A Johnson Electric Company

FB Positioning

Systems

User Guide

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Nanomotion Ltd. POB 623, Yokneam 20692, Israel

Tel: 972-73-2498000 Fax: 972-73-2498099
Web Site: www.nanomotion.com
E-mail: nano@nanomotion.com

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1 Preface

1.1 About This User Guide

This user guide provides instructions for unpacking, connecting and tuning the FB positioning system. It also includes details of the various Nanomotion FB positioning systems' available configurations, motor performance specifications and mechanical layouts. For user's convinience, the FB positioning system is refered to as stage, further in this user guide.

1.2 Who Should Use This User Guide

This user guide is intended for engineers or technicians, directly involved in installation, operation and maintenance of positioning systems and control systems.

Before starting the procedure outlined in this user guide, make sure that you read the Safety Precautions section outlined below and follow all safety guidelines as described further on in this user guide.

1.3 Nanomotion Products Reference Documentation

The following documents contain additional information, related to the FB Positioning Systems, which can be found on Nanomotion website as well:

- AB5/AB51 Drivers User Manual
- AB1A / AB2 / AB4 Driver User Manuals
- FlexDC Controller HW User Manual (includes Quick Start!)
- FlexDC Controller SW User Manual
- HR 2 / 4 / 8 Motor User Manuals
- Nanomotion Vacuum and Ultra High Vacuum Motors Bake-out Procedure.

1.4 Safety Precautions

WARNING!

- **Do not remove the cover of the motor or disassemble its connector. High voltage hazard!**
- **Before operating the motor, ensure it is grounded.**

CAUTION:

- **Ensure that the stage system is not subjected to mechanical shock.**
- **Do not immerse the stage in any liquid or cleaning agent. Use only a clean cloth to wipe the stage.**
- **The HR motors are not user-serviceable.**
- **In case the motor had been remounted, perform the conditioning procedure (refer to motor user manual).**
- **Follow the Quick Start instructions provided in this guide before operating the system.**
- **Motor operation must adhere to a specific duty cycle (refer to motor user manual or see the EOP tables, further in this user guide).**

2 FB Series

2.1 Introduction

The FB series product line is a family of standard linear positioning systems (stages), designed for modular single and multi-axis, applications. The stage configuration utilizes cross roller bearings, a linear optical encoder and Nanomotion ceramic servo motors. The stages are offered in a wide range of widths and travel lengths and encoder resolutions to achieve a range of performance criteria. Various motors sizes are available for each configuration to meet necessary force/acceleration requirements.

2.2 Features

- Compact stage design with low profile.
- Direct drive motor with simple, robust construction.
- Linear encoder mounted in the center for optimum positioning (eliminating Abby Error).
- Easily configurable in multi-axis.
- Wide range of slide sizes, travels and motor sizes.

2.3 Stage Configurations

Series	Width	Motor Options	Standard Travels (mm)
FB050	50 mm	HR2 or HR4	20, 50, 75
FB075	75 mm	HR4 or HR8	40, 60, 100, 150
FB100	100 mm	HR4 or HR8	60, 100, 150, 200, 300
FB150	150 mm	HR4 or HR8	100, 150, 200, 300

2.4 Available Configurable Assemblies

Nanomotion supplies the FB stages in following multi-axes configurations:

- X/Y
- X/Z using angle bracket
- X/Y/Z using angle bracket
- Vacuum versions available

Nanomotion also configures assemblies with integrated Theta and Goniometer stages providing rotation/tip/tilt. Contact Nanomotion technical support for more information.

IMPORTANT:

- **Nanomotion supplies lubricated vacuum and ultra high vacuum stages by means of "Apiezon® Grease, Type M" high vacuum grease.**
- **Each stage has integrated non-adjustable mechanical hard stops.**

2.5 Encoder Options

- 1 µm optional
- 0.5 µm optional
- 0.1 µm standard
- 50 nm optional
- 10 nm optional
- Analog output (Sin/Cos) optional

Note:

- *All standard FB stages are provided with 0.1µm resolution linear encoders.*
- *All FB stages are provided with Reference Mark (magnetic non-adjustable Home Sensor) only.*

3 Quick Start

3.1 Unpacking the Stage

3.1.1 Nanomotion delivers the FB stage for vacuum environment double-bagged per Class1000 clean room standards. The non-vacuum FB stages are delivered in a Nanomotion standard packaging.

3.1.2 All FB stages are delivered with their axes locked by shipping brackets. Before stage operation remove the shipping bracket by means of screwdriver, see Figure 1:

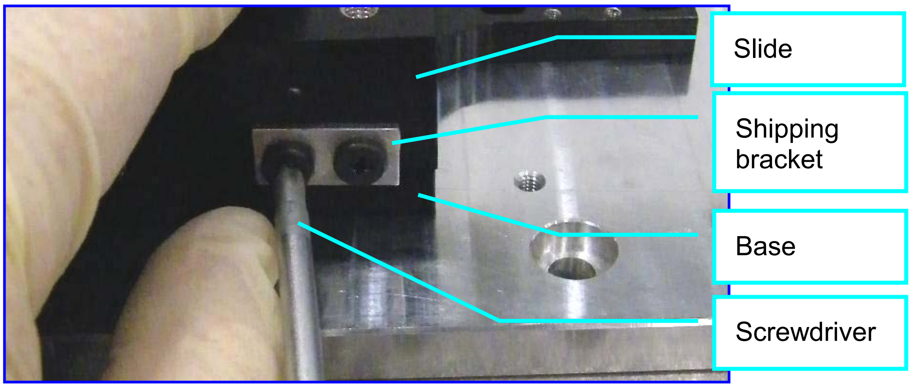


Figure 1: Removing the Shipping Bracket

3.1.3 After removing the shipping bracket, fasten the screws back to their original location at the end of the rail, by applying a proper torque.

