FLOAT	Position Report Offset	
0x07001500	1	PiezoWalk Channel	1 / 2 3 / *	FLOAT	PiezoWalk Forward Correction 1	Coefficients of step forward linearization polynomial of piezo-voltage-to-position-calculation. Coefficients are used to compensate for the piezo nonlinearity. If 0x07001500 is set to 1 and all other coefficients are set to 0, linearization is disabled.
0x07001501	1	PiezoWalk Channel	1 / 2 3 / *	FLOAT	PiezoWalk Forward Correction 2	
0x07001502	1	PiezoWalk Channel	1 / 2 3 / *	FLOAT	PiezoWalk Forward Correction 3	
0x07001503	1	PiezoWalk Channel	1 / 2 3 / *	FLOAT	PiezoWalk Forward Correction 4	
0x07001504	1	PiezoWalk Channel	1 / 2 3 / *	FLOAT	PiezoWalk Forward Correction 5	
0x07001505	1	PiezoWalk Channel	1 / 2 3 / *	FLOAT	PiezoWalk Forward Correction 6	
0x07001600	1	PiezoWalk Channel	1 / 2 3 / *	FLOAT	PiezoWalk Backward Correction 1	Coefficients of step backward linearization polynomial of piezo-voltage-to position-calculation. Coefficients are used to compensate for the piezo nonlinearity. If 0x07001600 is set to 1 and all other coefficients are set to 0, linearization is disabled.
0x07001601	1	PiezoWalk Channel	1 / 2 3 / *	FLOAT	PiezoWalk Backward Correction 2	
0x07001602	1	PiezoWalk Channel	1 / 2 3 / *	FLOAT	PiezoWalk Backward Correction 3	
0x07001603	1	PiezoWalk Channel	1 / 2 3 / *	FLOAT	PiezoWalk Backward Correction 4	
0x07001604	1	PiezoWalk Channel	1 / 2 3 / *	FLOAT	PiezoWalk Backward Correction 5	

Parameter ID (hexa-decimal)	Command Level for Write Access	Item Type	Max. No. of Items	Data Type	Parameter Description	Notes
0x07001605	1	PiezoWalk Channel	1 / 2 3 / *	FLOAT	PiezoWalk Backward Correction 6	
0x07001900	1	PiezoWalk Channel	1 / 2 3 / *	FLOAT	PiezoWalk Clamp-Free Voltage	Used for nanostepping mode only. See the E712T0010 user manual.
0x07001a00	1	PiezoWalk Channel	1 / 2 3 / *	INT	PiezoWalk Driving Mode	Selects the mode of driving: 0 = Full-step mode 1 = Nanostepping mode 2 = Analog mode (if selected, no stepping motion is possible)
0x07001f00	1	External Axis	16	INT	External Axes Status Input Channel	Specifies the input signal channel to be used for state feedback of an external axis (= axis of an external SPI slave connected to an E-711.iS3 or E-711.iS6 SPI interface module in the E-711/E-712 system)
0x07002000	1	External Axis	16	INT	External Axes Command Output Channel	Specifies the output signal channel to be used for commanding an external axis (= axis of an external SPI slave connected to an E-711.iS3 or E-711.iS6 SPI interface module in the E-711/E-712 system)
0x07011700	1	PiezoWalk Channel	1 / 2 3 / *	FLOAT	PiezoWalk Step Size	[µm] The feed caused by one step cycle, with maximum amplitude of the shearing voltages ($V_{Dmax} – V_{Dmin}$). Can be determined as follows: Perform n steps using OSM, measure the position difference and divide it by the number of steps.

Parameter ID (hexa-decimal)	Command Level for Write Access	Item Type	Max. No. of Items	Data Type	Parameter Description	Notes
0x07011800	1	PiezoWalk Channel	1 / 2 3 / *	FLOAT	PiezoWalk Shearing-To-Clamping Ratio	Used for full-step mode only. Must be in the range of 0.01 to 0.5 See the E712T0010 user manual.
0x07011900	1	PiezoWalk Channel	1 / 2 3 / *	FLOAT	PiezoWalk Min Step Cycle Time	[s] Minimum time per step cycle. This value will be rounded to a multiple of the sample time. See the E712T0010 user manual.
0x07011b00	1	PiezoWalk Channel	1 / 2 3 / *	FLOAT	PiezoWalk Max Acceleration	[µm/s²] Maximum acceleration of a NEXLINE® drive.
0x07011d00	1	PiezoWalk Channel	1 / 2 3 / *	INT	PiezoWalk Type	1 = NEXLINE 2 = NEXACT (also required for PICMAWalk)
0x07011e00	1	PiezoWalk Channel	1 / 2 3 / *	FLOAT	NEXACT Drive Weight	Specifies the ratio of the shearing voltage amplitude to the clamping voltage amplitude. This ratio influences the feed caused by one step cycle, i.e. the step size. Only used if PiezoWalk Type (ID 0x07011d00) = 2 (NEXACT, PICMAWalk).
0x07011f00	2	PiezoWalk Channel	1 / 2 3 / *	INT	PiezoWalk Driven Cycles	Counter for the electrical cycles performed by a PiezoWalk drive.
0x07012400	2	PiezoWalk Channel	1 / 2 3 / *	INT	To PiezoWalk Linked Sensor Chan	Specifies the ID of an input signal channel with limit switches that is assigned to the PiezoWalk channel. 0 (default) = no channel assigned

Parameter ID (hexa-decimal)	Command Level for Write Access	Item Type	Max. No. of Items	Data Type	Parameter Description	Notes
0x07012500	1	PiezoWalk Channel	1 / 2 3 / *	INT	To PiezoWalk Linked Brake Output Chan	Specifies the ID of an output signal channel with brake that is assigned to the PiezoWalk channel. The brake of the assigned output signal channel is open if the PiezoWalk channel is not in the relaxed state (opened when switching to closed-loop operation, closed when switching to open-loop operation). 0 (default) = no channel assigned
0x07012600	1	PiezoWalk Channel	1 / 2 3 / *	FLOAT	Time To Open Brake	Time to open the brake assigned to a PiezoWalk channel, in s To open the brake, for the assigned output signal channel first the lower limit for the piezo voltage output is set, and afterwards the upper limit.
0x07012700	1	PiezoWalk Channel	1 / 2 3 / *	FLOAT	Time To Close Brake	Time to close the brake assigned to a PiezoWalk channel, in s To close the brake, for the assigned output signal channel first the lower limit for the piezo voltage output is set, and afterwards the zero voltage value.
0x7012800	1	PiezoWalk Channel	1 / 2 3 / *	FLOAT	Time To Relax PiezoWalk Channel	[s] Duration of the simple relax procedure for PiezoWalk® drives If the parameter value is zero (default setting), the duration depends on the setting of the PiezoWalk Open-Loop Velocity parameter (0x07000204). See the E712T0010 user manual.

Parameter ID (hexa-decimal)	Command Level for Write Access	Item Type	Max. No. of Items	Data Type	Parameter Description	Notes
0x07022000	3	Logical Axis	3 / 6 1 / 2	INT	Open-Loop Control Mode	0 = position control 1 = velocity control 2 = velocity control for PiezoWalk drives, use OSM and SVA in open-loop operation
0x07030100	1	Logical Axis	3 / 6 1 / 2	INT	Closed-Loop Control Mode	Specifies the control modes to be used for closed-loop operation. See "Control Algorithms for Closed-Loop Operation" (p. 145).
0x07030200	1	Logical Axis	3 / 6 1 / 2	INT	Servo Instability Detection	Configuration of control instability detection.
0x07030202	3	Logical Axis	3 / 6 1 / 2	INT	Servo Instability Indicator	
0x07030300	1	Logical Axis	3 / 6 1 / 2	FLOAT	Referencing Velocity	Velocity for referencing moves. See "How to Reference an Axis" (p. 117).
0x07030600	1	Logical Axis	3 / 6 1 / 2	FLOAT	Feed Forward in n-1th Derivative of Position n = 1	
0x07030601	1	Logical Axis	3 / 6 1 / 2	FLOAT	Feed Forward in n-1th Derivative of Position n = 2	See "Feedforward" (p. 149).
0x07030900	1	Logical Axis	3 / 6 1 / 2	INT	Input Channel For Feed Forward Signal	
0x07030a00	1	Logical Axis	3 / 6 1 / 2	FLOAT	On-Target Tolerance To Fix I-Term	[µm] Specifies a window in which the I-term of the control algorithm stays fixed. See "Control Algorithms for Closed-Loop Operation" (p. 145).
0x07030b00	1	Logical Axis	3 / 6 1 / 2	FLOAT	HLT Deceleration	Deceleration applied when HLT is sent for an axis, in phys. unit/s^2

<table>
<tr><th>Parameter ID (hexa-decimal)</th><th>Command Level for Write Access</th><th>Item Type</th><th>Max. No. of Items</th><th>Data Type</th><th>Parameter Description</th><th colspan="2">Notes</th></tr>
<tr><td>0x07030c00</td><td>1</td><td>Logical Axis</td><td>3 / 6
1 / 2</td><td>INT</td><td>ID-Chip Chan. to Axis Map Ctrl</td><td colspan="2">Mapping of axis identifiers when stages with ID chip are connected to the E-711/E-712 system.
See "ID Chip Support / Stage Replacement" (p. 260).</td></tr>
<tr><td>0x07030d00</td><td>1</td><td>Logical Axis</td><td>3 / 6
1 / 2</td><td>INT</td><td>Zeroing Control Value If I-Term Is Fixed</td><td colspan="2">Determines the control value when the current position is in the window specified by parameter 0x07030a00. See "Control Algorithms for Closed-Loop Operation" (p. 145).</td></tr>
<tr><td>0x07030f00</td><td>1</td><td>PiezoWalk Channel</td><td>1 / 2
3 / *</td><td>FLOAT</td><td>Special Relax Process Gain</td><td colspan="2">Specifies a gain value for the iterative relax procedure. Change the default value only after consultation with PI!
See the E712T0010 user manual.</td></tr>
<tr><td>0x07031000</td><td>1</td><td>PiezoWalk Channel</td><td>1 / 2
3 / *</td><td>FLOAT</td><td>Max Special Relax Process Time</td><td colspan="2">[s]
Maximum total duration of the iterative relax procedure
Default: 2 s
See the E712T0010 user manual.</td></tr>
<tr><td>0x07031100</td><td>1</td><td>PiezoWalk Channel</td><td>1 / 2
3 / *</td><td>INT</td><td>Special Relax Type</td><td colspan="2">Mode of driving for the closed-loop part of the iterative relax procedure.
1 = nanostepping mode
2 = analog mode (default)
See the E712T0010 user manual.</td></tr>
<tr><td>0x08000100</td><td>1</td><td>Logical Axis</td><td>3 / 6
1 / 2</td><td>FLOAT</td><td>Notch Frequency 1</td><td>ID chip</td><td rowspan="6">See "Notch Filters" (p. 151).</td></tr>
<tr><td>0x08000101</td><td>1</td><td>Logical Axis</td><td>3 / 6
1 / 2</td><td>FLOAT</td><td>Notch Frequency 2</td><td>ID chip</td></tr>
<tr><td>0x08000200</td><td>1</td><td>Logical Axis</td><td>3 / 6
1 / 2</td><td>FLOAT</td><td>Notch Rejection 1</td><td>ID chip</td></tr>
<tr><td>0x08000201</td><td>1</td><td>Logical Axis</td><td>3 / 6
1 / 2</td><td>FLOAT</td><td>Notch Rejection 2</td><td>ID chip</td></tr>
<tr><td>0x08000300</td><td>1</td><td>Logical Axis</td><td>3 / 6
1 / 2</td><td>FLOAT</td><td>Notch Bandwidth 1</td><td>ID chip</td></tr>
<tr><td>0x08000301</td><td>1</td><td>Logical Axis</td><td>3 / 6
1 / 2</td><td>FLOAT</td><td>Notch Bandwidth 2</td><td>ID chip</td></tr>
</table>

