

# Servo Motor Linear Actuators

## Classical Motor-Leadscrew / Ballscrew Linear Actuators

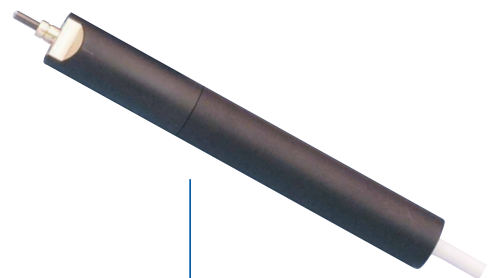
HIGH FORCE



PRECISE



ECONOMICAL



## M-230 Precision Linear Actuator with Closed-Loop Servo Motor Non-Rotating Tip, Limit Switches, Stroke to 25 mm



M-230.10, M-230.25, high-resolution DC-Mike actuators, 10 and 25 mm travel range

### Ordering Information

**M-230.10**  
High-Resolution DC-Mike Linear Actuator, 10 mm, Limit Switches

**M-230.25**  
High-Resolution DC-Mike Linear Actuator, 25 mm, Limit Switches

- Travel Range 10 & 25 mm
- Min. Incremental Motion to 0,05 µm
- Non-Rotating Tip
- Max. Velocity 1.5 mm/s
- Closed-Loop DC Motors
- Non-Contact Limit and Reference Switches
- Front Mount or Clamp Mount
- MTBF>20.000 h

M-230 are ultra-high-resolution linear actuators providing linear motion up to 25 mm with sub-micron resolution in a compact package. They consist of a micrometer with non-rotating tip driven by a 2-phase stepper motor or a closed-loop DC motor / gearhead combination with motor-shaft-mounted, high-resolution encoder.

### 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
- Elimination of wear at the contact point
- Elimination of tip-angle-dependent wobble

### High Accuracy & Long Life

M-230 actuators provide a cost-effective solution for heavier-duty industrial and OEM environments. They feature extremely low-stiction, low-friction construction, allowing for minimum incremental motion as low as 50 nanometers.

### 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 au-

tomation applications with high precision.

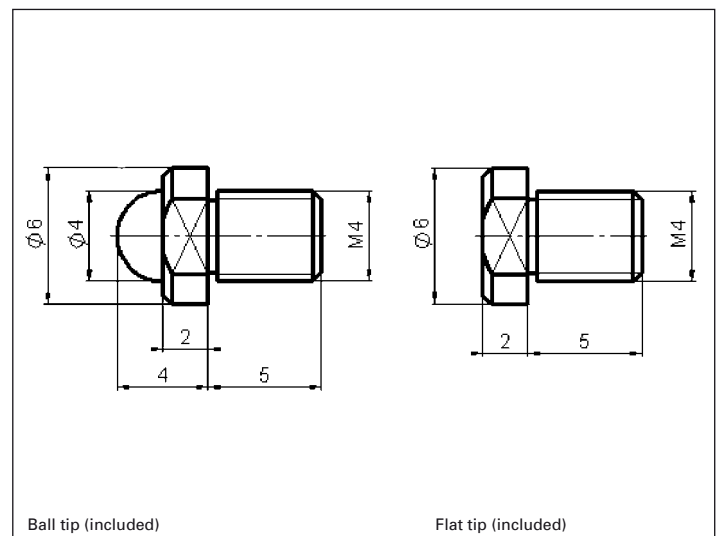
### Integrated Line Drivers

All actuators include an integral 0.5 m cable with 15-pin sub-D connector and come with a 3 m extension cable. On the DC servo versions, the connector features integrated line drivers for cable lengths up to 10 meters between actuator and controller.

### High-Load Versions

For higher loads and travel ranges refer to the M-235 (see p. 1-50) and M-238 (see p. 1-52).

A screw-in ball tip and a flat tip are included.

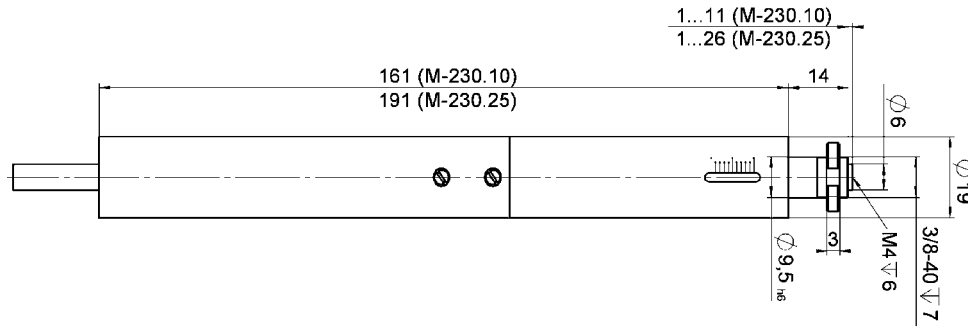


Ball tip (included)

Flat tip (included)

### Application Examples

- Fiber positioning
- Metrology
- Photonics packaging
- Quality assurance testing
- Testing equipment



M-230. Cable length: 500 mm, 15-pin sub-D connector with integrated line drivers (DC motor models). Dimensions in mm

## Technical Data

Model	M-230.10	M-230.25	M-230.10S	M-230.25S	Units
Active axes	X	X	X	X	
<b>Motion and positioning</b>					
Travel range	10	25	10	25	mm
Integrated sensor	Rotary encoder	Rotary encoder			
Sensor resolution	2,048	2,048			Cts./rev.
Design resolution	0.0046	0.0046	0.037	0.037	μm
Min. incremental motion	0.05	0.05	0.05	0.05	μm
Backlash	2	2	2	2	μm
Unidirectional repeatability	0.1	0.1	0.1	0.1	μm
Max. velocity	0.8	0.8	1.5	1.5	mm/s
Reference switch repeatability	1	1	1	1	μm
<b>Mechanical properties</b>					
Spindle	Leadscrew	Leadscrew	Leadscrew	Leadscrew	
Spindle pitch	0.4	0.4	0.4	0.4	mm
Gear ratio	42.92063:1	42.92063:1	28.44444:1	28.44444:1	
Motor resolution**			384**	384**	steps/rev.
Max. push/pull force	70	70	45*	45*	N
Max. lateral force	30	20	30	20	N
<b>Drive properties</b>					
Motor type	DC-motor, gearhead	DC-motor, gearhead	2-phase stepper motor**	2-phase stepper motor**	
Operating voltage	0 to ±12	0 to ±12	24	24	V
Electrical power	2	2			W
Limit and reference switches	Hall-effect	Hall-effect	Hall-effect	Hall-effect	
<b>Miscellaneous</b>					
Operating temperature range	-20 to +65	-20 to +65	-20 to +65	-20 to +65	°C
Material	Al (anodized), steel	Al (anodized), steel	Al (anodized), steel	Al (anodized), steel	
Mass	0.3	0.35	0.3	0.35	kg
Cable length	0.5	0.5	0.5	0.5	m
Connector	15-pin sub-D connector	15-pin sub-D connector	15-pin sub-D connector	15-pin sub-D connector	
Recommended controller/driver	C-863 single-axis C-843 PCI board, for up to 4 axes	C-863 single-axis (p. 4-114) C-843 PCI board, for up to 4 axes (p. 4-120)	C-663 single-axis	C-663 single-axis (p. 4-112)	

\*at velocities of up to 1 mm/s

\*\*2-phase stepper motor, 24 V chopper voltage, max. 0.25 A/phase, 24 full steps/rev., motor resolution with C-663 stepper motor controller

# M-231 Compact Linear Actuator with Closed-Loop Servo Motor

## With Limit Switches, Suitable for Fiber Alignment



M-231.17 high-resolution DC-Mike actuator, 17 mm travel range

### Ordering Information

**M-231.17**  
High-Resolution DC-Mike Linear Actuator, 17 mm, Limit Switches

- Travel Range 17 mm
- Min. Incremental Motion to 0.1  $\mu\text{m}$
- Max. Velocity 2.5 mm/s
- Closed-Loop DC-Motors
- Non-Contact Limit and Reference Switches
- Fits M-105 Fiber Aligners
- MTBF >5.000 h

The M-231 is an ultra-high-resolution linear actuator providing linear motion up to 17 mm with sub-micron resolution in a compact package. It consists of a leadscrew which is driven by a closed-loop DC-motor/gearhead combination with motor-shaft-mounted, high-resolution encoder (2048 counts/rev.).

