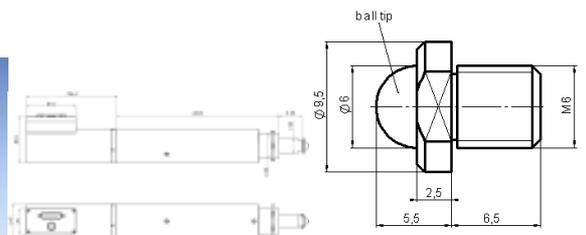# MP 77E User Manual

M-238 Heavy-Duty DC-Mike Actuator

Release: 1.0.0 Date: 02.08.2006

This document describes the following product(s):

■ **M-238.5PL**
  Heavy-Duty DC-Mike Actuator, Linear Encoder

■ **M-238.5PG**
  Heavy-Duty DC-Mike Actuator, Rotary Encoder

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About this Document

Users of this Manual

This manual is designed to help the reader to install and operate the M-238 Heavy-Duty DC-Mike Actuator. It assumes that the reader has a fundamental understanding of basic servo systems, as well as motion control concepts and applicable safety procedures.
The manual describes the physical specifications and dimensions of the M-238 Heavy-Duty DC-Mike Actuator as well as the procedures which are required to put the associated motion system into operation.

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.

CAUTION

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

NOTE

Provides additional information or application hints.

The motion controller and the software tools which might be mentioned within this documentation are described in their own manuals. All documents are available on the respective product CD. Current releases can be downloaded from the PI Website as PDF files (www.pi.ws (http://www.pi.ws)), obtained from your Physik Instrumente sales engineer or from info@pi.ws (mailto:info@pi.ws).

Contents

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1   Introduction

1.1   Product Description

Figure 1: M-238.5PL Heavy-Duty Mike actuator (with CD for size comparison)

- ■ High Load Capacity to 400 N

- ■ Optional 0.1 µm Direct-Metrology Linear Encoder for Exceptional Precision

- ■ Travel Range 50 mm

- ■ Resolution to 0.1 µm

- ■ Max. Velocity 30 mm/s

- ■ Preloaded Frictionless Ball Screw

- ■ MTBF> 20,000 h

- ■ Vacuum-Compatible Versions Available for 10^{-6} hPa

The M-238 is a high-load, high-precision actuator providing linear motion up to 50 mm, a load capacity to 400 N and high velocity to 30 mm/s. It consists of a low-friction, heavy-duty ballscrew, driven by a closed-loop, ActiveDrive™ DC motor with gearbox. An optional linear encoder provides exceptional accuracy and repeatability.

Direct Metrology Linear Encoder to Compensate Mechanical Play

The M-238.5PL model is equipped with a non-contact, optical, linear encoder (direct metrology) with an output resolution of 0.1 µm. Because the encoder measures the actual position of the non-rotating actuator tip, drive-train errors like backlash and elastic deformations are eliminated. A lower-cost version with a rotary encoder is available as model number M-238.5PG.

ActiveDrive™ DC Motor

DC motor drives offer several advantages, such as high dynamics, high torque at low rotational speed, low heat and low vibration.
The ActiveDrive™ design, developed by PI, features a high-efficiency PWM (pulse width modulation) servo-amplifier mounted side-by-side with the DC motor and offers several advantages:

- Increased efficiency, by eliminating power losses between the amplifier and motor

- Reduced cost of ownership and improved reliability, because no external driver is required

- Elimination of PWM amplifier noise radiation, by mounting the amplifier and motor together in a single, electrically shielded case

Non-Rotating Tip

Compared to conventional rotating-tip micrometer drives, the non-rotating-tip design offers several advantages:

- Elimination of torque-induced positioning errors

- Elimination of sinusoidal motion errors

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- Elimination of wear at the contact point

- Elimination of tip-angle dependent wobble.

The lateral guiding of the tip withstands lateral forces of up to 100 N.

Ballscrews for High Speed, Precision and Lifetime

The precision-ground ballscrew is maintenance-free and preloaded to eliminate mechanical play. Its significantly reduced friction, compared to conventional leadscrews, allows for higher velocity, lower power consumption and longer lifetime. The M-238 is therefore well suited for high duty-cycle operation in industrial environments.