Parameter ID (hexa-decimal)	Command Level for Write Access	Item Type	Max. No. of Items	Data Type	Parameter Description	Notes
0x08000400	1	Logical Axis	3 / 6 1 / 2	FLOAT	Creep Factor T1/sec	ID chip
0x08000401	1	Logical Axis	3 / 6 1 / 2	FLOAT	Creep Factor T2/sec	ID chip
0x08000500	1	Logical Axis	3 / 6 1 / 2	INT	Enable Notch in Open Loop	See "Notch Filters" (p. 151).
0x08000600	1	Logical Axis	3 / 6 1 / 2	INT	Notch Filter Calculation Method	
0x09000000	1	Logical Axis	3 / 6 1 / 2	FLOAT	Driving Factor of Piezo 1	ID chip
0x09000001	1	Logical Axis	3 / 6 1 / 2	FLOAT	Driving Factor of Piezo 2	ID chip
0x09000002	1	Logical Axis	3 / 6 1 / 2	FLOAT	Driving Factor of Piezo 3	ID chip
0x09000003	1	Logical Axis	3 / 6 1 / 2	FLOAT	Driving Factor of Piezo 4	ID chip
0x09000004	1	Logical Axis	3 / 6 1 / 2	FLOAT	Driving Factor of Piezo 5	ID chip
0x09000005	1	Logical Axis	3 / 6 1 / 2	FLOAT	Driving Factor of Piezo 6	ID chip
0x09000006	1	Logical Axis	3 / 6 1 / 2	FLOAT	Driving Factor of Piezo 7	ID chip
0x09000007	1	Logical Axis	3 / 6 1 / 2	FLOAT	Driving Factor of Piezo 8	ID chip
0x09000008	1	Logical Axis	3 / 6 1 / 2	FLOAT	Driving Factor of Piezo 9	
0x09000009	1	Logical Axis	3 / 6 1 / 2	FLOAT	Driving Factor of Piezo 10	
0x0900000a	1	Logical Axis	3 / 6 1 / 2	FLOAT	Driving Factor of Piezo 11	
0x0900000b	1	Logical Axis	3 / 6 1 / 2	FLOAT	Driving Factor of Piezo 12	
0x0900000c	1	Logical Axis	3 / 6 1 / 2	FLOAT	Driving Factor of Piezo 13	
0x0900000d	1	Logical Axis	3 / 6 1 / 2	FLOAT	Driving Factor of Piezo 14	
0x09000100	1	PiezoWalk Channel	1 / 2 3 / *	INT	PiezoWalk Shear Channel 1	Specifies the piezo amplifier channel to be used for the first pair of shearing segments of the PiezoWalk® drive
0x09000101	1	PiezoWalk Channel	1 / 2 3 / *	INT	PiezoWalk Shear Channel 2	Specifies the piezo amplifier channel to be used for the second pair of shearing segments of the PiezoWalk® drive

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Parameter ID (hexa-decimal)	**Command Level for Write Access**	**Item Type**	**Max. No. of Items**	**Data Type**	**Parameter Description**	**Notes**
0x09000200	1	PiezoWalk Channel	1 / 2 3 / *	INT	PiezoWalk Clamp Channel 1	Specifies the piezo amplifier channel to be used for the first pair of clamping segments of the PiezoWalk® drive
0x09000201	1	PiezoWalk Channel	1 / 2 3 / *	INT	PiezoWalk Clamp Channel 2	Specifies the piezo amplifier channel to be used for the second pair of clamping segments of the PiezoWalk® drive
0x0a000003	1	Output Signal Channel	4 / 8 12	INT	Select Output type	See "Using the Analog Output" (p. 202).
0x0a000004	1	Output Signal Channel	4 / 8 12	INT	Select Output index	
0x0b000007	2	Output Signal Channel	4 / 8 12	FLOAT	Min Output Voltage of Amplifier	
0x0b000008	2	Output Signal Channel	4 / 8 12	FLOAT	Max Output Voltage of Amplifier	
0x0b000009	2	Output Signal Channel	4 / 8 12	FLOAT	Voltage of Amplifier with zero to Dac	
0x0b00000a	1	Output Signal Channel	4 / 8 12	FLOAT	Voltage Offset of Amplifier	
0x0b000500	1	Output Signal Channel	4 / 8 12	INT	Output Numerical Format	0 = IEEE 32 bit float format 1 = unsigned integer 16 bit 2 = unsigned integer 24 bit 3 = unsigned integer 32 bit 4 = signed integer 16 bit (a zero is zero) 5 = signed integer 24 bit (a zero is zero) 6 = signed integer 32 bit (a zero is zero) 7 = raw format (used for driver/DAC issues)
0x0b000800	1	Output Signal Channel	4 / 8 12	INT	Input Index To Feed Back	Can be used to test SPI channels and data transfer: The parameter value specifies the ID of an input signal channel. This input signal channel is connected to the output signal channel to provide feedback on the output.

Parameter ID (hexa-decimal)	Command Level for Write Access	Item Type	Max. No. of Items	Data Type	Parameter Description	Notes
0x0B000900	1 / 3	Output Signal Channel	4 / 8 12	FLOAT	Max Output Current (A)	For systems that support DC motors (E-711.C82 motor driver module is present). The command level for write access is 1 for channels that belong to E-711.C82 motor driver modules, and 3 for all other channels.
0x0c000000	1	Output Signal Channel	4 / 8 12	FLOAT	Soft Voltage Low Limit	ID chip Specifies the lower limit for the piezo voltage output
0x0c000001	1	Output Signal Channel	4 / 8 12	FLOAT	Soft Voltage High Limit	ID chip Specifies the upper limit for the piezo voltage output.
0x0c000200	1	Output Signal Channel	4 / 8 12	FLOAT	Percentage Dead Zone (0|1) 1	Amplifier linearization
0x0c000201	1	Output Signal Channel	4 / 8 12	FLOAT	Percentage Dead Zone (0|1) 2	Amplifier linearization
0x0c000300	1	Output Signal Channel	4 / 8 12	FLOAT	Percentage Effective Zone (0|1) 1	Amplifier linearization
0x0c000301	1	Output Signal Channel	4 / 8 12	FLOAT	Percentage Effective Zone (0|1) 2	Amplifier linearization
0x0c000400	1	Output Signal Channel	4 / 8 12	INT	Type Of Output Linearisation	Type of amplifier linearization 0 = not used 1 = dead band linearization 2 = hysteresis linearization
0x0d000000	2	System	1	CHAR	Device S/N	
0x0d000100	2	Hardware Module	8	CHAR	Hardware S/N	
0x0d000200	2	Hardware Module	8	CHAR	Hardware Name	
0x0e000100	2	System	1	FLOAT	Sensor Sampling Time	
0x0e000200	3	System	1	FLOAT	Servo Update Time	Control loop sampling time

Parameter ID (hexa-decimal)	**Command Level for Write Access**	**Item Type**	**Max. No. of Items**	**Data Type**	**Parameter Description**	**Notes**
0x0e000301	1	System	1	INT	Disable Error 10	This parameter can be used to avoid that error code 10 is set when axes are stopped with the STP, #24 or HLT commands. 0 = OFF (Error code 10 is set.) 1 = ON (Error code 10 is **not** set.)
0x0e000400	1	System	1	INT	DDL License	
0x0e000401	3	System	1	INT	DDL License Valid	
0x0e000b00	3	System	1	INT	Number Of Input channels	
0x0e000b01	3	System	1	INT	Number Of Output Channels	
0x0e000b02	2	System	1	INT	Number Of System Axes	
0x0e000b03	3	System	1	INT	Number Of Sensor Channels	
0x0e000b04	3	System	1	INT	Number Of Piezo Channels	
0x0e000b05	3	System	1	INT	Number Of Trigger Outputs	
0x0e000b06	3	System	1	INT	Number Of PiezoWalk Channels	Maximum possible number of PiezoWalk channels.
0x0e000b07	3	System	1	INT	Number Of Conf. PiezoWalk Chan.	Number of PiezoWalk channels which are configured for use.

Parameter ID (hexa-decimal)	Command Level for Write Access	Item Type	Max. No. of Items	Data Type	Parameter Description	Notes
0x0e000e00	1	Logical Axis	3 / 6 1 / 2	INT	Adv. Piezo Control License	Advanced Piezo Control (APC) license number; must be valid before APC can be used. Advanced Piezo Control is an alternative control algorithm for closed-loop operation of piezo actuator systems. The APC license must be expressly ordered (order number E-712.U1). The Closed-Loop Control Mode parameter (ID 0x07030100) must be set to 2. See the E712T0007 technical note for more information.
0x0e000f00	3	Logical Axis	3 / 6 1 / 2	INT	Adv. Piezo Control License-Valid Flag	Check if APC license activation was successful
0x0e001100	1	System	1	INT	Digital IO Synchronisation	Enables/disables synchronization of digital input and output lines: 1 = enabled 0 = disabled
0x0e001200	1	System	1	INT	PCI Busmaster DMA Enable	Enables/disables PCI bus mastering DMA for reading sensors and writing amplifiers 1 = enabled 0 = disabled
0x0e001300	1	System	1	INT	Number Of SPI Inputs	Number of additional input signal channels and output signal channels to be provided by the E-711/E-712 system for the SPI slave interface. See "Accessible Items and Their Identifiers" (p. 127).
0x0e001400	1	System	1	INT	Number Of SPI Outputs	
0x0e001500	1	System	1	INT	Reboot on DIO Input	The value of the parameter enables/disables the reset input on pin 19 of the MDR20 connector (see p. 335).