3.2 Stage Instalation

CAUTION: Install the stage in a location free of excessive vibration.

3.2.1 Attach the stage to a user-prepared mounting surface (refer to chapter 4 "Mechanical Drawings" for interface). The recommended level of flatness for attachment surface is **20µm or less**.

3.2.2 Attach the payload to the stage (refer to chapter 4 "Mechanical Drawings" for interface).

3.3 Connections

IMPORTANT:

- **Make sure all stage motors and encoders are connected to the corresponding axis on the servo controller.**
- **The motors and the encoders are already aligned and adjusted by Nanomotion and their performance is verified.**
- **Nanomotion guarantees proper driver and motor performance only when using Nanomotion-supplied cables.**
- **Nanomotion supplies conditioned stages. Perform conditioning only in case a motor had been remounted (refer to motor user manual).**
- **As to vacuum (V) and ultra-high vacuum (UHV) stages: Nanomotion supplies clean V and UHV motors, yet the bake-out is required in order to remove residual contaminants and absorbed humidity from the motors and other system components. Refer to the "Nanomotion Vacuum and Ultra High Vacuum Motors Bake-out Procedure", D/N: HR00458001.**

CAUTION:

- **Shortening the motor cable length may damage the motor. Do not attempt to shorten the cable without prior confirmation by Nanomotion.**
- **Extending the motor cable does not damage the motor; however it might affect its performance.**

3.3.1 Connect the motor to Nanomotion driver (refer to driver user manual for more information). Refer to section 7.1 for Standard Motor Connector Pinout and section 7.2 for Ultra-High Vacuum Motor Cable.

- The Motor_Connected interlock is available on Nanomotion standard motor connector. It disables high voltage on the bare driver output connector, when the motor disconnected from the driver.
- Nanomotion's motors run at a resonant frequency and are sensitive to the capacitance of the electrical circuit. Changing cable length affects the total capacitance (refer to driver user manual for maximum allowed cable length).
- Nanomotion provides motors with specific low capacitance cable as follows:
  - Standard motors: 210pF/meter
  - Vacuum motors: 43pF/meter

3.3.2 Connect the driver to the user's servo controller (refer to driver user manual and controller user manual for pinouts and interconnection information).

3.3.3 Connect the encoder to the servo controller (refer to section 7.3 and section 7.4 for encoders' pinouts; refer to controller user manual for pinout and interconnection details).

3.3.4 Connect the servo controller to the PC.

3.4 Turning On the System

3.4.1 Connect the proper external power supply to the driver (refer to the driver user manual for more information).

3.4.2 Connect the servo controller to power supply source (refer to the controller user manual for more information).

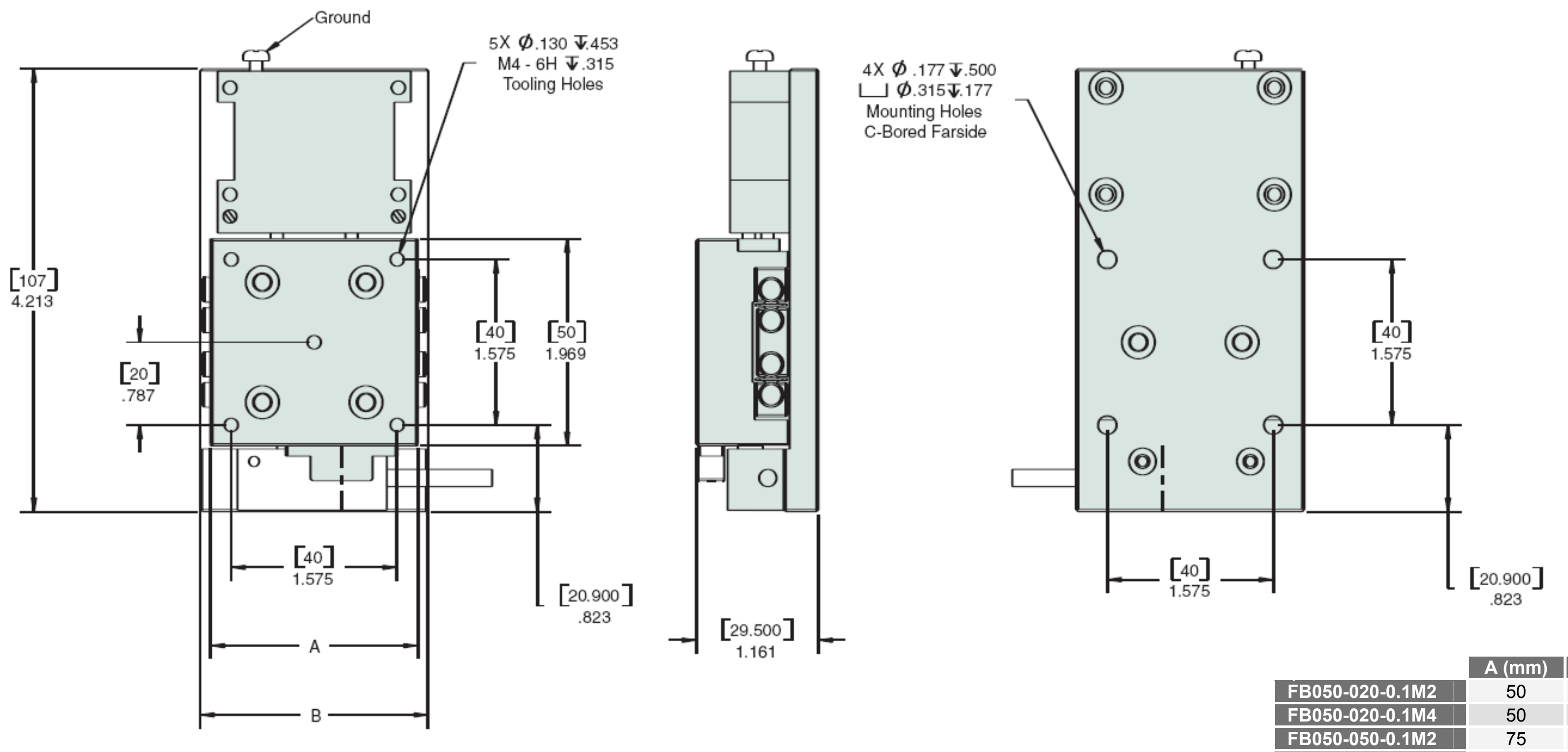
3.4.3 Turn the servo controller on (ensure there is no command when turning the power on).