Limit and Reference Switches
For the protection of your equipment, non-contact Hall-effect limit and reference switches are installed. The direction-sensing reference switch supports advanced automation applications with high precision.

Notes
Please note, that in this manual the following product names are used synonymously: DC-Mike, positioner, linear actuator.

1.2 Prescribed Use

Correct operation of the M-238 Mikes is only possible in combination with a suitable controller/driver (ordered separately) and software.
To ensure proper performance of the servo-control system,, the controlling device must be able to read out and process the signals from reference and limit switches and the incremental position encoder.

Based on their design and realization, the M-238 Mikes are intended for single-axis positioning, adjusting and shifting of loads at various velocities. M-238 Mikes can be mounted in any orientation. To achieve the specified guiding accuracy, the Mikes have to be mounted according to the load specifications given in the technical data tables.

The Mikes may only be used for applications suitable according to the device specifications.

Respect the safety instructions given in this User Manual. The user is responsible for the correct installation and operation of the M-238.

The verification of the technical specifications by the manufacturer does not imply the validation of complete applications. In fact the user is responsible for the process validation and the appropriate releases.

The M-238 is a laboratory apparatus as defined by DIN EN 61010. It meets the following minimum specifications for safe operation (any more stringent specifications in the technical data table are, of course, also met):

- Indoor use only

- Altitude up to 2000 m

- Temperature range 5°C to 40°C

- Max. relative humidity 80% for temperatures up to 31°C, decreasing linearly to 50% relative humidity at 40°C

- Line voltage fluctuations not greater than ±10% of the line voltage

- Transient overvoltages as typical for public power supply
  Note: The nominal level of the transient overvoltage is the standing surge voltage according to the overvoltage category II (IEC 60364-4-443).

- Degree of pollution: 2

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1.3 Safety Precautions

Read carefully the User Manuals of all other components involved such as controllers or software.

Read the following before operating the equipment covered in this manual:

CAUTION

!

Read this before operating the equipment covered in this manual. Always keep the User Manual safe and close to the described device. In case of loss or or damage to the instructions, please order a new copy from your PI distributor. Also keep and add all further information (e.g. extended instructions or Technical Notes) to the User Manual.

WARNING—CRUSH HAZARD

⚠

Never put anything where the tip or any connected object could possibly trap it.

WARNING

⚠

M-238 stages are powered by powerful electric motors and can accelerate to high speeds. Be aware that automatic limit switch halt may not be supported by, or activated at the motor control electronics.

Be aware that failure of the motor controller may drive the mechanics into a hard stop at high speeds.

When the mechanics is first connected to the motor controller, be aware that it could start an undesired move.

CAUTION

!

Do not let the mike run into the hard stop

Due to the high power of the motor and the high speed that can be achieved, crashing can damage the gear head and / or the whole actuator.

1.4   Model Survey

The M-238 Heavy-Duty DC-Mike Actuator is available in 2 versions that differ only in terms of the position encoder as listed in the table below. For further specifications see the Technical Data section.

Model	Description
M-238.5PG	Heavy-Duty DC-Mike Actuator, 400 N, 50 mm, ActiveDrive™
M-238.5PL	Heavy-Duty DC-Mike Actuator, 400 N, 50 mm, ActiveDrive™, Direct-Metrology Encoder

1.5   Unpacking

Unpack the M-238 Heavy-Duty DC-Mike Actuator with care. Compare the contents against the items covered by the contract and against the packing list.
The following components are included:

■   M-238 Heavy-Duty DC-Mike Actuator with ball tip and flat tip

■   C-815.38 motor cable for connecting to motor controller, 3 m, sub-D 15 pin (m/f)

■   M-500.PS power supply with line cord

■   User manual for M-238 in printed form (this document)

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 need be shipped again.

2 Start-Up

2.1 Mounting

The M-238 Heavy-Duty DC-Mike Actuator can be mounted in any orientation.