Parameter ID (hexa-decimal)	Command Level for Write Access	Item Type	Max. No. of Items	Data Type	Parameter Description	Notes
0x0e001d00	1	System	1	INT	Trigger Input Filter Enable	The value of the parameter enables/disables a filter for the digital trigger input as follows: 0 = OFF: Filter is disabled. Processing of the trigger input is done immediately. 1 = ON: Filter is enabled to reduce the influence of noise at the trigger input line. Default setting.
0x0e001e00	1	System	1	INT	Disconnect Analog Target Input When Stopping	Determines the behavior when the analog input is used as a control source. See p. 196 for details.
0x0e001f00	1	System	1	INT	Check Sensor Position Plausibility	Enables or disables plausibility check of sensor position. See "Plausibility Check of Sensor Position" (p. 259).
0x0e002000	1	System	1	INT	Move To Last Commanded Position	Determines the target positions to be set when switching to closed-loop operation: 0 = The target positions are set to the current positions of the axes (default). 1= The target positions are set to the last commanded target positions for the axes. This can cause an abrupt motion.
0x0e002200	1	System	1	INT	Use Autofocus Functions	Enables or disables the autofocus functionality. 0 = Autofocus functionality disabled 1 = Autofocus functionality enabled. Additional commands and parameters are available. See the E712T0017 technical note for more information.

Parameter ID (hexa-decimal)	Command Level for Write Access	Item Type	Max. No. of Items	Data Type	Parameter Description	Notes
0xe002400	1	System	1	INT	Trigger Input Filter Samples	Number of samples that must be equal to change the digital input state 1 to 10 This parameter is only used if the digital input value should be filtered, i.e. if parameter 0x0e001d00 has the value 1 (= ON).
0x0f000000	1	Input Signal Channel	3 / 7 6 / 10 1 / 2	INT	Power Up Read ID-Chip	See "ID Chip Support / Stage Replacement" (p. 260).
0x0f000100	1	Input Signal Channel	3 / 7 6 / 10 1 / 2	CHAR	Stage Type	ID chip
0x0f000200	1	Input Signal Channel	3 / 7 6 / 10 1 / 2	CHAR	Stage Serial Number	ID chip
0x0f000300	1	Input Signal Channel	3 / 7 6 / 10 1 / 2	CHAR	Stage assembly Date	ID chip
0x0f000700	3	Input Signal Channel	3 / 7 6 / 10 1 / 2	INT	ID-Chip Data Valid	Read-only flag 1 = ID chip found and data valid. ID chip could be read successfully. 0 = no ID chip found, or data corrupted
0x11000400	1	System	1	INT	Uart Baudrate	See "Communication" (p. 154).
0x11000600	1	System	1	CHAR	IP-Address	
0x11000700	1	System	1	CHAR	IP-Mask	
0x11000800	1	System	1	INT	IP-Configuration	
0x11000b00	2	System	1	CHAR	MAC-Address	
0x11000c00	1	System	1	INT	Max. TCP/IP Connections	
0x13000004	3	System	1	INT	Max Wave Points	See "Wave Generator" (p. 214).
0x13000109	1	System	1	INT	Wave Generator Table Rate	
0x1300010a	3	System	1	INT	Number of Waves	
0x1300010b	1	Logical Axis	3 / 6 1 / 2	FLOAT	Wave Offset	
0x13000202	1	System	1	INT	Wave Multi Start By Trigger	

Parameter ID (hexa-decimal)	Command Level for Write Access	Item Type	Max. No. of Items	Data Type	Parameter Description	Notes
0x14000001	1	Logical Axis	3 / 6 1 / 2	INT	DDL Repeat Number	See "Dynamic Digital Linearization (DDL)" (p. 235).
0x14000006	1	Logical Axis	3 / 6 1 / 2	FLOAT	Time Delay Max	
0x14000007	1	Logical Axis	3 / 6 1 / 2	FLOAT	Time Delay Min	
0x14000008	1	Logical Axis	3 / 6 1 / 2	INT	Time Delay Change Rule	
0x1400000a	1	Logical Axis	3 / 6 1 / 2	INT	DDL Zero Gain Number	
0x1400000b	3	System	1	INT	Max DDL Points	
0x16000000	1	System	1	INT	Data Recorder Table Rate	See "Data Recording" (p. 164).
0x16000100	3	System	1	INT	Max Number of Data Recorder Channels	
0x16000200	3	System	1	INT	Data Recorder Max Points	
0x16000300	1	System	1	INT	Data Recorder Chan Number	
0x16000700	1	Data recorder table	12	INT	DRC Data Source	
0x16000701	1	Data recorder table	12	INT	DRC Record Option	
0x18000201	1	Digital Output Line	7	FLOAT	CTO Trigger Step	See "Configuring Trigger Output" (p. 168).
0x18000202	1	Digital Output Line	7	INT	CTO Axis	
0x18000203	1	Digital Output Line	7	INT	CTO Trigger Mode	
0x18000205	1	Digital Output Line	7	FLOAT	CTO Min. Threshold	
0x18000206	1	Digital Output Line	7	FLOAT	CTO Max. Threshold	
0x18000207	1	Digital Output Line	7	INT	CTO Polarity	
0x18000208	1	Digital Output Line	7	FLOAT	CTO Start Threshold	
0x18000209	1	Digital Output Line	7	FLOAT	CTO Stop Threshold	
0x18000210	1	Digital Output Line	7	INT	CTO Trigger Out Mask	

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Parameter ID (hexa-decimal)	Command Level for Write Access	Item Type	Max. No. of Items	Data Type	Parameter Description	Notes
0x18000300	1	Digital Output Line	7	INT	Pos. Distance Trig. Single Direction	Additional settings for the "Position Distance" trigger mode. See "Example—"Position Distance" Trigger Mode" (p. 171).
0x18000301	1	Digital Output Line	7	FLOAT	Pos. Distance Trig. Filter Time	
0x18000302	1	Digital Output Line	7	FLOAT	Pos. Distance Trig. Filter Level	
0x18000400	1	Digital Output Line	7	INT	Pos. Distance Trig. High Time Definition	
0x18000401	1	Digital Output Line	7	FLOAT	Pos. Distance Trig. High Time	
0x1a00000*n*	1	System	1	FLOAT	Max. Position Error to Stop *n*	Safety shutdown Configuration and activation/deactivation of the safety shutdown functionality. See "Protective Functions" (p. 256).
0x1a000100	1	System	1	INT	Number of Trigger Input to Stop	
0x1a00020*n*	1	System	1	FLOAT	Absolute Input Value to Stop *n*	
0x1a00030*n*	1	System	1	INT	Usage of Limit Switch *n*	
0x1a00040*n*	1	System	1	INT	Usage of Position Error to Stop *n*	
0x1a00050*n*	1	System	1	INT	Observe Sensor Signal *n*	
0x1a000600	1	System	1	INT	Safety Shutdown Activation Register	
0xffff0001	2	Firmware Unit	4 / 5 6 / 7 3	INT	Firmware Mark	
0xffff0002	2	Firmware Unit	4 / 5 6 / 7 3	INT	Firmware CRC	
0xffff0003	2	Firmware Unit	4 / 5 6 / 7 3	INT	Firmware Desc. CRC	
0xffff0004	2	Firmware Unit	4 / 5 6 / 7 3	INT	Firmware Desc. Version	
0xffff0006	2	Firmware Unit	4 / 5 6 / 7 3	CHAR	Firmware Matchcode	

Parameter ID (hexa-decimal)	Command Level for Write Access	Item Type	Max. No. of Items	Data Type	Parameter Description	Notes
0xffff0007	2	Firmware Unit	4 / 5 6 / 7 3	CHAR	Hardware Matchcode	
0xffff0008	2	Firmware Unit	4 / 5 6 / 7 3	INT	Firmware Version	
0xffff000b	2	Firmware Unit	4 / 5 6 / 7 3	INT	Firmware Max. Size	
0xffff000c	2	Firmware Unit	4 / 5 6 / 7 3	CHAR	Firmware Device	
0xffff000d	2	Firmware Unit	4 / 5 6 / 7 3	CHAR	Short Description of Firmware	
0xffff000e	2	Firmware Unit	4 / 5 6 / 7 3	CHAR	Date of Firmware	
0xffff000f	2	Firmware Unit	4 / 5 6 / 7 3	CHAR	Firmware Developer	
0xffff0010	2	Firmware Unit	4 / 5 6 / 7 3	INT	Firmware Length	
0xffff0011	2	Firmware Unit	4 / 5 6 / 7 3	INT	Firmware Compatibility	
0xffff0012	2	Firmware Unit	4 / 5 6 / 7 3	INT	Firmware Rel. Address	
0xffff0013	2	Firmware Unit	4 / 5 6 / 7 3	CHAR	Firmware Device Type	
0xffff0014	2	Firmware Unit	4 / 5 6 / 7 3	INT	Hardware Revision	
0xffff0015	2	Firmware Unit	4 / 5 6 / 7 3	INT	Firmware Dest. Addr.	
0xffff0016	2	Firmware Unit	4 / 5 6 / 7 3	INT	Firmware Configuration	

19 Maintenance

19.1 Cleaning

1. Switch off the E-711/E-712 system.
2. Remove the line cord.
3. Wait a minute to be sure that any residual voltage has dissipated.
4. Clean the housing surfaces of the E-711/E-712 system using mild detergents or disinfectant solutions.

19.2 AC Power and Line Fuses

NOTICE

!

Both fuses are active and must be checked if there is a fault.

The AC power connection and line fuses are located on the rear panel of the housing. To access the line power fuses, proceed as follows:

1. Switch off the E-711/E-712 system.
2. Remove the line cord.
3. Wait a minute to be sure that any residual voltage has dissipated.
4. Pry open the door that covers the fuse carrier and pry out the fuse carrier (see figures below).
5. Be sure to replace both fuses with fuses of the suitable type (IEC standard):

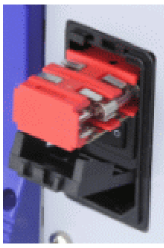
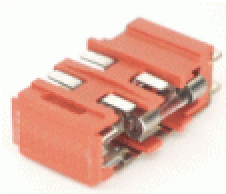
   E-712.R5 housing: 2 x T3.15AH, 250 V*

   E-712.R1, .R2, .R3, .R4 housing: 2 x T1.6AH, 250 V*

   * Unless otherwise noted on the type plate on the rear panel of the housing.

