NANOMOTION

A Johnson Electric Company

AB4 Driver
User Manual

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5,453,653; 5,616,980; 5,714,833; 111597; 5,640,063; 6,247,338; 6,244,076; 6,747,391; 6,661,153; 69838991.3; 6,384,515; 7,119,477; 7,075,211; 69932359.5;1186063; 7,211,929; 69941195.5; 1577961; 4813708; 6,879,085; 6,979,936; 7,439,652; 7061158 ;1800356; 1800356; 1800356; 2007-533057 (pending); 2011-093431 (pending); 7,876,509; 10-2007-7009928 (pending); 200780019448.6 ; 7713361.9 (pending); 12/294,926 (pending); GB2008000004178 (pending); GB2009000003796 (pending); 12/398,216 (pending); GB2446428; 12/517,261 (pending); 08702695.1 (pending); 10-2009-7017629 (pending); 12/524,164 (pending); 12/581,194 (pending)

Revision History

ECO	Revision	Release date	Details
NA	NA	Aug. 2012	Administrative change – added patent information section in front matter.

CE Compliance

This product was tested for Electrical Safety and Electromagnetic Compatibility.
It conforms with EMC Directive 89/336/EEC, Article 7(1), with FCC 47 CFR part 15 subpart B, and with LV directive 73/23/EC, Article 5 and satisfies the requirements of the following standards:

EN 61800-3:1996 + A11: 2000 for second environment.
EN 61000-3-2:2000, EN 61000-3-3:1995 + A1: 2001.
FCC 47 CFR: 2002 part 15, subpart B, class A.
EN 61010 – 1:2001.

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List of Abbreviations

A	Ampere
AC	Alternating Current
DC	Direct Current
LED	Light Emitting Diode
LSB	Least Significant Bit
mA	Milliampere
MSB	Most Significant Bit
mW	Milliwatt
SPI	Serial Peripheral Interface
TTL	Transistor-Transistor Logic
Vrms	Volts Root Mean Square

1 AB4 Description

1.1 General

The AB4 is a single axis 12V amplifier box designed to drive up to 4 Nanomotion motor elements. The motor types currently driven by the AB4 are HR and ST.

1.2 Main Features

- High precision (11-bit) control of the power output stage
- Drives either a single HR4 or ST motors; up to two HR2s, four HR1s.
- Step/Gate modes of operation, enabling low velocity in open loop.
- Interface with an analog controller
- Interface with a digital controller
- Interface with a joystick
- Discrete inputs enable feedback from external sources such as limit switches, emergency stop command, etc.
- LED indicators.
- Protected from Over Current, Over Voltage and No Load condition
- Minimized sensitivity to cable length – up to 20 Meters
- Compact dimensions
- Low Pass Filter 2.7 kHz

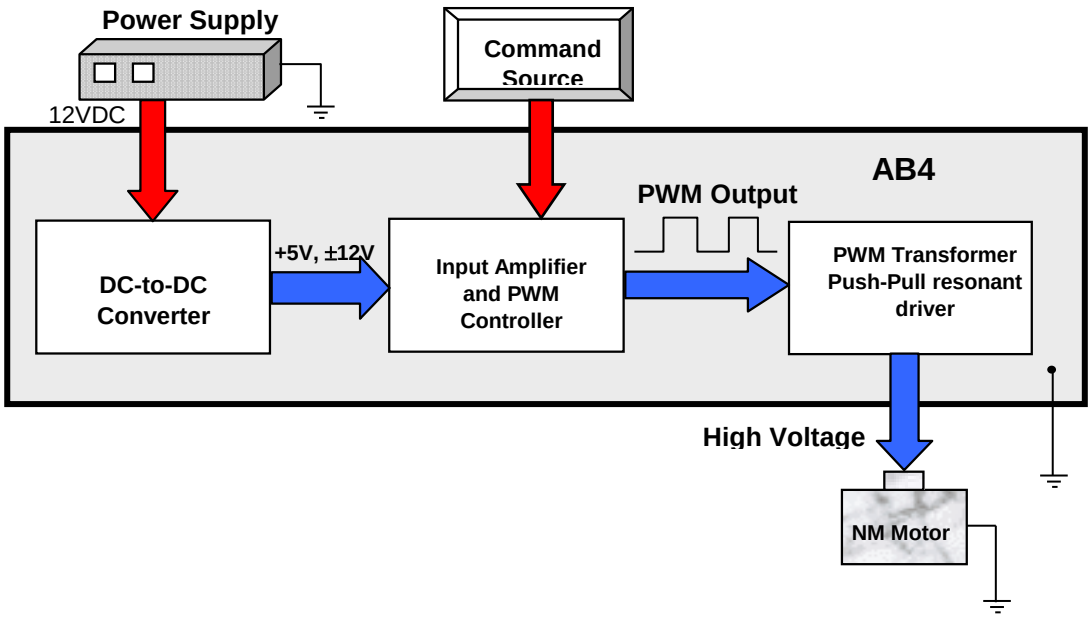
1.3 Operating Principles

The AB4 Box consists of a single card (command source) that converts the input command signal into a corresponding PWM output signal. In this mode the output transformer-amplifier circuit converts the PWM output signal into a sine wave high voltage that drives the motor. The PWM controller is power-fed from an internal DC-to-DC converter that is fed from an external +12V power supply.

