NANOMOTION

A Johnson Electric Company

AB7 Driver

AB07458000-00

User Guide

AB7 Driver DN: AB07458001-00 REV:B **MAY 2021**

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Contact Information

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Revision History

Ver/Rev	Date	Details
00/A	Sep 2020	Initial Release
00/B	MAY 2021	Added snapshots of Voltage vs Command (%) for Normal and Linear modes for SE8 motor.

Glossary

A	Ampere
AC	Alternating Current
DC	Direct Current
LED	Light Emitting Diode
LUT	Look Up Table
mA	Milliampere
SNR	Signal to Noise Ratio
Vrms	Voltage Root Mean Square

Table of Contents

1. Overview

This chapter provides an overview of the Nanomotion Ltd. AB7™ Driver and includes:

1.1. Scope of Manual

This user guide provides instructions for connecting and operating the Nanomotion Ltd. AB7™ Driver. The AB7 includes hardware infrastructure for a single axis controller driver (future upgrade). The AB7 contains two firmware and software programs.

This manual contains the following chapters:

- Safety
- Introduction
- Installation and Setup
- Operation
- Troubleshooting
- System Specifications
- Appendix A: Drawings

2. Safety

This chapter explains the safety precautions and requirements that must be adhered to and includes the following:

- Conventions Used in This Manual
- Safety Precautions

2.1. Conventions Used in This Manual

Throughout this manual, commands are shown in bold and parameter values are shown in italics.

NOTE: Notes provide additional information that is not included in the normal text flow.

CAUTION: Provides information about actions that will adversely affect system performances

DANGER: Indicates operations or activities that may cause damage to equipment or injury to personnel.

BKM

BEST KNOWN METHODS: Provides additional detailed information about operations and methods.

2.2. Safety Precautions

DANGER: Do not remove the motor cover or disassemble its connector. High voltage hazard!

Before operating the stage, ensure that the motor is grounded.

CAUTION: Ensure that the stage 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.

3. Certificates of Conformity

The AB7 complies with the following EMI/RFI standards:

- FCC 47CFR part 15:2019, subpart B, Class B standard
- EN 61326-1:2013, industrial locations equipment standard, Class A, Harmonized under article 13 of EMC Directive 2014/30/EU
- EN 55011:2009/A1:2010 (Europe)
- EN 61000-6-2:05 (Europe)

The AB7 complies with the following safety standards:

- EN 61010-1:2010
- IEC 61010-1:2010 (Third Edition)

The AB7 controller comply with the following ROHS directives:

- Directive 2015/863 (RoHS3)

4. Introduction

The manual provides operating information about the Nanomotion Ltd. AB7 driver which includes:

- Product Overview
- Electrical and Mechanical Interface
- LED Indication
- Personality Board

4.1. Product Overview

The AB7 is a single-axis amplifier box for driving Nanomotion piezo-ceramic motors. The AB7 is designed for multi configuration of load drives of up to 32 motor elements in parallel. The AB7 driver includes an internal personality board for configuration setting (quantity & type of elements).

The AB7 driver is developed as part of the introduction of a new SE motor to the market. It supports and enhances the new motor's performance to its full capabilities of dynamic performance, heavy duty operation and ultra-high precision at the sub nano-meter range.

In addition to supporting the new motor family, it is also compatible with the HR motor family, and has maximum compatibility with older drivers that enable easy replacement of any old drivers (AB5, AB1A, AB2) with the new AB7 driver.

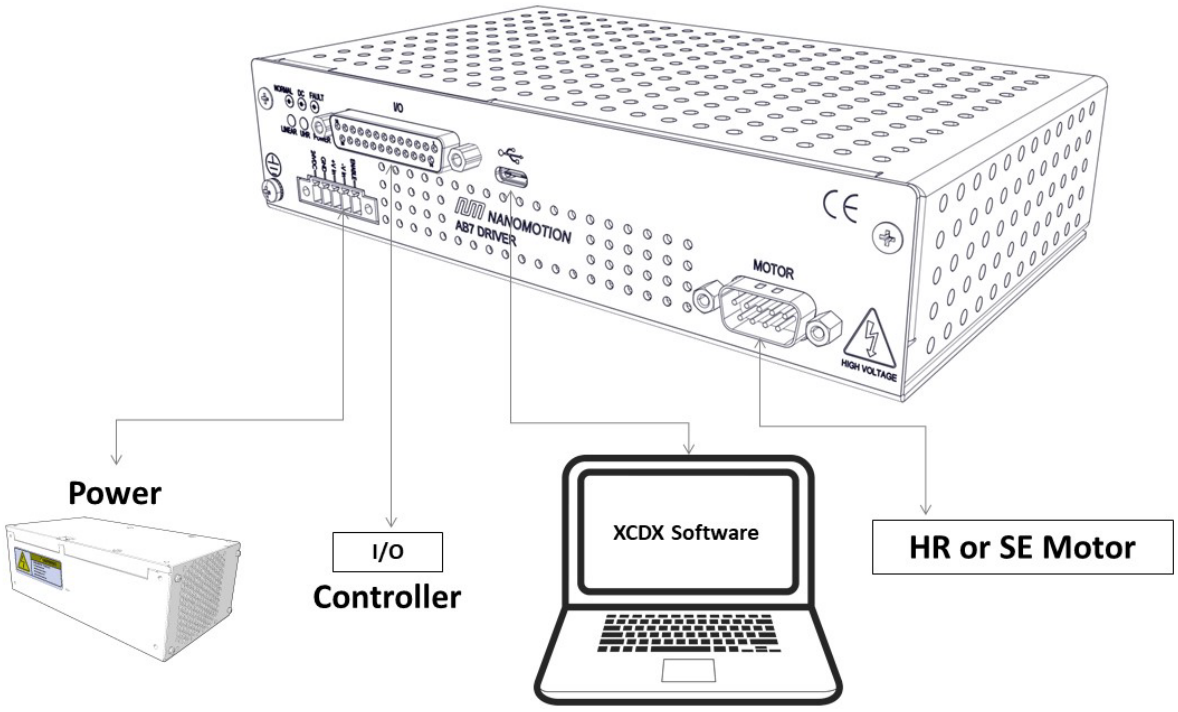

Figure 1: Product overview

4.2. Electrical and Mechanical Interface

The electrical interface includes the following:

- Terminal Block Interface (5)
- Motor Connector Pinout (6)
- Ground Screw (4)
- I/O Connector – Control Interface (2)
- USB (Type-C) Interface (3)
- LED Indication (1)

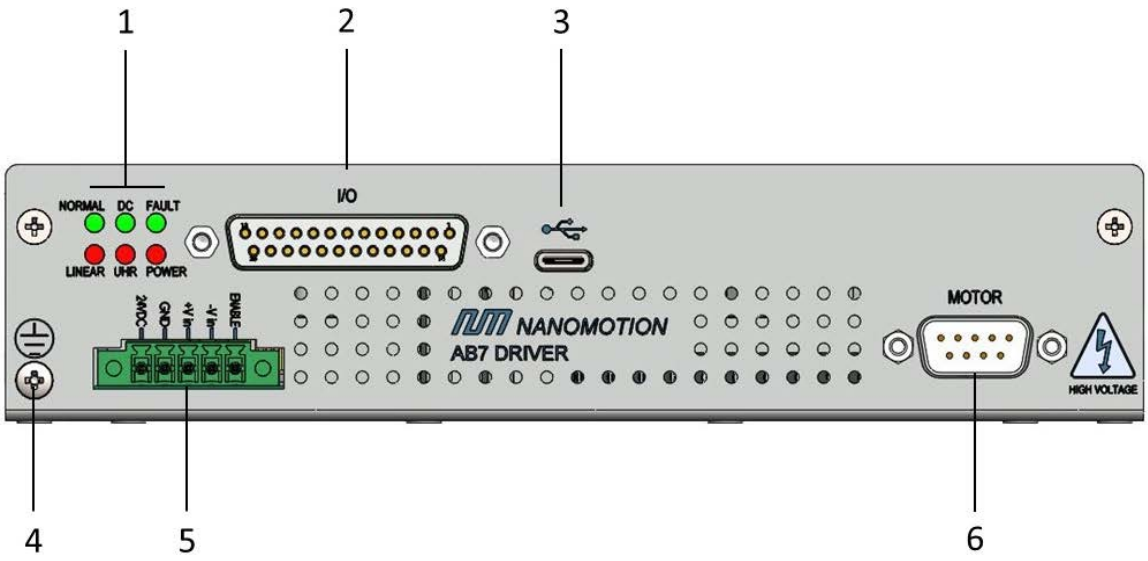

Figure 2: Electrical interface - Front panel view

4.2.1. Terminal Block Interface

Terminal block pinout:

Table 1: Terminal block pinout

Pin	Signal Name	Function	Description
1	+24V	Input	+24Vdc Power Supply
2	GND	Ground	
3	+Vin	Input	Analog command from controller
4	-Vin	Input	Analog command from controller
5	Enable	Input	Enable (Connect to GND to enable)

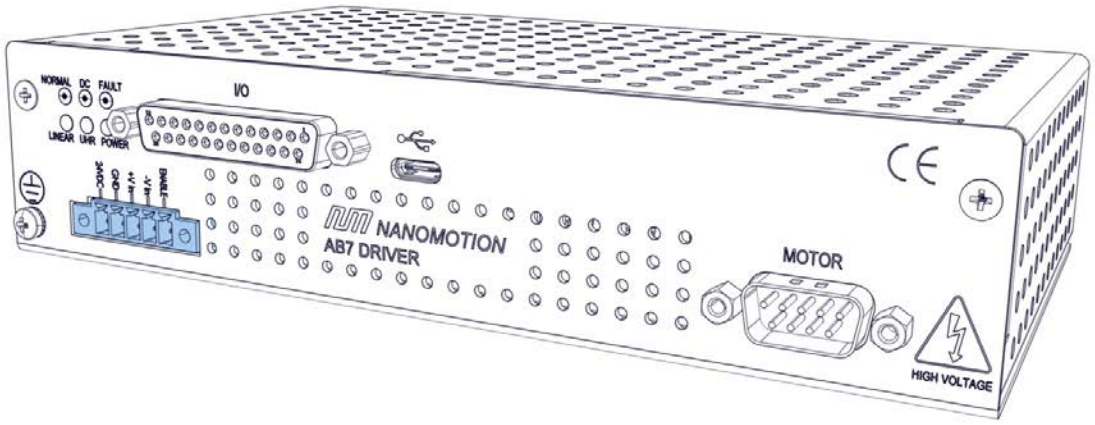

Figure 3: Terminal block interface

4.2.2. Motor Connector

Motor Connector Pinout:

Table 2: Motor connector pinout

Pin	Signal Name	Function	Description
1	GND	Power supply ground	Safety input: shorted to pin 6 in order to verify the motor connection and to prevent driver operation without the motor.
2	N.C.	Not used	
3	Motor Up	High voltage output	Connected to the white motor terminal.
4	Motor Common	High voltage output	Connected to the black motor terminal.
5	Motor Down	High Voltage output	Connected to the red motor terminal.
6	Motor Connected	Input	Safety input: shorted to pin 1 to verify the motor connection and to prevent driver operation without the motor.
7	GND	Power supply ground	Shorted to the shield
8	N.C.	Not used	
9	N.C.	Not used	