3.4.4 Before operating the system, refer to the controller user manual for servo parameters tuning and operation instructions.

CAUTION: Avoid prolonged operation in an unstable condition (excessive vibration and noise) during the tuning process.

4 Mechanical Drawings

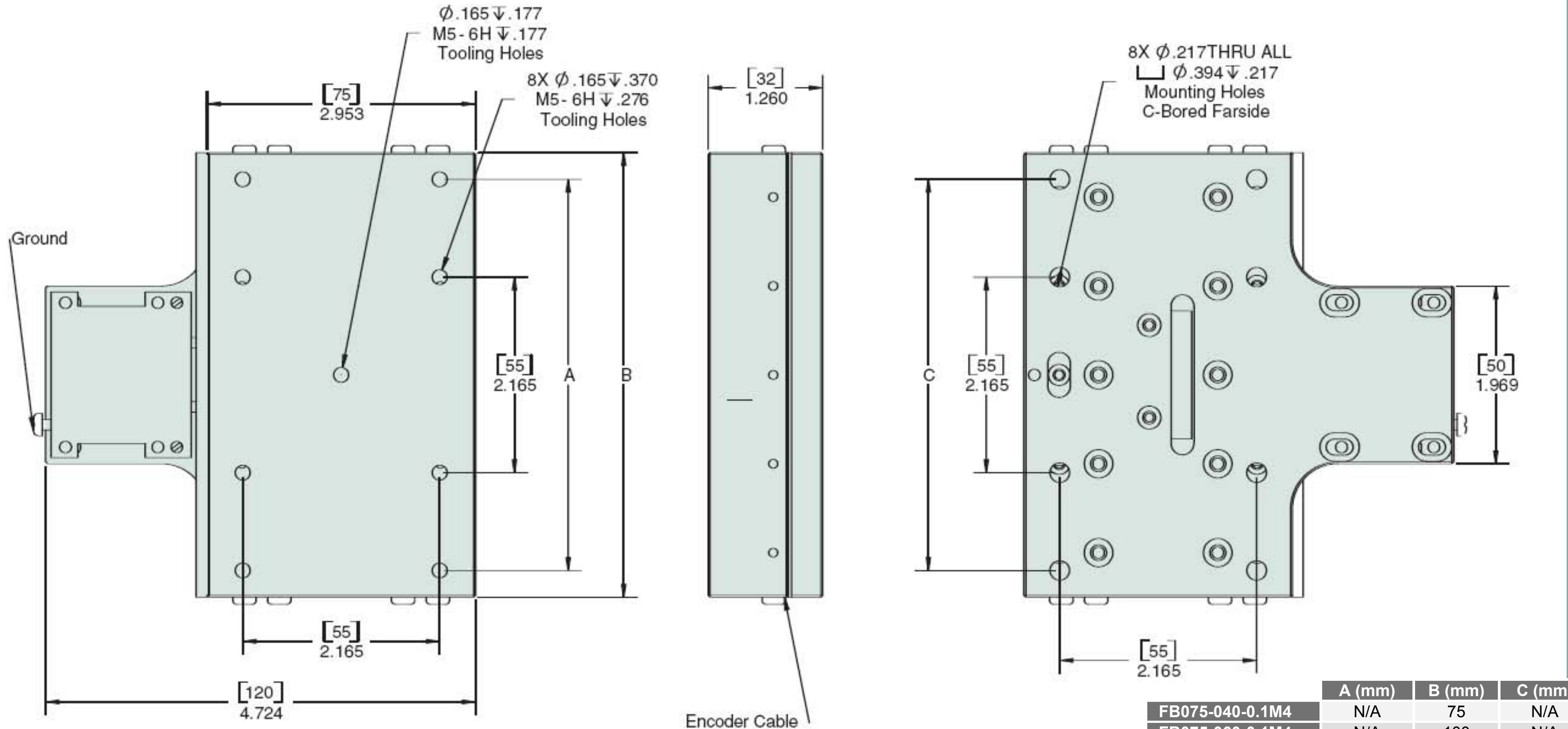
4.1 FB050 Layout



	A (mm)	B (mm)
FB050-020-0.1M2	50	55
FB050-020-0.1M4	50	55
FB050-050-0.1M2	75	80
FB050-050-0.1M4	75	80
FB050-075-0.1M4	100	105