### Upgrade for Manual Aligners

The M-231 was especially designed to fit existing manual translation stages (e.g. M-105, see p. 4-50 ff) as a direct replacement for a manual micrometer.

### Limit and Reference Switches

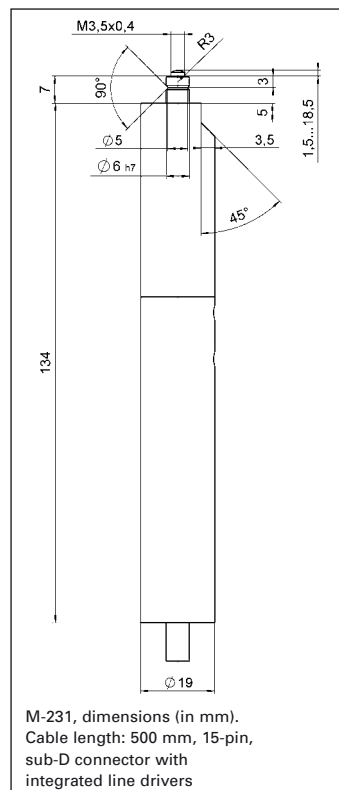
For the protection of your equipment, non-contact Hall-effect limit and reference switches are installed. The reference switch supports advanced automation applications with high precision.

### Application Examples

- Fiber positioning
- Metrology
- Photonics packaging
- Quality assurance testing
- Testing equipment

### Integrated Line Drivers

All actuators include an integral 0.5 m cable with 15-pin sub-D connector and come with a 3 m extension cable. On the DC servo versions, the connector features integrated line drivers for cable lengths up to 10 meters between actuator and controller.



For higher loads and travel ranges, refer to the M-230 (see p. 1-46), M-235 (see p. 1-50) and M-238 (see p. 1-52).



M-231 mounted on M-105 XYZ positioning systems

### Technical Data

Model	M-231.17	Units
Active axes	X	
<b>Motion and positioning</b>		
Travel range	17	mm
Integrated sensor	Rotary encoder	
Sensor resolution	2,048	Cts./rev.
Design resolution	0.007	$\mu\text{m}$
Min. incremental motion	0.1	$\mu\text{m}$
Backlash	2	$\mu\text{m}$
Unidirectional repeatability	0.2	$\mu\text{m}$
Max. velocity	1.5	mm/s
Reference switch repeatability	1	$\mu\text{m}$
<b>Mechanical properties</b>		
Spindle	Leadscrew	
Spindle pitch	0.4	mm
Gear ratio	28.44444:1	
Max. push/pull force	40	N
<b>Drive properties</b>		
Motor type	DC-motor, gearhead	
Operating voltage	0 to $\pm 12$	V
Electrical power	2	W
Limit and reference switches	Hall-effect	
<b>Miscellaneous</b>		
Operating temperature range	-20 to +65	$^{\circ}\text{C}$
Material	Al (anodized), steel	
Mass	0.17	kg
Recommended controller/driver	C-863 single-axis (p. 4-114) C-843 PCI board, for up to 4 axes (p. 4-120)	

# M-232 Folded Linear Actuator with Closed-Loop Servo Motor

## Compact Package, Suitable for Fiber Alignment



M-232.17 high-resolution DC-Mike actuator mounted on M-105 translation stage

- Travel Range 17 mm
- Min. Incremental Motion to 0,1 µm
- Max. Velocity 2,5 mm/s
- Closed-Loop DC-Motors
- Non-Contact Limit and Reference Switches
- Fits M-105 Fiber Aligners
- MTBF >5.000 h

The M-232 is an ultra-high-resolution linear actuator providing linear motion up to 17 mm with sub-micron resolution in a compact package. It features a space-saving design with a leadscrew side-by-side to a closed-loop DC-motor/gearhead combination and a high-resolution encoder (2048 counts/rev.). They feature a low-stiction, low-friction construction allowing for minimum incremental motion of 100 nanometers at speeds of up to 2.5 mm/sec.

### Upgrade for Manual Aligners

The M-232 was especially designed to fit existing manual translation stages (e.g. M-105 see p. 4-50 ff) as a direct replacement for a manual micrometer.

### Application Examples

- Fiber positioning
- Metrology
- Photonics packaging
- Quality assurance testing
- Testing equipment

### Limit and Reference Switches

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

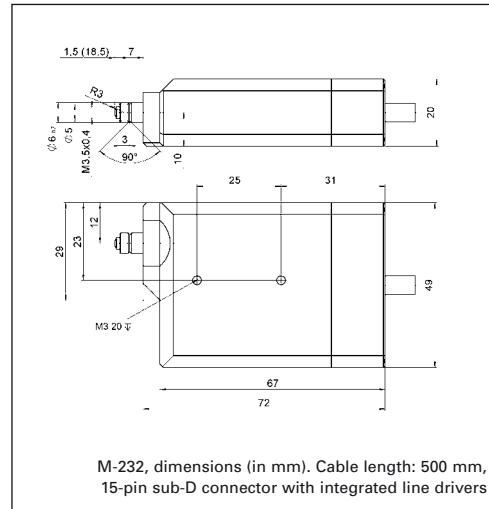
### Integrated Line Drivers

All actuators include an integral 0.5 m cable with 15-pin sub-D connector and come with a 3 m extension cable. On the DC servo versions, the connector features integrated line drivers for cable lengths up to 10 meters between actuator and controller.

For higher loads and travel ranges, refer to the M-230 (see p. 1-46), M-235 (see p. 1-50) and M-238 (see p. 1-52).

### Ordering Information

**M-232.17**  
Compact High-Resolution DC-Mike  
Linear Actuator, 17 mm,  
Limit Switches



### Technical Data

Model	M-232.17	Units
Active axes	X	
<b>Motion and positioning</b>		
Travel range	17	mm
Integrated sensor	Rotary encoder	
Sensor resolution	2,048	Cts./rev.
Design resolution	0.007	µm
Min. incremental motion	0.1	µm
Backlash	2	µm
Unidirectional repeatability	0.2	µm
Max. velocity	1.5	mm/s
Reference switch repeatability	1	µm
<b>Mechanical properties</b>		
Spindle	Leadscrew	
Spindle pitch	0.4	mm
Gear ratio	28.44444:1	
Max. push/pull force	40	N
<b>Drive properties</b>		
Motor type	DC-motor, gearhead	
Operating voltage	0 to ±12	V
Electrical power	2	W
Limit and reference switches	Hall-effect	
<b>Miscellaneous</b>		
Operating temperature range	-20 to +65	°C
Material	Al (anodized), steel	
Mass	0.17	kg
Recommended controller/driver	C-863 single-axis (p. 4-114) C-843 PCI board, for up to 4 axes (p. 4-112)	

# M-235 Ball-Screw Linear Actuator w/ Closed-Loop Servo Motor

## High-Dynamics, Stroke to 50 mm, Forces to 120 N



M-235.2DG (top) and M-235.5DG (bottom) high-resolution DC-Mike, ballscrew

- Travel Range 20 & 50 mm
- Min. Incremental Motion to 0.1  $\mu\text{m}$
- High-Speed Direct Drive Option
- Push/Pull Load 120 N
- Lateral Force 100 N
- Recirculating Ballscrew Drives Provide High Speeds & Long Lifetimes
- Closed-Loop DC Motors
- Non-Contact Limit and Reference Switches
- MTBF >20.000 h
- Vacuum-Compatible Versions Available to  $10^{-6}$  hPa

The M-235 is an ultra-high-resolution linear actuator providing linear motion of up to 50 mm with sub-micron resolution in a compact package. It consists of a preloaded ultra-low-friction, heavy-duty ballscrew which is driven by a 2-phase stepper motor or a closed-loop DC motor with motor-shaft-mounted, high-resolution encoder (2048 counts/rev.).

### Three Different Drives

The M-235 is available with three different motor drives:

#### Application Examples

- Fiber positioning
- Automation
- Metrology
- Photonics packaging
- Quality assurance testing
- Testing equipment

The M-235.5DD version is equipped with a direct drive motor for high-speed positioning applications. The DC-motor models provide a minimum incremental motion of 100 nm only and are equipped with high-resolution rotary encoders for position control. The M-235.x2S versions have a high-power, low-vibration 2-phase stepper motor.