The AB4Card (see Figure 1) consists of DC/DC converters that provide the voltages necessary to operate the amplifier circuit: +5V, ±12V. In addition, the card contains two indicators LED's and the external interface connectors for the CONTROL, MOTOR, and I/O signals.

Figure 1 illustrates a typical application of the AB4 Driver Box.

Figure 1: AB4 Block Diagram



This square wave from the PWM Controller is filtered through the serial inductance circuit and fed to the push-pull transformer circuit to produce a sine-wave high output voltage on the secondary coil of the transformer. The secondary coil and the motor capacitance serve as the LC resonance circuit.

The motor is a three-terminal component: “UP”, “DOWN” and “COMMON.” The voltage applied between the “UP” and “COMMON” terminals causes the motor to move in one direction; while voltage applied between the “DOWN” and “COMMON” terminals causes the motor to move in the opposite direction.

Figure 2 is a schematic drawing of the power output.

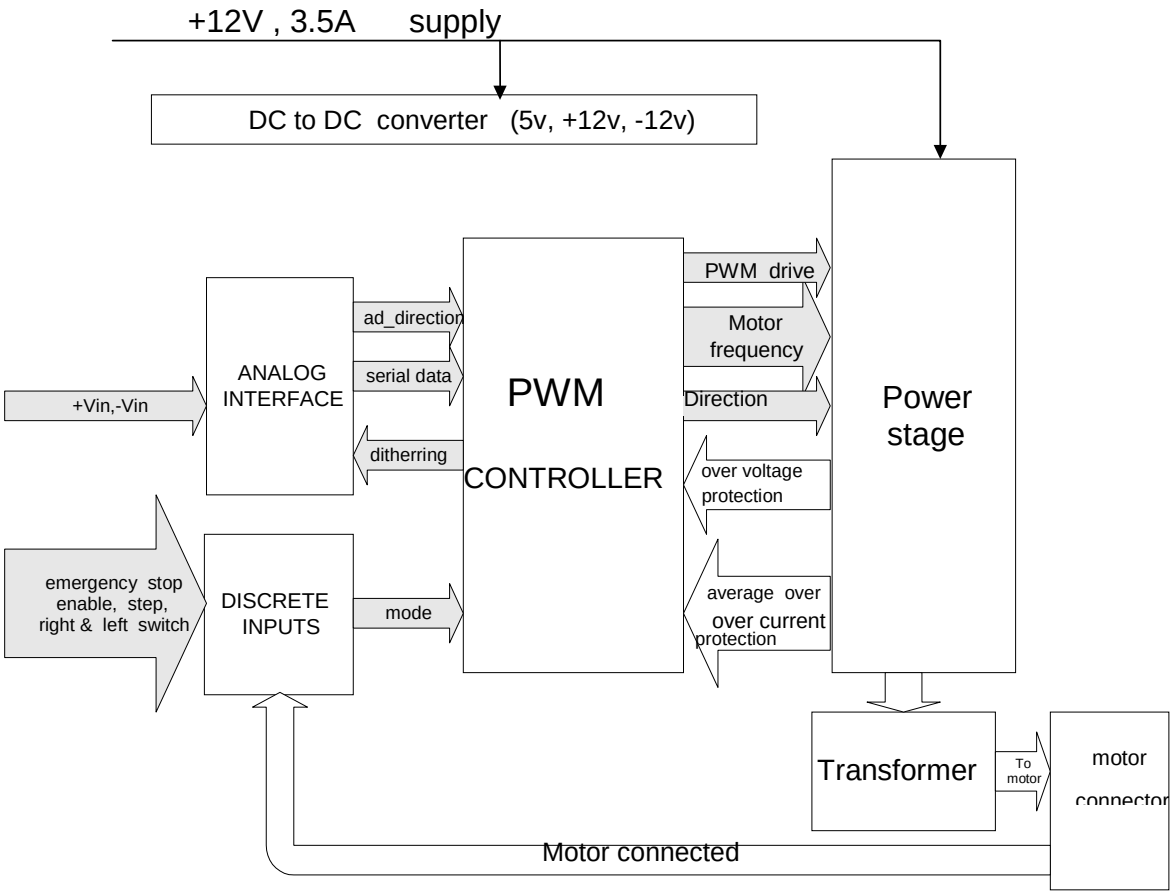


Figure 2: Schematic Diagram of the Output Stage in a Single Motor Configuration

1.4 Operation Modes

The AB4 can be operated in one of the following operation modes:

- **Velocity Mode**, in which the motor is driven continuously.
- **Step Mode**, in which the driver output is turned OFF and ON at predefined intervals, in order to drive the motor in discrete steps.
- **Gate Mode**, in which the motor is driven at low velocity by turning the driver output ON and OFF in time intervals defined by outside TTL signal in an open loop.

