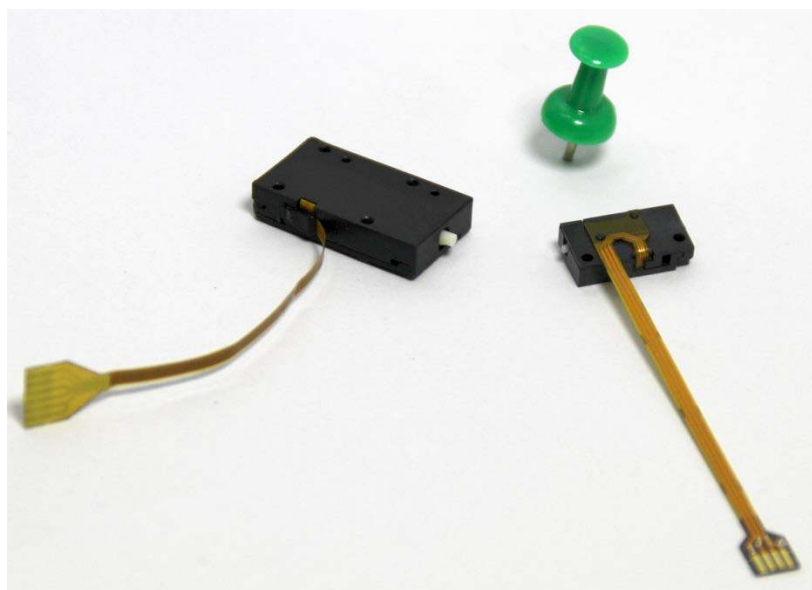


EDGE & EDGE-4X Motors User Manual



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Patent Information

Nanomotion products are covered under one or more of the following registered or applied for patents.

5,453,653; 5,616,980; 5,714,833; 111597; 5,640,063; 6,247,338; 6,244,076; 6,747,391;
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NA	August 2012	Administrative change – added patent information to the front matter.
00/B	July 2013	Corrected the related documents on page 8
01/A	Nov 2016	Add EDGE-4X and combine to one User manual for EDGE & EDGE-4X family motors

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List of Abbreviations

ASIC	Application Specific Integrated Circuit Refers specifically to Nanomotion Controller Driver chip.
AC	Alternating Current
DC	Direct Current
ICD	Interface Controlled Document
IPA	Isopropyl Alcohol used for cleaning
PCB	Printed circuit board
FPC	Flexible Printed Circuit

1 General

The purpose of this user manual is to help the user to install and operate the EDGE & EDGE-4X Piezoceramic Motor.

This manual describes the physical dimensions, mechanical and electrical properties as well as the installation procedures of the motors.

This manual assumes that the user has a fundamental understanding of basic motion systems, as well as motion control concepts and applicable safety procedures.

1.1 General Handling Guidelines

1. Do not remove the cover of the motor!
2. Switch the power on only when the motor is properly mounted and connected to the driver / controller.
3. Do not immerse the motor in any liquid or cleaning agent. Use only a clean room lint free cloth to wipe the motor.
4. Ensure that the motor, and especially the "fingertip", is not subjected to direct high mechanical shock.
5. Follow the installation instructions provided in this manual when mounting the motor. The EDGE & EDGE-4X motor is not user-serviceable. For any installation and mounting inquiries, please contact Nanomotion.

1.2 Reference Documentation

Nanomotion ASIC NM8SiP user manual, document No.: ASIC458000-XX.

XCD EDGE Driver-Controller, document No.: XCDE458000.

XCD2 Edge-4X driver-control ref PN - XCDE458000-XX.

EDGE INTERFACE DRAWING, document No.: EDGE458101-01.

EDGE-4X INTERFACE DRAWING, document No.: EDG4129000-00.

2 Introduction

2.1 The EDGE Motor

The EDGE motor is the smallest industrial motor of its kind available in the marketplace today. Providing typical 0.4N stall force, maximum velocity of 200 mm/sec and unlimited linear or rotary motion, the EDGE motor offers extensive opportunities in applications that suit a wide range of industries. The EDGE motor works with a uniquely designed, compact ASIC-based driver, XCD and XCD2 controller / driver. The EDGE motor can be easily integrated with most types of bearing structures and it is ideal for mass production applications.

2.2 The EDGE-4X Motor

The EDGE-4X motor expands the EDGE product line of low voltage piezo motors, bringing four times the force of the Edge motor. The EDGE-4X provides up to 1.3N stall force and unlimited travel for linear or rotary applications. Continuing to optimize size, weight and power.

2.3 EDGE & EDGE-4X Motor Features

- Compact size
- Lightweight
- High durability for demanding applications
- Low voltage
- Excellent move and settle characteristics
- Suitable for linear or rotary applications

- ASIC, XCD and XCD2 drive and control:
 - Standard Driving Mode
 - Linear Driving Mode
 - Wide dynamic velocity range
 - Inherent brake at power off
 - High resolution
 - Silent

3 Motor Operation

3.1 Operation Principle of EDGE & EDGE-4X

Motors

The Piezoelectric effect in piezo materials converts an electrical field into mechanical strain. Under special electrical excitation drive and specific geometry of Nanomotion motors, longitudinal extension and transverse bending oscillation modes are excited simultaneously at a single frequency. The simultaneous excitation of the longitudinal extension mode and the transverse bending mode creates a small elliptical trajectory of the ceramic tip, thus achieving the dual mode standing wave motor patented by Nanomotion. By coupling the ceramic tip to a precision stage, a resultant driving force is exerted on the stage, causing stage movement. The periodic nature of the driving force at frequencies much higher than the mechanical resonance of the stage allows continuous smooth motion for unlimited travel, while maintaining high resolution and positioning accuracy typical of piezoelectric devices. Motion can be linear or rotary, depending on the coupling mechanism.

3.2 Driving Modes

The EDGE & EDGE-4X motors can be driven by a custom NM ASIC driver, or alternatively by an XCD and XCD2 EDGE & EDGE-4X Driver-Controller (refer to section 1.2 for Reference Documentation). The drivers can drive the motor in two driving modes:

- **Standard Driving Mode** – standard motor operation mode. In this mode the motor is motionless up to approximately $\pm 1.5V$ command (Dead Band). Nanomotion motion algorithm enables smooth motion as well as micron-level displacement. This drive mode is the default mode for open / close-loop.

- **Linear Driving Mode** – this mode facilitates a linear response of the motor from 0 (zero) command level. This mode is recommended for scanning applications and micron-level displacement. The Linear Mode drive is preferable for perfect servo tracking and/or very low ripple constant velocity.

4 Motor Installation

This chapter provides detailed information about bonding the Ceramic Driving Strip and mounting and connecting the EDGE & EDGE-4X motors before operation.

To ensure peak motor performance, use of the Ceramic Driving Strip provided by Nanomotion is recommended. The Ceramic Driving Strip is specifically designed to work with Nanomotion's EDGE & EDGE-4X motors. Substituting this Strip with any other material might reduce motor performance or damage the motor and will void product warranty.

4.1 Mounting Base Design Considerations

Refer to chapter 7 for motor and mounting base drawings - note that mounting base dimensions refer to the front surface of the Ceramic Driving Strip. The mounting base should be perpendicular to the Ceramic Driving Strip.

Both screws securing the motor to the mounting surface are inserted from the top of the motor. In multi axis application make sure that any protrusion of the screws does not interfere with motion on another axis.

IMPORTANT:

- **The mounting base, the stage and the method used for mounting should be designed for maximum mechanical rigidity and stiffness $\geq 5 \text{ N}/\mu\text{m}$ for EDGE motor and $> 10 \text{ N}/\mu\text{m}$ for EDGE 4X motor.**
- **The ceramic strip surface should move parallel to the motion. The maximum allowable run-out of the strip should not exceed $\pm 0.03\text{mm}$ (chapter 7)**

4.2 Bonding the Driving Strip to the Stage

Bond the Ceramic Driving Strip to the stage surface according to the following steps:

1. Clean the bonding area of the stage, using a suitable agent such as Acetone, IPA or Ethanol.
2. Remove the Acrylic adhesive Tape backing paper from the Ceramic Driving Strip.

Attach the Ceramic Driving Strip to the previously cleaned stage area (see Figure 1), making sure no air bubbles are trapped between the stage and the ceramic.