### 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
- Elimination of wear at the contact point
- Elimination of tip-angle-dependent wobble

### Ballscrews for High Speed and Long Lifetime

The recirculating ballscrew is maintenance-free and pre-loaded to eliminate mechanical play. Its significantly reduced friction, compared to conventional lead screws, allows for higher velocity, lower power consumption and longer service life. Thus, a bidirectional repeatability of 1  $\mu\text{m}$  is made possible!

### 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.

### Integrated Line Drivers

All actuators include an integral 0.5 m cable with 15-pin sub-D connector and come with a 3 m extension cable. On the DC servo versions, the connector features integrated line drivers for cable lengths up to 10 meters between actuator and controller (DC-motors only).

A screw-in ball tip and a flat tip are included.

### Ordering Information

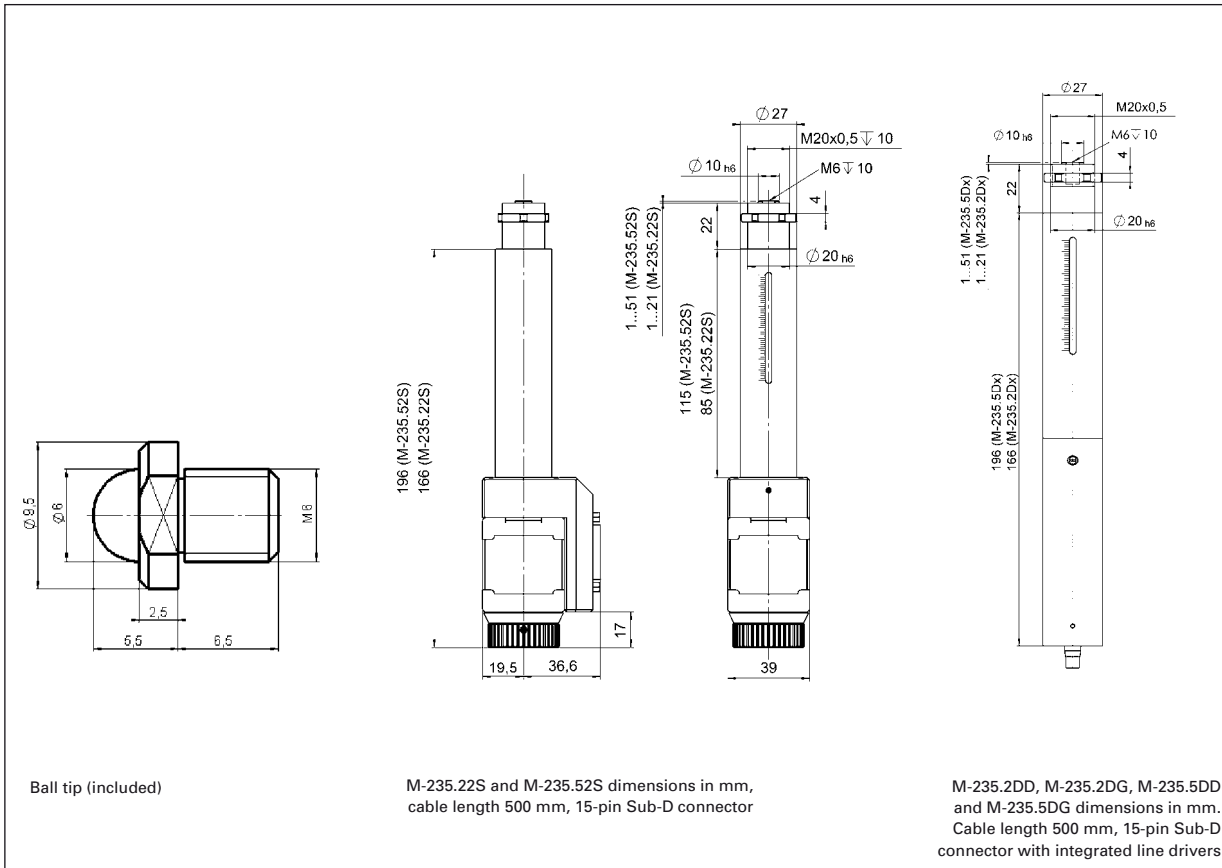
- M-235.2DD**  
High-Power Linear Actuator, 20 mm, Ballscrew, Direct-Drive DC Motor
- M-235.2VD**  
Vacuum Version of M-235.2DD
- M-235.2DG**  
High-Power Linear Actuator, 20 mm, Ballscrew, DC Motor Gearhead
- M-235.2VG**  
Vacuum Version of M-235.2DG
- M-235.5DD**  
High-Power Linear Actuator, 50 mm, Ballscrew, Direct-Drive DC Motor
- M-235.5VD**  
Vacuum Version of M-235.5DD
- M-235.5DG**  
High-Power Linear Actuator, 50 mm, Ballscrew, DC Motor Gearhead
- M-235.5VG**  
Vacuum Version of M-235.5DG

**Ask about custom designs!**



M-235.22S high-resolution Stepper-Mike, 20 mm travel range, ballscrew





## Technical Data

Model	M-235.2DG	M-235.2DD	M-235.22S	M-235.5DG	M-235.5DD	M-235.52S	Units
Active axes	X	X	X	X	X	X	
<b>Motion and positioning</b>							
Travel range	20	20	20	50	50	50	mm
Integrated sensor	Rotary encoder	Rotary encoder		Rotary encoder	Rotary encoder		
Sensor resolution	2.048	2.048		2.048	2.048		Cts./rev.
Design resolution	0.016	0.5	0.156	0.016	0.5	0.156	µm
Min. incremental motion	0.1	0.5	0.1	0.1	0.5	0.1	µm
Unidirectional repeatability	0.1	0.5	0.2	0.1	0.5	0.2	µm
Bidirectional repeatability	1	1	1	1	1	1	µm
Max. velocity	2.6	>30	20	2.6	>30	20	mm/s
<b>Mechanical properties</b>							
Gear ratio	29.6:1			29.6:1			
Motor resolution*			6,400*			6,400*	steps/rev.
Max. push/pull force	120	50	100**	120	50	100**	N
Max. lateral force	100	100	100	100	100	100	N
<b>Drive properties</b>							
Motor type	DC-motor, gearhead	DC-motor	2-phase stepper motor*	DC-motor, gearhead	DC-motor	2-phase stepper motor*	
Operating voltage	0 to ±12	0 to ±12	24	0 to ±12	0 to ±12	24	V
Electrical power	4	17	4.75	4	17	4.75	W
Limit and reference switches	Hall-effect	Hall-effect	Hall-effect	Hall-effect	Hall-effect	Hall-effect	
<b>Miscellaneous</b>							
Operating temperature range	-20 to +65	-20 to +65	-20 to +65	-20 to +65	-20 to +65	-20 to +65	°C
Material	Al (anodized), steel	Al (anodized), steel	Al (anodized), steel	Al (anodized), steel	Al (anodized), steel	Al (anodized), steel	
Mass	0.55	0.5	0.65	0.7	0.65	0.8	kg
Recommended controller/driver	C-863 single-axis C-843 PCI board, for up to 4 axes	C-863 single-axis C-843 PCI board, for up to 4 axes	C-663 single-axis	C-863 single-axis C-843 PCI board, for up to 4 axes	C-863 single-axis (p. 4-114) C-843 PCI board, for up to 4 axes (p. 4-120)	C-663 single-axis (p. 4-112)	

\*2-phase stepper motor, 24 V chopper voltage, max. 0.8 A/phase, 400 full steps/rev., motor resolution with C-663 stepper motor controller

\*\*at up to 10 mm/sec

Data for vacuum versions may differ.

# M-238 High-Load, Linear Actuator with Closed-Loop Servo Forces to 400 N, Optional Direct Position Measurement



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

- High Load Capacity to 400 N
- Travel Range 50 mm
- Resolution to 0.1  $\mu\text{m}$
- Max. Velocity 30 mm/s
- Preloaded Frictionless Ball Screw
- Optional 0.1  $\mu\text{m}$  Direct-Metrology Linear Encoder for Exceptional Precision
- 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. The M-238 is therefore well suited for high duty-cycle operation in industrial environments. 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  $\mu\text{m}$ . 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
- 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.