M-238 Mikes are intended for front mounting at the 35-mm sleeve, using the included nut.
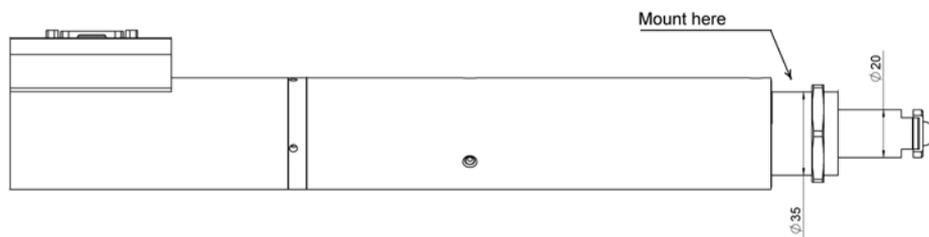
Figure 2: Mounting instruction

Changing the tips:
For mounting, please be sure to hold both the tip and the spindle of the Mike with suitable open-end wrenches, to avoid applying torque to internal parts.

2.2 Interconnecting the System

WARNING

M-238 stages are powered by powerful electric motors and can accelerate to high speeds. Be aware that automatic limit switch halt may not be supported by, or activated at the motor control electronics.

Be aware that failure of the motor controller may drive the mechanics into a hard stop at high speeds.

When the mechanics is first connected to the motor controller, be aware that it could start an undesired move.

⚠ WARNING—CRUSH HAZARD

Never put anything where the tip or any connected object could possibly trap it.

! CAUTION

Before operating the device make sure that it is correctly mounted / fastened to the operating environment.

Prior to operation, read the documentation for the motor controller.
Read the section about PWM amplifiers (p. 12) carefully.

To operate a Mike, proceed as follows:

1 Install/connect the controller following the instructions in the controller manual. If you are using a host computer, install the host software in the host computer. The procedure is described in the controller User Manual and/or associated software manuals.

2 Connect the Mike to the controller using the connecting cable (included as part number C-815.38), which comes with the Mike. With multi-axis controllers, be sure to note the axis designation of the connection selected.

3 Connect the Mike to the included M-500.PS power supply and connect the power supply to line power (wide range). To activate the M-500.PS power supply switch the "-/o"-rocker to the "-" position.

4 Command a few test moves to make sure th system is working properly. If your controller comes with graphic user-interface software, use it for such testing.

5 Extend the tip by commanding positive directions, retract it by commanding negative directions.

For optimal performance and system compatiblity we recommend using PI controllers.
Most PI controllers come with graphic user-interface software which is easy to set up and allows quick installation and testing.

NOTE

Most standard controllers and / or software from PI use a DAT file which contains information on all standard micropositioners and installs automatically with the host software. This file, called pistages.dat, also includes an initial set of PID servo-control parameters for each stage type. If your system does not use pistages.dat, possible PID parameters are included in this manual.

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3   Operational Considerations

3.1   PWM Amplifiers

The M-238 Heavy-Duty DC-Mike Actuator feature a DC servo-motor with a high-efficiency PWM amplifier mounted side by side. This ActiveDrive™ system provides maximum dynamic performance. An external plug-in power supply (M-500.PS) is provided to supply the built-in amplifier. This architecture allows high torque and high velocities while loading the motor controller with control signals only.

3.2   Limit Switches

All M-238 positioners are equipped with non-contact, Hall-effect limit switches (with TTL drivers).
Each limit switch sends an overtravel signal on its own dedicated line to the controller. It is the controller that is then responsible for stopping the motion. If it does not do so in time, the positioner will run into the hard stop.

Limit switch outputs are active-high.

!   CAUTION

Crashes can cause irreparable damage. Do not disable limit switches in software. Test limit switch operation at low speeds. Stop system if necessary. Do not let it run against a hard stop.

Limit Switch Specifications:

Type:	Magnetic (Hall-effect) sensors
Supply voltage	+5 V / GND, supplied by the motor controller through the motor connector.
Signal output:	TTL level
Sink / source capab.	20 mA at 18°C
Signal logic:	Active-high; normal motor operation: low, limit sensor reached: high

3.3   Reference Switch

The M-238 Heavy-Duty DC-Mike Actuator equipped with a direction-sensing Hall-effect reference switch, which is located at about the midpoint of the travel range. This sensor provides a TTL signal indicating whether the positioner is to the positive or negative side of a fixed point. The rising or falling edge of this signal can be used to indicate a known reference position within 0.5 µm accuracy (depending on the controller). The difference in the reference point when approached from the positive or the negative side is about 0.2 mm to 0.4 mm. See the controller User Manual and/or associated software manuals for the commands which make use of the reference signal.