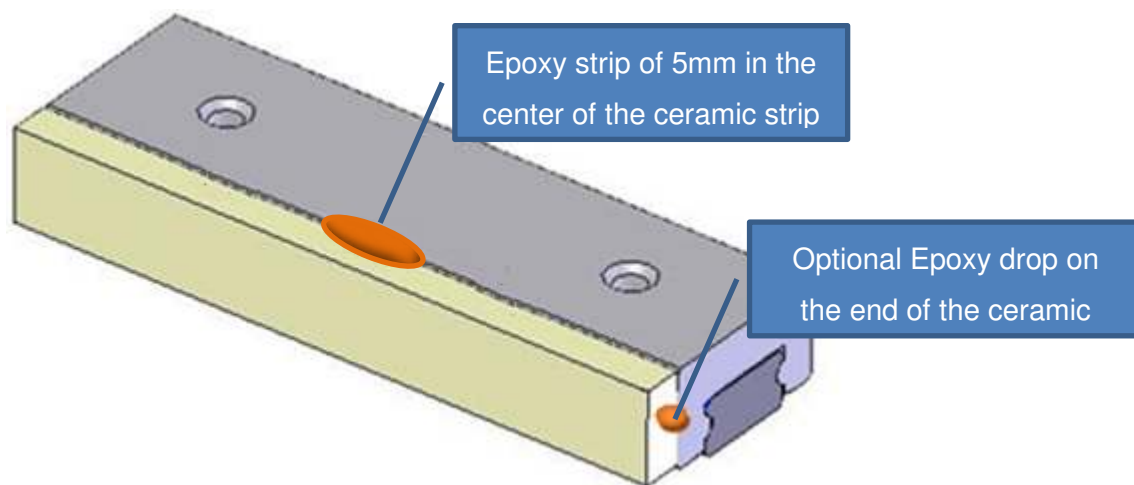


Figure 1: Bonding the Ceramic Driving Strip

3. Verify that there is a maximum gap of 0.5mm between the lower edge of the Ceramic Driving Strip and the motor mounting surface (refer to chapter 7) to assure enough clearance for the motor tip.
4. Apply Epoxy adhesive on the center of the Ceramic Driving Strip surface, about 5 mm length (see Figure 1). For short strips up to 10mm, a single drop can be applied on each end of the Ceramic Driving Strip (see Optional Epoxy drop in Figure 1). The Epoxy must bond the strip to the slide. Recommended adhesive: Araldite 2014-1 or compatible.
5. Allow the required time period for curing, according to the epoxy manufacturer's specifications.

IMPORTANT:

- Ensure that the epoxy is in contact with the surfaces of both the strip and slide, but that it does not flow over the Ceramic Driving Strip front surface or over the upper working surface of the slide.

4.3 Mounting and Connecting the EDGE Motor

In order to mount the motor against the moving slide (see Figure 2 and chapter 7) perform the following steps:

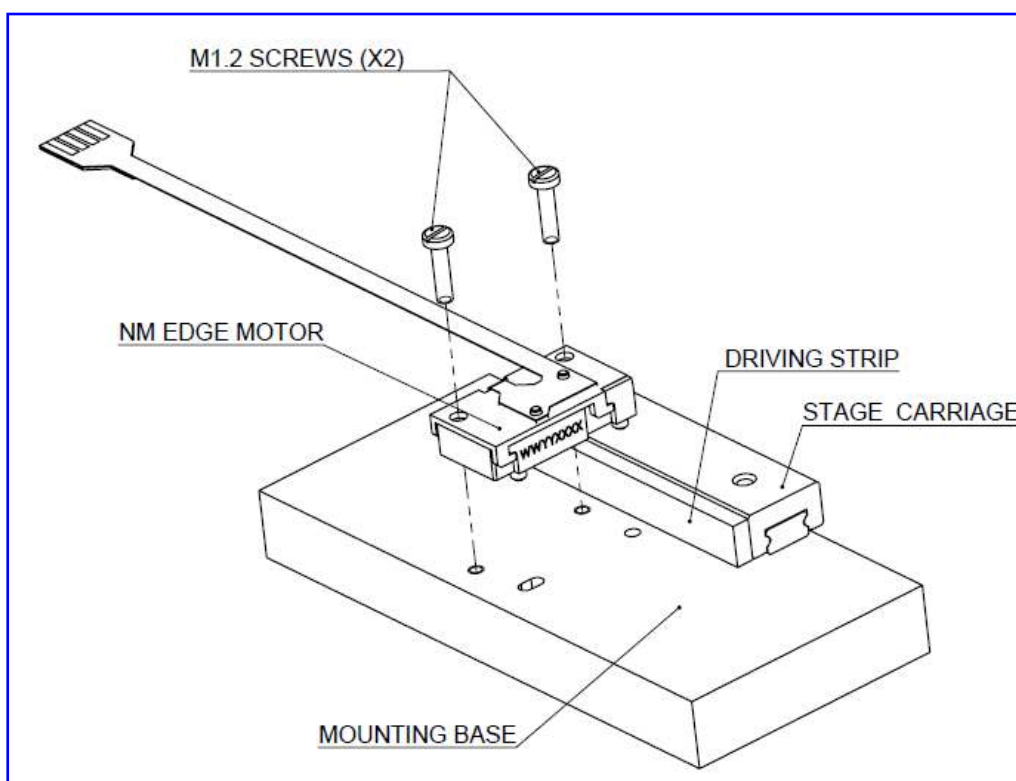


Figure 2: EDGE motor motion system mechanical parts overview

Assemble the slide with the ceramic strip upon the mounting plate. Make sure the slide position is according to Figure 16. The slide should be perpendicular to the holes and at the correct distance to enable proper mounting of the motor. This can be achieved by designing an alignment feature in the base plate or by using a jig which fits to the motor pin holes.

1. Place the motor “fingertip” against the ceramic plate and gently press the motor toward the ceramic plate until the motor pins can be inserted into the corresponding holes in the base. The motor is now correctly positioned.
2. Insert two M1.2 screws into their corresponding holes on the motor and tighten them to a torque of 10-30 mNm. The motor is now properly secured in

its place. It is recommended using a bonding material such as *LOCTITE™* 242 to secure the screws.

3. Connect the motor's FPC to the motor interface connector (see chapter 7.1 for details), located on the user's PCB. PCB and FPC design may change for different applications.

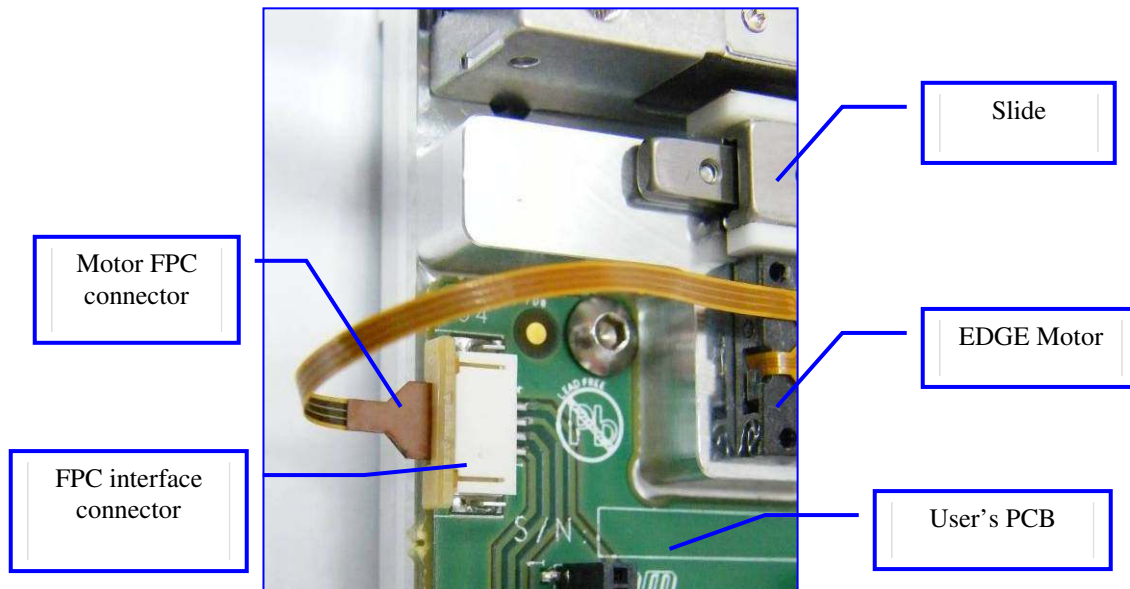


Figure 3: Connecting the Motor FPC to the FPC Electrical Interface (example of design used for EDGE EVALUATION KIT)