### Ordering Information

**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

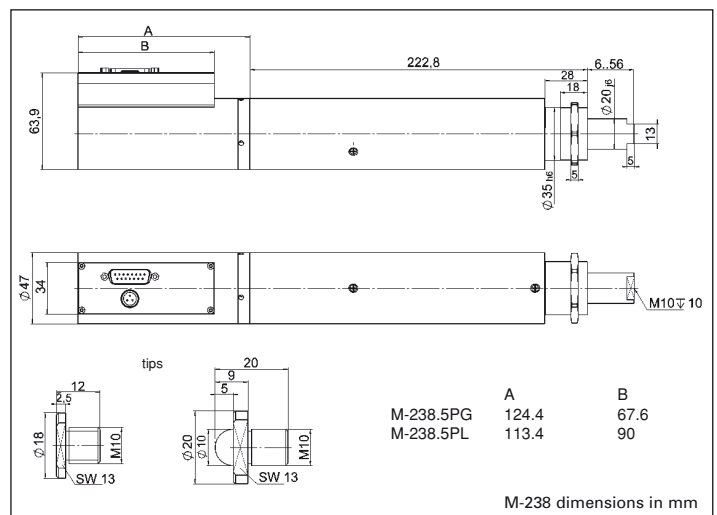
\*Ask for availability in your region

### Ballscrews for High Speed, Precision and Lifetime

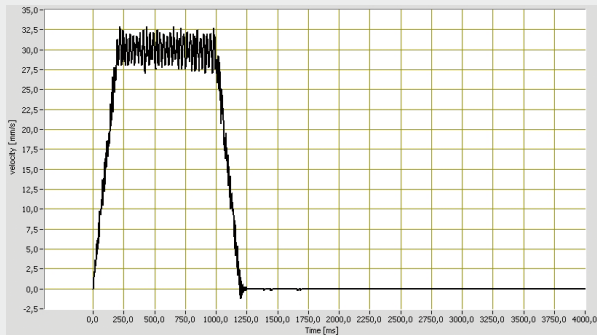
The precision-ground ballscrew is maintenance-free and preloaded to eliminate mechanical play. Its significantly reduced friction, compared to conventional leadscrews, allows for higher velocity, lower power consumption and longer lifetime.

### Limit and Reference Switches

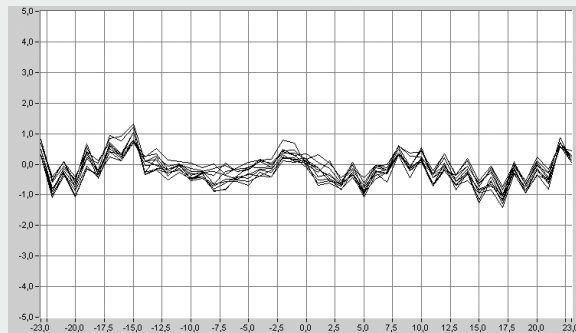
For the protection of your equipment, non-contact Hall-effect limit and reference switches are installed. The direction-sensing reference switch supports advanced automation applications with high precision.



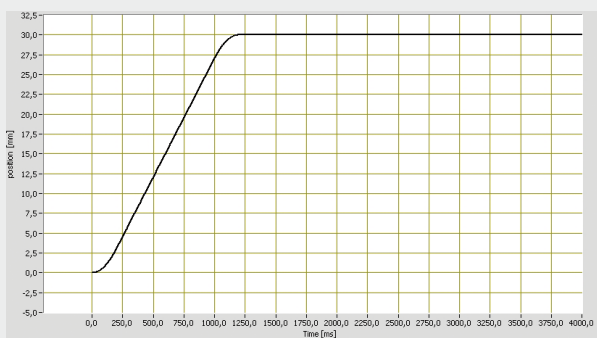




M-238.5PL velocity at 30 mm/s is highly constant.



M-238.5PL repeatability is better than 0.3  $\mu\text{m}$ .



The settling time for a 30 mm step is less than 1.5 seconds.

## Technical Data

Model	M-238.5PG	M-238.5PL	Units	Tolerance
Active axes	X	X		
<b>Motion and positioning</b>				
Travel range	50	50	mm	
Integrated sensor	Rotary encoder	Linear encoder		
Sensor resolution	4000 cts/rev.	0.1 $\mu\text{m}$		
Design resolution	0.13	0.1	$\mu\text{m}$	typ.
Min. incremental motion	0.5	0.3	$\mu\text{m}$	typ.
Backlash	3	1	$\mu\text{m}$	typ.
Unidirectional repeatability	1	0.3	$\mu\text{m}$	typ.
Max. velocity	30	30	mm/s	
Origin repeatability	1	1	$\mu\text{m}$	$\pm 20\%$
<b>Mechanical properties</b>				
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.
<b>Drive properties</b>				
Motor type	DC-motor, ActiveDrive™	DC-motor, ActiveDrive™		
Operating voltage	24 (PWM)	24 (PWM)	V	
Electrical power	80	80	W	nominal
<b>Miscellaneous</b>				
Operating temperature range	-10 to 50	-10 to 50	$^{\circ}\text{C}$	
Material	Al (anodized), steel	Al (anodized), steel		
Mass	2.4	2.4	kg	$\pm 5\%$
Cable length	3	3	m	$\pm 10\text{ mm}$
Connector	D-Sub 15 (m)	D-Sub 15 (m)		
Recommended controller/driver	C-863, C-843	C-863 (p. 4-114), C-843 (p. 4-120)		

# M-227 Servo Motorized Micrometer Linear Actuator

## Non-Rotating Tip, Long Stroke to 50 mm



M-227.10 (w/ piezo tip), M-227.25, M-227.50 (w/ ball tip), high-resolution DC-Mike actuators and several tip options

### Ordering Information

- M-227.10**  
High-Resolution DC-Mike Linear Actuator, 10 mm
- M-227.25**  
High-Resolution DC-Mike Linear Actuator, 25 mm
- M-227.50**  
High-Resolution DC-Mike Linear Actuator, 50 mm
- M-219.10**  
Ball Tip
- P-855.20**  
Piezo Actuator for Micrometer Drive

- Travel Ranges 10, 25 and 50 mm
- Min. Incremental Motion to 0.05  $\mu\text{m}$
- Non-Rotating Tip
- Closed-Loop DC-Motors
- Sub-nm Resolution with Optional PZT Drive
- MTBF >5,000 h

M-227 are ultra-high-resolution linear actuators providing linear motion up to 50 mm with sub-micron resolution in a compact package. They consist of a micrometer with non-rotating tip, driven by a closed-loop DC-motor/gearhead combination with motor-shaft-mounted high-resolution encoder. The combination of an extremely low stiction/friction construction and high-resolution encoder allows for a minimum incremental motion of 50 nanometers at speeds up to 1 mm/sec.

### 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
- Elimination of wear at the contact point
- Elimination of tip-angle-dependent wobble

### Compact, High-Precision, Cost-Effective

M-227 actuators provide a cost-effective solution for industrial and OEM environments.

### Integrated Line Drivers

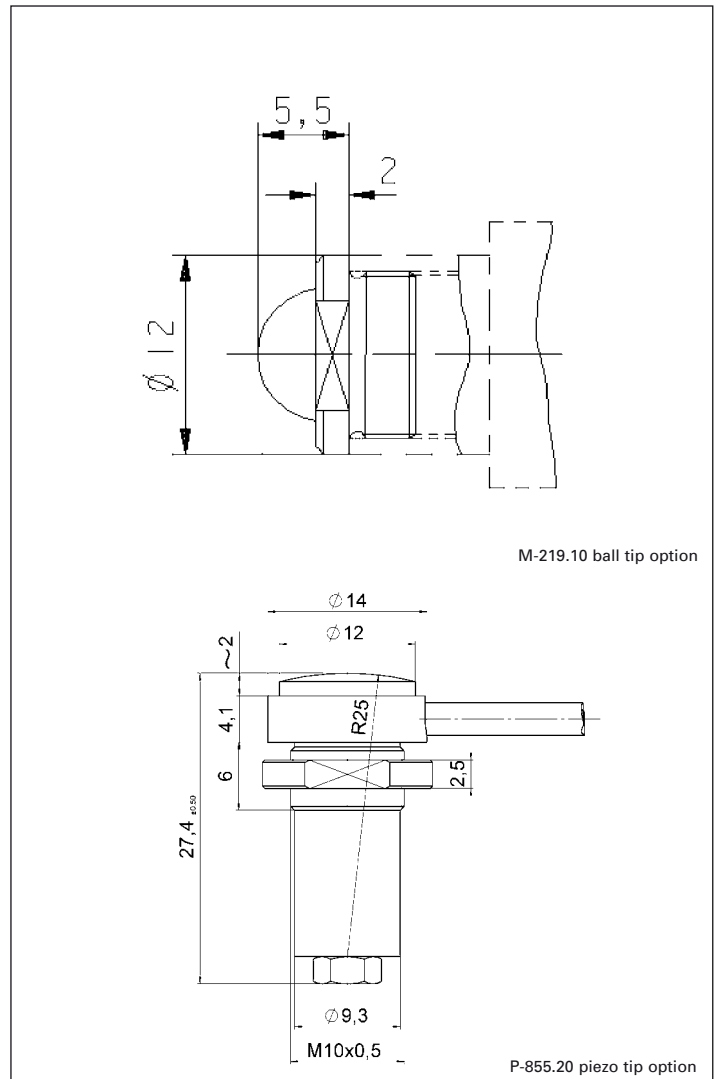
All actuators include an integral 0.5 m cable with 15-pin sub-D connector and come with a 3 m extension cable. On the DC servo versions, the connector features integrated line drivers for cable lengths up to 10 meters between actuator and controller.