1.4.1 Velocity Mode Operation

In this operation mode, the motor is driven continuously by applying the analog command voltage (± 10 V) using a relevant interface device (joystick or motion controller).

1.4.2 Step Mode operation

In this operation mode the motor is turned on and off for fixed time intervals defined in the hardware as follows:

- ON phase - 1/16 second
- OFF phase - 0.5 second

The amplitude of the output corresponds to the analog command input value and thus determines the speed of the motor.

1.4.2.1Enabling the Step Mode

Enable the Step operation mode, by shorting pin 15 (see Table 7 to the ground..

1.4.3 Gate Mode Operation

In this operation mode the motor is driven at low velocity in open loop by turning the driver output ON and OFF in time intervals defined by an external switching signal.

The amplitude of the output corresponds to the analog command input value and thus determines the speed of the motor.

In Gate Mode, as opposed to Step Mode the pulse width and pulse frequency are user-defined.

The allowable parameter values for the external switching signal are as follows:

- Voltage level: 0V(on); 5V(off). Open collector logic is also optional.
- Minimum pulse width: 50 µsec
- Maximum pulse frequency : 1 kHz.

1.4.3.1Enabling the Gate Mode

Enable the Gate mode of operation by shorting pin 8 (see Table 5) to the ground. Verify that pin 15 is not shorted to the ground at the same time. Once pin 8 is shorted, the driver is in Gate Mode. The external signal should now be conducted through pin 15.

2 Connections and I/O Settings

2.1 Front Panel Description

The AB4 front panel (see Figure 3) contains the following connectors and indicators:

- Control Terminal
- Motor Output Port
- Enable Indicator
- Fault Indicator
- Ground Screw

Figure 3: AB4 Driver Box Front Panel

2.1.1 Front Panel Connectors

Connector	Description
Control terminal	5-pin connector – Provides input from an external +12VDC power supply (3.5A maximum). Provides direct control of the motor ENABLE signal. **Note:** The motor may be operated with minimum control signals applied to the Control Terminal: +12V,GND POWER, VIN+, VIN-, ENABLE_IN. The primary voltage (+12V) is supplied from an external source.
Motor Out	D-type 9-pin connector male -Interfaces to the motor.

2.1.2 Front Panel LED Indicators

	Power supply on	Motor connected	Motor connected and Driver enabled	Motor disconnected and driver enabled	Fault
ENABLE	Off	Off	Green	Green	Off
FAULT	Red	Off	Off	Red	Red

2.2 Input/Output Port

The Input/Output Port of the AB4 Driver Box is a 26 pin header located on the rear panel as shown in Figure 4. Mating connector is CA21-26SA100 and CA21-26SR100 by Cvilux, or compatible.
For the I/O port Pin Out description, please refer to Table 7.

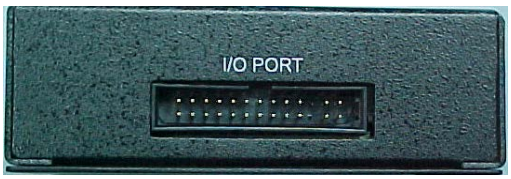


Figure 4: I/O Connector on Rear Panel

2.3 Motion Control Interfaces

The AB4 Driver Box can receive the input signals either from a motion controller or from a joystick. The schematic diagrams of the motion controllers and joystick connections to the AB4 Driver Box are provided in following sections.

2.3.1 Analog Controller Connection

There are two options of an analog connection of a motion controller to the AB4 Driver Box:

- Differential connection (see Figure 5)
- Single-Ended Connection (see Figure 6)

The differential connection enhances noise immunity.