   Note: IEC-standard fuses are designed to carry the nominal current indefinitely. Other fuse rating standards differ.
6. Reinstall the carrier and close the door.



19.3 Firmware Updates

!

NOTICE

A faulty or incomplete firmware update of the E-711/E-712 system may mean that the E-711/E-712 system can only be made operational again by the PI customer service department.

➔ Update the firmware of the E-711/E-712 system only after consulting our customer service department. If possible, ask our customer service department to do the firmware update for you.

➔ Before updating the firmware, make sure that you have received a suitable firmware from our customer service department and have saved it at a location that is accessible to the update program.

The overall firmware revision of your E-711/E-712 system can be identified in the response to the IDN? command or the *IDN? command.

Each hardware module in the E-711/E-712 system has its own firmware which can be updated separately.

Detailed information regarding the individual firmware can be obtained from the parameters with ID 0xffff0001 to ID 0xffff0016. See "Parameter Overview" (p. 279) for a detailed parameter list. Query with the SPA? or SEP? command.

All firmware updates can be made by running the PIFirmwareManager on a PC. The PIFirmwareManager is included in the PI Software Suite (p. 90).

The PIFirmwareManager guides you through the update of the firmware for the hardware modules of your E-711/E-712 system.

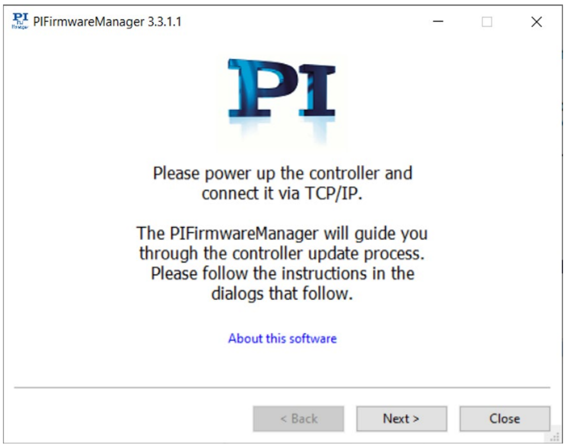


Figure 77: The PIFirmwareManager Start Screen

20 Troubleshooting

The E-711/E-712 system is switched off automatically

Maximum output power of the E-711/E-712 has been exceeded

⇒ Exceeding the maximum output power of the E-711/E-712 system is possible, for example, if all axes are moved simultaneously at too high velocities or in case of failure. If the maximum output power is exceeded, the system reboots automatically. Furthermore, a resettable fuse of the power supply may be tripped. In either case, proceed as follows:

1. Switch the E-711/E-712 system off.
2. Wait 5 minutes.
3. Switch the E-711/E-712 system on again.

How to avoid exceeding the maximum output power:

- ➔ Do not move all axes simultaneously at maximum velocity.
- ➔ Move only one axis with maximum velocity at a time.
- ➔ Do not move the axes permanently at maximum velocity.

Communication with controller does not work

Communication cable is wrong or defective

⇒ Check cable. Does it work properly with another device?

For RS-232, a null-modem cable must be used.

TCP/IP interface: Connect the controller to an Ethernet connector in the PC using the included cross-over network cable. When connecting to a network hub or router, it might be necessary to use a straight-through network cable.

Switching on or rebooting had not finished

⇒ After switching on or rebooting the E-711/E-712 system, wait at least 40 seconds before you establish communication or send commands. If you have a network without DHCP server or a point-to-point connection via TCP/IP, note that even if the *POWER* LED glows permanently, it might take another period of about 30 seconds before communication between controller and PC can be established.

The interface is not configured correctly

⇒ With the RS-232 interface, check port and baud rate (depending on your controller, the baud rate may be set via DIP switches on the front panel or via a parameter). It is recommended that the PC have a "genuine" RS-232 interface on board. If the PC uses a USB-to-serial adapter instead, data loss could occur during communication, especially when transferring large amounts of data.

⇒ With the TCP/IP interface, connect the controller to a network access point **before** you power it on. Check IP address and IP mask (the settings of the devices in the network must be compatible, e.g., the IP address of each device must be unique). Make sure that your network administrator has not set the network to forbid unknown devices like the E-711/E-712 system to log on. Note that he maximum number of TCP/IP connections can be configured via the Max. TCP/IP Connections parameter (ID 0x11000c00; default value: 1).

Controller was switched off or rebooted

⇒ With TCP/IP and USB interfaces, communication cannot be maintained after the E-711/E-712 system is switched off or rebooted.

Another program is using the interface

⇒ Close the other program.

Specific software has problems

⇒ See if the system works with some other software, e.g., a terminal or development environment. You can, for example, test the communication by simply starting a terminal program, e.g., PI Terminal, and entering commands like *IDN? or HLP?. Note that multi-character commands are transferred as terminated by a LF (Line Feed) character and are executed only after the LF is received.

Stage does not move

Cable not connected properly

⇒ Check the connecting cables.

Stage or stage cable is defective

⇒ Exchange stage with a working stage to test a new combination of controller and stage.

Wrong command or wrong syntax

⇒ Check the error code with the ERR? command. "Error Codes" in the PZ233 GCS commands manual contains the complete error reference.

Wrong axis commanded

⇒ Check if the correct axis identifier is used and if the commanded axis is that of the desired stage (axis identifier also required with single-axis systems!)

Motion commands or wave generator output provoke errors and are ignored

⇒ The axis motion can result from multiple control sources (see "Control Value Generation" (p. 139) for more information). The sources have different write priorities:

Motion commands like MOV, MVR, SVA, SVR, IMP and STE are not allowed (will cause an error) when analog control input or wave generator output are active.

It is possible to configure an axis for control by an analog input line while the wave generator output is active for that axis. In this case, the wave generator will continue running, but its output will no longer be used for control value generation. If the corresponding axis is set up to be commanded by analog control input, you can stop the wave generator output, but not restart it.

The analog control input is ignored

⇒ When the analog input is used as control source and the axis motion is stopped with STP or #24, the analog input channel may be disconnected from the axis. To recommence commanding the axis via the analog input, the corresponding input signal channel must be reconnected to the axis. See "How to Work with the Analog Input—Overview" (p. 123) for more information.

Offset between axis position range and voltage range is too large so that the commanded control value cannot be realized

⇒ For systems with linear piezo actuators and capacitive sensors or strain gauge sensors, both the range of sensor position values and the range of the output drive voltages are limited. If mechanical drift of the piezo actuator causes too great a shift in the relation between these ranges, then the usable closed-loop travel range will be reduced. Such an offset can be compensated by the AutoZero procedure. If the AutoZero procedure is suitable for your application, start it in PIMikroMove or use the ATZ command.

Incorrect configuration

⇒ Check the parameter settings on the controller with the SPA? and SEP? commands.

The piezo voltage output of the controller is deactivated, while the communication with the controller is still possible

⇒ With amplifier modules, the piezo voltage output is deactivated automatically when the internal temperature sensor detects 75 °C. The output will be reactivated automatically when the internal temperature has fallen to 60 °C. The *OVER TEMP* LED of the amplifier module glows if the piezo voltage output is deactivated.

Wait a few minutes to let the E-711/E-712 system cool down. Note that the wave generator output will continue even if the piezo voltage output is deactivated, i.e. if a certain number of output cycles was set, they may have already finished when the piezo voltage output is reactivated.

How to avoid overheating:

Keep the ambient temperature at a noncritical value: Note that the difference between ambient temperature and internal temperature of the E-711/E-712 system normally is about 20 °C (36 °F).

Place the system in a location with adequate ventilation. Allow at least 15 cm clearance from the rear of the housing and 1 cm from the bottom (ensured by the feet of the housing). Never cover any ventilation openings as this will impede ventilation.

When using the wave generator, it is recommended to reduce the frequency and/or the amplitude and/or the output duration to avoid overheating. See "Wave Generator" (p. 210) for more information.

When working with PiezoWalk® drives, do not move all axes simultaneously at maximum velocity. Move only one axis with maximum velocity at a time. Do not move the axes permanently at maximum velocity. Change the parameters for the PiezoWalk® drive performance only after careful consideration.

Unsatisfactory system performance

The sensor values are not reliable, and the whole system is instable.

⇒ Only thermally stable systems can have the best performance. For a thermally stable system, switch on the E-711/E-712 system at least one hour before you start working with it.

Stage is oscillating or positions inaccurately.

⇒ The load was changed. Unsuitable settings of the notch filter and the control parameters of the E-711/E-712 system can cause the stage to oscillate or to position inaccurately. Oscillations can damage the stage and/or the load affixed to it.

If the stage is oscillating (unusual operating noise), immediately switch to open-loop operation or switch off the E-711/E-712 system.

Only switch to closed-loop operation after you have modified the settings of the notch filter and the control parameters of the E-711/E-712 system. See "Adjusting the Notch Filters in Open-Loop Operation" (p. 266) and "Checking and Optimizing the Control Parameters" (p. 270) for more information.

Stage is oscillating or positions inaccurately.

Electromagnetic signal causes noise of the sensor signal.

⇒ Check the sensor signal.

If the sensor signal seems to be abnormal:

⇒ Avoid interfering signals.

⇒ Take particular care to ensure suitable shielding and grounding. Download the "Guide to Grounding and Shielding":

1. Open the website www.pi.ws.
2. Search for A000T0074.
3. In the search results, select the Downloads tab.
4. Download the A000T0074 technical note "Guide to Grounding and Shielding".

The waveform output is incomplete, the last points are missing

⇒ All waveform output is synchronized because there is a common pulse generator used by all wave generators. For that reason, wave tables which are supposed to run at the same time (each with one wave generator) should have the same length. If the wave tables have different lengths, an output cycle will comprise only the number of points contained in the shortest table. This means that all waveform output is cut to the length of the shortest waveform currently output.

A phase shift between the trigger output and the actual position is observed when the wave generator is running with the "Use DDL" or "Use and reinitialize DDL" options.

⇒ If the actual position (measured with external device) is ahead of the trigger output, check the cut-off-frequency f_g of the IIR low-pass filter used for digital filtering and increase it to shorten the duration of the digital filtering.