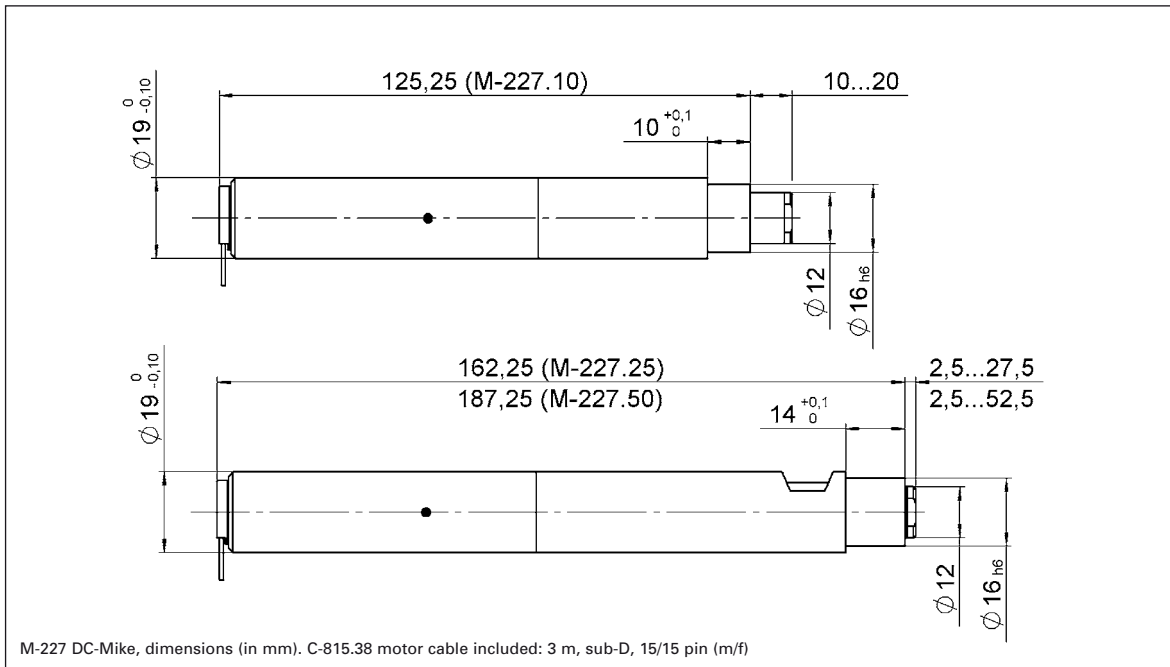
### High-Resolution Piezo Option

All models come with standard flat tips. A variety of other tips are also available, such as a piezoelectric tip featuring 20  $\mu\text{m}$  travel with sub-nanometer resolution for dynamic scanning and tracking see p. 1-73 and 1-58.

For higher loads and integrated limit switches refer to the

M-230 (see p. 1-46 ff), M-235 (see p. 1-50 ff) and M-238.





### Technical Data

Model	M-227.10	M-227.25	M-227.50	Units
Active axes	X	X	X	
<b>Motion and positioning</b>				
Travel range	10	25	50	mm
Integrated sensor	Rotary encoder	Rotary encoder	Rotary encoder	
Sensor resolution	2048	2048	2048	Cts./rev.
Design resolution	0.0035	0.0035	0.0035	µm
Min. incremental motion	0.05	0.05	0.05	µm
Backlash	2	2	2	µm
Unidirectional repeatability	0.1	0.1	0.1	µm
Max. velocity	0.75	0.75	0.75	mm/s
<b>Mechanical properties</b>				
Drive screw	Leadscrew	Leadscrew	Leadscrew	
Thread pitch	0.5	0.5	0.5	mm
Gear ratio	69.12:1	69.12:1	69.12:1	
Max. push/pull force	40	40	40	N
Max. lateral force	0.1	0.1	0.1	N
<b>Drive properties</b>				
Motor type	DC-motor, gearhead	DC-motor, gearhead	DC-motor, gearhead	
Operating voltage	0 to ±12	0 to ±12	0 to ±12	V
Electrical power	1.25	1.25	1.25	W
<b>Miscellaneous</b>				
Operating temperature range	-20 to +65	-20 to +65	-20 to +65	°C
Material	Al (anodized), steel	Al (anodized), steel	Al (anodized), steel	
Mass	0.16	0.22	0.26	kg
Cable length	0.1	0.1	0.1	m
Connector	15-pin sub-D connector	15-pin sub-D connector	15-pin sub-D connector	
Recommended controller/driver	C-863 single-axis C-843 PCI-board, for up to 4 axes	C-863 single-axis C-843 PCI-board, for up to 4 axes	C-863 single-axis (see p. 4-114) C-843 PCI-board, for up to 4 axes (see p. 4-120)	

\*Higher forces on request

# C-863 Mercury DC Servo Motor Controller & Driver

## 1-Axis DC-Servo-Motor Controller with Network Feature



The C-863 Mercury DC servo controller features USB and RS-232 interfaces and incremental encoder signal processing at 20 MHz bandwidth

- High Performance at Low Cost
- DC Servo-Motor Controller Supplies up to 30 W
- 20 MHz Encoder Input for High Speed & Resolution
- Macro Programmable Stand-Alone Functionality
- Data Recorder
- Network Capability for Multi-Axis Applications
- Non-Volatile EEPROM for Macros and Parameters
- Digital I/O Lines (TTL)
- Motor-Brake Control
- USB and RS-232 Interface
- Optional Joystick for Manual Control

The latest generation Mercury C-863 servo motor controller is even more powerful and versatile than its predecessors. Easy data interchange with laptop or PC is possible via the USB in-

terface. The RS-232 interface provides for easy integration in industrial applications. The compact design with its integrated amplifier makes it ideal for building high-performance, cost-effective micropositioning systems.

### Application Examples

- Fiber positioning
- Automation
- Photonics/integrated optics
- Quality assurance testing
- Testing equipment

### Flexible Automation

The Mercury offers a number of features to achieve automation and handling tasks in research and industry in a very cost-effective way. Programming is facilitated by the high-level mnemonic command language with macro and compound-

command functionality. Macros can be stored in the non-volatile memory for later recall.

Stand-alone capability is provided by a user-programmable autostart macro to run automation tasks at power up (no runtime computer communication required!).

For easy synchronization of motion with internal or external trigger signals four input and four output lines are provided.

### Multi-Axis Control

Up to 16 Mercury class controllers can be networked and controlled over a single PC interface.

Such daisy chain networks are flexible, can be extended at any time and are compatible with other PI controllers for DC servo-motors or stepper motors, PLine® ultrasonic piezomotor drives or piezo stepping drives.

### Easy Programming

All servo and stepper motor controllers of the Mercury family can be operated using the PI general command set (GCS). PI-GCS allows networking of different controller units, both for piezo-based and motorized positioning units, with minimal programming effort.

### Cost-Saving Due to Integrated Amplifier and PWM Outputs

The unique Mercury concept combines a high-performance motion controller and an integrated power amplifier in a small package. Additional PWM control outputs allow the direct operation of any DC-motor-driven PI micro-positioning system—even high-speed stages such as the M-500 ActiveDrive Translation Stages—reducing costs, increasing reliability and simplifying the setup.