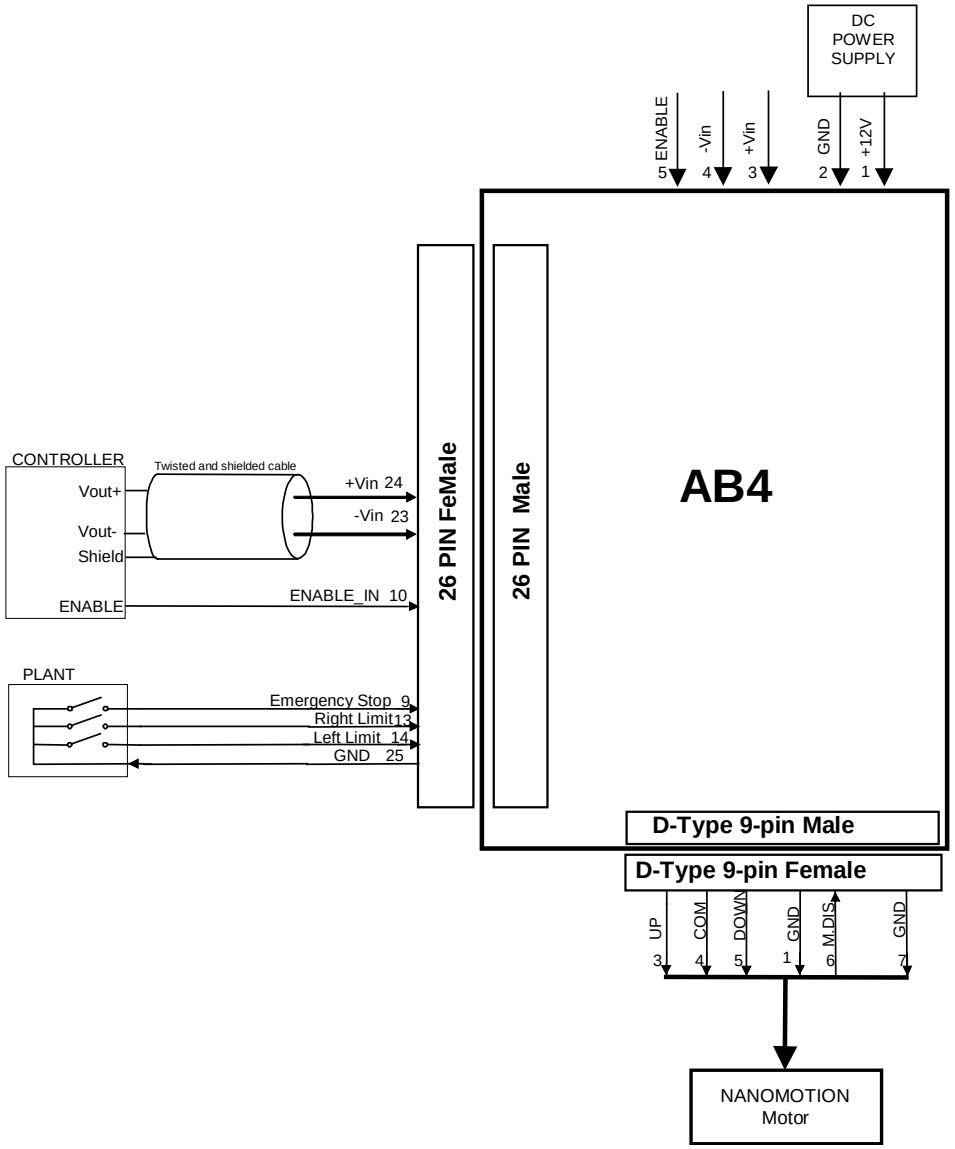


Figure 5: Differential Analog Input Connection

The other option of an analog controller connection is the single-ended connection.