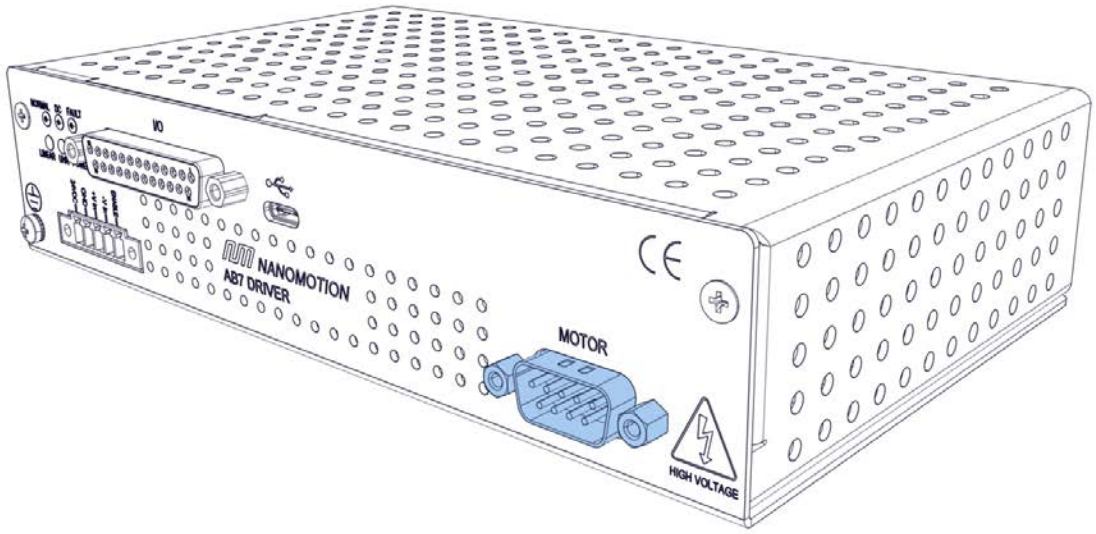

Figure 4: Motor connector

4.2.3. Ground Screw

To comply with EMI/RFI standards, the AB7 driver must be grounded to protective ground.

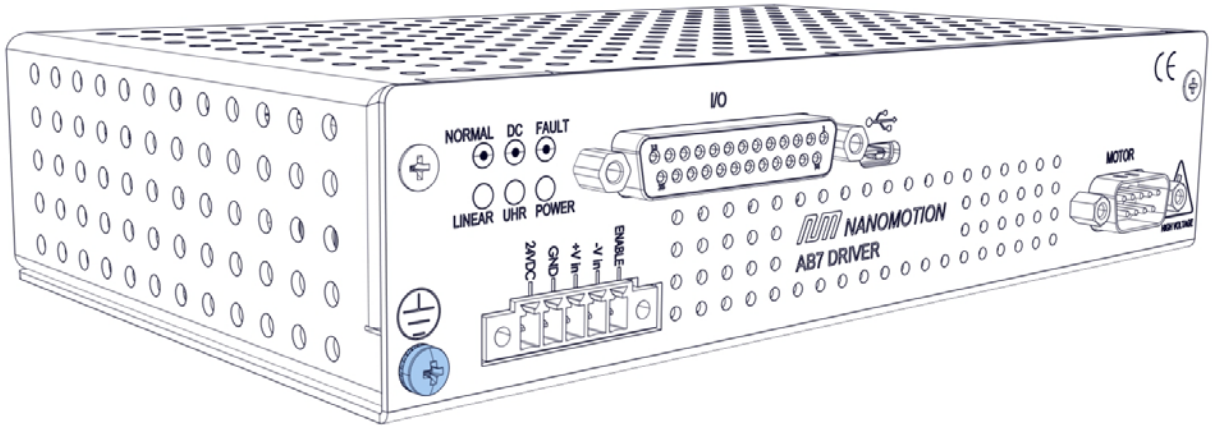

Figure 5: Ground cable

. **DANGER:** Do not operate the driver before the driver is grounded to an infrastructure earth. A ground cable is necessary to prevent electrical shock.

4.2.4. I/O Connector – Control Interface

I/O connector pinout:

Table 3: I/O Connector – Control interface

Pin	Signal Name	Description
1	VIN+	Positive analog command input
2	GND	Ground
3	FAULT	Digital output - Driver in fault mode
4	GND	Ground
5	AI	Analog input 0-10V (future Infrastructure C/D configuration)
6	AO	Analog out 0-10V- Monitor output (see SW user manual DN: TBD)
7	Brake On	Digital input- Brake on Linear mode- currently not applied
8	D/O-1	Digital output - (future Infrastructure C/D configuration)
9	GND	Ground
10	Limit LEFT	Digital input-limit SW left (future Infrastructure C/D configuration)
11	NC	
12	EMERGENCY_STOP	Digital input - Protection input
13	USER VOLTAGE	External power supply for the opto-isolated type inputs
14	VIN-	Negative analog command input
15	FAULT_RTN	To allow chaining in series of a fault signal of two or more drivers (JP3)
16	UHR_MODE	Digital input - UHR MODE ENABLE - see UHR section
17	RESET	Digital input - Driver reset - reset driver MCU
18	NC	
19	SET_OFFSET	Digital input - Set command offset - Normal, linear and DC modes
20	LINEAR_MODE	Digital input - Linear mode Enables input
21	DC_MODE	Digital input - DC mode Enables input
22	Limit RIGHT	Digital input - Limit SW right (phase 2 C/D configuration)
23	NC	
24	ENABLE	Digital input - Driver Enable input
25	NC	

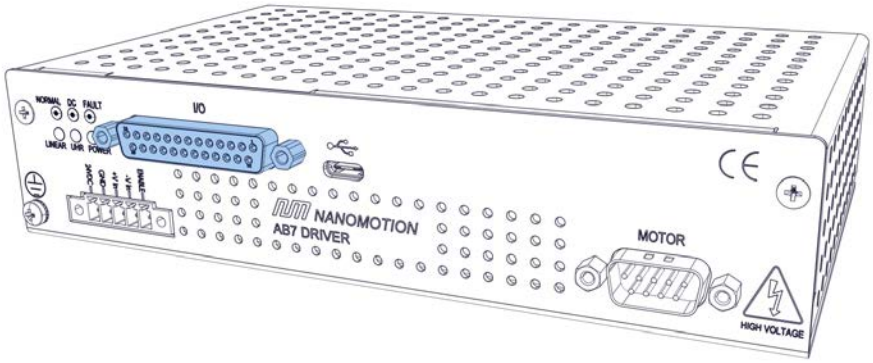

Figure 6: I/O connector – Control interface

4.2.5. USB (Type-C) Interface

The USB interface (for AB7 GUI) is designed for advanced technician mode setting and should not be used as part of normal operation.

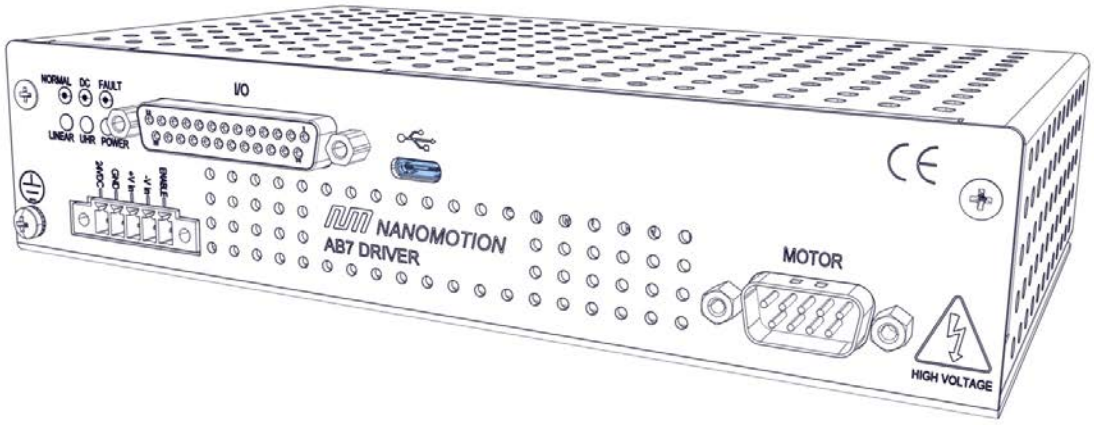

Figure 7: USB (Type-C) interface

4.3. LED Indication

Refer to Table 4 for a detailed description of the LED indications.

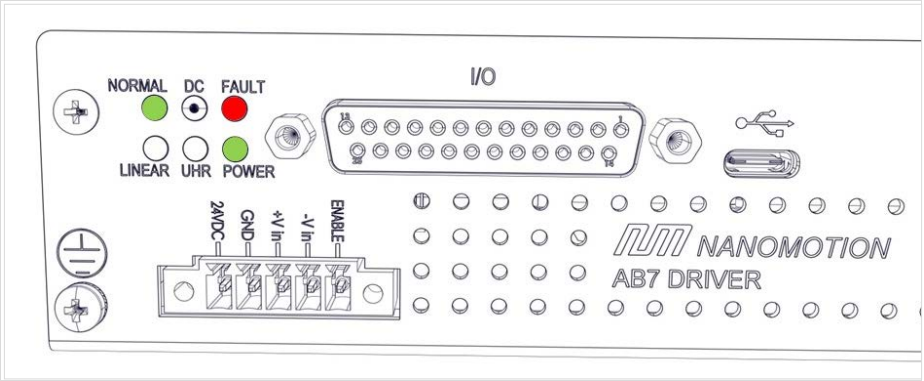

Figure 8: LED indication

Table 4: LED indicators

Fault Led	• Off = O.K • Blinking Red = thermal protection warning • Red = all faults including TP (thermal protection)
Power Led	• Green = power supply ON • Off = power supply OFF
UHR LED	• Green = UHR Mode active • Off = UHR Mode inactive
DC LED	• Green = DC Mode active • Off = DC Mode inactive
Linear LED	• Green = Linear Mode active • Off = Linear Mode inactive
Normal LED	• Green = Normal Mode active • Off = Normal Mode inactive

4.4. Personality Board

Configuration settings (quantity & type of elements).

- The AB7 driver box consists of three main boards. The Control board and Driver board are common to all AB7 configurations, while the Personality board is configuration specific and can be replaced, by an authorized technician, to drive a different motor.
- The firmware recognizes the Personality board and sets the motor frequency for the correct motor type HR/SE and the correct current limit for number of elements.
- To upgrade the personality board please contact Nanomotion Ltd.