### Ordering Information

**C-863.11**  
Mercury DC-Motor Controller, 1 Channel, with Wide-Range Power Supply

**C-819.20**  
2-Axis Analog Joystick for Mercury Controller

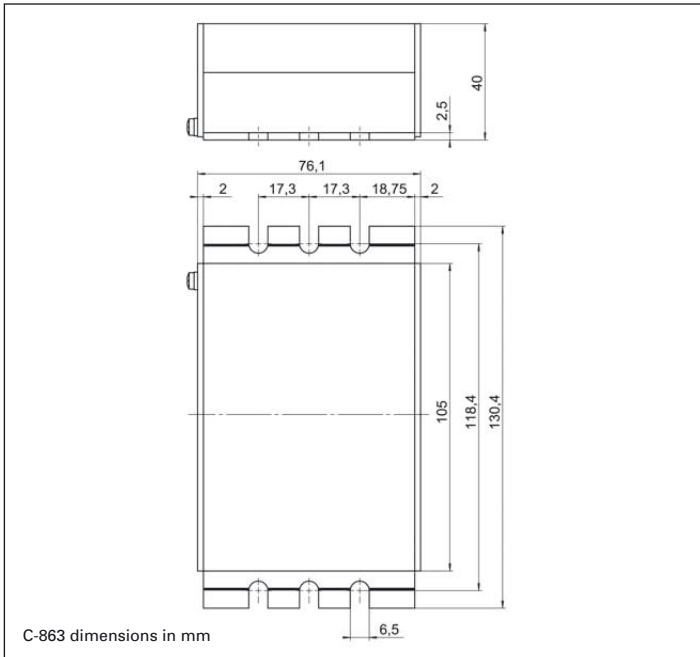
**C-819.20Y**  
Y-Cable for Connecting 2 Controllers to C-819.20

**C-170.IO**  
I/O Cable, 2 m, Open End

**C-170.PB**  
Push Button Box, 4 Buttons and 4 LEDs

### Contents of Delivery

Each controller is delivered with a wide-range power supply, USB and RS-232 communication cable, a daisy-chain network cable and a comprehensive software package.

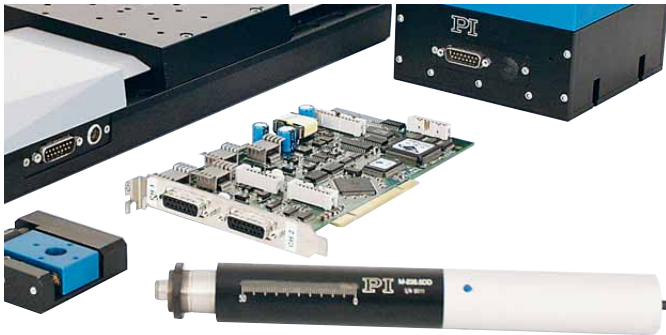


## Technical Data

<b>Model</b>	<b>C-863.11</b>
Function	DC-servo-motor controller, 1 channel
<b>Motion and control</b>	
Servo characteristics	P-I-D servo control, parameter change on-the-fly
Trajectory profile modes	Trapezoidal, point-to-point
Encoder input	AB (quadrature) single-ended or differential TTL signal, 20 MHz
Stall detection	Servo off, triggered by programmable position error
Input limit switch	2 x TTL (pull-up/pull-down, programmable)
Input reference switch	1 x TTL
Motor brake	1 x TTL, software controlled
<b>Electrical properties</b>	
Output power	max. 30 W (PWM)
Output voltage	0 to 15 V
Current	80 mA + motor current (3 A max.)
<b>Interfaces and operation</b>	
Communication interfaces	USB, RS-232 (9-pin [m] sub-D)
Motor connector	15-pin (f) sub-D
Controller network	Up to 16 units on single interface
I/O ports	4 analog/digital in, 4 digital out (TTL)
Command set	PI General Command Set (GCS)
User software	PIMikroMove®
Software drivers	LabVIEW drivers
Supported functionality	Start-up macro, data recorder for recording parameters as motor input voltage, velocity, position or position error; internal safety circuitry: watchdog timer
Manual control (optional)	2-axis joystick, Y-cable for 2D motion, pushbutton box
<b>Miscellaneous</b>	
Operating voltage	15 to 30 V included: external power supply, 15 V / 2 A
Operating temperature range	+5 to +50 °C
Mass	0.3 kg
Dimensions	130 x 76 x 40 mm

# C-843 DC-Servo-Motor Controller w/ Integrated Drivers

## Servo Motion Controller/Driver PCI Board for 2 or 4 Axes



C-843.41 DC-motor controller board with M-110.DG linear stage, M-235.5DG heavy duty linear actuator, M-511.DD direct drive translation stage and M-501.1DG vertical stage. No external amplifier is required to drive any of these or other PI stages. Small motors are driven through the C-843's onboard linear amplifiers, direct-drive PI stages (e.g. M-511.DD) employ ActiveDrive™ controlled off the C-843's PWM outputs.

- **Two and Four Axis Version**
- **Very Cost-Effective: Servo Amplifiers On-Board**
- **Additional PWM Outputs for High-Power Motors**
- **Trapezoidal Curve, S-Curve and Velocity Profile**
- **32 kSamples RAM for High-Speed Buffer Operations**
- **16 I/O Lines for Flexible Automation**
- **Fast PCI Communication, 120 μs for Position Read**
- **Motor-Brake Control Output**
- **Extensive Software Support**
- **General Command Set (GCS) Compatible**

The C-843 PCI motion controller card drives up to 4 axes of micropositioning equipment. Because there is no need for external servo-amplifiers, this new card is a very cost-effective, easy-to-set-up solution.

### On-Board Servo-Amplifiers

Unlike other PCI controller cards, the new C-843 comes with on-board, low-noise linear amplifiers for the small DC motors used in most compact micropositioning stages and actuators.

In addition, PWM outputs are available to drive more powerful equipment (all direct-drive

translation and rotation stages from PI feature the integrated ActiveDrive™ PWM amplifiers, and also connect to the C-843 with no external power amplifiers).

The PWM mode and linear amplifier mode can be programmed individually for each of the 4 (or 2) channels.

### High-Performance PID Control

The C-843 employs a fast DSP (digital signal processor) providing high-performance PID motion control with many options for trajectory generation and filter settings for superior positioning and tra-

cking accuracy. Position, velocity, acceleration and several other motion parameters can be programmed individually for each axis on-the-fly. High-bandwidth counters (5 MHz) support differential encoder feedback (incremental rotary encoders or linear scales) for fast and accurate positioning.

### I/O for Flexible Automation

In addition to 3 TTL inputs per channel for limit and reference signals, 16 more I/O lines are available for flexible automation tasks (trigger functions, etc.). The C-843 also features motor-brake output lines (e.g. for M-531.DDB stages).

### High-Speed Buffering

The integrated 32 k-sample trace memory allows online buffering (read and write) at integer multiples of the servo-loop time of up to four independent system variables (positions, velocities, internal register contents, etc.) This allows the observation of the motion system and also performing customized trajectory profiles.

### PI General Command Set (GCS)

The comprehensive command structure is based on the PI General Command Set (GCS). With GCS the development of custom application programs is simplified, because the commands for all supported devices are identical in syntax and function. PI controllers for nanopositioning systems, for piezomotors and servo or stepper motors can be commanded with GCS.

### Software / Programming

In addition to the user software for setup, system optimization and operation, comprehensive LabVIEW and DLL libraries are

### Ordering Information

- C-843.21**  
DC-Motor Controller PCI PC Board, 2-Axis
- C-843.41**  
DC-Motor Controller PCI PC Board, 4-Axis
- C-843.JS**  
Joystick and PCI Interface Board for C-843 Motor Controller

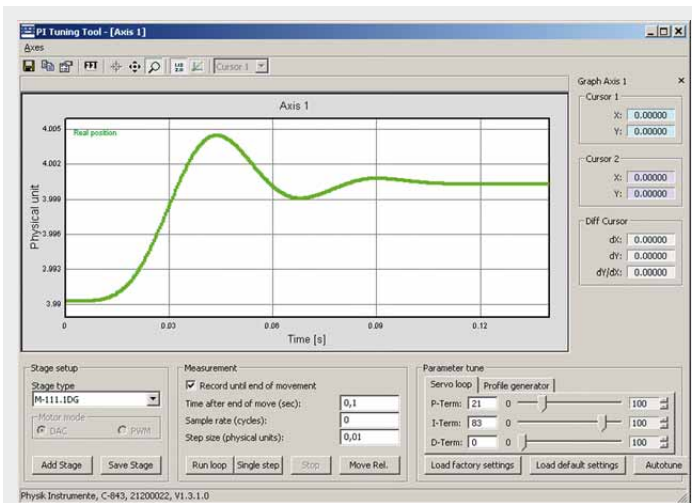
provided. The user friendly PI MikroMove™ provides a convenient interface for stage operation including tuning tool, joystick operation, terminal and macro editor.