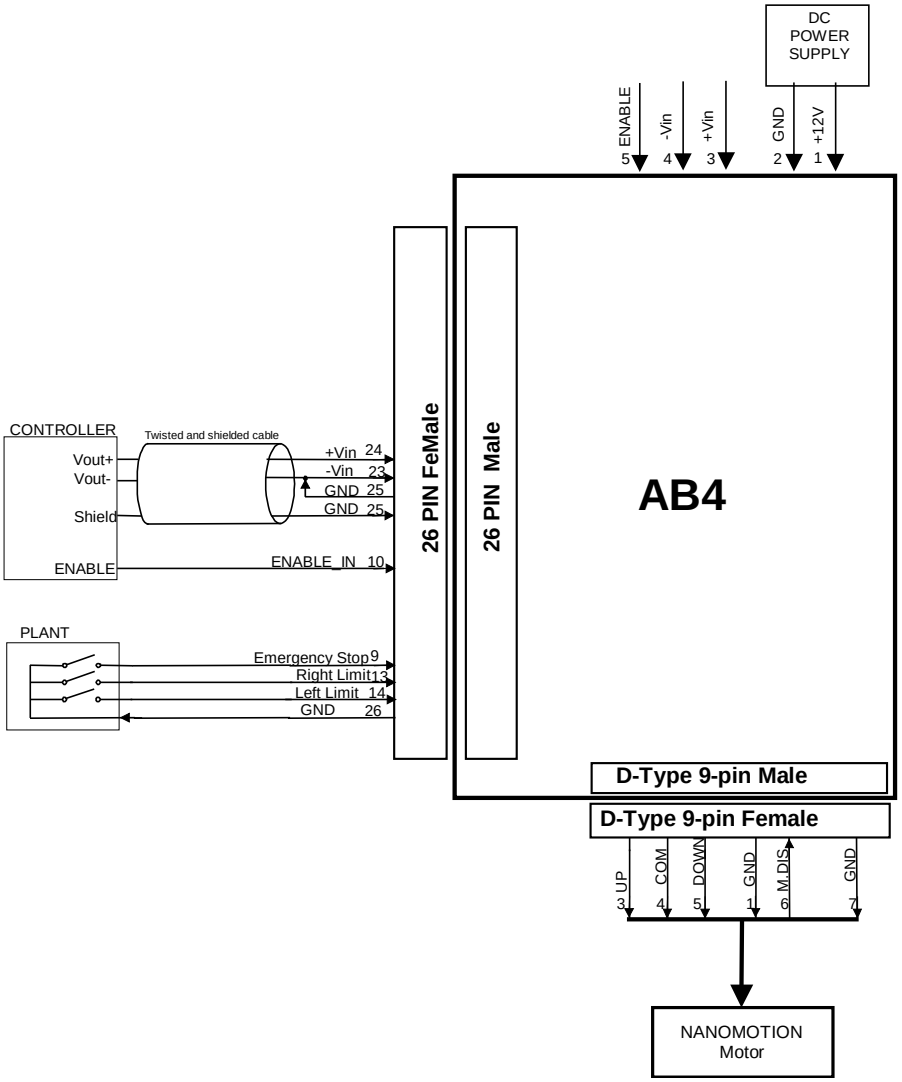


Figure 6: Non-Differential (single-ended) Analog Input Connection.

2.3.2 Digital Controller Connection

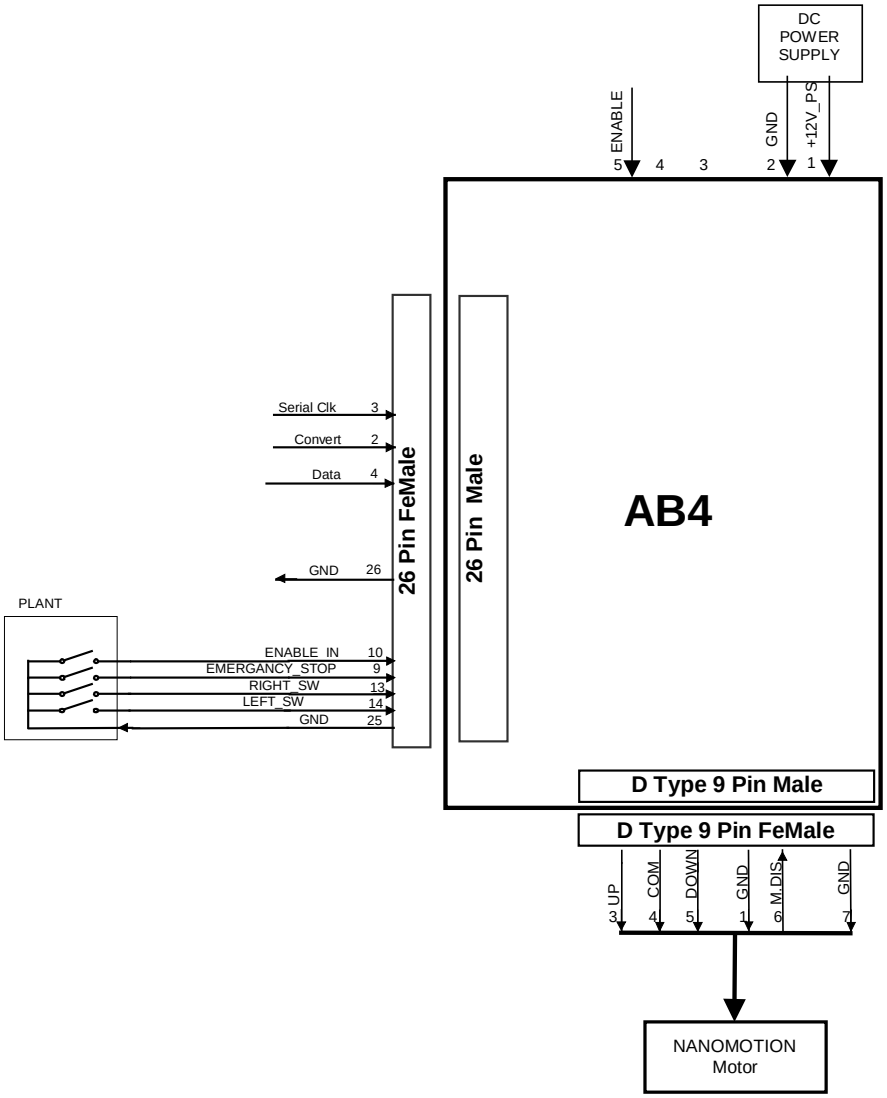


Figure 7: Digital Controller Connection

For further details regarding the SPI protocol, please refer to Appendix 1.