Figure 2: FB050 Stage Layout

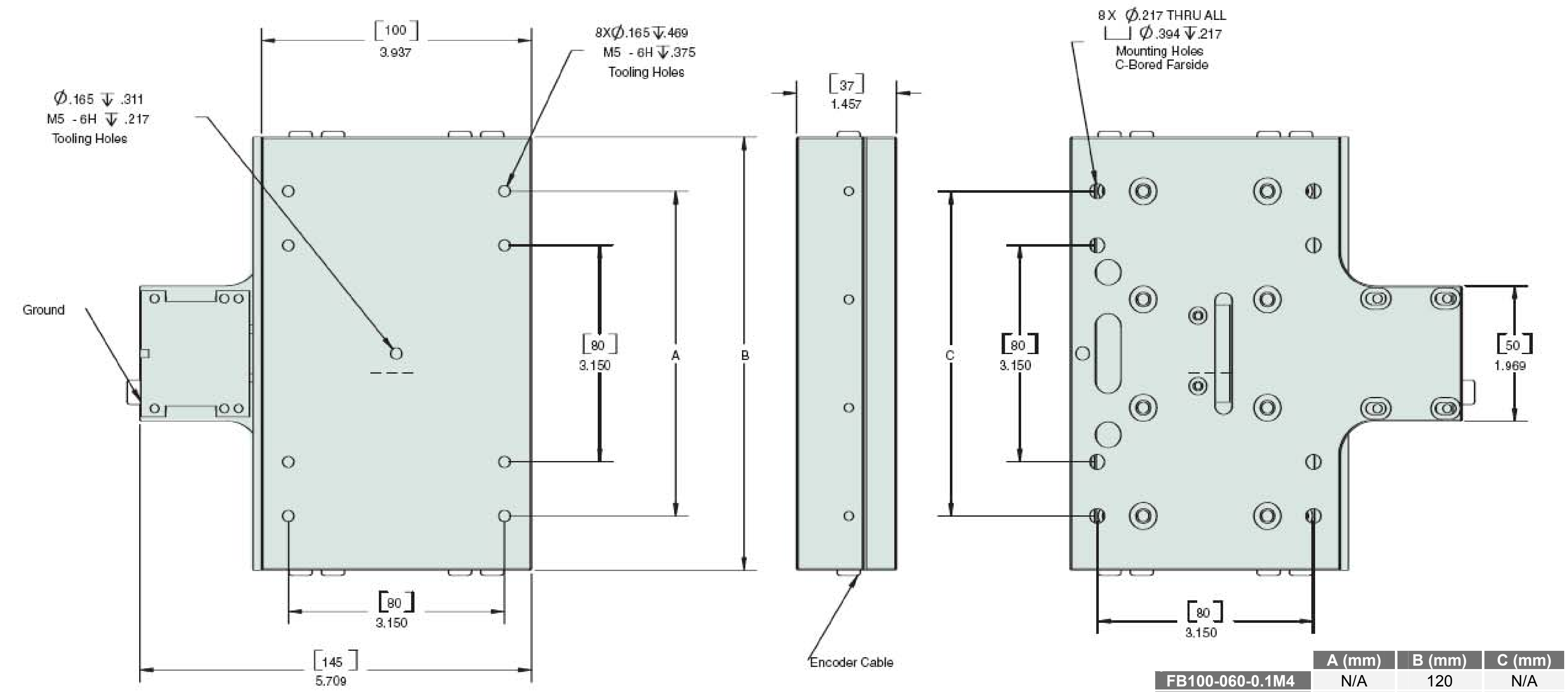
4.2 FB075 Layout



	A (mm)	B (mm)	C (mm)
FB075-040-0.1M4	N/A	75	N/A
FB075-060-0.1M4	N/A	100	N/A
FB075-060-0.1M8	N/A	100	N/A
FB075-100-0.1M4	110	125	110
FB075-100-0.1M8	110	125	110
FB075-150-0.1M4	160	175	160
FB075-150-0.1M8	160	175	160