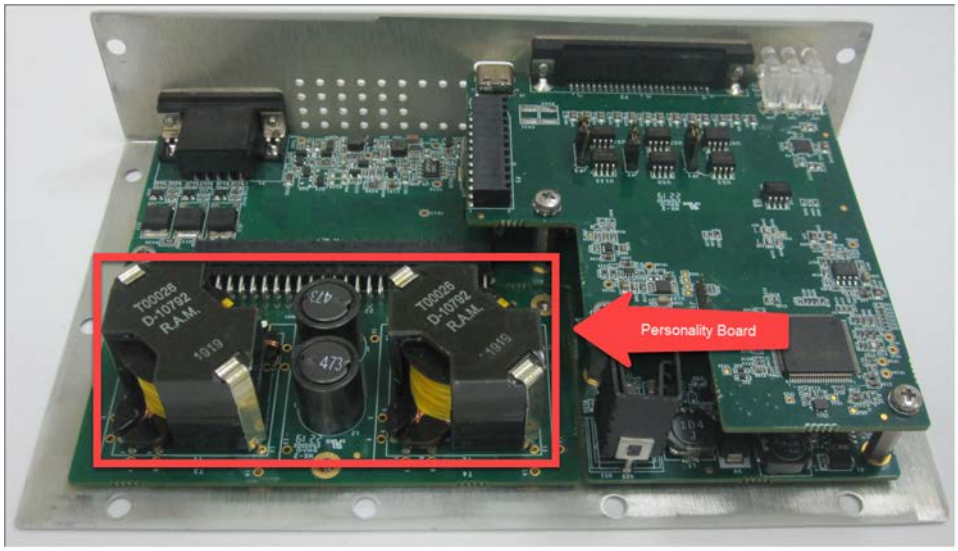

Figure 9: AB7 Personality board

5. Installation and Setup

This chapter reviews installation and initial setup and includes:

- Connecting the devices

5.1. Connecting the devices

This section explains how to connect the device and includes the following:

- Ground Cable
- Terminal Block Cable
- I/O Connector Cable
- Motor Cable

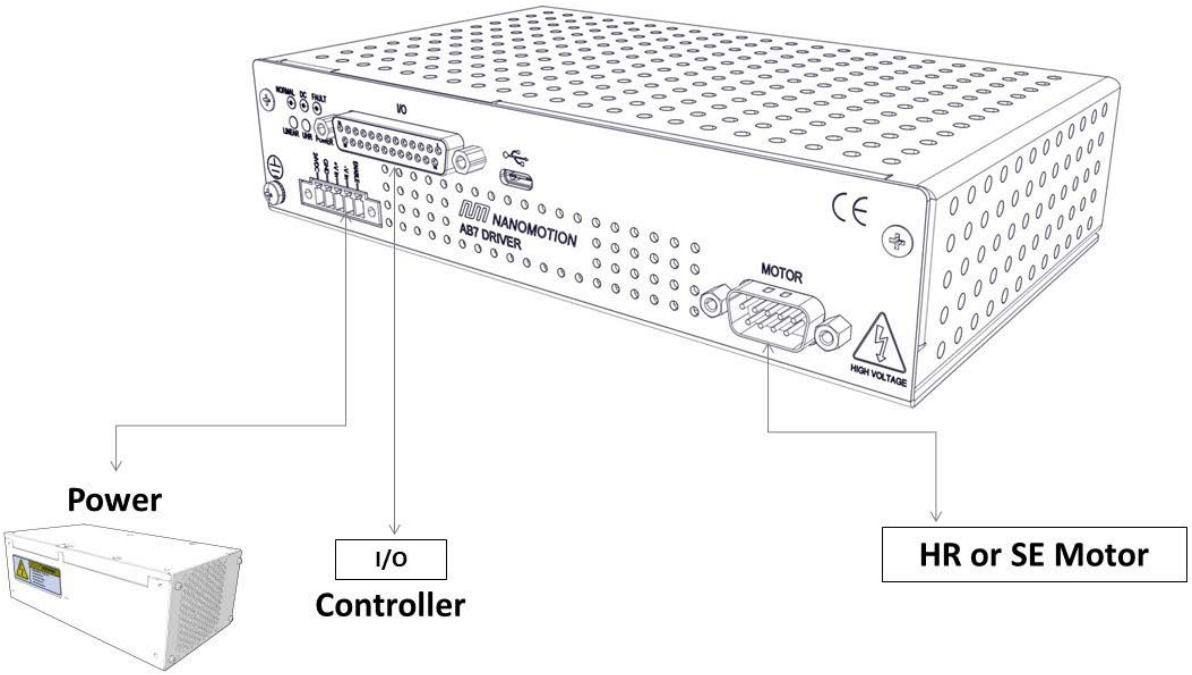

Figure 10: Connecting the devices

5.1.1. Ground Cable

- The cable should be connected to the ground screw with a ring terminal that fits an M3 screw.
- Cable gauge should be 22-16 AWG and connected to the earth GND.

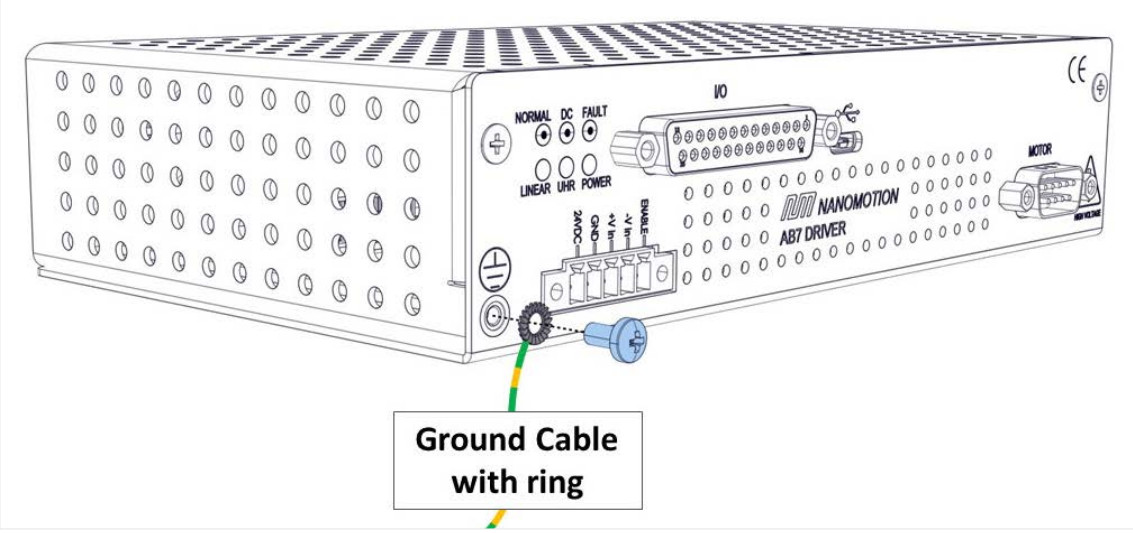

Figure 11: Ground cable ring

5.1.2. Terminal Block Cable

Power cable (Pin1 & Pin2) should be 16-20 AWG.

NOTE: The terminal block includes a fast connection for analog command (Pin3 & Pin4) and enable input (Pin 5). However, for the best quality command quality and quieter radiated emission EMI it is recommended that those signals be connected to the I/O connector.

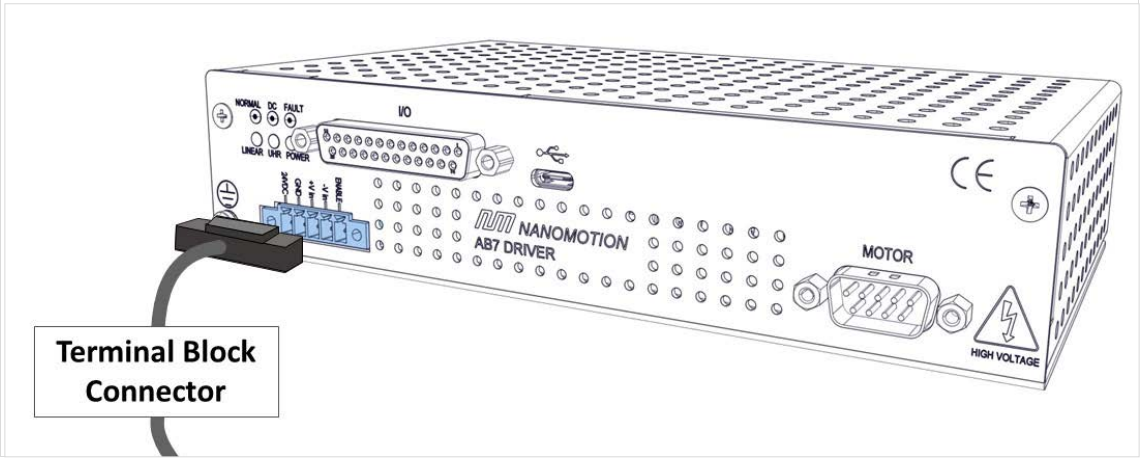

Figure 12: Terminal block connector

5.1.3. I/O Connector Cable

- The use of a shielded cable is recommended for the I/O interface to get a high quality of EMI and command input SNR. The shield should be connected to the DB25 hood.
- The use of a twisted pair cable is recommended for analog command (Pins 1&14) to get high quality of SNR.

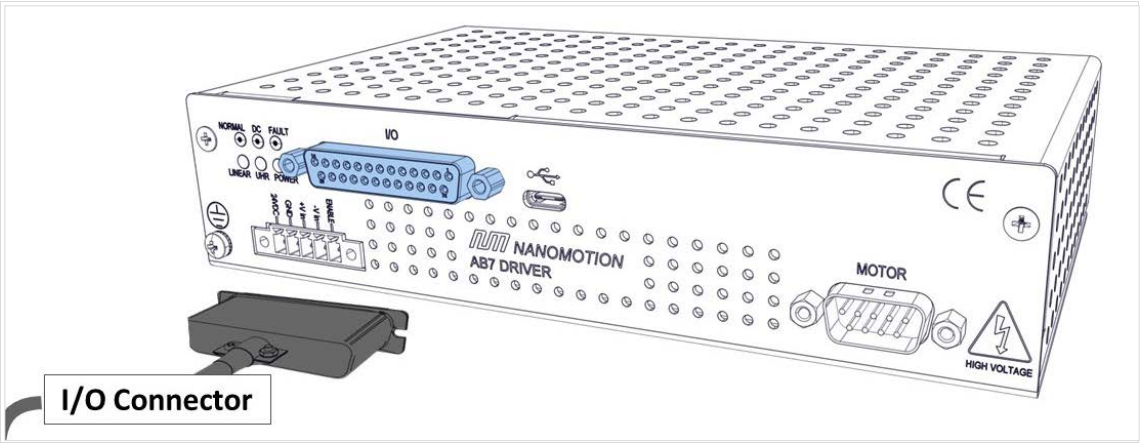

Figure 13: I/O connector

5.1.4. Motor Cable

NOTE: Nanomotion Ltd. guarantees proper driver and motor performance only when Nanomotion Ltd. standard cables are used.

- The Motor Connected interlock is available on the motor connector. It disables high voltage on the driver output connector when the motor is not connected.
- Nanomotion Ltd. provides a split cable use when the AB7 is required to drive more than one motor and extension cable.
- The total allowed maximum motor cable length (connecting the AB7 driver to the motor/s) is up to 10 meters for the HR\SE motors.

. **DANGER:** The safety warranty is valid only when cables manufactured by Nanomotion Ltd. or approved by Nanomotion Ltd. are used. (Refer to motor cables, split cables and extension cables).