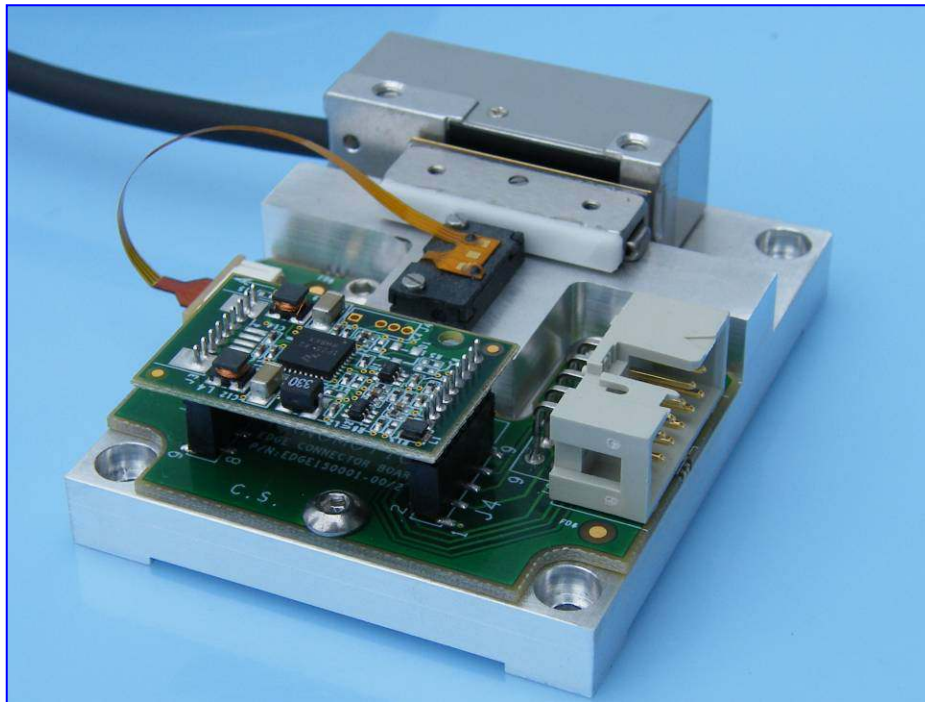


Figure 4: Example of stage based on EDGE motor including ASIC EDGE driver and position encoder (EDGE MOTOR EVALUATION KIT stage).

4.4 Mounting and Connecting the EDGE-4X Motor

In order to mount the motor against the moving slide (see Figure 5 and chapter 7) perform the following steps:

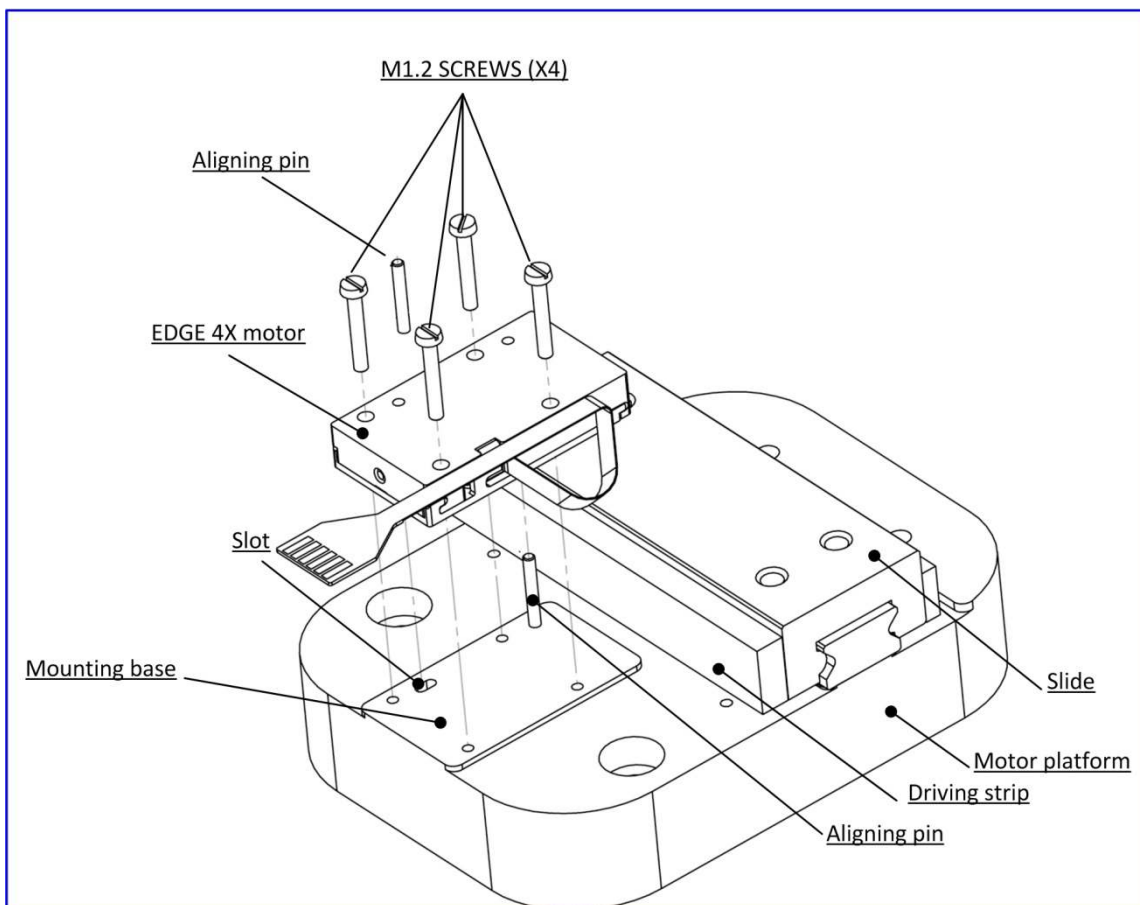


Figure 5: EDGE-4X Motor Motion System Mechanical Parts Overview

1. Insert the location pin into the corresponding hole on the motor by placing the motor “fingertip” against the ceramic plate and gently press the motor toward the ceramic plate, and then insert the additional location pin through the motor until the pin affixed into the slot. Alternatively, use spacer with 0.6 mm space between the motor front wall and the ceramic strip. The motor is now correctly positioned.

2. Insert four M1.2 screws into their corresponding holes on the motor and tighten them to a torque of 10-30 mNm. The motor is now properly secured in its place. For applications which are exposed to external vibrations it is recommended using a bonding material such as *LOCTITE™ 242* to secure the screws.
3. Check that the distance of mounting from alumina is **0.6 mm**.
4. Connect the motor's FPC to the motor interface connector (see chapter for details), located on the user's PCB. PCB and FPC design may change for different applications.

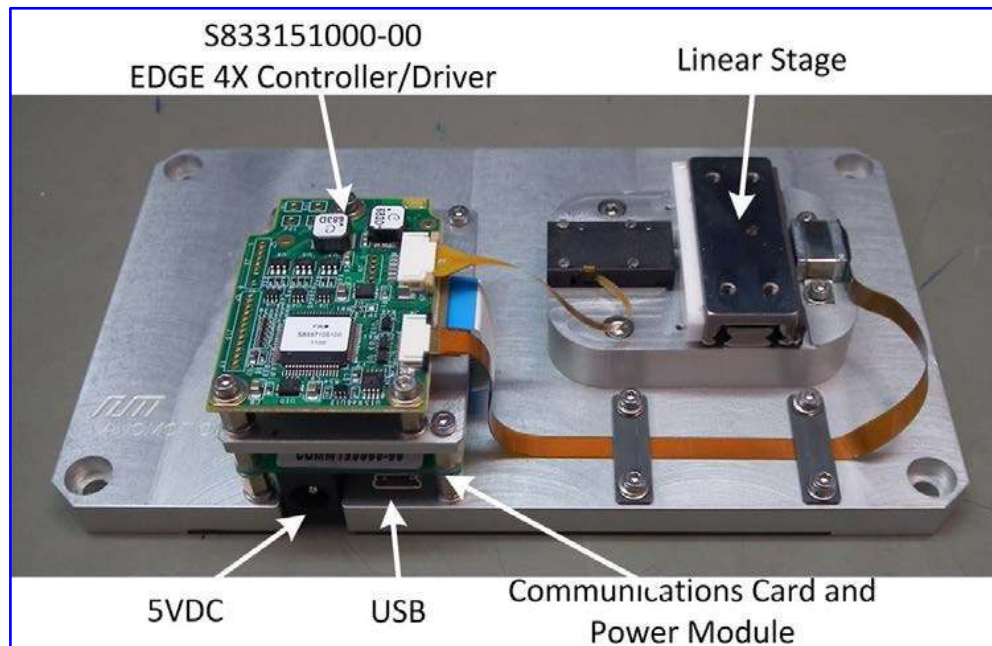


Figure 6: Connecting the Motor FPC to the FPC Electrical Interface (example of design used for EDGE-4X MOTOR EVALUATION KIT)

4.5 Operating the motor

1. Connect the power supply and the communication line to the control board.
The communication line may be either an IIC line or an analogue command depending on the specific application. For specific applications, please ask Nanomotion for SW ICD.

Note: Please refer to the ASIC and the XCD/XCD2 EDGE driver user manuals (see chapter 1.2)

2. Choose the driving mode (see section 3.2). The motor is now ready for conditioning (see chapter 5).
3. For operating in close-loop, install an encoder and connect a controller to the motor driver.