3.4   Rotary Encoder (M-238.5PG)

The M-238.5PG is equipped with a DC-motor with a shaft-mounted position encoder. It provides highly accurate signals whenever the position changes by a known, small amount. By monitoring the encoder pulses, called *counts,* the controller can keep track of the relative motion of the stage. To discover the absolute position, it is necessary to drive the stage to a limit or reference switch. Most controllers have commands to automate this procedure, which is called *referencing.*

3.5   Linear-Scale Position Encoder (M-238.5PL)

An optical linear encoder is mounted in the M-238.5PL Heavy-Duty DC-Mike Actuator featuring 0.1 µm linear resolution.
Optical linear encoders measure the actual position directly, thus eliminating drivetrain errors such as non-linearity, backlash and elastic deformations.

3.6   Motor Controllers

M-238-series micropositioners can be connected to the same motor controllers as other micropositioners from PI.
DC motor controllers from PI can control both analog and ActiveDrive™ (PWM) motor versions. The required operating mode is set automatically—depending on the controller model, either directly when the controller is powered up, or when the user chooses the connected positioner type in the control software.
If networking several positioners, you have to keep in mind that stepper motor devices can only be networked with other stepper-motor devices. This manual includes a list of suitable controllers.

3.7   Host PC

Most controllers from PI are in turn controlled by a host PC provided by the user.

The controller is either installed directly in the PC (e.g. C-843 PCI board) or connected to it over a communications interface. See the controller User Manual for details.

PI provides software and/or drivers that run on the host PC to control the system. Typically, there will be a control program with a graphic user interface for testing and simple operation, and, in addition, DLL, COM and/or LabView drivers for users who wish to use custom software. If the controller is a PC ISA or PCI card, there will also be hardware drivers to install. See the controller user and software manuals for installation details.

4   Troubleshooting

4.1   Diagnosis

Positioner does not move.

Cables not connected properly:
■   Check the connecting cables.

Check if power supply is connected:
■   Verify that the included MS-500.PS power supply is connected and turned on.

Mechanics has passed limit switch (is outside of allowable travel range):
■   Disconnect the device and try to move it manually. If this is not possible please call your local distributor.

Positioner or positioner cable is defective:
■   Replace positioner with a working positioner of the same type to test a new combination of controller and positioner (positioners of a different type may malfunction due to unsuitable parameter settings on the controller).

Test cable and / or replace with a working cable of the syme type.
Wrong command or wrong syntax:
■   Check the error code (with PI-GCS command set, use ERR?; see controller and software manuals for the error code explanations).

Positioner is not referenced:
■   In the GCS command set, some closed-loop motion commands are not executed if the mechanics has not been referenced—(ERR? replies "5", see controller and software manuals). Reference the axis as described in the controller and user manuals.

Wrong axis commanded:
■   Check if commanded axis is that of the desired positioner.

Incorrect configuration:

■ Check for anomolous parameter settings on the controller.

Positioner does not reach position with expected accuracy.

Motion parameters are not optimized:

■ Adjust the motion parameters according to the values given in this document.

Positioner runs jerkily and not smooth enough.

Motion parameters are not optimized:

■ Adjust the motion parameters according to the values listed in this document.

Positioner did not stop in time and ran into a hard stop.

The controller did not stop the positioner in time:

■ Too high velocity. See also chapter "Limit Switches".

■ Turn off the motor. If possible, you may push the positioner out of the end zone manually.

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4.2　Customer Service

Still having problems? Call your local distributor or write to info@pi.ws; please have the following information about your system ready:

■　Product codes and serial numbers of all products in the system

■　Current firmware version of the controller

■　Software version of drivers and / or host software

■　Operating system on host PC

5 Maintenance

The actuator is designed for protection class IP4x. When operated in this environment, no maintenance is required. If the actuator must be operated in extremely dusty or humid environments, we recommend to contact your PI sales engineer.