2.3.3 Joystick Connection

Using the joystick for supplying the command voltage to the AB4 Driver Box allows the user to manually drive the motor without using a motion controller.

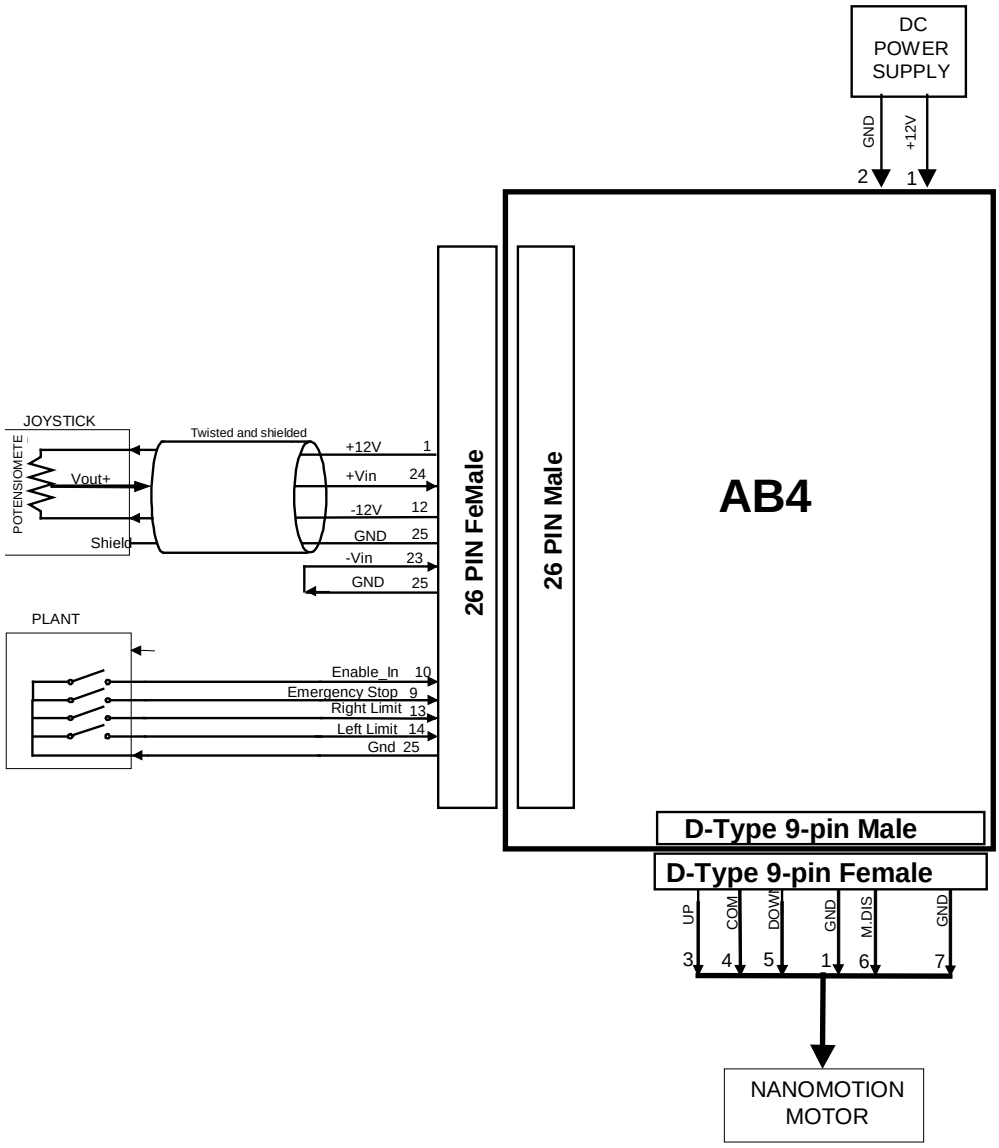


Figure 8: Joystick Connection

2.4 Cable Connections

Connect the following groups of cables together, isolating each of the signals:

- POWER SUPPLIES – use 22 AWG (or lower AWG) wires for the power supplies. For noisy surroundings, it is recommended to twist the ground line and the power line together.
- ANALOG COMMAND – a twisted shielded cable is recommended.
- DISCRETE INPUTS – These signals are not sensitive to noise and can be grouped together in the same harness with any of the other groups.