4.5.1 Driver/Controller

4.5.1.1 EDGE motor

The NM ASIC driver can work either as a driver or as a controller-driver (see chapter 1.2 for ASIC and the EDGE driver user manuals reference).

4.5.1.2 EDGE/EDGE-4X

The XCD EDGE/XCD2 driver can work either as a driver or as a controller-driver (see chapter 1.2 for XCD EDGE/XCD2 driver user manuals reference).

For other drive and control configurations please contact Nanomotion.

5 Motor Conditioning

The EDGE & EDGE-4X motors must be conditioned before operating to stabilize the motor's dynamic performance and to assure expected lifetime of the system. Conditioning should be performed any time the motor is remounted on the stage.

5.1 The Conditioning Procedure

In order to condition the motor, perform the following steps:

1. Conditioning is optimally performed in close loop.
2. Conditioning must cover the entire expected travel distance on the Ceramic Driving Strip with additional margins.
3. Set the driver to Standard Driving Mode (see Section 3.2).
4. Run the stage repetitively from point to point in closed loop under the following conditions.
 - a. Velocity – 70~80 mm/s.
 - b. Acceleration/Deceleration – up to 2 m/s²
 - c. Duty cycle – 50%. This means that the dwell time (the driver is disabled) should be the same as the move time (the driver is enabled).
 - d. Conditioning duration: >30 minutes. For applications where control performance is not too demanding 10-15 min. conditioning is sufficient.
5. When the conditioning is completed, carefully wipe the Ceramic Driving Strip surface with a Q-Tip soaked with IPA or Ethanol, without dismounting the motor. Run the motor for additional 1 min.
6. The motor is now ready for operation.

Note: This procedure is performed only for motors either assembled to the ceramic slide for the first time, or removed and reassembled.

6 Technical Data

6.1 Motor Model for Control Simulations

The EDGE & EDGE-4X motor moving a slide in a given direction can be modeled as a linear system driven by a DC motor by a voltage amplifier, as illustrated in Figure 8.

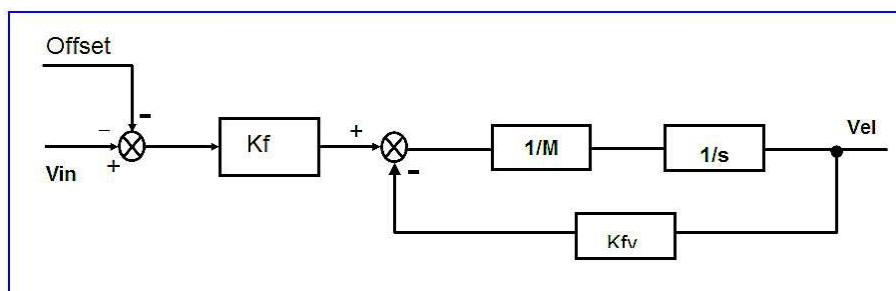


Figure 7: Block Diagram of the Motor and Driver

- V_{in} - Command to the driver ($0V \leq V_{in} \leq 10V$)
- K_f - Force constant [N/V]
- Offset (*) - Starting voltage [V]
- K_{fv} - Velocity damping factor (similar to back EMF) [N•s/m]
- Vel - Motor velocity [m/s]
- M - Moving mass [kg]
- s - Laplace variable [1/s]

(*) The diagram refers to both standard and linear modes. In linear drive mode Offset is designed to be zero.

6.2 Specifications EDGE

6.2.1 Performance

Property	EDGE Value	EDGE-4X Value	Unit
Maximum Velocity	>150	>180	mm/s
Max Dynamic Stall Force	>0.32	>1.3	N
Static Holding Force	>0.29	>1.2	N
Static Stiffness	0.06 to 0.09	0.25 to 0.31	N/μm
Preload on Stage	1.55 to 1.95	5.5-6.5	N
Kf	30 to 50	269-411	mN /[V]
Kfv	1.0 to 2.7	5-11	N s/m
Offset (Dead Band) In standard drive mode	1.0 to 3.5	10 to 33	[V]
Attainable Resolution	0.5 *	0.5 *	μm
Nominal Lifetime	20000 *	20000 *	hr

6.2.2 Electrical

Property	EDGE Value	EDGE-4X Value	Unit
Motor Voltage at max command	8.5 to 11	14	V AC
Motor Current at max command	130 *	250 *	mA AC
Motor Power Consumption at max command	400 to 750	1.5-2 [W]	mW
Motor Capacitance (between Phase and COMMON)	9.5 *	23.5 *	nF

6.2.3 Environmental

Property		EDGE Value	EDGE-4X Value	Unit
Ambient Operating Temperature	Standard	-10 to 60	-10 to 60	°C
	Extended **	-45 to 71	-40 to 71	°C
Storage Temperature		-55 to 85	-55 to 85	°C
Humidity		0 to 80%	0 to 80%	

* Reference Value

** With NM Controller-Driver and algorithm

6.3 Dimensions

In the following table are the external dimensions of the motor. For detailed dimensions refer to section 7.1.

Physical Dimensions (Nominal Values)			
Property	Unit	EDGE Value	EDGE-4X Value
Length	mm	13.5	22.8
Width	mm	7.6	12.4
Height	mm	3.15	4.3
Weight	g	0.55	2.2g

6.4 Thermal Envelope of Performance (EOP)

6.4.1 EDGE Motor

Motor operating temperature is a result of the balance between heat generation and heat dissipation.

- The heat generation depends on motor's work regime (driver command level).
- The heat is dissipated through the following heat transfer mechanisms: conduction, radiation and convection by air.

The heat dissipation mechanisms should be able to dissipate the heat generated in order to avoid overheating. The EOP gives the user the tools to assess the permitted operating conditions (for a set ambient temperature and dynamic performance) deriving the Duty Cycle and/or Maximal Continuous Operation that assures safe operation.

The user can operate the motor at a specific Duty Cycle for a periodic time interval which does not exceed the continuous time interval specified under "Maximal Continuous Operation".

For a given application at a given motion profile, the work regime is determined by the F-V curve given in Figure 10.

Figure 8 and Figure 9 display the minimal Motor Velocity vs. Driver command in Standard and Linear Modes correspondingly, for correlation between driver settings, motor performance, and EOP.

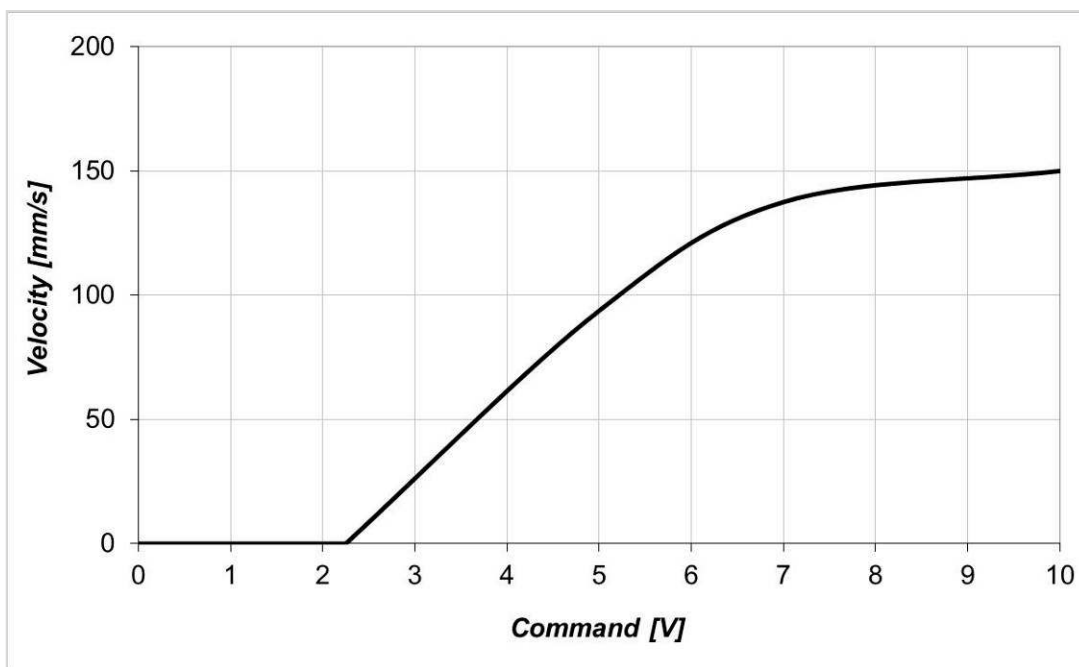


Figure 8: Typical EDGE Motor Velocity vs. Command Operating in Standard Driving Mode

Note:

The motor operates horizontally at room temperature and nominal conditions. It interfaces with the Ceramic Driving Strip (according to Nanomotion Specifications) and a cross-roller high quality slide.