Figure 3: FB075 Stage Layout

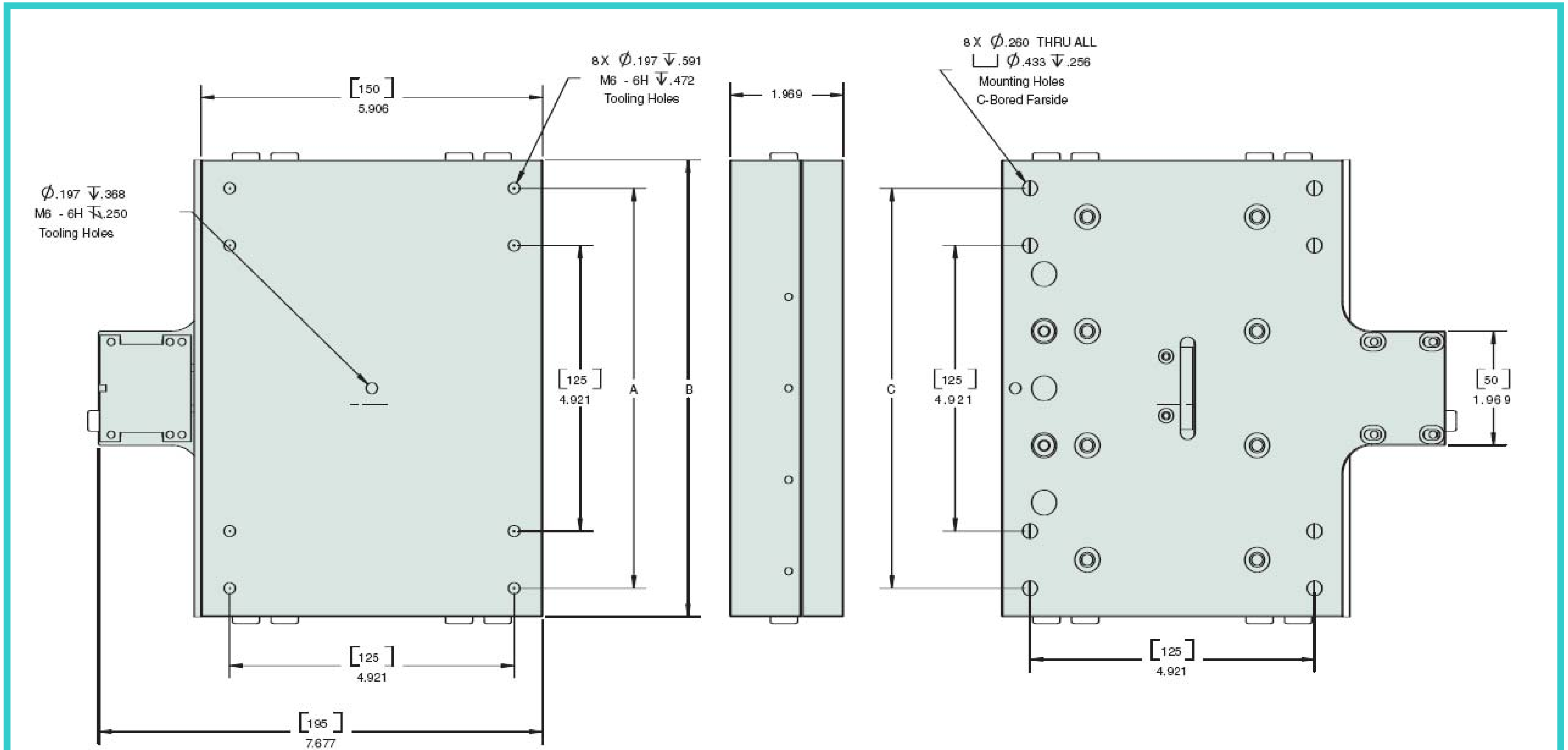
4.3 FB100 Layout



	A (mm)	B (mm)	C (mm)
FB100-060-0.1M4	N/A	120	N/A
FB100-060-0.1M8	N/A	120	N/A
FB100-100-0.1M4	120	160	120
FB100-100-0.1M8	120	160	120
FB100-150-0.1M8	160	200	160
FB100-200-0.1M8	200	280	200

Figure 4: FB100 Stage Layout

4.4 FB150 Layout



	A (mm)	B (mm)	C (mm)
FB150-100-0.1M8	N/A	150	N/A
FB150-150-0.1M8	175	200	175
FB150-200-0.1M8	225	250	225

Figure 5: FB150 Stage Layout

5 Technical Specifications

5.1 Straightness and Flatness

	FB050	FB075	FB0100	FB150
Starightness & Flatness	2.5µm/25mm travel	2.5µm/25mm travel	2.5µm/25mm travel	1.5µm/25mm travel

5.2 Maximum Load Capacity

	Maximum Load Capacity (in kg)			
Travel (mm)	**FB050**	**FB075**	**FB0100**	**FB150**
20	2	N/A	N/A	N/A
40	N/A	5	N/A	N/A
50	5	N/A	N/A	N/A
60	N/A	5	10	N/A
75	7	N/A	N/A	N/A
100	N/A	7	12	20
150	N/A	10	12	25
200	N/A	N/A	N/A	25

5.3 Position Repeatability

Encoder	FB050	FB075	FB0100	FB150
0.1µm standard	±0.5 µm			
10nm optional	±50 nm			
50nm optional	±200 nm			
0.5µm optional	±2 µm			
1.0µm optional	±3 µm			

5.4 FB050 Series

	Travel (mm)	Dynamic Stall Force (N) *	Static Holding Force (N) *	Stage Mass (g)	Moving Mass (g)
FB050-020-0.1M2	20	8	7	385	150
FB050-020-0.1M4	20	16.5	14	400	150
FB050-050-0.1M2	50	8	7	595	266
FB050-050-0.1M4	50	16.5	14	610	266
FB050-075-0.1M4	75	16.5	14	700	400

* Specified values are within ±10% range.

5.5 FB075 Series

	Travel (mm)	Dynamic Stall Force (N) *	Static Holding Force (N) *	Stage Mass (g)	Moving Mass (g)
FB075-040-0.1M4	40	16.5	14	650	302
FB075-060-0.1M4	60	16.5	14	920	405
FB075-060-0.1M8	60	33	28	1035	412
FB075-100-0.1M4	100	16.5	14	1125	505
FB075-100-0.1M8	100	33	28	1230	515
FB075-150-0.1M4	150	16.5	14	1515	710
FB075-150-0.1M8	150	33	28	1620	720

* Specified values are within ±10% range.

5.6 FB100 Series

	Travel (mm)	Dynamic Stall Force (N) *	Static Holding Force (N) *	Stage Mass (g)	Moving Mass (g)
FB100-060-0.1M4	60	16.5	14	1580	690
FB100-060-0.1M8	60	33	28	1690	700
FB100-100-0.1M4	100	16.5	14	2040	920
FB100-100-0.1M8	100	33	28	2145	930
FB100-150-0.1M8	150	33	28	2625	1160
FB100-200-0.1M8	200	33	28	3500	1600

* Specified values are within ±10% range.