2.4.1 Shielding

Since the high motor voltage is induced on the cable shield, it is required to ground the shield on both sides. Both the driver box and the motor should be grounded to the infrastructure earth.

2.5 Motor Connections

The “Motor Disconnect” signal is available only at the motor connector, where it is shorted to ground (see Table 6). This ensures that unprotected motor pins will not be exposed to high voltage when the motor is not connected.

If more than one motor is connected to the AB4 Driver Box, use a suitable branch cable.

If the motor type or the number of motor elements is changed, consult Nanomotion for the appropriate driver configuration changes that may be required.

2.5.1 Motor Cable Length

The maximum allowed total cable length connecting the AB4 to the motor(s) is 20 meters in the HR types and 10 meters in the ST.

NOTE: ***Use Nanomotion standard cables. Branching is possible to two and four identical motors. Branch cables must be of identical length, the sum of which not exceeding the allowed total cable length.***

NOTE: ***Nanomotion can guarantee proper driver and motor performance only if Nanomotion standard cables are used.***

2.6 Opto-isolated Inputs

The following inputs are opto-isolated and are activated by shorting them to ground:

- Powering
  - **Emergency Stop (ES).** Disables the AB4 output (see Table 7).
  - **Enable**. Should be activated before the motor can be run (see Table 7).
- Mode Enabling
  - **Step in**. Enables Step/Gate Mode operation (see Table 7).
- Direction Restrictions
  - **Left Limit.** Disables the motor motion to the left (see Table 7).
  - **Right Limit.** Disables the motor motion to the right (see Table 7).

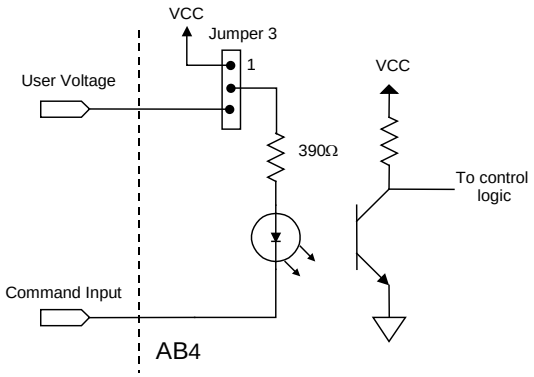


Figure 9: Opto-Isolated Input Interface

2.6.1 Voltage Source Configuration

The opto-isolated input signals (2.2.1) are activated as short-to-ground. The voltage for the opto-isolated circuit (see Figure 10) is provided by either the internal +5V supply (default state) or an external voltage supply via pin 16 on the I/O Port connector. The input to be activated should be shorted to external voltage supply ground.

Configure jumper JP 3 (located near LC card) on the AB4 card according to the voltage source:

- Pin 1 shorted to Pin 2, for an internal +5V source (factory setting)
- Pin 2 shorted to Pin 3, for an external voltage source

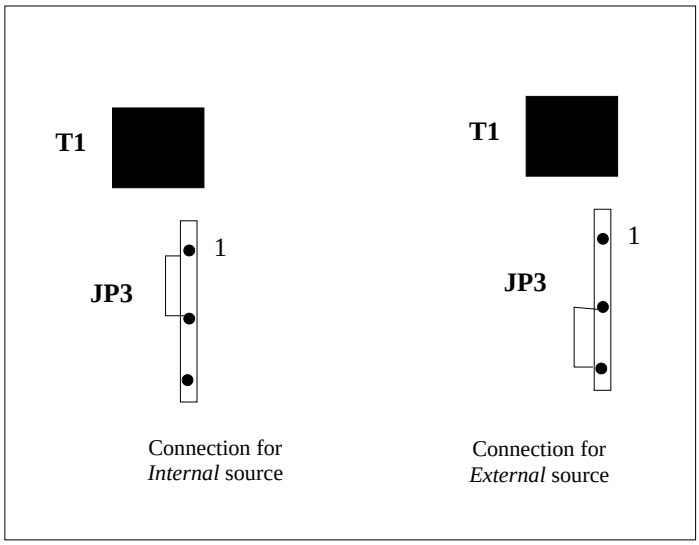


Figure 10: Jumper 3 Configuration

ATTENTION: ***Do not short Pin 1 to Pin 3 on JP3. Doing so shorts the external power supply to the +5V supply! The input circuit is limited to sink up to 10 mA but not less than 3 mA.***

2.7 Fault Output

Fault: An open collector logic output that is active “high”, under the following conditions:

- Over-current (3A or higher)
- The motor is not connected and the “Motor Disconnect” signal (section 2.5) is floating
- The AB4 is disabled or the Emergency Stop input is activated
- One of the Limit Switches is activated

NOTE: ***The Fault output is capable of sinking a maximum of 20 mA, and is not protected from over current.***

2.8 Before Operating the Motor

Before operating the AB4, verify the following:

- ☐ The AB4 configuration matches the motor(s) to be driven.
- ☐ Jumper JP3 is set to the required mode of operation.
- ☐ The external power supply complies the power consumption of the AB4.
- ☐ There is no command when switching the power to “ON”.
- ☐ Make sure that all motors that are to be driven by the AB4 are correctly mounted.