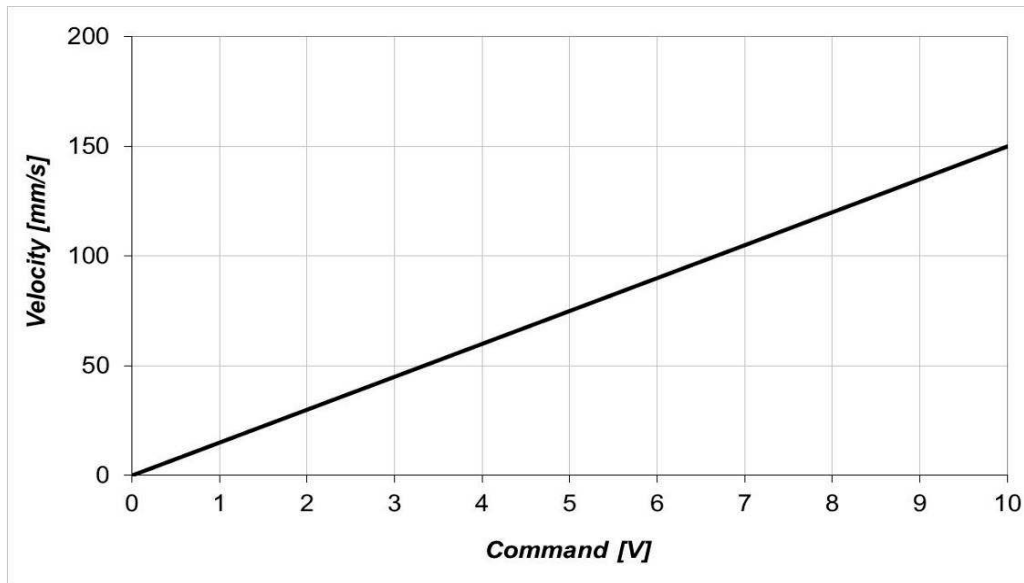


Figure 9: Typical Motor Velocity vs. Command Operating in Linear Driving Mode

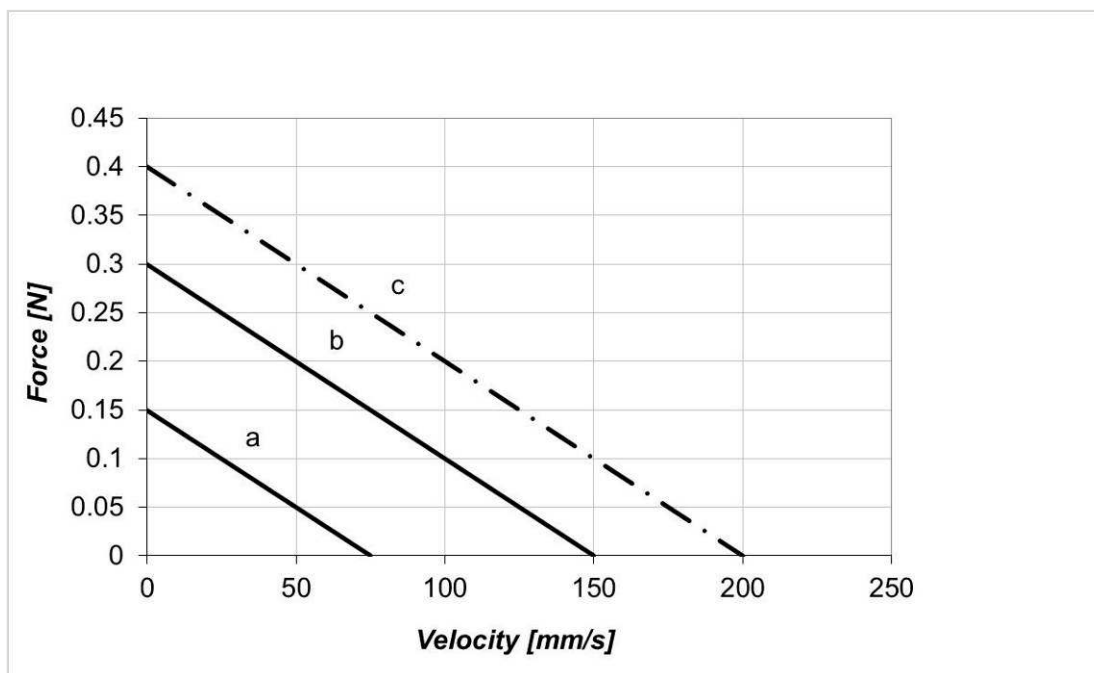


Figure 10: EDGE motor Force vs. Velocity at different work regimes

Considering the above Figure 11, there is a corresponding limiting Duty Cycle and Maximum Continuous Operation time for each point on the motor force-velocity plane.

Table 1 and Figure 11 are designed to assist the user in determining the correct envelope of performance and avoid overheating and damaging the motor.

Table 1 shows the limiting Duty Cycle and Maximum Continuous Operation time corresponding to the reference curves in Figure 9 for Standard and Linear drive mode when the motor is kept in an environment of up to 70°C.

Curve	Ambient Temperature <60 °C				
	Standard		Linear		
	Duty Cycle [%]	Maximum Continuous Operation [sec]	Duty Cycle [%]		Maximum Continuous Operation [sec]
			“Brake ON”	“Brake OFF”	
a	100	∞	100	100	∞
b					
c (*)					
Curve	Ambient Temperature 60-70 °C				
	Standard		Linear		
	Duty Cycle [%]	Maximum Continuous Operation [sec]	Duty Cycle [%]		Maximum Continuous Operation [sec]
			“Brake ON”	“Brake OFF”	
a	100	∞	100	100	∞
b	100	∞	80	30	60
c (*)	80	60	70	15	30

Table 1: EOP for EDGE Motor in Standard or Linear Driving Mode

(*) For reference only.

Notes:

The Duty Cycle is the ratio of the operation time and the total work cycle (operation time + idle time).

During the idle time, the driver can be DISABLED ("BRAKE ON") or set to 0 V command ("BRAKE OFF"). In Linear Driving Mode "BRAKE ON" and "BRAKE OFF" are not equivalent. Under "BRAKE OFF", although the driver is set to 0 V command, power is still consumed (and therefore, heat is generated) by the motor, effectively reducing the allowable Duty Cycle.

6.4.2 EDGE-4X Motor

Figure 11 and Figure 12 display the minimal Motor Velocity vs. Driver command in Standard and Linear Modes correspondingly, for correlation between driver settings, motor performance, and EOP.

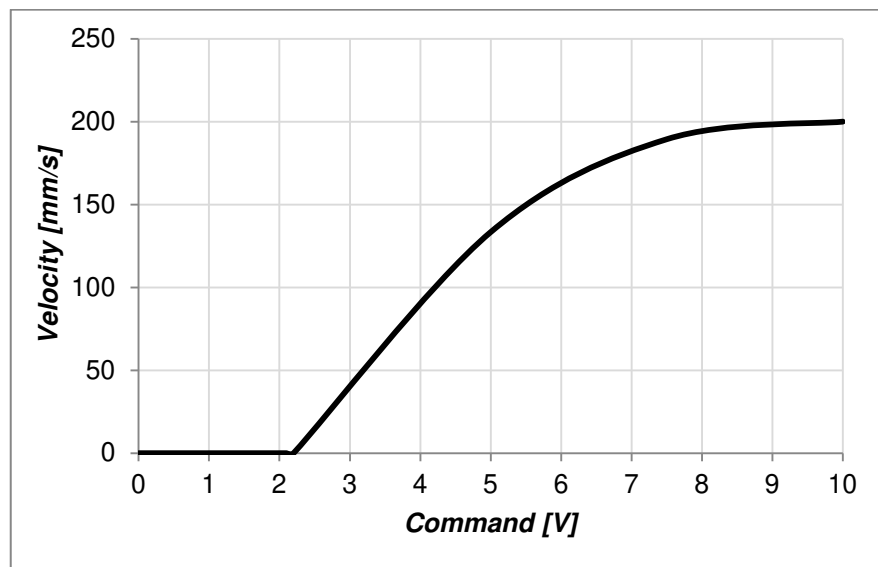


Figure 11: Typical EDGE 4X Motor Velocity vs. Command Operating in Standard Driving Mode