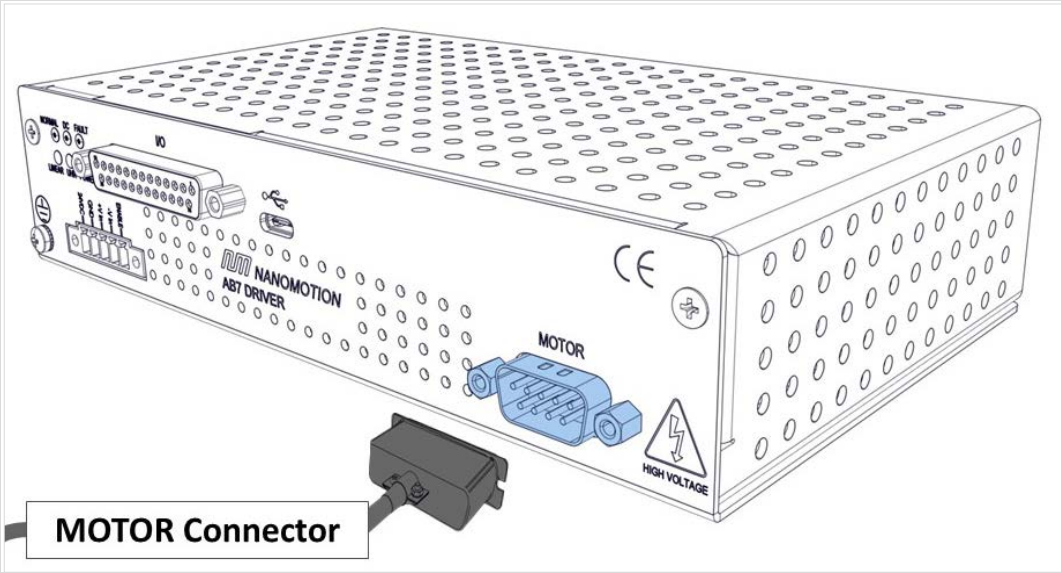

Figure 14: Motor cable

6. Operation

This chapter reviews operation instructions, modes and features and includes:

- Operation Prerequisites
- Operation Modes and Features

6.1. Operation Prerequisites

Before operating the AB7 Driver perform the following actions:

6.1-1 Verify that all motors are properly mounted and preloaded.

6.1-2 Connect all cables (See section 4.2. Electrical and Mechanical Interface) and lock connectors with mechanical screws.

6.1-3 Verify that the external power supply can supply the required power consumption (See section 8.1. Power Consumption).

6.1-4 Verify that no commands are active when turning power on.

DANGER: Do not assemble or disassemble I/O and motor cables when the power supply is on.

6.2. Operation Modes and Features

This section reviews operation modes and includes:

- Normal Mode
- Linear Mode (AB5)
- DC Mode (Position Mode)
- UHR Mode

6.2.1. Normal Mode

Normal mode is the standard operation mode for driving Nanomotion motors. It includes the following options:

- Velocity Voltage Transmission

Normal mode operates in the following way:

- The AB7 receives an analogue command input (±10V Suitable ±100%) from the customer's controller.
- The command is converted by the AB7 to PWM signals, with optimal frequency for motor mechanical resonance and duty cycle, according to command LUT.

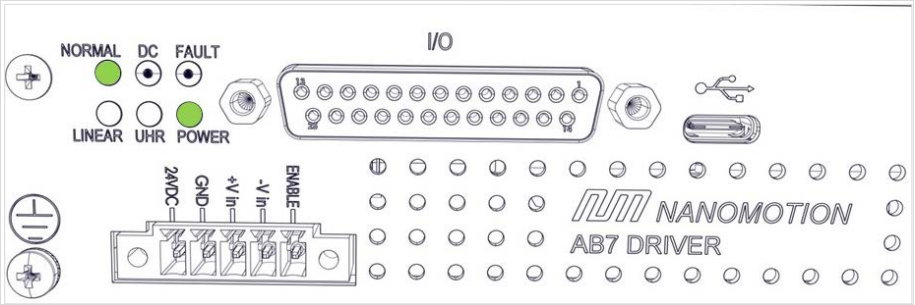

Figure 15: Normal mode LED indication

- The PWM signals are passed through the resonance gain unit and transferred to a sine wave signal.
- PWM Resolution is 11 bit.

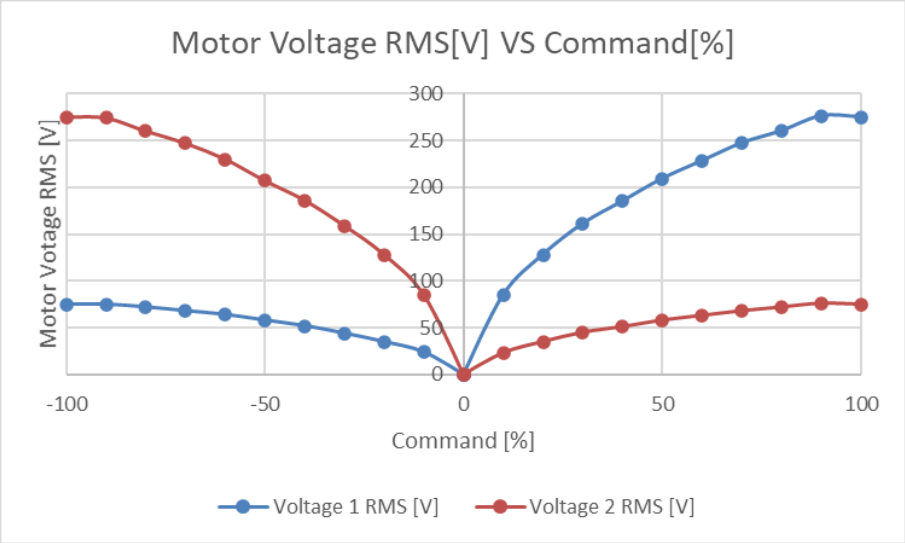

Figure 16: HR8 Motor Voltage vs Command AB7 Normal mode

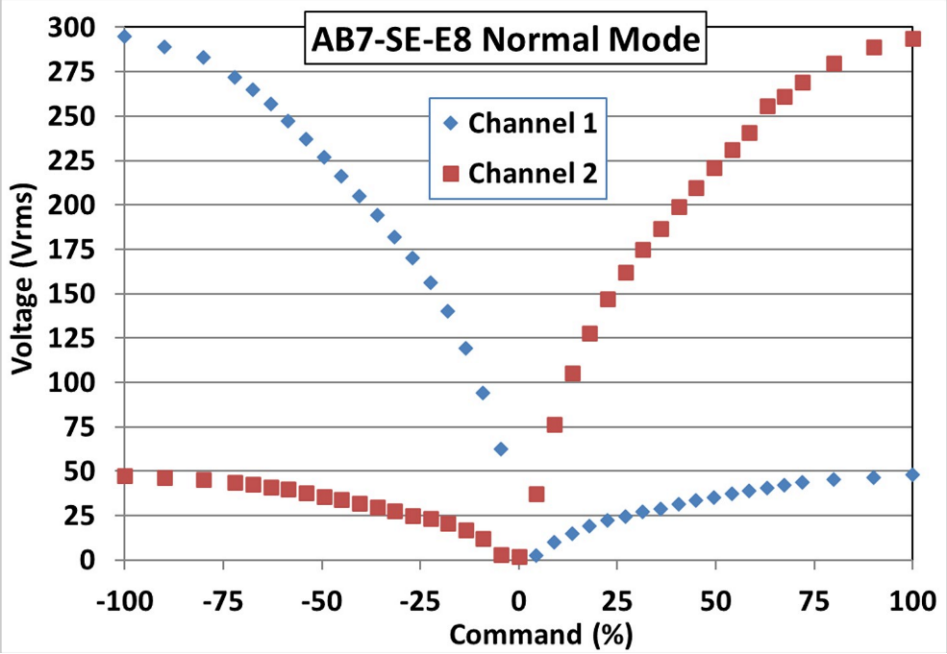

Figure 17: SE8 Motor Voltage vs Command AB7 Normal mode

6.2.1-1 Velocity Voltage Transmission

The Nanomotion motor's force transfer is based on friction applied on the motor's elements and the drive strip. This drive mechanism has many advantages, such as, high precision, zero backlash, inherent brake etc. However, it causes a control challenge at low command due to nonlinearity of velocity & motor voltage transmission (see Figure 16: HR8 Motor Voltage vs Command AB7 Normal mode), an effect known in Nanomotion user manuals, as the **Dead Zone** (see notes below).

NOTE: Dead zone range – The range within which the motor receives voltage but is still not moving.

Dead zone command - The minimal command that a motor needs to start moving.

The Dead zone is different in each system and in located at different places on the script.

6.2.2. Linear Mode (AB5)

The Linear mode is designed to eliminate the Dead zone and to facilitate a linear response from a 0 (zero) command level (see Figure 21: Motor Velocity vs. Command- Linear mode). This design allows for the driver's easy control using basic servo controllers.

Linear mode includes:

- Velocity Voltage Transmission
- Customize option
- Motor voltage frequency

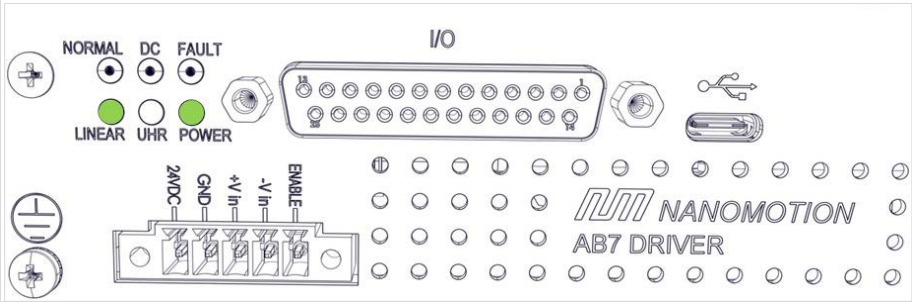

Figure 18: Linear mode LED indication

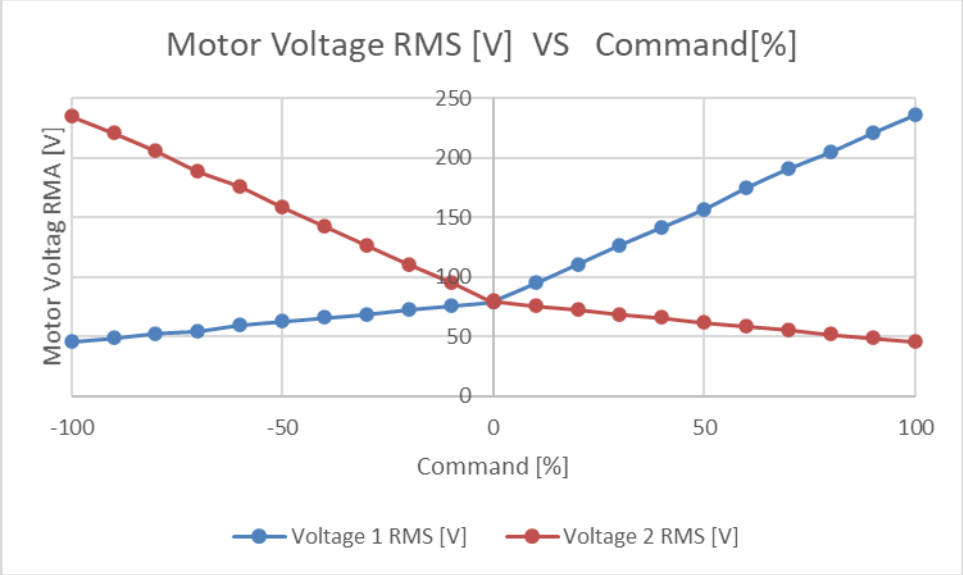

Figure 19: HR8 Motor Voltage vs Command AB7 Linear mode

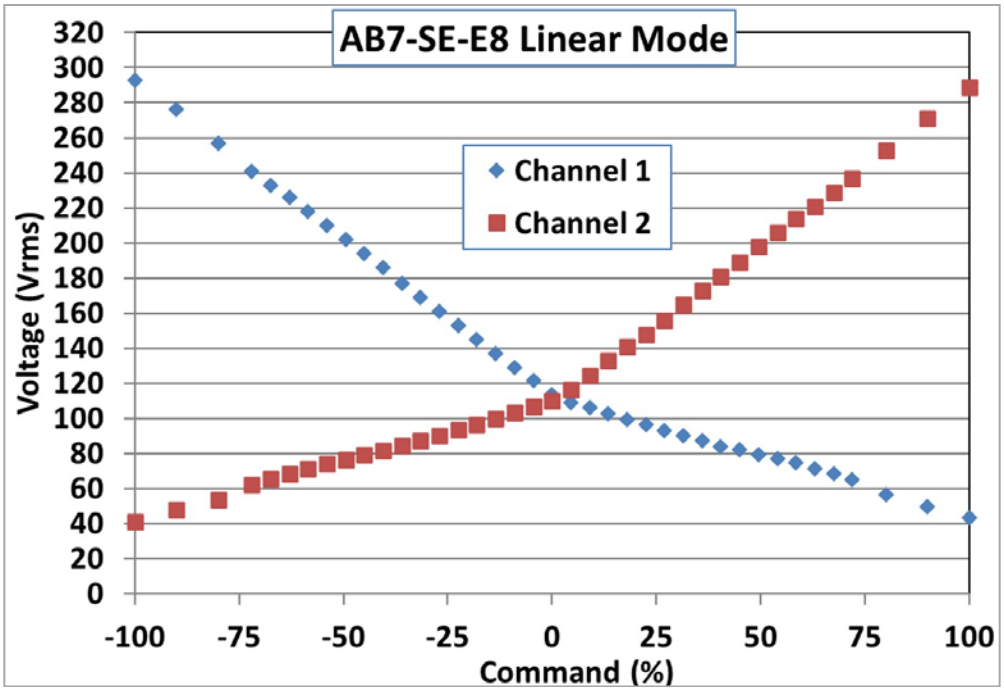

Figure 20: SE8 Motor Voltage vs Command AB7 Linear mode

6.2.2-1 Velocity Voltage Transmission

The linear response is achieved by the dual excitation of the motor's up/down direction. The difference between the excitations determines the direction and velocity of the motion. When the up and down directions are activated with equal excitation, the stage does not move resulting in reduced friction. By gradually increasing the difference between up and down excitations, the motor begins driving the stage smoothly and continuously. Increasing the difference will increase the velocity. Thus, a linear response is achieved with no apparent "Dead zone".

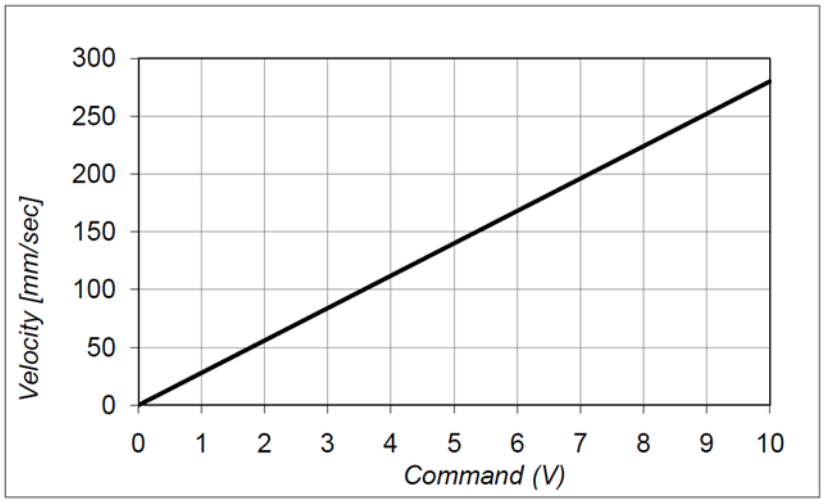

Figure 21: Motor Velocity vs. Command- Linear mode

6.2.2-2 Customize option

- Set offset - Linear mode includes the option to set the command offset Set Offset

6.2.2-3 Motor voltage frequency

- Motor voltage frequency is derived from the following equation:

$$f\_motor\ [kHz]=43.6-0.04\times command[\%]$$

6.2.3. DC Mode (Position Mode)

In DC mode the motor works as a piezo actuator, enabling accurate positioning of sub manometers. DC mode in AB7 is designed to improve DC mode resolution (when comparing to the AB2 Driver) by improving SNR on DC motor voltage. Motor voltage is a linear to command input however the DC generator has a natural offset of a few volts. This offset can be calibrated using the Set Offset . The typical full command voltage is in the region of 380V (±100% command suitable to ±380V). DC mode includes:

- Typical Use in DC Mode
- Motor voltage resolution

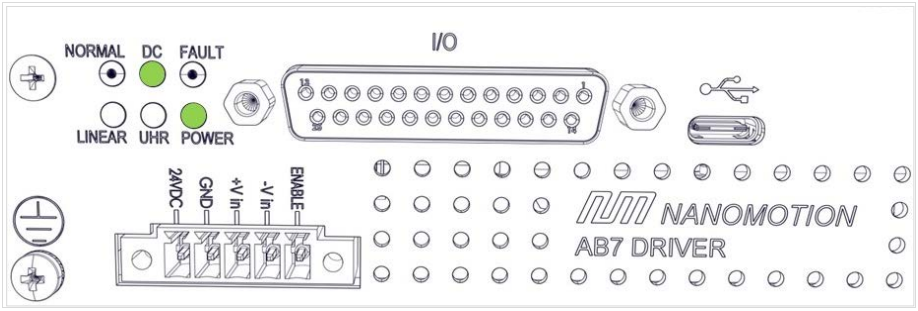

Figure 22: DC Mode LED Indication

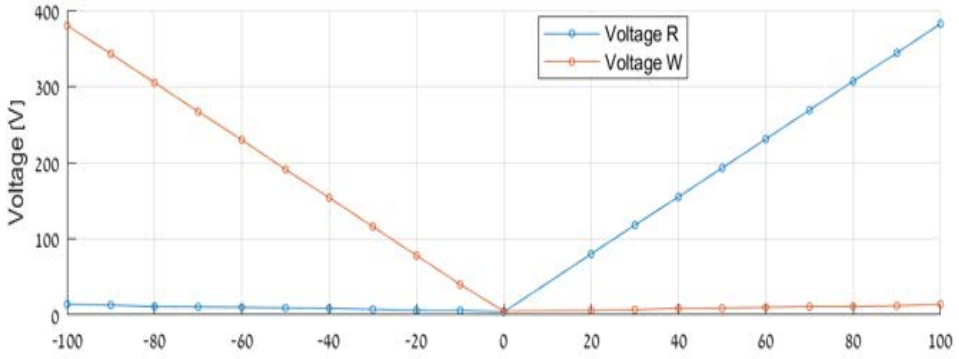

Figure 23: Motor Voltage vs Command AB7 DC mode

6.2.3-1 Typical Use in DC Mode

- Typical travel in DC mode is approximately ±300 nm and Convergence Ability is less than 1nm.
- For convergence in this resolution the driver starts operating in regular Velocity mode (Normal or Linear) and converges to a point that is acceptably close to the desired point (maximum distance less than available DC mode travel).
- After Velocity mode converts the servo switches from driver mode to DC Mode and the driver converts to point in Position mode (DC).
- The position is a linear function of the command voltage, with certain hysteresis. Some asymmetry is normal and expected (See Figure 24: Motor Voltage vs Command AB7 linear mode).

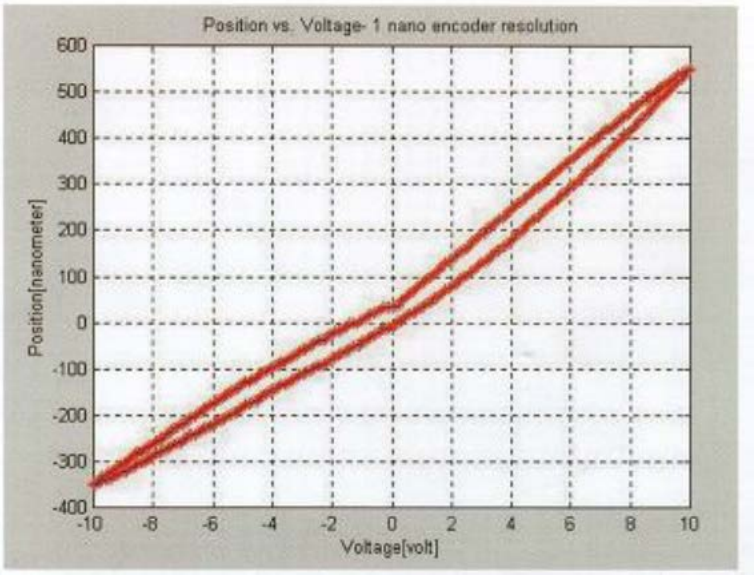

Figure 24: Motor Voltage vs Command AB7 linear mode

6.2.3-2 Motor voltage resolution

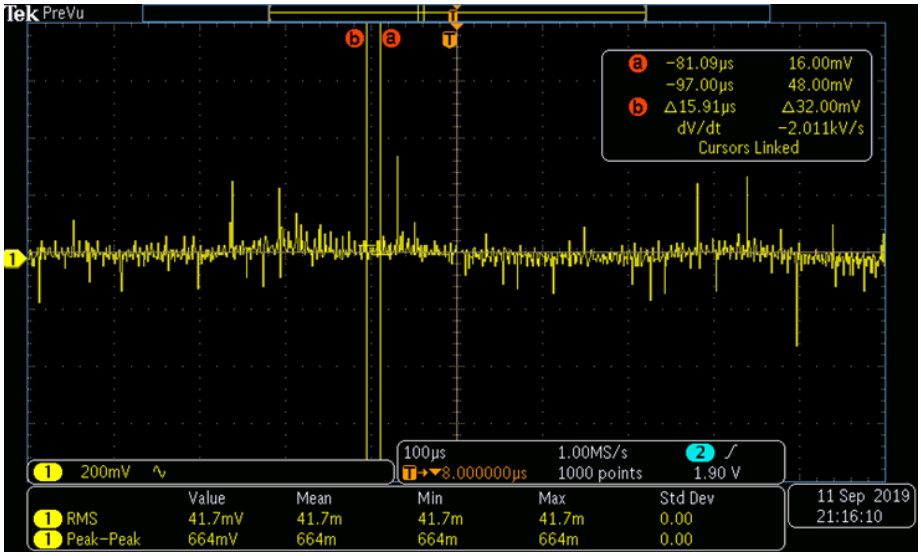

Figure 25: Motor voltage resolution: 1/8000 noise at full command

- Full command motor voltage: max 419V, typical 380V
- BW- Maximum 300Hz (limit by natural frequency)

6.2.4. UHR Mode

- Available in normal & linear modes.
- Command modulation- 1KHz ,10% D.C
- Enable – UHR pin I/O connector