The duration of the signal processing for a capacitive sensor results from two portions:

- Duration of the analog sensor processing
- Duration of the digital filtering. If the Digital Filter Type parameter (ID 0x05000000) is set to "IIR low-pass filter, 2nd order", the required time depends on the cut-off-frequency f_g of the IIR low-pass filter which is specified by the Digital Filter Bandwidth parameter (ID 0x05000001). For

signal frequencies $f < f_g/2$, the duration of the filtering can be estimated as follows:

$t \approx 0.216 / f_g$

If required, increase f_g. Examples:

f_g = 300 Hz: t = 0.72 ms

f_g = 1000 Hz: t = 0.216 ms

Custom software accessing PI drivers does not run.

Wrong combination of driver routines/VIs

⇒ Check if system runs with a terminal program. If yes read the software manual and compare your program code with the sample code on the data storage device with the PI Software Suite.

21 Customer Service

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

If you have questions concerning your system, have the following information ready:

- Product and serial numbers of all products in the system
- Firmware version of the controller (if applicable)
- Version of the driver or the PC software (if applicable)
- PC operating system (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 on our website (www.pi.ws).

Only PI service personnel must repair the E-711/E-712 system.

22 Old Equipment Disposal

In accordance with the applicable EU law, electrical and electronic equipment may not be disposed of with unsorted municipal wastes in the member states of the EU.

When disposing of your old equipment, observe the international, national and local rules and regulations.

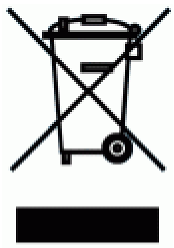
To meet the manufacturer's product responsibility with regard to this product, Physik Instrumente (PI) GmbH & Co. KG will ensure environmentally correct disposal of old PI equipment that was first put into circulation after 13 August 2005, free of charge.

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

Physik Instrumente (PI) GmbH & Co. KG

Auf der Roemerstr. 1

76228 Karlsruhe, Germany



23 Pin Assignments

See the descriptions of E-711.0CT/.0CT0 (p. 54), E-711.S3XC (p. 59), and E-711.0ET/.0ET0 (p. 64) for the pinout of the digital sensor signal transmission between interface module and sensor box.

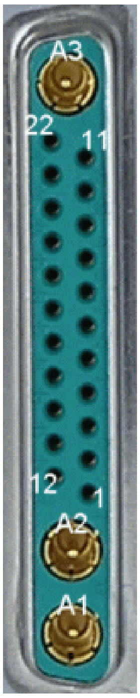
See the E711T0001 technical note for the pinout of the E-711.IP PIO interface module.

23.1 E-711.SC3H: Connector for Piezo Actuators and Capacitive Sensors

The connector for the piezo actuators and the capacitive sensors is located on the E-711.SC3H sensor module.

Connector type: D-sub mixed 25W3 connector for 3 coax lines and 22 single pins

Pin	Signal	Function
Coax inner lines:		
A1	Input	Sensor probe ch 2
A2	Input	Sensor probe ch 3
A3	Input	Sensor probe ch 1
Standard contacts:		
1	Output	Sensor target ch 2
2	Output	Sensor target ch 3
3	GND	ID chip GND axis 1
4	Bidirectional	ID chip axis 1
5	GND	ID chip GND axis 2
6	Bidirectional	ID chip axis 2
7	Output	Piezo ch 4 +
8	Output	Piezo ch 3 +
9	Output	Piezo ch 2 +
10	Output	Piezo ch 1 +
11	Output	Sensor target ch 1
12	GND	Sensor target ch 2 shield
13	GND	Sensor target ch 3 shield
14	-	Not connected
15	-	Not connected
16	GND	ID chip GND axis 3
17	Bidirectional	ID chip axis 3
18	Output	Piezo ch 4 -
19	Output	Piezo ch 3 -
20	Output	Piezo ch 2 -
21	Output	Piezo ch 1 -
22	GND	Sensor target ch 1 shield



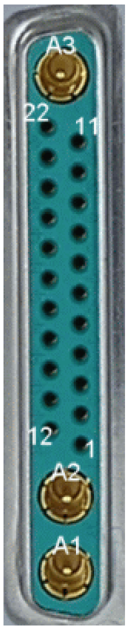
Note:
Sensor probe and sensor target are the connections of the capacitive sensor in the mechanics.
The piezo lines carry the piezo voltage for the actuators in the mechanics, in the range of -30 V to +135 V.

23.2 E-711.0ET and .0ET0: Connectors for Piezo Actuators and PISeca Capacitive Sensors

The *PZT* connector for the piezo actuators is located on the sensor box (in the *TO ACTUATORS* frame)

Connector type: D-sub mixed connector for 3 coax lines and 22 single pins

Pin	Signal	Function
Coax inner lines:		
A1	-	Not connected
A2	-	Not connected
A3	-	Not connected
Standard contacts:		
1	-	Not connected
2	-	Not connected
3	GND	GND
4	Bidirectional	ID chip axis 1
5	GND	GND
6	Bidirectional	ID chip axis 2
7	Output	Piezo output + ch 4
8	Output	Piezo output + ch 3
9	Output	Piezo output + ch 2
10	Output	Piezo output + ch 1
11	-	Not connected
12	-	Not connected
13	-	Not connected
14	-	Not connected
15	-	Not connected
16	GND	GND
17	Bidirectional	ID chip axis 3
18	Output	Piezo output - ch 4
19	Output	Piezo output - ch 3
20	Output	Piezo output - ch 2
21	Output	Piezo output - ch 1
22	-	Not connected



Note:
The piezo output lines carry the piezo voltage for the actuators in the mechanics, in the range of -30 V to +135 V.

The sensor connection is located on the sensor box:

- Triaxial LEMO connectors *SENSOR CH1* to *SENSOR CH3* for connection of the PISeca sensor probes

Pin	**Function**
Center pin (core)	Capacitive sense line
Inner shield	Active shielding
Outer shield	Measurement ground

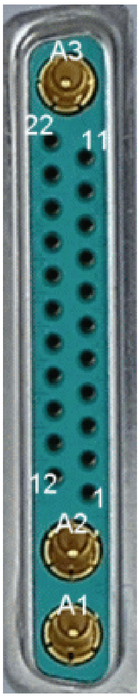
- *SENSOR GND* banana socket for ground connection of the target plane, see p. 65 for more information.

23.3 E-711.AL41: Connector for Piezo Actuators

The connector for the piezo actuators is located on the E-711.AL41 amplifier module.

Connector type: D-sub mixed 25W3 connector for 3 coax lines and 22 single pins

Pin	Signal	Function
Coax inner lines:		
A1	-	Not connected
A2	-	Not connected
A3	-	Not connected
Standard contacts:		
1	-	Not connected
2	-	Not connected
3	-	Not connected
4	-	Not connected
5	-	Not connected
6	-	Not connected
7	Output	Piezo ch 4 +
8	Output	Piezo ch 3 +
9	Output	Piezo ch 2 +
10	Output	Piezo ch 1 +
11	-	Not connected
12	-	Not connected
13	-	Not connected
14	-	Not connected
15	-	Not connected
16	-	Not connected
17	-	Not connected
18	Output	Piezo ch 4 -
19	Output	Piezo ch 3 -
20	Output	Piezo ch 2 -
21	Output	Piezo ch 1 -
22	-	Not connected

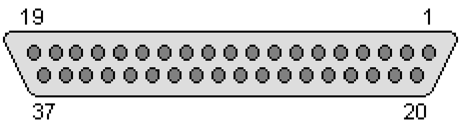


Note:
The piezo lines carry the piezo voltage for the actuators in the mechanics, in the range of -30 V to +135 V.

23.4 E-711.AL4A: Connector for Piezo-Driven Mechanics with Encoder

The connector for the piezo actuators and the incremental encoder is located on the E-711.AL4A amplifier module.

Connector type: D-sub 37 (f)



Pin	Signal	Function
1	-	-
2	GND	GND
3	-	-
4	-	-
5	-	-
6	-	-
7	-	-
8	-	-
9	-	-
10	-	-
11	Input	ENC_PL
12	Input	REF+
13	Input	COS+
14	Input	SIN+
15	Output	5V_OUT
16	Output	HV_OUT1
17	Output	HV_OUT2
18	Output	HV_OUT3
19	Output	HV_OUT4
20	-	-
21	Bidirectional	ID chip data
22	GND	GND
23	-	-
24	-	-
25	-	-
26	-	-
27	-	-
28	-	-
29	-	-
30	Input	ENC_NL
31	Input	REF-
32	Input	COS-
33	Input	SIN-
34	GND	HV_GND1
35	GND	HV_GND2
36	GND	HV_GND3
37	GND	HV_GND4

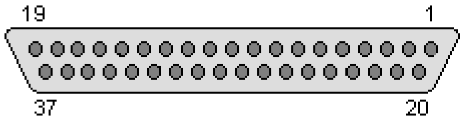
Note:

The HV_OUT lines carry the piezo voltage for the actuators in the mechanics, in the range of -30 V to +135 V.

23.5 E-711.SS3: Connector for Piezo Actuators and Strain Gauge Sensors

The connector for the piezo actuators and the strain gauge sensors (SGS) is located on the E-711.SS3 sensor module.

Connector type: D-sub 37 (f)



Pin	Signal	Function
1	Input / Output	PT1000 +
2	GND	GND
3	Bidirectional	ID chip 2 data
4	Bidirectional	ID chip 3 data
5	GND	GND
6	Input	SGS 4 -
7	GND	SGS 4 GND
8	Input	SGS 3 -
9	GND	SGS 3 GND
10	Input	SGS 2 -
11	GND	SGS 2 GND
12	Input	SGS 1 -
13	GND	SGS 1 GND
14	-	Not connected
15	-	Not connected
16	Output	Piezo 1 +
17	Output	Piezo 2 +
18	Output	Piezo 3 +
19	Output	Piezo 4 +
20	Input	PT1000 -
21	Bidirectional	ID chip 1 data
22	GND	GND
23	Bidirectional	ID chip 4 data
24	Input	SGS 4 +
25	Output	SGS 4 reference
26	Input	SGS 3 +
27	Output	SGS 3 reference
28	Input	SGS 2 +
29	Output	SGS 2 reference
30	Input	SGS 1 +
31	Output	SGS 1 reference
32	-	Not connected
33	-	Not connected
34	Output	Piezo 1 -
35	Output	Piezo 2 -
36	Output	Piezo 3 -
37	Output	Piezo 4 -

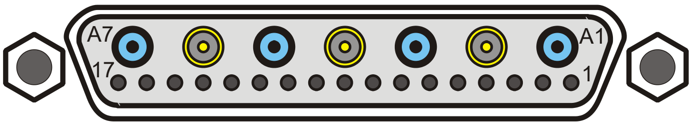
Note:

The piezo lines carry the piezo voltage for the actuators in the mechanics, in the range of -30 V to +135 V.