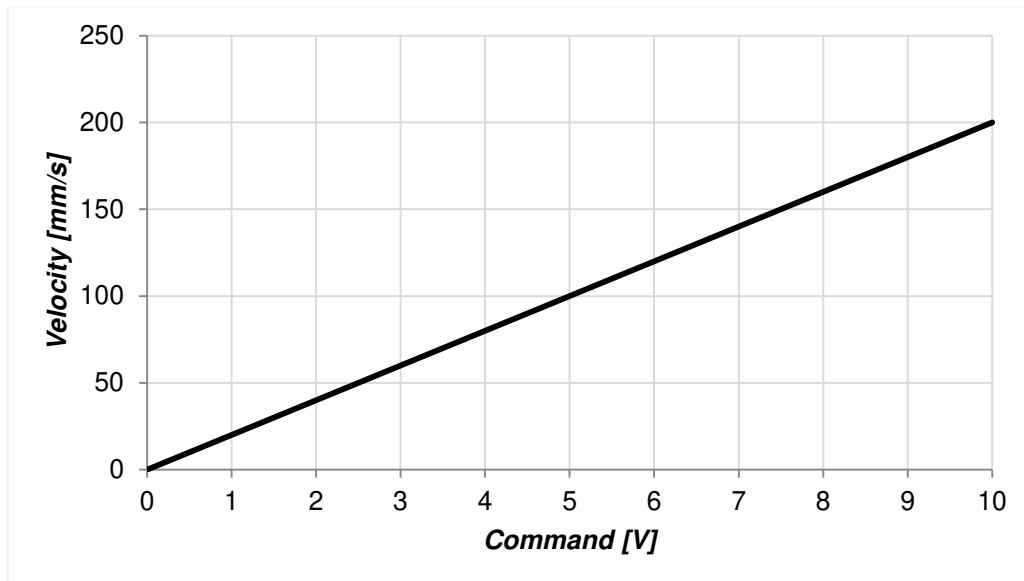


Figure 12: Typical EDGE 4X Motor Velocity vs. Command Operating in Linear Driving Mode

For a given application at a given motion profile, the work regime is determined by the F-V curve given in Figure 13.

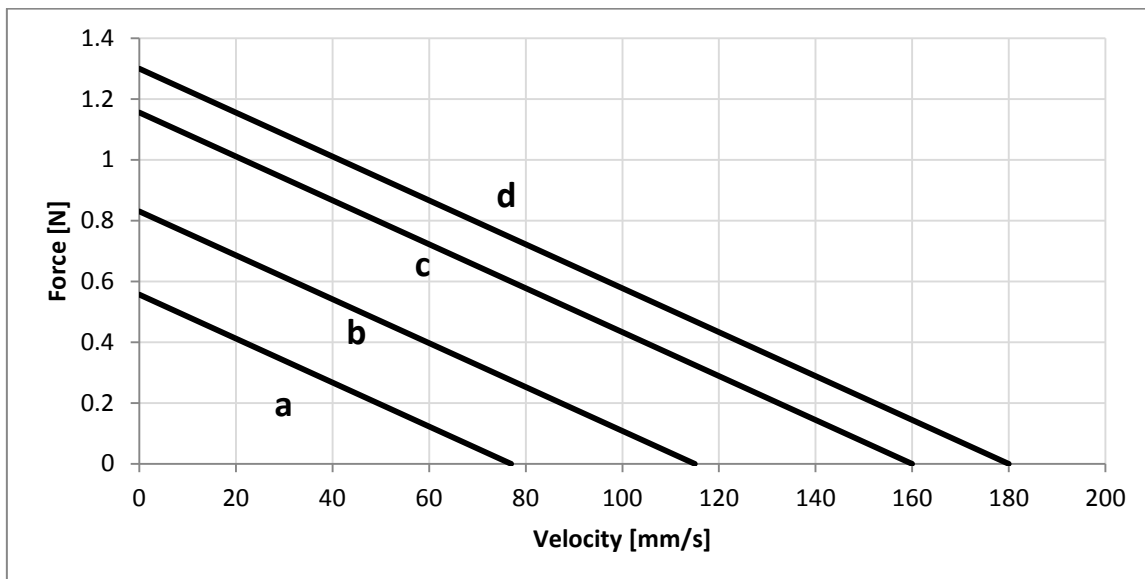


Figure 13: EDGE-4X motor Force vs. Velocity at different work regimes

Considering the above Figure 13, there is a corresponding limiting Duty Cycle and Maximum Continuous Operation time for each point on the motor force-velocity plane.

Table 2 and Figure 13 are designed to assist the user in determining the correct envelope of performance and avoid overheating and damaging the motor.

Table 2 shows the limiting Duty Cycle and Maximum Continuous Operation time corresponding to the reference curves in Figure 13 for Standard and Linear drive mode when the motor is kept in an environment of up to 70°C.

Curve	Ambient Temperature <60 °C				
	Standard		Linear		
	Duty Cycle [%]	Maximum Continuous Operation [sec]	Duty Cycle [%]		Maximum Continuous Operation [sec]
			"Brake ON"	"Brake OFF"	
a	100	∞	100	100	∞
b					
c					
Curve	Ambient Temperature 60-70 °C				
	Standard		Linear		
	Duty Cycle [%]	Maximum Continuous Operation [sec]	Duty Cycle [%]		Maximum Continuous Operation [sec]
			"Brake ON"	"Brake OFF"	
a	100	∞	100	100	∞
b	100	∞	85	59	130
c	57	39	62	28	45
d	47	31	61	25	38

Table 2: EOP for EDGE-4X Motor in Standard or Linear Driving Mode

Notes:

The Duty Cycle is the ratio of the operation time and the total work cycle (operation time + idle time).

*During the idle time, the driver can be DISABLED ("BRAKE ON") or set to 0 V command ("BRAKE OFF"). In **Linear Driving Mode** "BRAKE ON" and "BRAKE OFF" are not equivalent. Under "BRAKE OFF", although the driver is set to 0 V command, power is still consumed (and therefore, heat is generated) by the motor, effectively reducing the allowable Duty Cycle.*

7 Electro-Mechanical Interfaces

7.1 EDGE Motor Layout

7.1.1 EDGE Motor Layout

Figure 14 shows the EDGE motor layout according to EDGE INTERFACE DRAWING, DOCUMENT NO. EDGE458101-01.

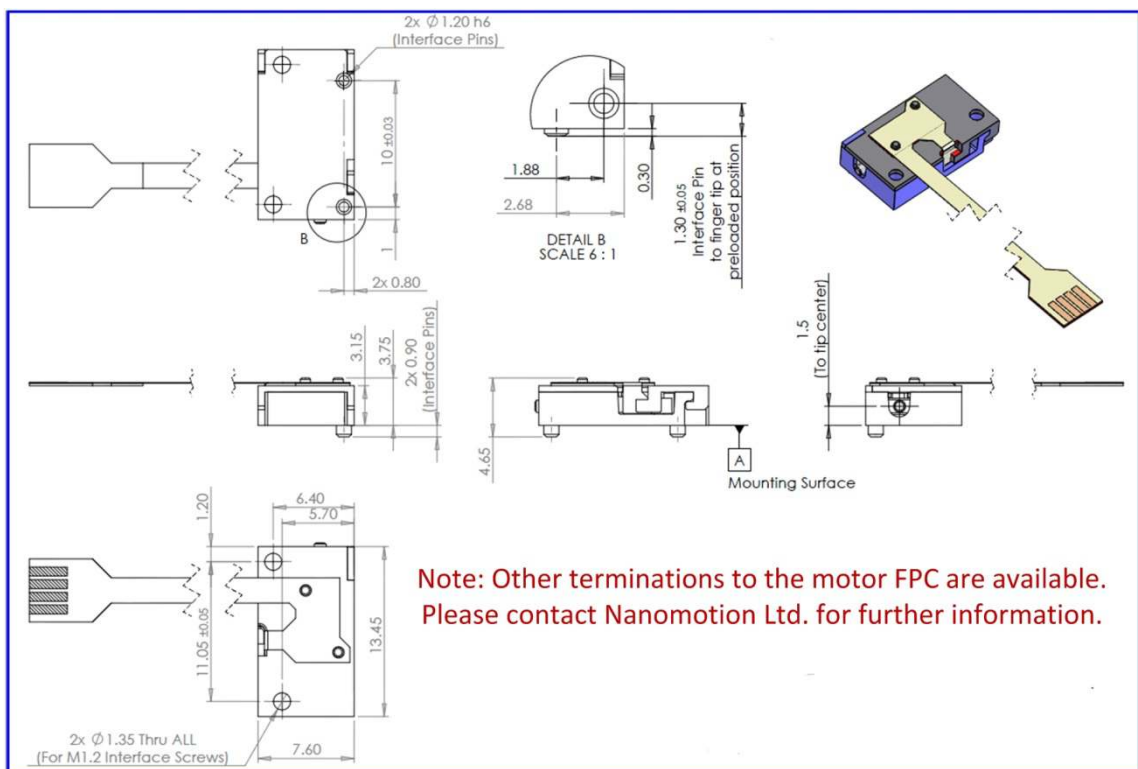


Figure 14: EDGE Motor Mechanical Layout

Note:

The dimensions are in mm

Preloaded Position refers to Motor installed on a mounting based according to Section 7.1.2.

7.1.2 EDGE Mounting Base Layout

Figure 15 shows the mounting base requirements for EDGE motors according to EDGE INTERFACE DRAWING, DOCUMENT NO. EDGE458101-01.