6   Technical Data

6.1   Specifications

Models	M-238.5PG	M-238.5PL	Unit	Tolerance
Active axes	X	X		
Motion and Positioning				
Travel range	50	50	mm	
Integrated sensor	Rotary Encoder	Linear Encoder		
Sensor resolution	4000 cts/rev	0.1µm		
Design resolution	0.13	0.1	µm	typ.
Min. incremental motion	0.5	0.3	µm	typ.
Backlash	3	1	µm	typ.
Unidirectional repeatability	1	0.3	µm	typ.
Max. velocity	30	30	mm/s	
Origin repeatability	1	1	µm	±20%
Mechanical Properties				
Spindle pitch	2	2	mm/rev	
Gear ratio	3.71:1	3.71:1		
Push/pull force	400	400	N	max.
Lateral force	100	100	N	max.
Drive properties				
Motor type	DC-motor, ActiveDrive™	DC-motor, ActiveDrive™		
Operating voltage	24 (PWM)	24 (PWM)	V	
Electrical power	80	80	W	nominal

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Miscellaneous				
Operating temperature range	-10 to 50	-10 to 50	°C	
Material	Al (anodized), steel	Al (anodized), steel		
Weight	2.4	2.4	kg	±5%
Cable length	3	3	m	±10 mm
Connector	Sub-D 15m	Sub-D 15m		
Recommended Controller	C-862, C-843	C-862, C-843		

6.2   Range and Transmission Ratio Values

	Range [mm]	Range [cts]	Transmission Ratio
M-238.5PL	50	500,000	10 cts/µm
M-238.5PG	50	371428	7.4285714 cts/µm

6.3 Dimensions

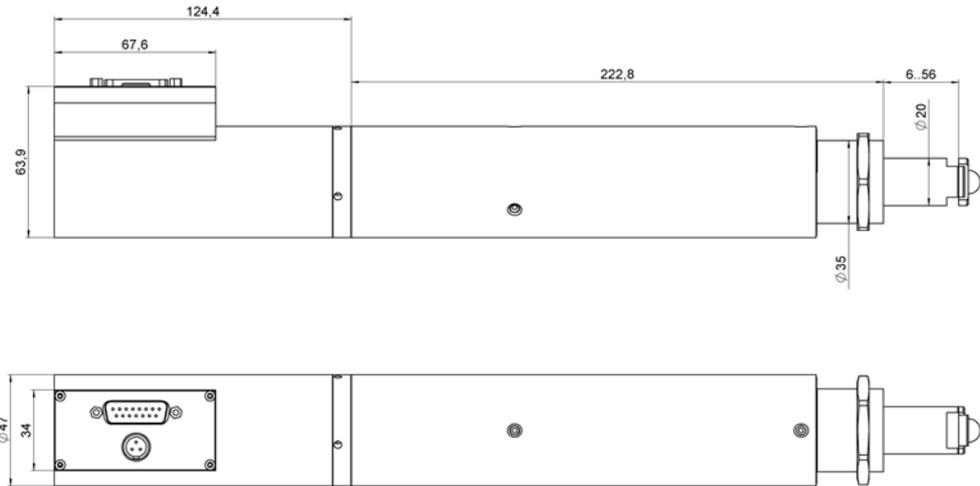All dimensions are given in mm, decimal places separated by commas in drawings.
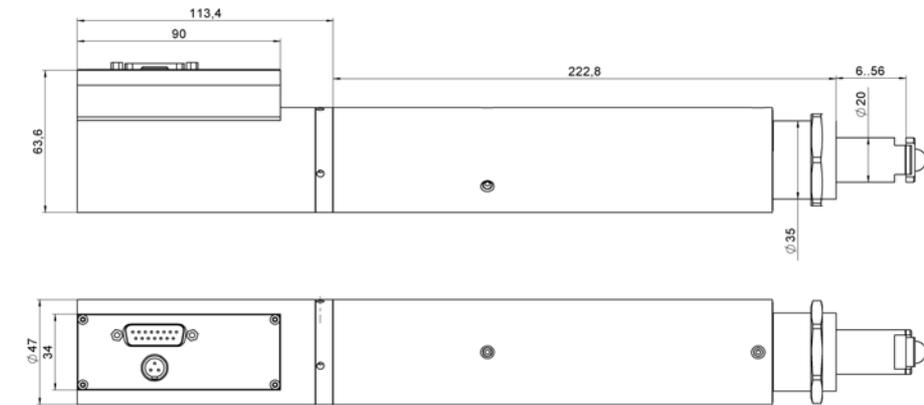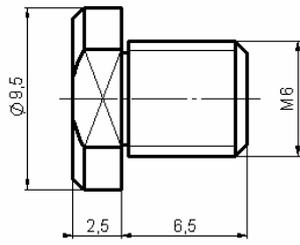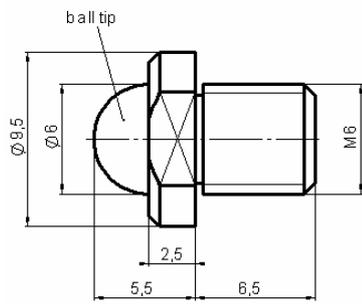
Figure 3: M-238.5PG