23.6 E-711.AM4: Connector for NEXLINE® Drive or Piezo Actuators

The connector is located on the E-711.AM4 amplifier module.

Connector type: D-sub mixed 24W7 for 7 coax lines and 17 single pins



Pin	Signal	Function
Coax inner lines:		
A1	Output	Piezo ch 1 +
A2	-	Not connected
A3	Output	Piezo ch 2 +
A4	-	Not connected
A5	Output	Piezo ch 3 +
A6	-	Not connected
A7	Output	Piezo ch 4 +
Standard contacts:		
1	Output	Piezo ch 1 -
2	-	Reserved
3	-	Reserved
4	-	Not connected
5	-	Not connected
6	Output	Piezo ch 2 -
7	-	Reserved
8	-	Reserved
9	-	Not connected
10	-	Not connected
11	Output	Piezo ch 3 -
12	-	Reserved
13	-	Reserved
14	-	Not connected
15	-	Not connected
16	-	Not connected
17	Output	Piezo ch 4 -

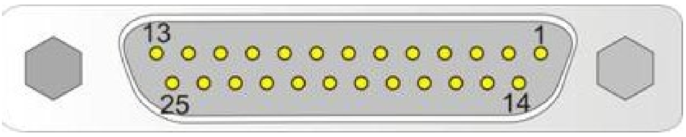
Note:

The piezo lines carry piezo voltages in the range of -250 V to +250 V. They can be used for the shearing and clamping segments of the NEXLINE® stack actuator pairs in a NEXLINE® drive, or for up to four conventional piezo actuators.

23.7 E-711.AM5: Connector for NEXLINE® Drive or Piezo Actuators

The connector is located on the E-711.AM5 amplifier module.

Connector type: D-sub 25 (f)



Pin	Signal	Function
1	Output	Piezo ch 1 +
2	-	Internal use
3	-	Internal use
4	Output	Piezo ch 2 +
5	-	Internal use
6	-	Internal use
7	Output	Piezo ch 3 +
8	GND	GND
9	GND	GND
10	Output	Piezo ch 4 +
11	-	Not connected
12	-	Internal use
13	-	Internal use
14	-	Internal use
15	Output	Piezo ch 1 -
16	-	Internal use
17	-	Internal use
18	Output	Piezo ch 2 -
19	-	Internal use
20	-	Internal use
21	Output	Piezo ch 3 -
22	-	Not connected
23	-	Internal use
24	Output	Piezo ch 4 -
25	-	Internal use

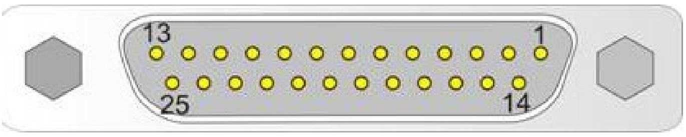
Note:

The piezo lines carry piezo voltages in the range of -250 V to +250 V. They can be used for the shearing and clamping segments of the NEXLINE® stack actuator pairs in a NEXLINE® drive, or for up to four conventional piezo actuators.

23.8 E-711.AM5A and .AM5B: Connector for NEXLINE® Drive with Encoder

The connector for a NEXLINE® drive with encoder is located on the E-711.AM5A amplifier module (incremental encoder) or on the E-711.AM5B amplifier module (absolute measuring encoder via BiSS interface).

Connector type: D-sub 25 (f)



Pin	Signal	Function
1	Output	Piezo ch 1 +
2	Output	5 V
3	Output	5 V
4	Output	Piezo ch 2 +
5	-	Not connected
6	-	Not connected
7	Output	Piezo ch 3 +
8	GND	GND
9	GND	GND
10	Output	Piezo ch 4 +
11	-	Not connected
12	Input	Ref-
13	Input	Ref+
14	Input	Enc positive limit
15	Output	Piezo ch 1 -
16	Input	E-711.AM5A: Sin+ E-711.AM5B: MA+
17	Input	E-711.AM5A: Sin- E-711.AM5B: MA-
18	Output	Piezo ch 2 -
19	Input	E-711.AM5A: Cos+ E-711.AM5B: SLI+
20	Input	E-711.AM5A: Cos- E-711.AM5B: SLI-
21	Output	Piezo ch 3 -
22	-	Not connected
23	Input	Enc negative limit
24	Output	Piezo ch 4 -
25	Bidirectional	ID chip

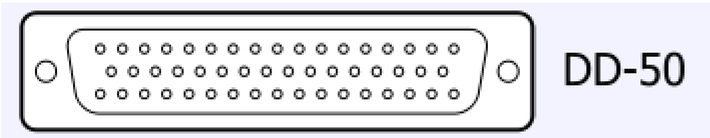
Note:

The piezo lines carry the piezo voltages for the shearing and clamping segments of the NEXLINE® stack actuator pairs in the NEXLINE® drive, in the range of -250 V to +250 V.

23.9 E-712.R5: Connector for NEXLINE® Drives or Piezo Actuators

The connector is located on the front panel of the E-712.R5 housing near the On/Off switch. It carries the output voltage of up to 6 E-711.AM6 amplifier modules that are present in the E-712.R5 housing.

Connector type: HD D-sub 50 (f)



Pin	Signal		Pin	Signal
1	Amp 1 piezo ch 1 -		26	Amp 4 piezo ch 1 -
2	Amp 1 piezo ch 1 +		27	Amp 4 piezo ch 1 +
3	Amp 1 piezo ch 2 -		28	Amp 4 piezo ch 2 -
4	Amp 1 piezo ch 2 +		29	Amp 4 piezo ch 2 +
5	Amp 1 piezo ch 3 -		30	Amp 4 piezo ch 3 -
6	Amp 1 piezo ch 3 +		31	Amp 4 piezo ch 3 +
7	Amp 1 piezo ch 4 -		32	Amp 4 piezo ch 4 -
8	Amp 1 piezo ch 4 +		33	Amp 4 piezo ch 4 +
9	Amp 2 piezo ch 1 -		34	Amp 5 piezo ch 1 -
10	Amp 2 piezo ch 1 +		35	Amp 5 piezo ch 1 +
11	Amp 2 piezo ch 2 -		36	Amp 5 piezo ch 2 -
12	Amp 2 piezo ch 2 +		37	Amp 5 piezo ch 2 +
13	Amp 2 piezo ch 3 -		38	Amp 5 piezo ch 3 -
14	Amp 2 piezo ch 3 +		39	Amp 5 piezo ch 3 +
15	Amp 2 piezo ch 4 -		40	Amp 5 piezo ch 4 -
16	Amp 2 piezo ch 4 +		41	Amp 5 piezo ch 4 +
17	Internal use		42	Amp 6 piezo ch 1 -
18	Amp 3 piezo ch 1 -		43	Amp 6 piezo ch 1 +
19	Amp 3 piezo ch 1 +		44	Amp 6 piezo ch 2 -
20	Amp 3 piezo ch 2 -		45	Amp 6 piezo ch 2 +
21	Amp 3 piezo ch 2 +		46	Amp 6 piezo ch 3 -
22	Amp 3 piezo ch 3 -		47	Amp 6 piezo ch 3 +
23	Amp 3 piezo ch 3 +		48	Amp 6 piezo ch 4 -
24	Amp 3 piezo ch 4 -		49	Amp 6 piezo ch 4 +
25	Amp 3 piezo ch 4 +		50	Internal use

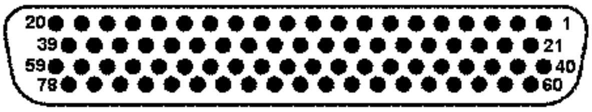
Note: The piezo lines carry piezo voltages in the range of -250 V to +250 V.

They can be used for the shearing and clamping segments of the NEXLINE® stack actuator pairs in up to 6 NEXLINE® drives, or for up to 24 conventional piezo actuators.

23.10 E-712.R5: Connector for NEXACT® Drives

The connector is located on the front panel of the E-712.R5 housing. It carries the output voltage for up to 6 NEXACT® drives (the appropriate number of E-711.AN40 amplifier modules must be present in the E-712.R5 housing).

Connector type: HD D-sub 78 (f)



Pin	Pin	Signal	Pin	Pin	Signal
1		Amp 1 CH1+	40		Amp 4 CH1+
	21	Amp 1 CH1-		60	Amp 4 CH1-
2		Amp 1 CH2+	41		Amp 4 CH2+
	22	Amp 1 CH2-		61	Amp 4 CH2-
3		Amp 1 CH3+	42		Amp 4 CH3+
	23	Amp 1 CH3-		62	Amp 4 CH3-
4		Amp 1 CH4+	43		Amp 4 CH4+
	24	Amp 1 CH4-		63	Amp 4 CH4-
5		Amp 1 enable*	44		Amp 4 enable*
	25	Not connected		64	Not connected
6		Not connected	45		Not connected
	26	Not connected		65	Not connected
7		Amp 2 CH1+	46		Amp 5 CH1+
	27	Amp 2 CH1-		66	Amp 5 CH1-
8		Amp 2 CH2+	47		Amp 5 CH2+
	28	Amp 2 CH2-		67	Amp 5 CH2-
9		Amp 2 CH3+	48		Amp 5 CH3+
	29	Amp 2 CH3-		68	Amp 5 CH3-
10		Amp 2 CH4+	49		Amp 5 CH4+
	30	Amp 2 CH4-		69	Amp 5 CH4-
11		Amp 2 enable*	50		Amp 5 enable*
	31	Not connected		70	Not connected
12		Not connected	51		Not connected
	32	Not connected		71	Not connected
13		Amp 3 CH1+	52		Amp 6 CH1+
	33	Amp 3 CH1-		72	Amp 6 CH1-
14		Amp 3 CH2+	53		Amp 6 CH2+
	34	Amp 3 CH2-		73	Amp 6 CH2-
15		Amp 3 CH3+	54		Amp 6 CH3+
	35	Amp 3 CH3-		74	Amp 6 CH3-
16		Amp 3 CH4+	55		Amp 6 CH4+
	36	Amp 3 CH4-		75	Amp 6 CH4-
17		Amp 3 enable*	56		Amp 6 enable*
	37	Not connected		76	Not connected

Pin	Pin	Signal	Pin	Pin	Signal
18		Not connected	57		Not connected
	38	Not connected		77	Not connected
19		Not connected	58		Not connected
	39	Not connected		78	Not connected
20		Not connected	59		Not connected

*This pin is connected to GND in the connector housing of the NEXACT® drive to enable the amplifiers. If this connection is removed, all piezo voltages will be zero.