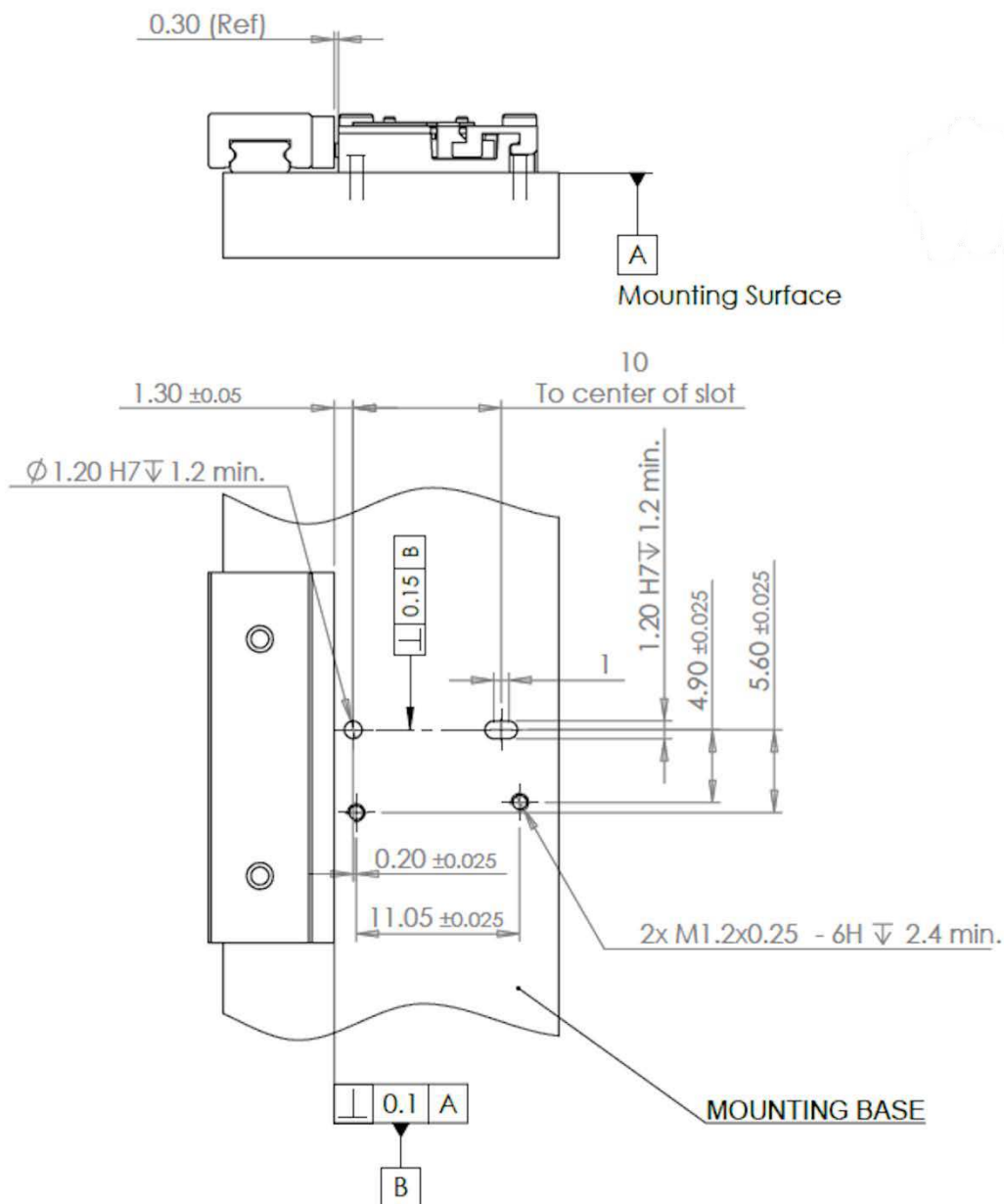


Figure 15: EDGE motor mounting base requirements

Note:

The dimensions are in mm

7.1.3 EDGE Motor Electro-Mechanical Interface

Standard EDGE Motor FPC is designed to be used with a standard 1mm FPC Connector (for example AMP, P/N 487951-4). See EDGE INTERFACE DRAWING, DOCUMENT NO. EDGE 458101 for details and pin out. Note that the EDGE motor is also available with a custom FPC for specific OEM applications. Please contact Nanomotion Ltd. for advice.

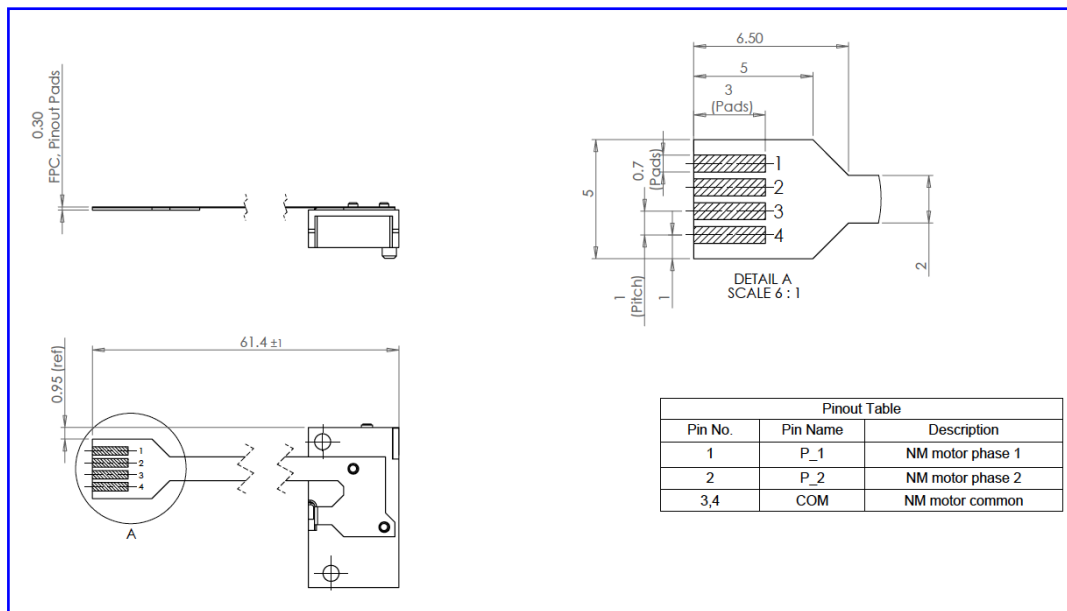


Figure 16: EDGE motor electro-mechanical interface

Note:

The dimensions are in mm.

7.2 EDGE-4X Motor Layout

7.2.1 EDGE-4X Motor Layout

Figure 17 shows the EDGE motor layout according to EDGE-4X INTERFACE DRAWING, DOCUMENT NO. EDG4129000-00.