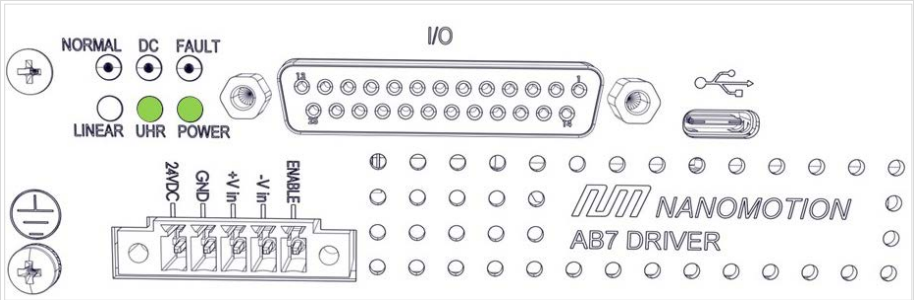

Figure 26: UHR mode LED indication

6.3. Driver Load

The Driver load has the following features:

- Up to 16 HR\SE elements
- Up to 32 HR\SE elements
- Multiple drivers can be connected on one axis to support a higher number of motors. In this case the controller monitors all driver fault signals. The Controller verifies that if one driver is in fault mode all drivers are disabled. There are two options:

o Option 1- Dedicated input in controller interface for all drivers

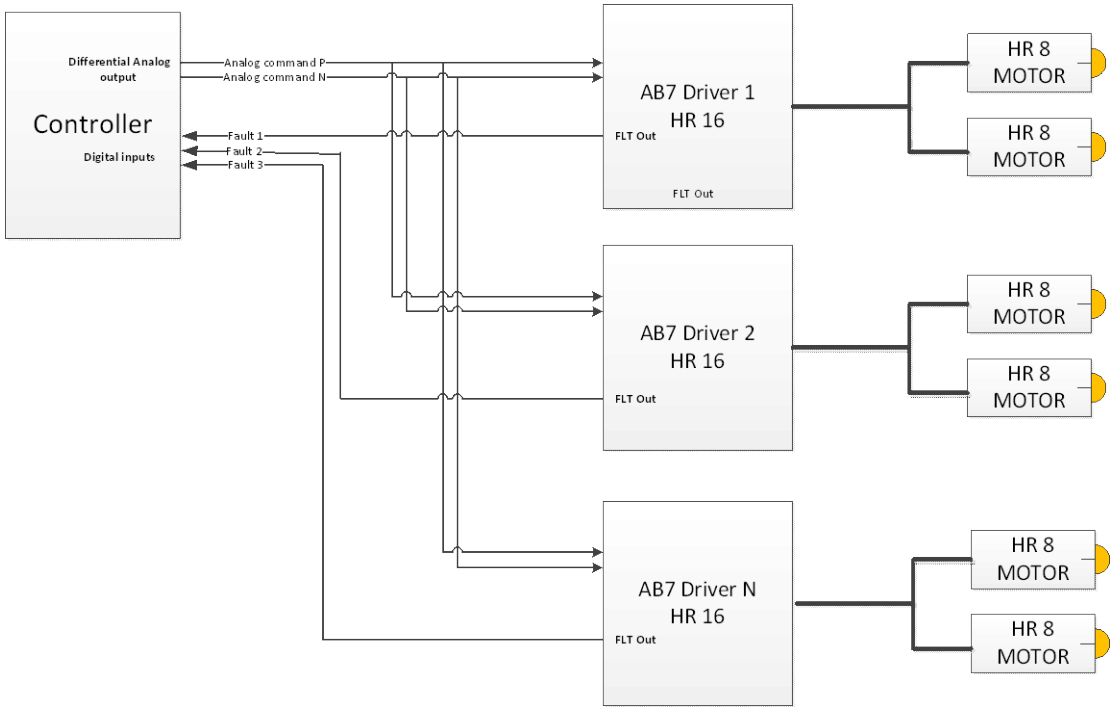

Figure 27: Interface for all drivers

- Option 2- Chain fault signals (see 7.2-1 Fault signals Daisy Chain mode)

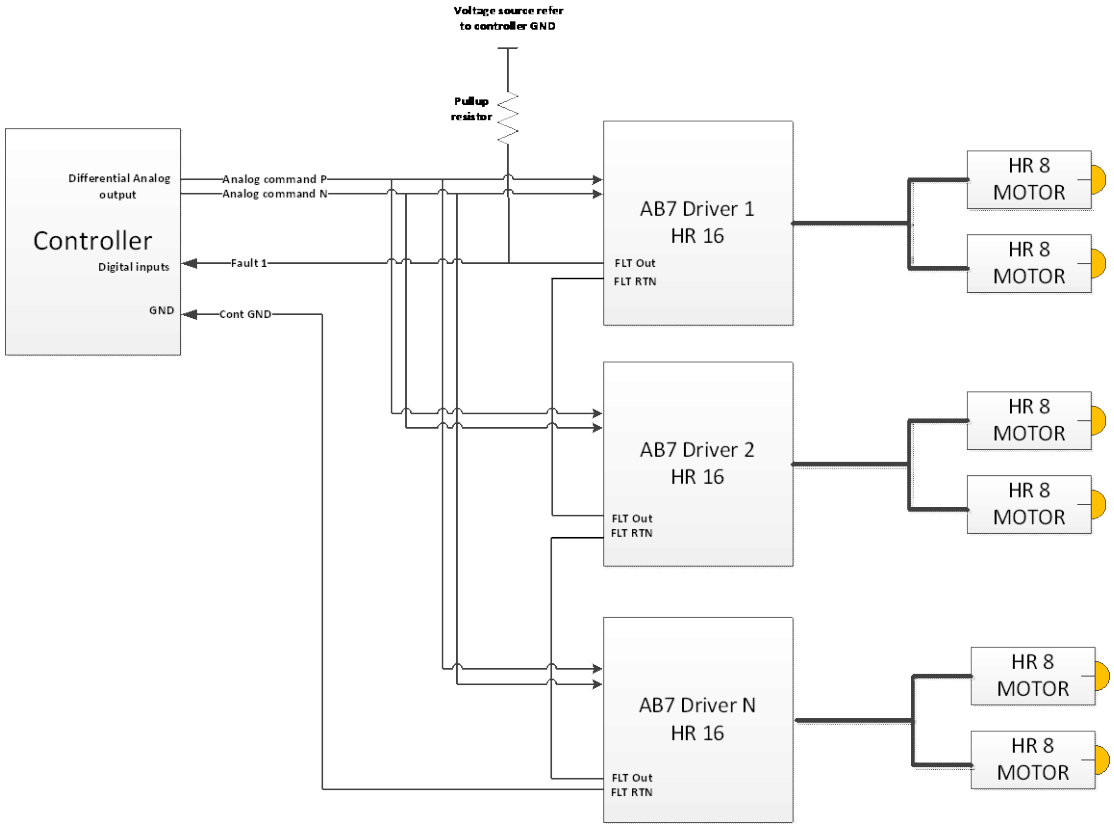

Figure 28: Chain fault signals

7. Troubleshooting

NOTE: Connect USB and GUI to check the nature of a fault using the AB07458001-00 SW User Manual.

Regarding all faults - contact the supplier.

7.1. Driver Faults

7.1-1 Fault indication:

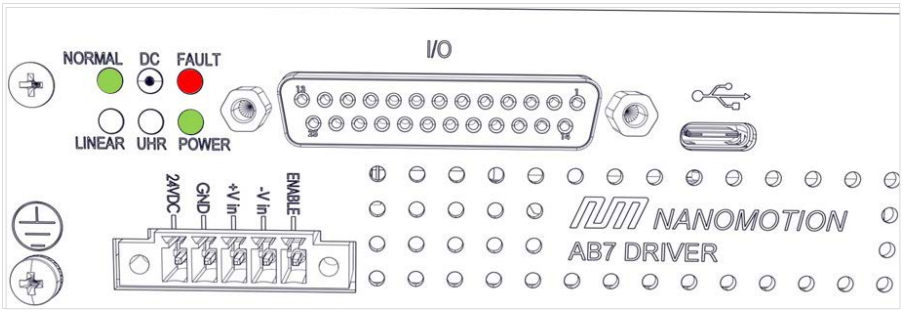

Figure 29: Fault indicator

- Indicated by red LED
- Fault line active (digital output)

7.1-2 Safety driver automated actions during the fault:

- Driver disables AC generator (high voltage)
- Driver disables DC generator (high voltage)
- Fault output (optocoupler) is active
- Fault number is sent to USB interface - (see AB07458001-00 SW User Manual)

7.1-3 Fault list

The fault can result from any of the following:

- Emergency stop active (Pin 12 I/O connector)
- Motor not connected
- DC generator error
- Overcurrent fault
- Voltage out of range ±10% (24V, 5V, 3.3V)

7.2. Clear Faults

- In order to clear the faults, disable and enable the driver (Pin 24).

7.2-1 Fault signals Daisy Chain mode

- Fault output signal is, by default, configured as a normal isolated digital output (see 8.1.1. Digital Opto-isolated Input / Output).
- In normal digital output mode, the opto-coupler emitter is shorted to driver GND, however the fault signal can be configured for daisy chain mode (as show in Figure 30: Chain mode – JP2 not connected).
- To Configure a single driver or daisy chain, configure (factory setting) jumper JP3 (see Figure 30: Chain mode – JP2 not connected).

7.2-2 Normal Digital output

- See section 7.2.1. Digital Opto-isolated Input / Output.

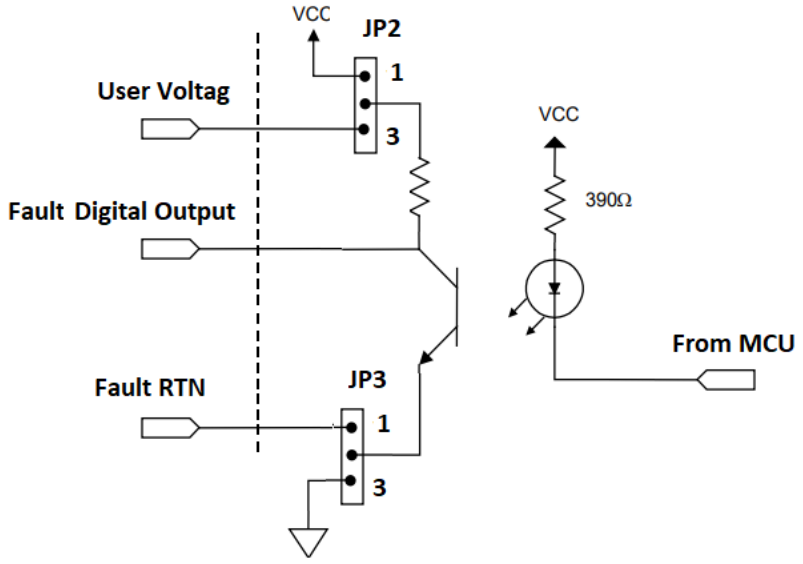

Figure 30: Chain mode – JP2 not connected

- In Chain mode, all AB7 drivers are configured as active high (not default configuration).
- In operation mode all opto-coupler transistors are active. The system has a closed current loop, and the controller reaches a low level.
- When one of drivers registers a fault, the current loop is cued, the controller reads a high level and disables all drivers.
- To set the external pullup, the resistor must take into account the customer's system.