Communications to/from the board consist of packet-based messages passed via memory access. An interrupt line is provided so that the chipset can signal the PC when special conditions arise, such as reception of an encoder index pulse. For system programmers the C-843 offers direct access to the DSP.



	Stage	k	<	Target	>	>	Step size	Position	HALT	State	Velocity	Servo
1	M-235.5DD	k	<	0.000000	>	>	0.100000	0.000000	HALT	on target	15.000000	✓
2	M-605.2DD	k	<	100.0000	>	>	0.1000	100.0000	HALT	unreferenced	25.000000	?
3	M-511.PD	k	<	56.0000	>	>	1.0000	56.0000	HALT	on target	62.500000	✓
4	M-110.1DG	k	<	0.000000	>	>	0.010000	0.000000	HALT	on target	1.000000	✓

PIMikroMove® tabular presentation of four connected axes with display of absolute and relative positioning input, current position, halt axis button, state and velocity setting.



The Tuning Tool which is integrated in PIMikroMove® demonstrates acquiring and displaying step and settle data of micropositioning systems. Controls allow adjustment of the PID parameters for best performance.

## Technical Data

<b>Model</b>	<b>C-843</b>
Function	PC plug-in DC-servo-motor controller board, 32-bit plug-and-play PCI-bus interface, supported by main boards with 3.3 V and 5 V PCI bus connectors (universal card)
Axes	2 (C-843.21); 4 (C-843.41)
Servo characteristics	Programmable PID V-ff filter, parameter changes on-the-fly
Profile modes	Trapezoidal, S-curve, velocity profile
Output power / resolution	Analog 6 watts/channel (drawn directly from PC power supply), 12-bit D/A converters, PWM 10-bit, 24.5 kHz
Current limitation	500 mA per channel (short-circuit-proof)
Encoder input	AB (quadrature) differential TTL signals, $5 \times 10^6$ counts/s
Stall detection	Servo off, triggered by programmable position error
Limit switches	2 TTL / axis (active high/low, programmable)
Reference switches	1 TTL / axis (active high/low, programmable)
I/O ports	8 TTL inputs, 8 TTL outputs
Motor connectors	15-pin (f) sub-D per channel (2 on board + 2 on bracket for C-843.41)
Interface/communication	PC PCI bus
Command set	PI General Command Set (see p. A-11)

# Motors & Drives Fundamentals

## Classic Drive Systems (Stepper & Servo Motors)

### 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.

### 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. 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.

### DC-Motor / Gearhead Drive

A few advantages of DC-motor/gearhead drives are very high angular resolution, small form factor and low power consumption with high torque. They can be operated by PC controller boards such as the C-843 without an external amplifier. PI uses various types with maximum power in the 2 to 3 watt range and optical rotary encoders with up to 4000 counts per revolution. Most models use preloaded gearheads to eliminate backlash.

### Stepper Motor

An electric motor providing motion in discrete angular

steps, without the need of position sensor or servo-loop. Stepper motors have very long lifetimes and are especially suited for applications where predictable positioning is required as opposed to fast response and extreme acceleration. Another advantage lies in the simple control electronics. Compared to closed-loop DC motors of the same size, stepper motors provide poorer dynamic performance and dissipate more heat, especially in steady state operation. PI offers microstepped 2-phase motors, which are very cost-effective.

## Drive Screws

### Leadscrews

Leadscrews can provide very high resolutions and very smooth motion. A leadscrew drive consists of a motor-driven screw with a nut coupled to the sled of the stage. The nut can be spring preloaded to reduce backlash. Leadscrews are self-locking but exhibit higher friction than recirculating ballscrews, with the predictable effect on velocity, required motor power, and lifetime. Typical leadscrews have a pitch between 0.4 and 0.5 mm/revolution, or up to 1 mm/revolution for longer travel ranges.

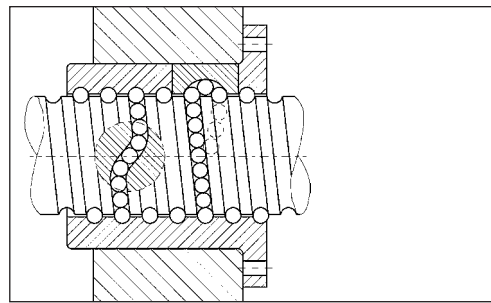
### Recirculating Ballscrews

Recirculating ballscrews have significantly less friction than leadscrews, because they replace sliding friction with rolling friction.

A recirculating ballscrew drive consists of a motor-driven screw with a nut (ball housing) coupled to the sled of the stage, and a number of balls riding between the screw and the nut in a closed-circuit passage. Backlash can be eliminated by selecting the proper ball-to-thread-diameter ratio. Ballscrews are not self-locking, but are maintenance free, very effi-

cient and offer high speeds and long lifetime in continuous operation. Standard PI ballscrews have pitches of 0.5, 1 or 2 mm/revolution.

The screw type is noted in the data sheet of each product.

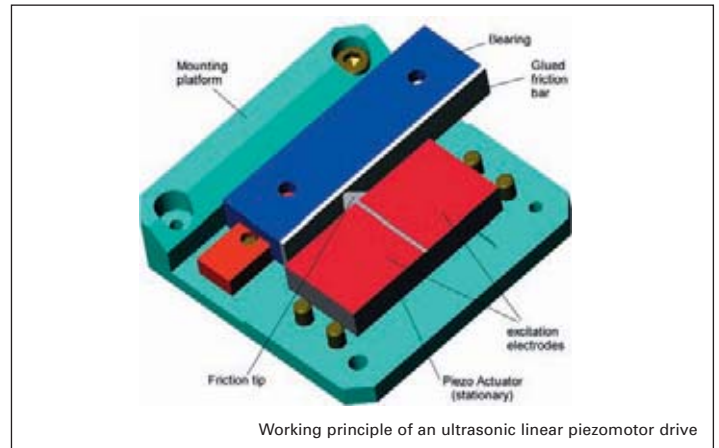


## Piezo Drives

It is important to distinguish between different types of piezo drives: classical piezo actuators (direct acting), flexure amplified actuators, and piezo linear motors. Direct-drive piezo actuators offering resolutions of under one nanometer can be combined with classical motorized actuators and stages to form coarse/fine systems or the more advanced hybrid systems (p. 4-132). Piezo linear motors provide basically unlimited travel ranges. PI offers two types: Ultrasonic (high-speed) motors and PiezoWalk® (high-force, high resolution) motors. Piezo actuators can achieve extremely high accelerations of many thousands of g's, are frictionless and backlash-free.

## Ultrasonic Piezomotors

Ultrasonic piezomotors are direct-drive systems; they do not use leadscrews or gearheads and are backlash-free. In addition, they neither create, nor are influenced by, magnetic fields. The drive consists of a stator, containing a piezoceramic oscillator and a slider (friction bar), which is attached to the moving part of the stage. With PI ultrasonic piezomotors speeds of up to 500 mm/s and resolutions of 0.1 µm in closed-loop are possible. They are also extremely compact, self-locking and have lifetimes of over 20,000 hours. PI piezomotors are used in miniature



translation stages like the M-661, M-662, M-663 and M-664 series, and in XY stages like the M-686.

## Voice-Coil Linear Drives

These friction-free electromagnetic linear drives are characterized by their good dynam-

ics, albeit with relatively low holding force. They are used primarily in scanning applications with travel ranges in the millimeter to low centimeter range. PI offers voice coil drives in the V-106 stages, as well as in custom-designed systems.