Figure 4: M-238.5PL

Figure 5: Flat tip

Figure 6: Ball tip

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6.4   Connector Pin Assignments

Connector J2 (Controller Connection)

Connector type on positioner: D-Sub15m

Pin#		Signal	Direction	Function
1		ENABLE	input	Enable signal for power amplifier and motor brake, (+5 V to +12 V)
	9	n.c.		Not connected
2		n.c.		Not connected
	10	PGND	input	Ground (Power)
3		MAGN	input	PWM signal magnitude (speed)
	11	SIGN	input	PWM signal sign (direction)
4		+5V	input	+5 V input for encoder and logic
	12	NLIM	output	Negative limit signal (active high), TTL
5		PLIM	output	Positive limit signal (active high), TTL
	13	REFS	output	Position reference signal, TTL
6		GND		Ground (logic)
	14	A(+)	output	Encoder signal A, TTL
7		A(-)	output	Encoder signal A-dash, TTL
	15	B(+)	output	Encoder signal B, TTL
8		B(-)	output	Encoder signal B-dash, TTL

Connector J1 (Power Supply)
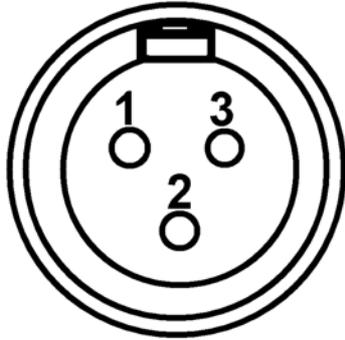
Figure 7: 3-pin power supply connector

Type: 3-pin, round socket

Pin	Function
1	GND (power)
2	Voltage input (+24 V ±3 V)
3	n.c.

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7   Recommended Motor Controllers

Each motorized device in the motion system must be connected to a motion controller. The controller is either networked with or installed in a PC: controller setup and/or operation is thus effectuated with software.

The M-238 Heavy-Duty DC-Mike Actuator can be used with C-843 Motor Controller Card or C-862 Mercury™ Controller.

Drive type	DC Motor	
Controller	C-862 Mercury™	C-843 motor controller card
Axes per controller	1	2 or 4
Host PC interface	RS-232 bus or daisy chain	Internal (PCI bus)
Multiple controllers on same host PC	yes, same or separate ports	yes, separate slots

NOTE

Most standard controllers and / or software from PI use a DAT file which contains information on all standard micropositioners and installs automatically with the host software. This file, called pistages.dat, also includes an initial set of PID servo-control parameters for each stage type. If your system does not use pistages.dat, possible PID parameters are included in this manual.

Parameter settings for C-862 Mercury™ DC-Motor Controller

The C-862 Mercury™ Controller is a compact palm-size, single-axis controller. C-862s are daisy-chain networkable and a multi-axis system can be controlled from a single PC RS-232 interface.
The Windows operating program for the C-862 Mercury™ controller allows choice of micropositioners as a start-up option for operation. The C-862 Mercury™ has the correct operating mode (analog or PWM) automatically enabled with no extra command required.