5.7 FB150 Series

	Travel (mm)	Dynamic Stall Force (N) *	Static Holding Force (N) *	Stage Mass (g)	Moving Mass (g)
FB150-100-0.1M8	100	33	28	3940	1600
FB150-150-0.1M8	150	33	28	5095	2125
FB150-200-0.1M8	200	33	28	6275	2660

* Specified values are within ±10% range.

6 Motor Dynamic Performance

6.1 Settling Time

The achievable settling time is mainly dictated by the damping of the motor and the natural frequency of the system. A typical number of three cycles is required for the motor damping to damp the system vibration along the motion axis, so the settling time is roughly according to the following formula:

$$Ts = \frac{3}{Fr}$$

where **Fr** is the natural frequency of the system, and is calculated according to the following formula:

$$Fr = \frac{1}{2\pi}\sqrt{\frac{K}{m}}$$

Where:

K – stiffness of the motor in Newton/meter

m – mass of the moving part in Kg

If the desired natural frequency is higher than the one calculated for a given configuration, adding another motor in parallel or in tandem increases the system's natural frequency due to the increased stiffness. The combined stiffness of several motors is the algebraic sum of stiffness of the individual motors.

The user should recalculate the natural frequency using the combined stiffness of the motors. It is worthwhile to note that the effective motor stiffness increases under close loop operation.

Driving vertically with a motor that actuates based on friction requires specific consideration to the static load, separate from the dynamic force.

A thumb rule: each 4.1N element can drive 120 grams vertically. Beyond this, consider a counter balance in a form of a spring, a continuous force gas spring, or opposing weight.

6.2 Thermal EOP for HR Motors Driven by AB51

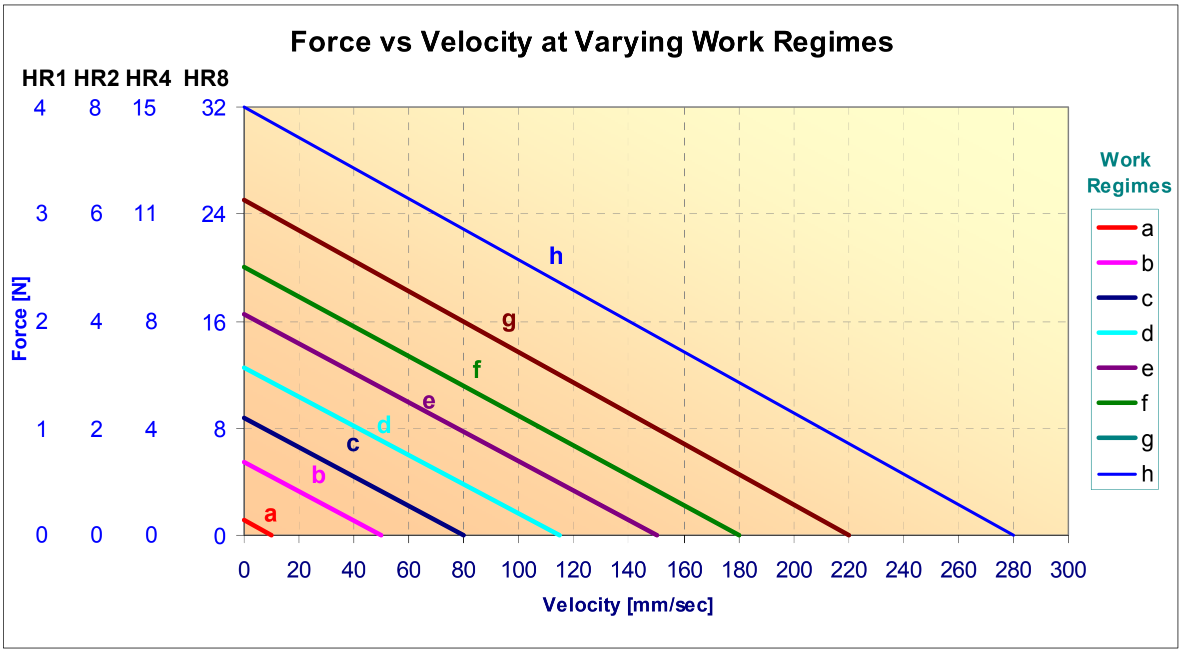


Figure 6: HR Motors – Force vs Velocity at Varying Work Regimes

Curve	Duty Cycle [%]			Maximal Continuous Operation time [sec]	
	Ambient Conditions			Ambient Conditions	
	Air 25°C Brake_Off	Air 25°C Brake_On	Vacuum Brake_On	Air 25°C	Vacuum Environment
a	100	100	56	∞	500
b	100	100	54	∞	450
c	100	100	45	∞	280
d	100	100	33	∞	170
e	99	99	23	∞	100
f	53	58	12	170	66
g	33	48	10	77	44
h	17	28	6.5	32	25