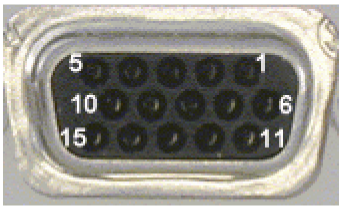
The lines CH1 to CH4 carry the piezo voltages for the actuator segments of the NEXACT® drives, in the range of -10 V to +45 V.

23.11 E-711.AN4: Connector for NEXACT® Drive

The connector for the NEXACT® drive is located on the E-711.AN4 amplifier module.

Connector type: HD D-sub 15 (f)

Pin	Signal direction	Function
1	Output	Piezo 1
2	Output	Piezo 3
3	-	Not connected
4	-	Not connected
5	-	Not connected
6	Output	Piezo 0
7	Output	Piezo 2
8	Input	AMP (amplifier enable)*
9	-	Not connected
10	-	Not connected
11	AGND	Piezo GND
12	AGND	Piezo GND
13	AGND	Piezo GND
14	AGND	Piezo GND
15	GND	Digital GND

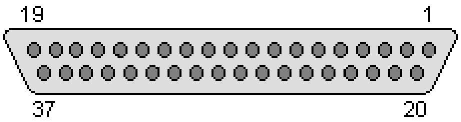


*This pin is connected to GND in the connector housing of the NEXACT® drive to enable the amplifiers. If this connection is removed, all piezo voltages will be zero.

23.12 E-712.xAN: Connector for PICMAWalk Drives with Encoder

The connector for a PICMAWalk drive with incremental encoder is located on the E-712.1AN, .2AN and .3AN digital controllers.

Connector type: D-sub 37 (f)



Pin	Signal	Function
1	-	Not connected
2	GND	GND
3	-	Not connected
4	-	Not connected
5	-	Not connected
6	-	Not connected
7	-	Not connected
8	-	Not connected
9	-	Not connected
10	-	Not connected
11	Input	ENC positive limit
12	Input	REF+
13	Input	COS+
14	Input	SIN+
15	Output	5 V
16	Output	Piezo 1 +
17	Output	Piezo 2 +
18	Output	Piezo 3 +
19	Output	Piezo 4 +
20	-	Not connected
21	Bidirectional	ID chip data
22	GND	GND
23	-	Not connected
24	-	Not connected
25	-	Not connected
26	-	Not connected
27	-	Not connected
28	-	Not connected
29	-	Not connected
30	Input	ENC negative limit
31	Input	REF-
32	Input	COS-
33	Input	SIN-
34	Output	Piezo 1 -
35	Output	Piezo 2 -
36	Output	Piezo 3 -
37	Output	Piezo 4 -

Note:

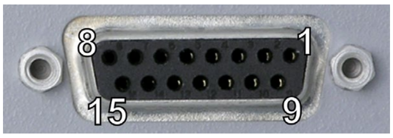
The piezo lines carry the piezo voltage for the actuators in the PICMAWalk drive, in the range of -30 V to +135 V.

23.13 E-711.C82: Connector for DC Motors

Connectors for DC motors are located on the E-711.C82 DC motor driver module.

Connector type: D-sub 15 (f)

Pin	Signal direction	Function
1	Output	Programmable motor brake (0 or + 5 V)
2	Output	Motor + (differential; power PWM); for stages without PWM amplifier
3	Output	PWM magnitude (TTL); for stages with PWM amplifier
4	Output	+5 V
5	Input	Positive limit switch
6	-	reserved
7	Input	A- / Sin- / BiSS MA1
8	Input	B- / Cos- / BiSS SL1
9	Output	Motor – (differential; power PWM); for stages without PWM amplifier
10	GND	Power GND
11	Output	PWM sign (TTL); for stages with PWM amplifier
12	Input	Negative limit switch
13	Input	Reference switch
14	Input	A+ / Sin+ / BiSS MA1
15	Input	B+ / Cos+ / BiSS SL1



The E-711.C82 supports the following encoder types:

- Incremental sensor: AB (quadrature) single-ended or differential TTL signal acc. to RS-422; 60 MHz
- Incremental sensor: Analog sin/cos; 1 Vpp
- Absolute measuring sensor via 32-bit BiSS interface

The encoder type is selectable via the Sensor Type parameter (ID 0x02000001).

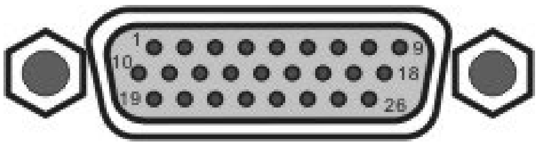
23.14 E-711.SA3 and E-711.SA6: Connector for Incremental Sensors

The *INCR. SENSOR* connector is located on the E-711.SA3 and E-711.SA6 sensor modules. Sensors cannot be connected directly to that connector but must be connected via an E-711.SAx sensor signal splitter box of the suitable type (x = P, H or N depending on the sensor type) and an E-711.SAX connection cable.

Connector type:

E-711.SA3: 1 x HD D-sub 26 (m)

E-711.SA6: 2 x HD D-sub 26 (m)

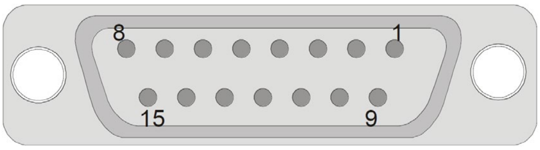


Pin Number	Type	Function
1	IN	Ch 1 sin+
2	IN	Ch 1 cos+
3	IN	REF CH1 (+)
4	IN	Ch 2 sin+
5	IN	Ch 2 cos+
6	IN	REF CH2 (+)
7	IN	Ch 3 sin+
8	IN	Ch 3 cos+
9	IN	REF CH3(+)
10	IN	Ch 1 sin-
11	IN	Ch 1 cos-
12	IN	REF CH1 (-)
13	IN	Ch 2 sin-
14	IN	Ch 2 cos-
15	IN	REF CH2 (-)
16	IN	Ch 3 sin-
17	IN	Ch 3 cos-
18	IN	REF CH3 (-)
19	IN	Positive limit CH1
20	IN	Negative limit CH1
21	IN	Positive limit CH2
22	IN	Negative limit CH2
23	IN	Positive limit CH3
24	IN	Negative limit CH3
25	OUT	5V
26	GND	GND

23.15 E-711.SAH: Connectors for Incremental Sensors

The connectors *Sensor 1* to *Sensor 3* are located on the E-711.SAH sensor signal splitter box. One Heidenhain incremental sensor can be connected per connector.

Connector type: D-sub 15 (f)



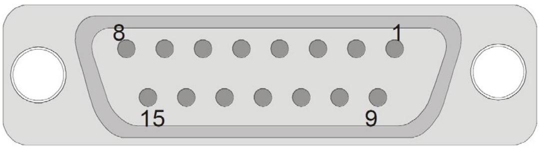
Pin Number	Type	Function
1	IN	Encoder sin+
2	GND	AGND
3	IN	Encoder cos+
4	OUT	5V
5	-	Not connected
6	IN	Negative limit
7	IN	REF(-)
8	IN	Positive limit
9	IN	Encoder sin-
10	GND	AGND
11	IN	Encoder cos-
12	OUT	5V
13	-	Not connected
14	IN	REF(+)
15	-	Not connected

The *Sensor In* connector (HD D-sub 26 (f)) on the E-711.SAH sensor signal splitter box has the same pinout as the *INCR. SENSOR* connectors on the E-711.SA3 and E-711.SA6 modules (see p. 327).

23.16 E-711.SAN: Connectors for Incremental Sensors

The connectors *Sensor 1* to *Sensor 3* are located on the E-711.SAN sensor signal splitter box. One Numeric Jena incremental sensor can be connected per connector.

Connector type: D-sub 15 (f)



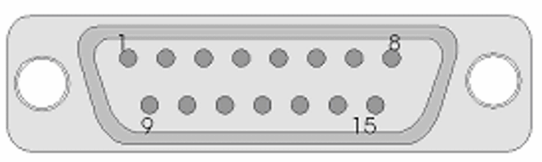
Pin	Type	Function
1	-	Not connected
2	IN	Negative limit
3	-	Not connected
4	IN	REF(-)
5	IN	Encoder cos-
6	IN	Encoder sin-
7	-	Not connected
8	OUT	5 V
9	GND	AGND
10	IN	Positive limit
11	-	Not connected
12	IN	REF(+)
13	IN	Encoder cos+
14	IN	Encoder sin+
15	GND	Shield

The *Sensor In* connector (HD D-sub 26 (f)) on the E-711.SAN sensor signal splitter box has the same pinout as the *INCR. SENSOR* connectors on the E-711.SA3 and E-711.SA6 modules (see p. 327).

23.17 E-711.SAP: Connectors for Incremental Sensors

The connectors *Sensor 1* to *Sensor 3* are located on the E-711.SAP sensor signal splitter box. One PIOne incremental sensor can be connected per connector.

Connector type: D-sub 15 (m)



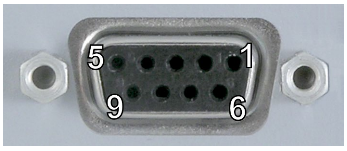
Pin Number	Type	Function
1	OUT	5 V
2	GND	AGND
3	IN	Encoder sin+
4	IN	Encoder sin-
5	-	Not connected
6	IN	Encoder cos+
7	IN	Encoder cos-
8	IN	Negative limit
9	-	Not connected
10	IN	REF (+)
11	-	Not connected
12	IN	REF (-)
13	-	Not connected
14	-	Not connected
15	IN	Positive limit

The *Sensor In* connector (HD D-sub 26 (f)) on the E-711.SAP sensor signal splitter box has the same pinout as the *INCR. SENSOR* connectors on the E-711.SA3 and E-711.SA6 modules (see p. 327).

23.18 E-711.0ATS: Connectors for Encoders with BiSS Interface

The connectors *Sensor 1* to *Sensor 8* are located on the E-711.0ATS sensor box. One absolute measuring or incremental encoder with 32-bit BiSS interface can be connected per connector.