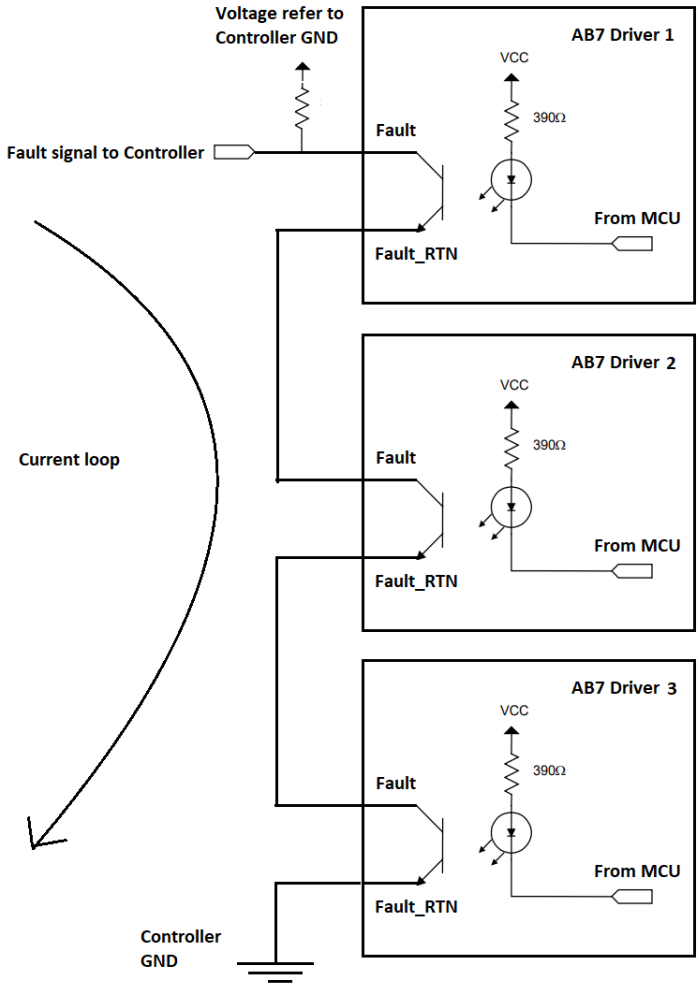

Figure 31: Chain mode – Current loop

8. System Specifications

8.1. Power Consumption

- The AB7 driver requires 24V ±5%. (See 4.2.1. Terminal Block Interface).
- Maximum current at full command.

Table 5: Power consumption

Number of elements	Current at full command HR motors	Current at full command SE motors
Motor disable	Up to 200mA	Up to 200mA
E1	1A	1A
E2	1A	1A
E4	1.5A	1.5A
E8	3A	3A
E16	6A	6A

8.1.1. Digital Opto-isolated Input / Output

- Active digital level - By default all digital signals are activated by shorting them to a ground.
- Optocoupler – Voltage Source Configuration. The digital signal goes through an opto-isolated circuit.

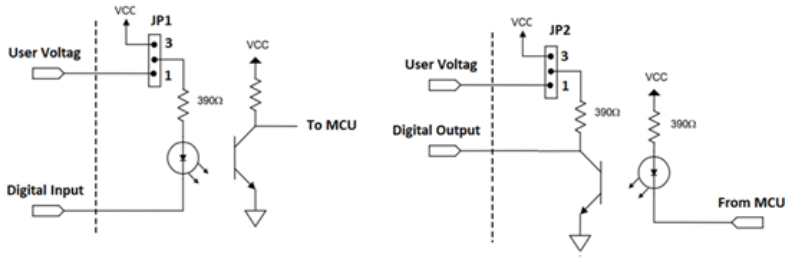

Figure 32: Opto-isolated circuit

- The voltage for the opto-isolated circuit is provided by either the internal +5V supply (default setting) or by an external voltage power supply via pin 20 on the I/O Connector.
- To configure internal or external voltage, configure the jumpers (factory setting) JP1(Input signals) and JP2 (output signals).
  - Pin 3 shorted to Pin 2 – Internal voltage
  - Pin 1 shorted to Pin 2 – External voltage

8.1.2. Mode Decision Table According to I/O Input

Refer to Table 6 for a detailed description of the mode decision table according to I/O input.

Table 6: Mode decision table according to I/O input

Enable (Pin 24)	DC_Mode (Pin 21)	Linear_Mode (Pin 20)	UHR_Mode (Pin 16)	Mode
N_Active	x	x	x	Disable
Active	N_Active	N_Active	N_Active	Normal
Active	Active	x	x	DC_Mode
Active	N_Active	Active	N_Active	Linear
Active	N_Active	N_Active	Active	Normal_UHR
Active	N_Active	Active	Active	Linear_UHR

8.2. Set Offset

8.2.1. Set Offset Description

- Set offset is a feature that allows an offset to be set to the command input.
- The main use of this feature is for 0% command calibration in linear mode to compensate for system asymmetry and to prevent Motor drift.
- This feature works the identically to the AB5 driver. However, this feature is also available in DC Mode and Normal Mode when relevant.

8.2.2. Setting Offset instructions

Perform the following steps to set offset instructions:

8.2.2-1 Set the required command as a zero-command level, to calibrate linear mode for 0% command motor drift.

8.2.2-2 Tune the command level until the motor stops moving.

8.2.2-3 While still applying the command level, activates pin 19 in I/O connector (this pin is active by default when shorted to ground).

8.2.2-4 Apply 0% command and verify the desired offset.

8.2.2-5 In cases where the 0% linear mode drift was calibrated, verify that the motor is not moving.

8.2.3. I/O Interface Compatibility With Other Drivers

The following table (Table 7) show detailed description of Interface compatibility with other drivers.

NOTE: The green cells represents the correlation with Nanomotion driver - Same pin has the same signal.

Table 7: I/O interface compatibility with other drivers

Pin	Signal Name AB7	Signal Name AB5	Signal Name AB2	Signal Name AB1
1	VIN+	VIN+	VIN+	VIN+
2	GND	GND	GND	GND
3	FAULT	FAULT	FAULT	FAULT
4	GND	GND	GND	GND
5	AI	SPI_Select (Not in use)	NC	NC
6	AO	Direction (Not in use)	DIRECTION (for factory use)	NC
7	Brake_On	SPI_Date (Not in use)	NC	NC
8	D/O-1	Acs_Int_Mode (Not in use)	GATE/INT_MODE	NC
9	GND	GND	GND	GND
10	Limit_LEFT	Set_Com_1 (Not in use)	Limit_LEFT	Limit_LEFT
11	NC	JOY_-10V	JOY_-12V	JOY_-12V
12	EMERGENCY_STOP	EMERGENCY_STOP	EMERGENCY_STOP	EMERGENCY_STOP
13	USER VOLTAGE	USER VOLTAGE	USER VOLTAGE	USER VOLTAGE
14	VIN-	VIN-	VIN-	VIN-
15	FAULT_RTN	GND	GND	GND
16	UHR_MODE	Step_Mode	STEP_IN/GATE	STEP_IN
17	RESET	Brake_On	RESET	RESET
18	NC	SPI_Clock (Not in use)	NC	NC
19	SET_OFFSET	ABS_Set_Offset	NC	NC
20	Linear Mode	Enable_Sign_In	NC	NC
21	DC Mode	NC	DC_MODE	GATE_MOD
22	Limit_RIGHT	Set_Com_2(Not in use)	Limit_RIGHT	Limit_RIGHT
23	NC	JOY_+10V	JOY_+12V	JOY_+12V
24	ENABLE	ENABLE	ENABLE	ENABLE
25	NC	NC	SV	SV

8.3. EOP - Envelope of Performance (Thermal Protection)

8.3.1. Description

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

- Heat generation depends on the motor's work regime (driver command level).
- Heat is dissipated through the following heat transfer mechanisms: conduction, radiation, and convection (the convection mechanism is negligible in a vacuum environment) (See Figure 33).

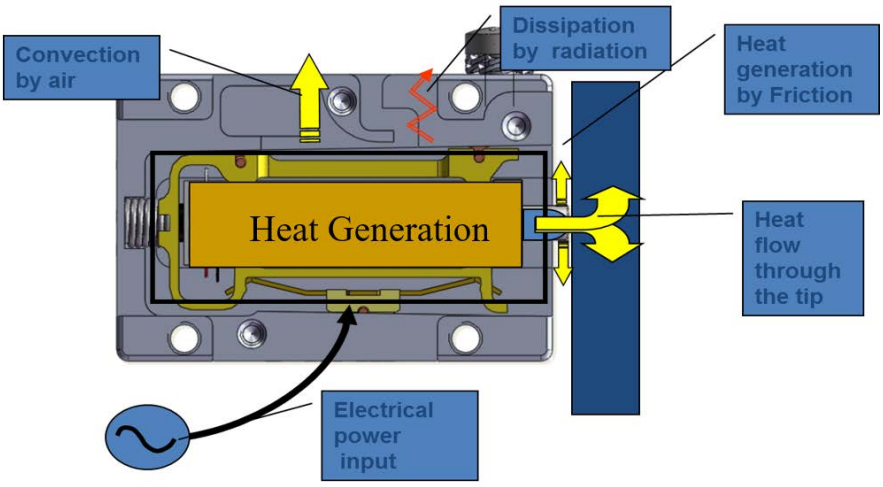

Figure 33: Heat Dissipation

- Heat dissipation mechanisms dissipate heat generated to avoid overheating.
- The EOP enables the assessment of the permitted operating conditions (for setting ambient temperature and command, identifying the duty cycle and maximum continuous operation to ensure safe operation).
- The motor can either be operated for an extended period of time at a specific duty cycle or alternatively, for a continuous time period specified under **Maximal Continuous Operation** Time (see Table 8: EOP table for HR motors driven by AB7 Normal mode). After the continuous operation period completes, the driver must be disabled for 400 sec in air and for 700 sec in vacuum environment to allow the motor to cool.

8.3.2. EOP for HR Motors at Normal Mode (AB1)

Motor velocity acts as a function of the applied driver command voltage at normal mode, allowing up to 30 mm/sec variations, (See Figure 34). This should be used as a reference and as a guideline for expected motor performance.

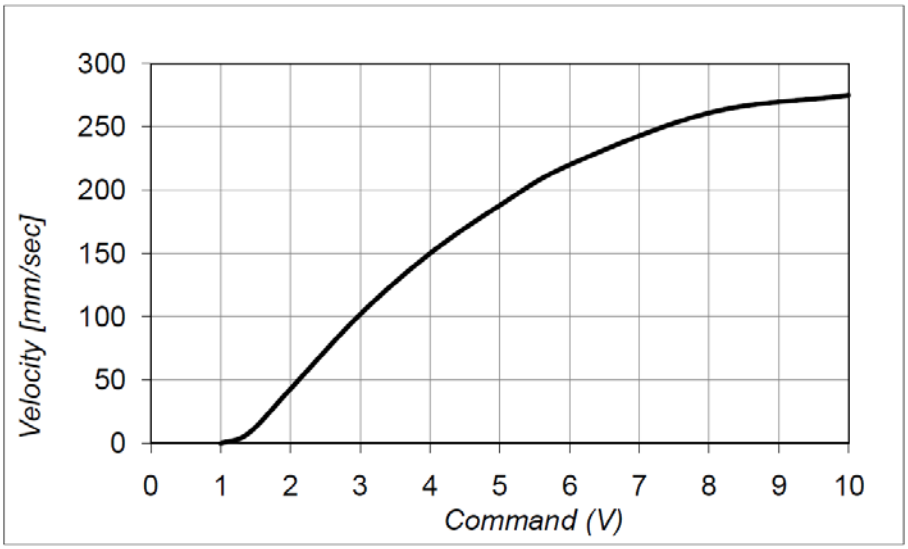

Figure 34: Motor Velocity vs. Command- Normal mode

- Determine the correct performance envelope in normal mode to avoid overheating and damage to the HR motor (See Figure 35 and Table 8).