## Hybrid Drives (Coarse / Fine)

### Classic Combinations

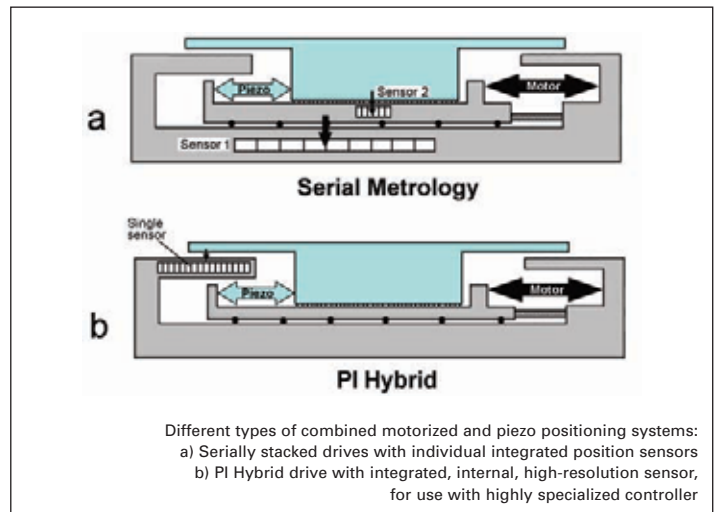
Combinations of different drive concepts are called hybrid drives. PI's micropositioning systems realize stacked systems of piezo and manual or motorized stages, where a motor/screw drive combination provides a long travel range and a piezo drive adds fine positioning accuracy and exceptional responsiveness over small ranges. For example, PI offers a fiber-scanning and coupling system comprising a 6-DoF micropositioner (F-206) mounted beside a multi-axis piezo system (P-611 Nanocube®) with high position resolution.

The servo-control algorithms with stacked systems like these generally operate independently, with the piezo system only

becoming activated after the motorized positioner has come to a complete stop. Because separate position sensors are used, the absolute accuracy (not the resolution) is limited by the precision of the motorized long-range positioner.

### Novel Hybrid Concept

A novel concept is implemented in the M-511.HD and M-714 Hybrid Translation Stages and C-702 Hybrid Controllers, that evaluate a nanometer-precision, long-range, sensor and provide nanometer accuracy over the whole travel range. The motor-leadscrew and the piezo actuator are fully integrated to form one motion system, and act simultaneously at all times. Thus every move benefits from the specific advan-



tages of both the motorized actuator and the piezo actuator from startup to settling. The result is immediate starting, smoothness of motion, and a highly constant velocity. This

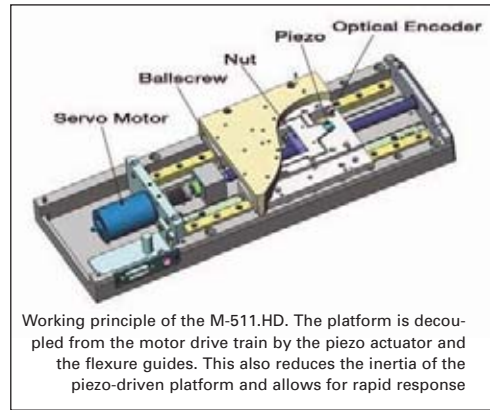
makes hybrid systems ideal for applications where the position of an incident needs to be read and repositioned precisely, or where an externally specified target position needs to be hit

within few a nanometers, such as in surface inspection or metrology.

On the mechanical side, this is accomplished by decoupling the motion platform of the hybrid positioning stage from the micropositioner's motor-spindle-drive by frictionless flexures and stiff, fast response piezo actuators. The piezo actuators actively smooth out the irregularities in the motion of

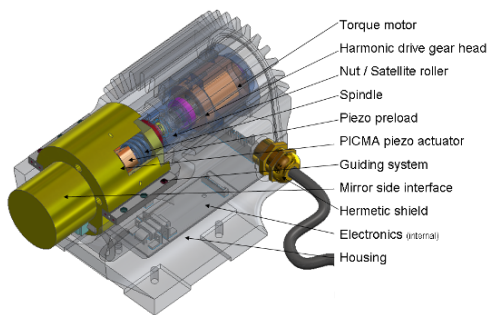
the platform caused by the motorized drive train to provide full move capability down to the sensor range.

The control algorithms treat the motor and piezo combination as one single drive unit and continuously compare the actual platform position (by reading the integrated linear encoder) with a calculated, smooth trajectory.



Working principle of the M-511.HD. The platform is decoupled from the motor drive train by the piezo actuator and the flexure guides. This also reduces the inertia of the piezo-driven platform and allows for rapid response

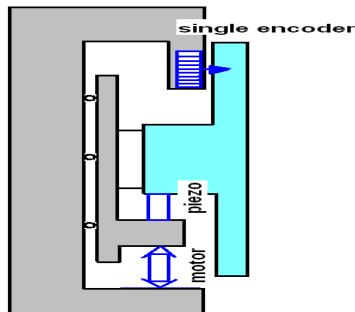
### Hybrid piezoelectric / motor actuator system



Hybrid piezoelectric and (brushless torque) motor actuator system with a long travel range and extremely high resolution. Travel range 15mm and extremely accurate positioning and tracing within

less than 2nm RMS. Force range of zero to 900N. Low power dissipation). Position command bandwidth: 1 kHz. Velocity up to :250µm/s

The position is measured via a high precision optical sensor. It's solid amplitude and phase stability allows for an interpolation factor of 2000 and results in a resolution of 0.125nm. The short term interpolation error does not exceed 1.7nm.



Principle of hybrid system

## Program Overview

- Piezo Ceramic Actuators & Motors
- Piezo Nanopositioning Systems and Scanners
- Active Optics / Tip-Tilt Platforms
- Capacitive Nanometrology Sensors
- Piezo Electronics: Amplifiers and Controllers
- Hexapod 6-Axis Positioners / Robots
- Micropositioning Stages & Actuators
- Photonics Alignment Systems, Solutions for Telecommunications
- Motor Controllers
- Ultrasonic Linear Motors

## Request or download the complete PI Nanopositioning & Piezo Actuator Catalog



### USA (East) & CANADA

**PI (Physik Instrumente) L.P.**  
16 Albert St.  
Auburn, MA 01501  
Tel: +1 (508) 832 3456  
Fax: +1 (508) 832 0506  
info@pi-usa.us  
www.pi-usa.us

### JAPAN

**PI Japan Co., Ltd.**  
Akebono-cho 2-38-5  
Tachikawa-shi  
J-Tokyo 190  
Tel: +81 (42) 526 7300  
Fax: +81 (42) 526 7301  
info@pi-japan.jp  
www.pi-japan.jp

### CHINA

**Physik Instrumente  
(PI Shanghai) Co., Ltd.**  
Building No. 7-301  
Longdong Avenue 3000  
201203 Shanghai, China  
Tel: +86 (21) 687 900 08  
Fax: +86 (21) 687 900 98  
info@pi-china.cn  
www.pi-china.cn

### FRANCE

**PI France S.A.S**  
244 bis, avenue Max Dormoy  
92120 Montrouge  
Tel: +33 (1) 55 22 60 00  
Fax: +33 (1) 41 48 56 62  
info.france@pi.ws  
www.pi-france.fr

### GERMANY

**Physik Instrumente (PI)  
GmbH & Co. KG**  
Auf der Römerstr. 1  
D-76228 Karlsruhe/Palmbach  
Tel: +49 (721) 4846-0  
Fax: +49 (721) 4846-100  
info@pi.ws · www.pi.ws

### USA (West) & MEXICO

**PI (Physik Instrumente) L.P.**  
5420 Trabuco Rd., Suite 100  
Irvine, CA 92620  
Tel: +1 (949) 679 9191  
Fax: +1 (949) 679 9292  
info@pi-usa.us  
www.pi-usa.us

**PI Japan Co., Ltd.**  
Hanahara Dai-ni Building, #703  
4-11-27 Nishinakajima,  
Yodogawa-ku, Osaka-shi  
J-Osaka 532  
Tel: +81 (6) 6304 5605  
Fax: +81 (6) 6304 5606  
info@pi-japan.jp  
www.pi-japan.jp

### UK & IRELAND

**PI (Physik Instrumente) Ltd.**  
Trent House  
University Way,  
Cranfield Technology Park,  
Cranfield,  
Bedford MK43 0AN  
Tel: +44 (1234) 756 360  
Fax: +44 (1234) 756 369  
uk@pi.ws  
www.physikinstrumente.co.uk

### ITALY

**Physik Instrumente (PI) S.r.l.**  
Via G. Marconi, 28  
I-20091 Bresso (MI)  
Tel: +39 (02) 665 011 01  
Fax: +39 (02) 873 859 16  
info@pionline.it  
www.pionline.it