Table 1: EOP Table for HR Motors Driven by AB51

6.3 EOP for HR Motors Driven by AB1A / AB2 / AB4

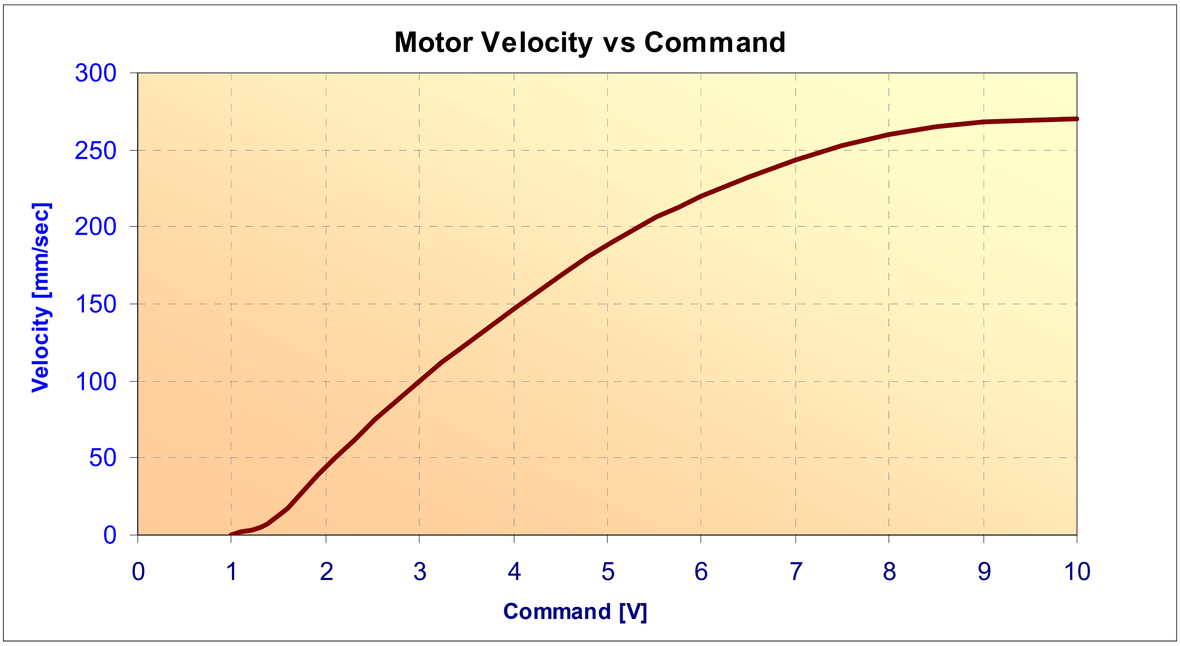


Figure 7: Motor Velocity vs Command

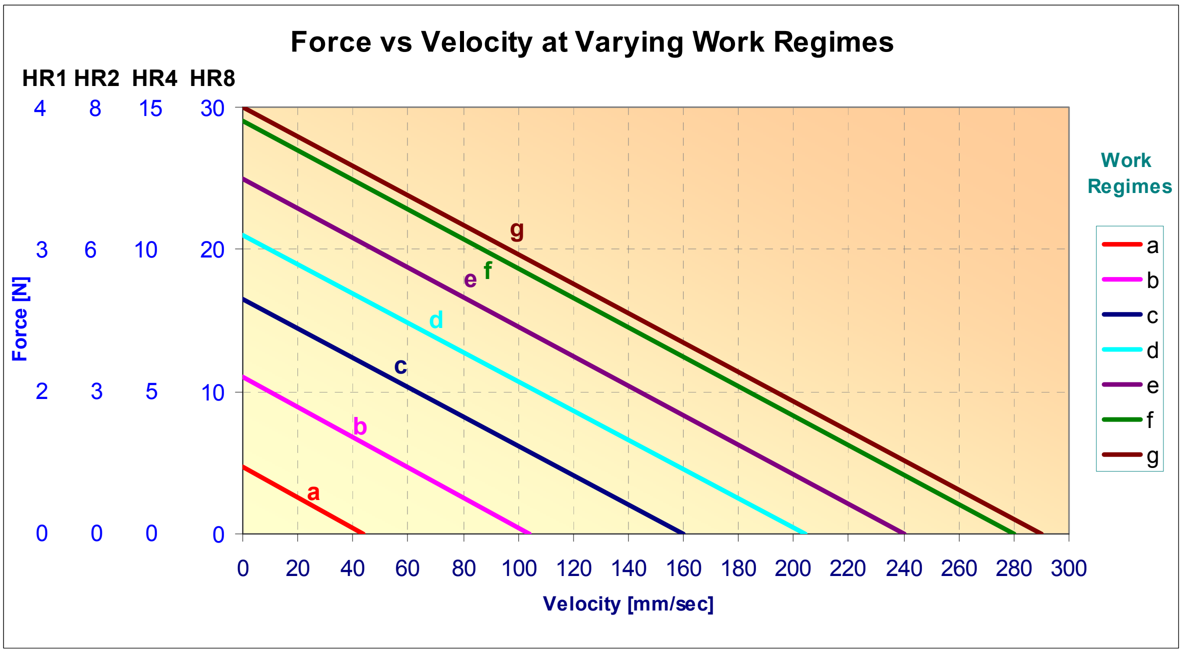


Figure 8: Force vs Velocity at Varying Work Regimes

Curve	25°C Environment Ambient Temperature		50°C Environment Ambient Temperature		Vacuum Environment	
	Duty Cycle [%]	Maximal Continuous Operation time [sec]	Duty Cycle [%]	Maximal Continuous Operation time [sec]	Duty Cycle [%]	Maximal Continuous Operation time [sec]
a	100	-	100	-	100	-
b	100	-	100	-	44	184
c	100	-	92	137	26	107
d	100	-	62	93	17	72
e	78	87	47	70	13	55
f	56	62	33	50	9	39
g	50	56	30	45	8	35