Connector type: D-sub 9 (f)



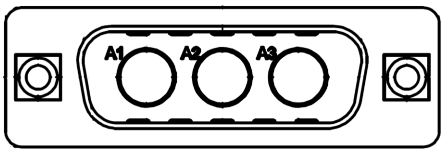
Pin Number	Type	Function
1	GND	GND
2	IN	MA+
3	IN	MA-
4	OUT	5V sensor
5	OUT	5V sensor
6	IN	SLI+
7	IN	SLI-
8	IN	GND
9	IN	GND

The *SPI* connector on the E-711.0ATS sensor box has the same pinout as the *SPI* connectors on the E-711.iS3 and E-711.iS6 SPI interface modules (see p. 333).

23.19 E-711.0ATS: Connector for Supply Voltage

The *24 V DC Power* connector for the supply voltage is located on the E-711.0ATS sensor box.

Connector type: D-sub 3W3 (m)



Pin Number	Type	Function
A1	GND	GND
A2	IN	24 V DC, max. 0.6 A from external power supply
A3	GND	GND

23.20 E-711.SE3: Connectors for Capacitive Sensor Probe

Up to three PISeca single-electrode capacitive sensors can be connected to the E-711.SE3 module. The sensor probes are connected to the connectors *Ch1* to *Ch3*, while the target surfaces of all sensors must be connected to the *GND* grounding stud.

Connector type for *Ch1* to *Ch3*: Triaxial, LEMO ECP.00.650.NLL.543

Pin	Function
Center pin (core)	Capacitive sense line
Inner shield	Active shielding
Outer shield	Measurement ground

23.21 Analog Input Connectors

The analog input lines *In 1* to *In 4* are located on the E-711.IA4 analog interface module. The identifiers representing these analog input lines in the firmware of the E-711/E-712 system depend on the number of sensor channels present in the E-711/E-712 system. See "Accessible Items and Their Identifiers" (p. 127) for more information.

Analog input lines which are not used should be deactivated to avoid interferences. See "Deactivation of Unused Analog Input Lines" (p. 123) for more information.

Connector type: LEMO EPG.00.302.NLN

Pin	Signal	Function
1	Input	A_{IN+} analog input, differential
2	Input	A_{IN-} analog input, differential

The connector housing is connected to GND.

$|A_{IN+} - A_{IN-}| \leq 10$ V in the range of -10 V to +10 V

Resolution: 18 bit

Bandwidth: 25 kHz

Input impedance: 150 kΩ

Application examples for the analog input:

1) A_{IN-} is connected to GND potential. A_{IN+} may then vary in the range of -10 V to +10 V.

2) A signal in the range of – 5 V to +5 V is connected to A_{IN+}, while A_{IN-} is connected to a corresponding inverted signal (+5 V to -5 V).

23.22 Analog Output Connectors

The analog output lines *Out 1* to *Out 4* are located on E-711.IA4 analog interface module.

Connector type: LEMO EPG.00.302.NLN

Pin	Signal	Function
1	Output	A_{OUT} analog output -12.775 V to +12.775 V
2	GND	GND

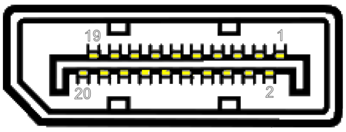
Resolution: 16 bit

Bandwidth: 12 kHz

23.23 SPI Connector for E-711/E-712 as an SPI Slave

The input lines and output lines of the SPI slave interface are located on the E-712.M1 and E-712.N1 digital processor modules of the E-711/E-712 system (p. 27). See "Control via SPI Master" (p. 210) for more information.

Connector type: DisplayPort socket



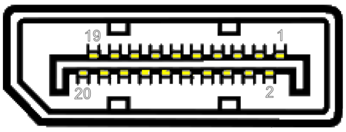
E-711/E-712 (SPI slave):

Pin	Signal Name	Direction
20	Not connected	-
19	LDAT-	Input
18	LDAT+	Input
17	CS-	Input
16	GND	
15	CS+	Input
14	GND	
13	GND	
12	SCLK+	Input
11	GND	
10	SCLK-	Input
9	MOSI+	Input
8	GND	
7	MOSI-	Input
6	MISO+	Output
5	GND	
4	MISO-	Output
3	DCLK+	Output
2	GND	
1	DCLK-	Output

23.24 E-711.iS3 and E-711.iS6: SPI Connectors

The connectors for connection of SPI slaves (e.g., sensor boxes from PI) are located on the E-711.iS3 and E-711.iS6 SPI modules.

Connector type: DisplayPort socket



E-711.iS3 and E-711.iS6: SPI master

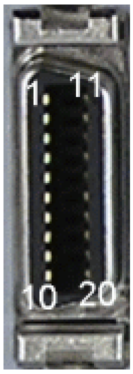
Pin	Signal Name	Direction
20	Not connected	-
19	LDAT-	Output
18	LDAT+	Output
17	CS-	Output
16	GND	
15	CS+	Output
14	GND	
13	GND	
12	DCLK-	Input
11	GND	
10	DCLK+	Input
9	MISO-	Input
8	GND	
7	MISO+	Input
6	MOSI-	Output
5	GND	
4	MOSI+	Output
3	SCLK-	Output
2	GND	
1	SCLK+	Output

23.25 Digital I/O Connector

The connector for the digital input and output lines is located on the E-712.M1 and E-712.N1 digital processor modules.

Connector type: MDR20 socket

Pin	Signal	Function
1	Output	*ServoTrigger* (TTL, digital output of the control loop cycle; not accessible by command)
2	Output	*OUT1* (TTL, active *high*; identifier is 1)
3	Output	*OUT2* (TTL, active *high*; identifier is 2)
4	Output	*OUT3* (TTL, active *high*; identifier is 3)
5	GND	GND
6	Output	*OUT4* (TTL, active *high*; identifier is 4)
7	Output	*OUT5* (TTL, active *high*; identifier is 5)
8	Output	*OUT6* (TTL, active *high*; identifier is 6)
9	Output	*OUT7* (TTL, active *high*; identifier is 7)
10	-	Reserved
11	Input	*IN1* (TTL, active *high*; identifier is 1)
12	Input	*IN2* (TTL, active *high*; identifier is 2)
13	Input	*IN3* (TTL, active *high*; identifier is 3)
14	Input	*IN4* (TTL, active *high*; identifier is 4)
15	GND	GND
16	Input	*IN5* (TTL, active *high*; identifier is 5)
17	Input	*IN6* (TTL, active *high*; identifier is 6)
18	Input	*IN7* (TTL, active *high*; identifier is 7)
19	Input	*IN8* (TTL, active *high*; identifier is 8)
20	-	Reserved



Digital inputs:

- TTL (*low*: 0 V to 0.8 V, *high*: 2 V to 5 V, max.: 5 V)
- When nothing is connected to a digital input, the state of the digital input line is *high* due to an internal pull-up with 10 kΩ resistor.
- The digital input lines can be used for the following purposes:
  - Safety shutdown: Configure the lines *IN1* to *IN8* via parameters. See p. 256 for more information.
  - Start data recording: Configure the lines *IN1* to *IN8* with DRT
  - Start the wave generator output (lines *IN1* and *IN2*) and stop it (line *IN2*). See p. 230 and the WGO command for more information.
- Line *IN8* (pin 19) can be configured as reset input using the Reboot On DIO Input parameter (ID 0x0e001500). Changes of the parameter value become effective immediately. The value of the parameter enables/disables the reset input as follows:
  - 0 = OFF: Reset input is disabled (default setting)
  - 1 = ON: Reset input is enabled. When the reset input line is set *low*, the E-711/E-712 system is rebooted (same behaviour as with the RBT command).

Digital outputs:

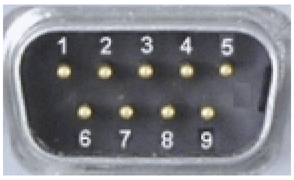
- *High* level:
  - at -2 mA output current => min. 2.2 V
  - at -0.1 mA output current => min. 3.0 V
- *Low* level:
  - at +2 mA output current => max. 0.6 V
  - at +0.1 mA output current => max. 0.21 V
- The digital output lines *OUT1* to *OUT7* can be configured with the commands CTO and TWS for trigger tasks.
- The output of the control loop cycle on pin 1 is not accessible for commands.

23.26 RS-232 Connector

The *RS-232* connector is located on the E-712.M1 and E-712.N1 digital processor modules.

Connector type: D-sub 9 (m)

Pin	Function
1	Not connected
2	RXD receive data
3	TXD send data
4	Not connected
5	DGND ground
6	Not connected
7	RTS hardware handshake, output
8	CTS hardware handshake, input
9	Not connected

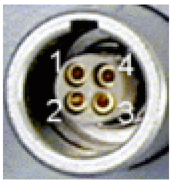


23.27 SYNC IN Connector

The *SYNC IN* connector is located on the E-712.M1 and E-712.N1 digital processor modules.

Connector type: LEMO EPG.00.304.NLN

Pin	Function
1	SYNCBASE_I_P (LVDS, 4.8 MHz)
2	SYNCBASE_I_N (LVDS, 4.8 MHz)
3	SYNC100_I_P (LVDS, 100 kHz)
4	SYNC100_I_N (LVDS, 100 kHz)



INFORMATION

If you apply external synchronization signals to the *SYNC IN* connector, make sure that these signals match the following specifications:

The tolerance of the 100 kHz input signal is ±2 kHz.

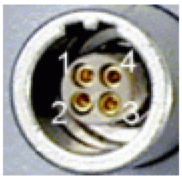
The 4.8 MHz signal must be synchronized with the 100 kHz signal, and both signals must be in a fixed ratio to each other.

23.28 SYNC OUT Connector

The *SYNC OUT* connector is located on the E-712.M1 and E-712.N1 digital processor modules.

Connector type: LEMO EPA.00.304.NLN

Pin	Function
1	SYNCBASE_O_P (LVDS, 4.8 MHz)
2	SYNCBASE_O_N (LVDS, 4.8 MHz)
3	SYNC100_O_P (LVDS, 100 kHz)
4	SYNC100_O_N (LVDS, 100 kHz)



24 EU Declaration of Conformity

For the E-711/E-712 modular digital multi-channel controller system, an EU Declaration of Conformity has been issued in accordance with the following European directives:

Low Voltage Directive

EMC Directive

RoHS Directive

The applied standards certifying the conformity are listed below.

Safety (Low Voltage Directive): EN 61010-1

EMC: EN 61326-1

RoHS: EN IEC 63000