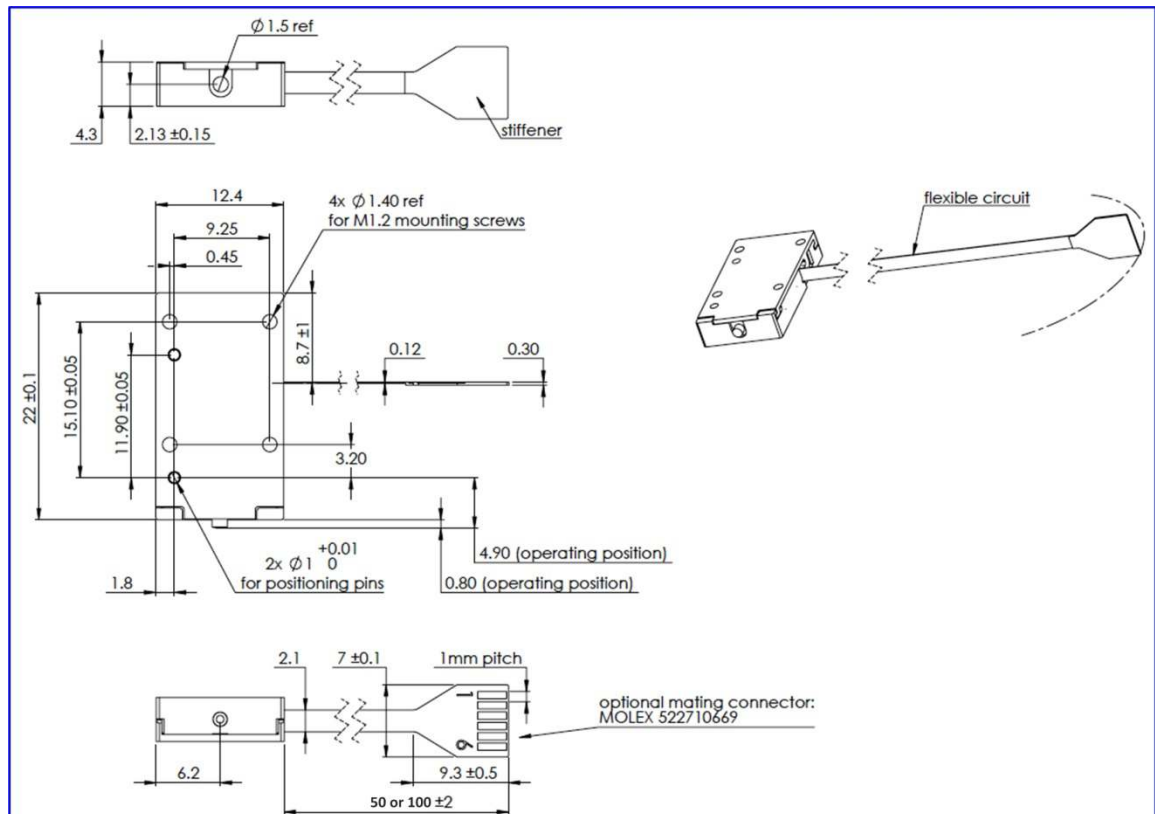


Figure 17: Edge-4X Motor Layout

7.2.2 EDGE-4X Mounting Base Layout

Figure 18 shows the mounting base requirements for EDGE-4X motors according to EDGE-4X INTERFACE DRAWING..

Note:

Use two holes for dowel pins (indicated in red on the below figure) to align the bearing with ceramic strip perpendicular to the motor and at the correct distance.

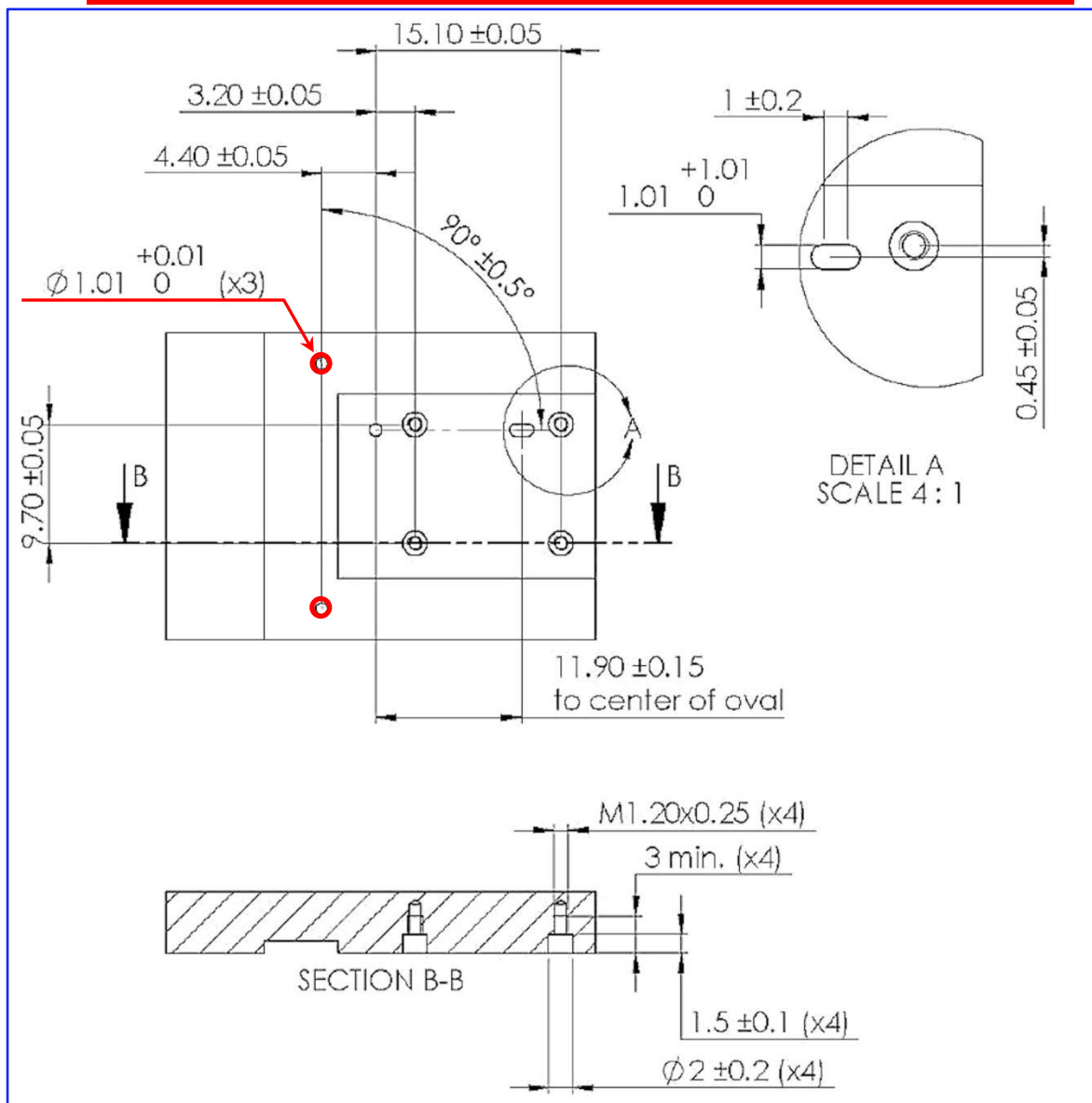


Figure 18: EDGE-4X motor mounting base requirements

Note:

The dimensions are in mm.

7.2.3 EDGE 4X Motor Electro-Mechanical Interface

Figure 19 shows the EDGE-4X motor layout according to EDGE-4X INTERFACE DRAWING, DOCUMENT NO. EDG4129000-00.

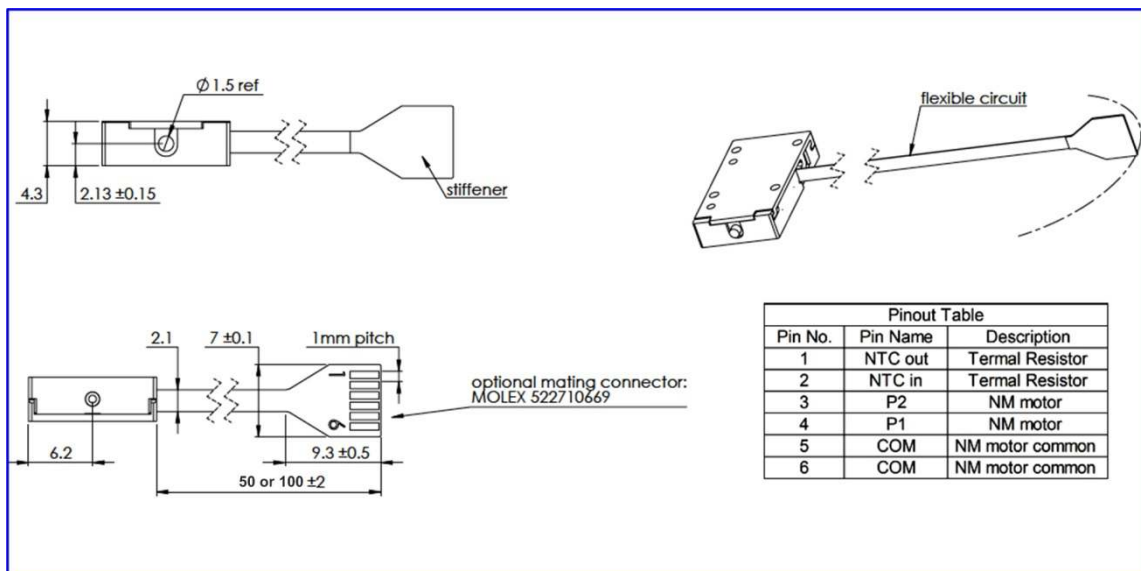


Figure 19: EDGE-4X motor electro-mechanical interface

Note:

The dimensions are in mm.

8 Contact Information

8.1 Customer Service

Contact your local distributor or email Nanomotion Ltd. Technical Support Department at techsupport@nanomotion.com, with detailed problem description.

8.2 General Inquiries and Ordering

Item	Part Number
EDGE 4X, STANDARD	EM4X-S-1-0
EDGE 4X, 100mm	EM4X-S-1-10
MOTOR, PIEZOELECTRIC, EDGE	EM1-S-0
Related Products/Accessories	
Controller/Driver for 1 EDGE-4X motor	XCD-E4X-BD1-XX*
Controller/Driver for 2 EDGE-4X motors in parallel	XCD-E4X-BD2-XX*
BOARD, EDGE	XCD-EDG-BD-XX*
BOARD, EDGE, 2 AXIS	XCD-EDGE2-BD-XX*
XCD2	XCD2 Controller driver

* Latest version

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