Table 2: EOP Table for HR Motors Driven by AB1A / AB2 / AB4

7 Connectors' Pinouts

7.1 Standard Motor Connector Pinout

This section describes the motor connector pinout. Make sure the driver is set to operate with the HR motor series. The motor driver connection is a standard 9 contacts D-type female connector, see Figure 9:

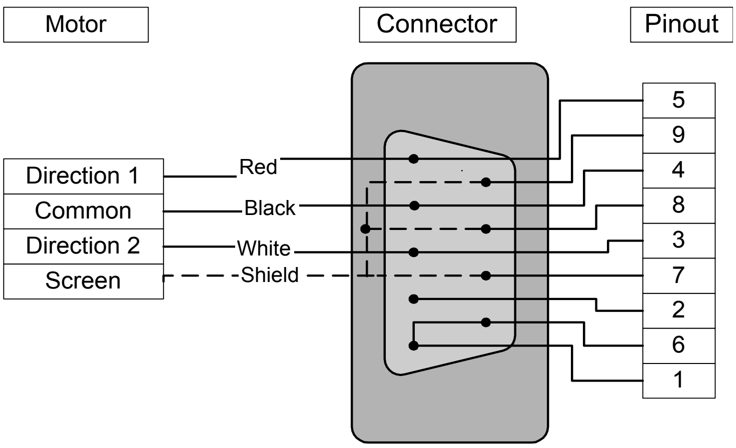


Figure 9: Motor Connector

CAUTION:

- **In case the user replaces the original standard motor connector with user's compatible connector, it is essential to short-circuit pins 1 and 6 for safety reasons, refer to Figure 9 and Table 3.**

Pin #	Pin Name	Function
1	GND	System ground
2	N.C.	Not connected
3	Motor_Up	High voltage output
4	Motor_Common	High voltage output
5	Motor_Down	High voltage output
6	Motor_Connected	Input
7	Inner	Inner shield
8	N.C.	Not connected
9	N.C.	Not connected

Table 3: Motor Connector Pinout

7.2 Ultra-High Vacuum Motor Cable

The HR UHV motor has 3 TFE jacketed flying wire leads at the end of the motor cable: black, red and white.

7.3 A Quad B Encoder Connector Pinout

The encoder connector is a D-Type 15pin, male.

Pin #	Pin Name	Function
7, 8	5V	Power
2, 9	0V	
14	A+	Incremental signals
6	A-	
13	B+	
5	B-	
12	Z+/Q-	Reference mark/Limit switch
4	Z-/Q+	
15	Inner	Inner shield
1, 3	N.C.	Not connected
10-11	N.C.	Not connected

Table 4: AqB Encoder Pinout

7.4 Sin/Cos Encoder Connector Pinout

The encoder connector is a D-Type 15pin, male.

Pin #	Pin Name	Function
4, 5	5V	Power
12, 13	0V	
9	V_1+/I_1+	Incremental signals
1	V_1-/I_1-	
10	V_2+/I_2+	
2	V_2-/I_2-	
3	V_0+/I_0+	Reference mark/Limit switch
11	V_0-/I_0-	
15	Inner	Inner shield
Case	Outer	Outer shield

Table 5: Sin/Cos Encoder Pinout

8 Ordering Information

8.1 Part Numbering Scheme

Available configurations for the FB stages:

Product	Width (mm)		Travel (mm)		Encoder resolution	HR Motor type
FB	**050**	-	**020** **050** **060** **075**	-	**10M** = 1 µm optional **05M** = .5 µm optional **01M** = 0.1 µm standard **50N** = 50 nm optional **10N** = 10 nm optional **ALG** = Sin/Cos optional	**2** = HR2 **4** = HR4
FB	**075**	-	**040** **060** **100** **150**	-	**10M** = 1 µm optional **05M** = .5 µm optional **01M** = 0.1 µm standard **50N** = 50 nm optional **10N** = 10 nm optional **ALG** = Sin/Cos optional	**4** = HR4 **8** = HR8
FB	**100**	-	**060** **100** **150** **300**	-	**10M** = 1 µm optional **05M** = .5 µm optional **01M** = 0.1 µm standard **50N** = 50 nm optional **10N** = 10 nm optional **ALG** = Sin/Cos optional	**4** = HR4 **8** = HR8
FB	**150**	-	**100** **150** **200** **300**	-	**10M** = 1 µm optional **05M** = .5 µm optional **01M** = 0.1 µm standard **50N** = 50 nm optional **10N** = 10 nm optional **ALG** = Sin/Cos optional	**4** = HR4 **8** = HR8

8.2 Example Configurations

- FB150 stage with 100mm travel, Sin/Cos encoder and HR8 motor:

FB	**150**	-	**100**	-	**ALG**	**8**

- FB050 stage with 20mm travel, -0.1M encoder resolution and HR2 motor:

FB	**050**	-	**020**	-	**10M**	**2**

9 Contact Information

9.1 Customer Service

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

9.2 General Inquiries and Ordering

- **Outside the USA**

Nanomotion Ltd. Headquarters

Nanomotion Ltd.

PO Box 223

Yokneam, Israel 20692

Tel: + 972-73-2498065

Fax: +972-73-2498099

Web site: www.nanomotion.com

Email: nano@nanomotion.com

- **In the USA**

Nanomotion Inc. (US) Headquarters

Nanomotion Inc

1 Comac Loop, Ste. 14B2

Ronkonkoma, NY 11779

Tel: (800)821-6266

Fax: (631)585-1947

Web site: www.nanomotion.com

Email: nanous@nanomotion.com