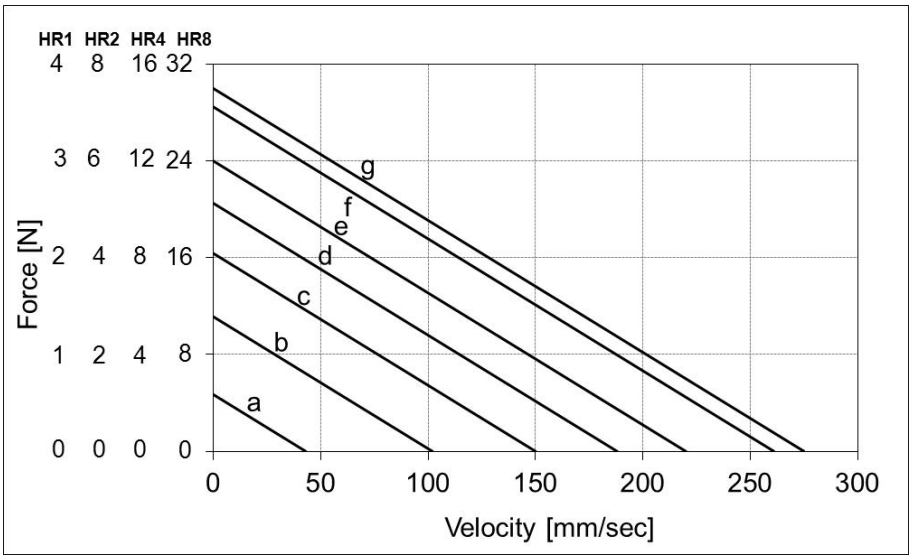

Figure 35: Motor Force vs. Velocity at the Various Work Regimes (a-g) normal mode

Table 8: EOP table for HR motors driven by AB7 Normal mode

Curve	Air 25°C		Air 50°C		Vacuum	
	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

8.3.3. EOP for HR Motors at Linear Mode (AB5)

- The AB7 driver linear mode is preferable to achieve perfect servo tracking and/or very low ripple constant velocity. The Linear mode's unique features result in the motor consuming more power and in a lower EOP, compared to the EOP for a motor operating in normal mode.
- Motor velocity as a function of the applied AB7 at linear mode driver command voltage (See Figure 36). This allows for up to 300 mm/sec variations and can be used as a reference and guideline for expected motor performance.

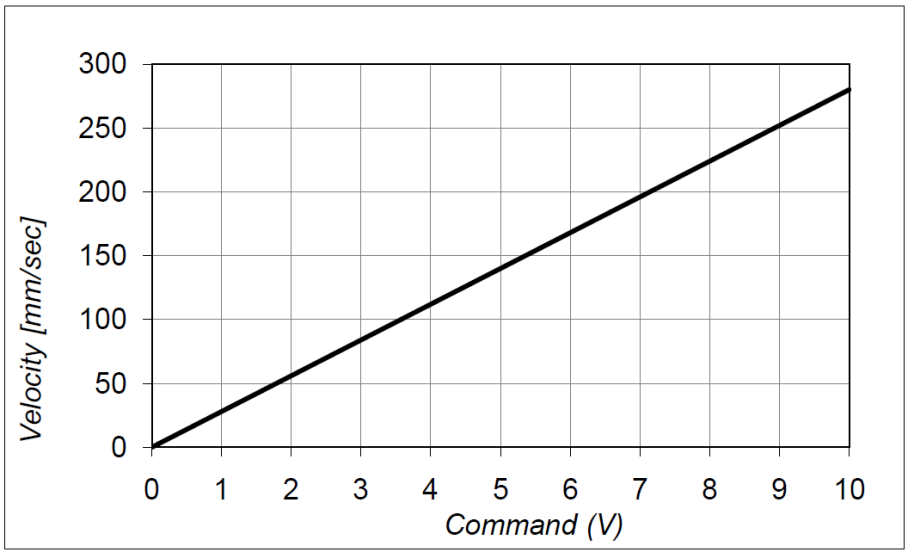

Figure 36: Motor Velocity vs. Command- Linear mode

- Determine the correct envelope of performance in Linear mode to avoid overheating and damaging the motor (See Figure 37 and Table 9).

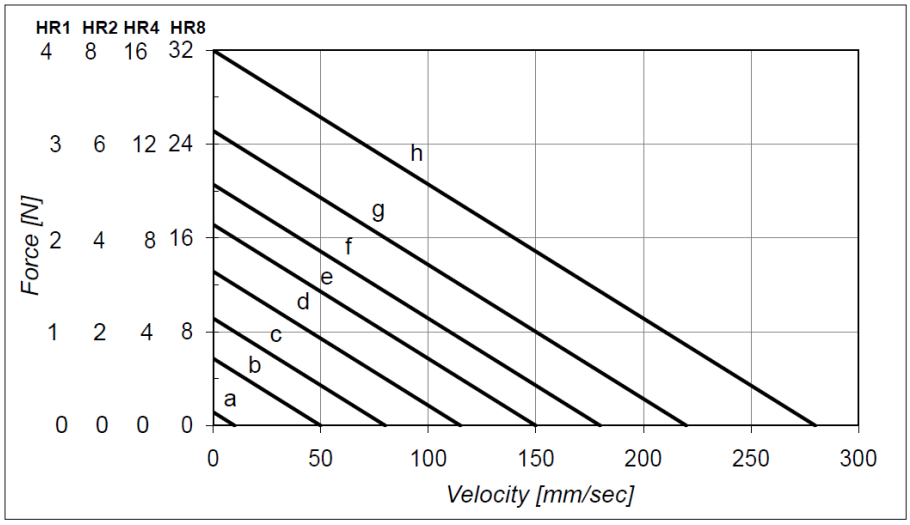

Figure 37: Motor Force vs. Velocity at the various work regimes linear mode (a-g)

Table 9: EOP table for HR motors driven by AB7 Normal mode

Curve	Air 25°C			Vacuum	
	Duty Cycle Brake_Off (%)	Duty Cycle Brake_On (%)	Continuos Operation (sec)	Duty Cycle Brake_On (%)	Continuous Operation (sec)
"0"÷a	100	100	∞	56	500
b	100	100	∞	54	450
c	100	100	∞	457	280
d	100	100	∞	33	170
e	100	100	∞	23	100
f	53	58	170	12	66
g	33	48	77	10	44
h	17	28	32	6.5	25

CAUTION: Working under the correct EOP is necessary for minimizing motor damages and for a long-life time.

8.4. Analog Board

8.4.1. Analog Command Input Interface

Table 10: Analog command input interface

Input range	±10V differential (Pin 1 +, Pin 14-). In case controller supply single ended analog command short Pin 14 to driver GND.
Input impedance	100kΩ
Input filter	4kHz cutoff
Command resolution	14bit
Sample rate	20ksps

NOTE: The terminal block includes fast connection for analog command (Pin3 & Pin4) and enable input (Pin 5). For achieving the best quality commands and quieter radiated emission, EMI is recommended to connect those signals to the I/O connector.

8.5. Environment

- Operation - 0°C to 50°C unforced air cooling, no humidity.
- Storage - 40°C to 70 °C

9. Appendix A: Drawings

9.1. Mechanical Interface Drawings

- ICD- AB7 dimensions (mm), see AB7 ICD DN: AB07129000

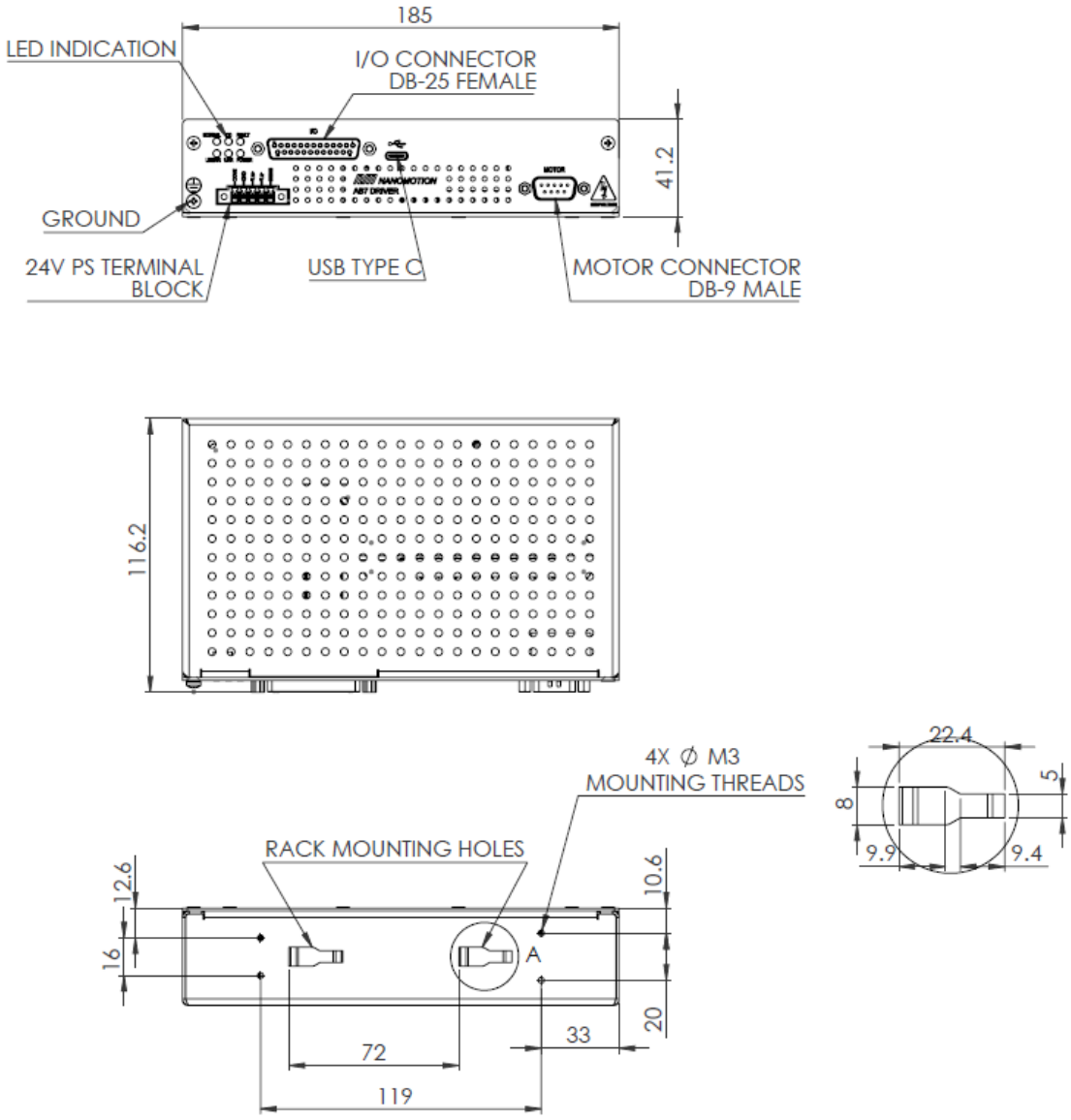

Figure 38: Mechanical Interface