Appropriate PID Parameters for M-238.5PL

Parameter	Recommended Value	Minimum Value	Maximum Value
p-term	80	30	100
i-term	50	0	80
d-term	100	0	300
i-limit	2,000	0	2,000
velocity [cts/s]	300,000	0	300,000
velocity [mm/s]	30	0	30
acceleration [cts/s²]	1,500,000	10,000	3,000,000
acceleration [mm/s²]	150	1	300

Appropriate PID Parameters for M-238.5PG

Parameter	Recommended Value	Minimum Value	Maximum Value
p-term	180	60	250
i-term	40	0	80
d-term	250	0	350
i-limit	2,000	0	2,000
velocity [cts/s]	222,000	0	222,000
velocity [mm/s]	30	0	30
acceleration [cts/s²]	1,100,000	10,000	2,200,000
acceleration [mm/s²]	150	1	300

8   Glossary of Terms

ActiveDrive™ DC Motor

Some of the advantages of DC-motor drives are good dynamic performance, fast response, high torque at low rpm, low heat dissipation and low vibration. The cost of a high-performance amplifier, however, is generally higher than that for a stepper motor.

The ActiveDrive™ system reduces this cost considerably, by integrating a PWM (pulse width modulation) driver and amplifier in the motor case. This design provides several advantages:

- Increased efficiency, by eliminating power losses between the amplifier and motor

- Reduced cost, more-compact system, and improved reliability, because no external driver and cabling are required

- Elimination of PWM amplifier noise radiation by mounting the amplifier and motor together in a single electrically shielded case

Positioning accuracy is assured with either rotary or optical linear encoders.

Backlash

Position error that appears upon reversing direction. Backlash is caused by play in the drive train components coming after the encoder, such as gearheads or bearings, and by friction in the guiding system. Unlike hysteresis, it can lead to instability in closed-loop setups because it causes a deadband in the servo-loop. Some manufacturers promote controllers with automatic backlash compensation that add the estimated amount of lost motion upon each reversal. This solution is very limited in practice, as backlash is not constant but varies with temperature, deceleration, acceleration, load, leadscrew position, direction, wear, etc.

Bidirectional Repeatability

The accuracy of returning to a position from any position, regardless of direction. Effects such as hysteresis and backlash affect bidirectional repeatability. See also "Unidirectional Repeatability".

DC Servo-Motor

A direct-current motor that is operated in a closed-loop system (servo-loop). Characteristics of DC servo-motors are lack of vibration, smooth running, wide speed range and very good low-speed torque. For optimum performance, a good motor controller with PID (proportional, integral, derivative) algorithm and filter settings is mandatory.

Design Resolution

The theoretical minimum movement that can be made. This is a calculated value based on the drive components (drive screw pitch, gear ratio, motor angular resolution etc.) and does not account for nonlinearities like friction, backlash, etc. Design resolution must not be confused with minimum incremental motion. In systems with high gear ratios or microstepping motors, the design resolution can be in the subnanometer range. In practice, incremental motion of less than 0.1 µm is prevented by guiding system friction (except with air bearings and flexures).

Maximum Push/Pull Force

Active and passive force limit in operating direction, at center of stage. Some stages may be able to generate higher forces at the cost of reduced lifetime.

Minimum Incremental Motion

The minimum motion that can be repeatedly executed for a given input, which is sometimes referred to as practical or operational resolution. Design resolution and practical resolution must be distinguished. Design resolutions of 1 nm or better can be achieved with many motor, gearbox and leadscrew combinations. In practical applications, however, stiction/friction, windup, and elastic deformation limit resolution to fractions of a micron. Minimum incremental motion must be determined by actual measurements. Repeatable nanometer or sub-nanometer resolution can be provided by solid-state actuators (PZTs) and PZT flexure stages (see the "PZT Flexure NanoPositioners" and "PZT Actuators" sections of the PI Catalog for details) such as those integrated in PI's M-511.HD and M-714 Hybrid Drive stages.

Pulse Width Modulation (PWM)

The PWM mode is a highly effective method of transmitting electrical energy at a variable rate by varying the width of pulses in a train rather than the amplitude of an analog signal.

Unidirectional Repeatability

The accuracy of returning to a given position from the same direction. Because unidirectional repeatability is almost unaffected by backlash and hysteresis, it is often considerably better than bidirectional repeatability.

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