ATTENTION:

1. ***The command should be limited according to the envelope of performance of the motor. Refer to the Motor User Manual.***
2. ***Driver should be grounded to infrastructure earth before operating.***

3 Thermal Envelope of Performance (EOP)

3.1 Description

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 (the convection mechanism is negligible in vacuum environment).

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 set ambient temperature and command, deriving the duty cycle and maximal continuous operation that assures safe operation).

The user can either operate the motor for an extended period of time at a specific duty cycle or alternatively, can operate the motor for a continuous time period specified under “Maximal Continuous Operation Time” (see graph and table in section 3.3). After the continuous operation is completed, the driver must be disabled to cool down the motor for 400 sec in air and for 700 sec in vacuum environment.

-  ***Notes:***
  - *The duty cycle is the ratio of the operation time and the total work cycle (operation time + idle time).*
  - *Upon operating a motion system in vacuum, it is expected that the Coefficient of Friction of the bearing structure will increase. This may require changing the system operation point on the thermal EOP curves.*

3.2 Stage Heat Dissipation Consideration

The motor heat dissipation mechanism is by convection and radiation to the motor case, and by conduction through motor’s ‘finger tips’. Hence, the motor and the Ceramic Driving Strip bases, must both be thermally designed to dissipate 2W each (per motor’s ‘finger tip’), with maximum temperature rise of 15°C.

3.3 Thermal EOP for HR Motor Driven by AB1A, AB2, AB4 Drivers

Figure 1 illustrates motor velocity as a function of the applied driver command voltage. Allowing up to 30 mm/sec variations, use it as a reference and as a guideline for expected motor performance:

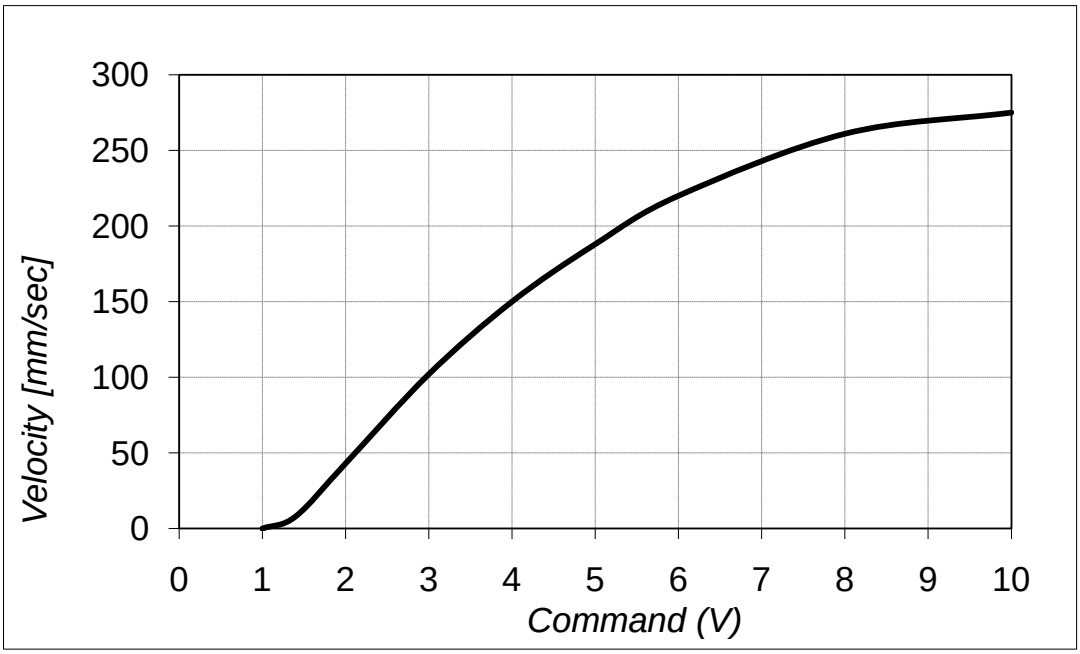


Figure 11: Motor Velocity vs. Command[1]

Figure 2 and Table 1 are designed to help the user determining the correct envelope of performance and avoid overheating and damaging the motor.

[1] The motor operates horizontally at room temperature and low duty cycle (< 10%). It interfaces with the Ceramic Driving Strip (according to Nanomotion Specifications) and a cross-roller high quality slide.

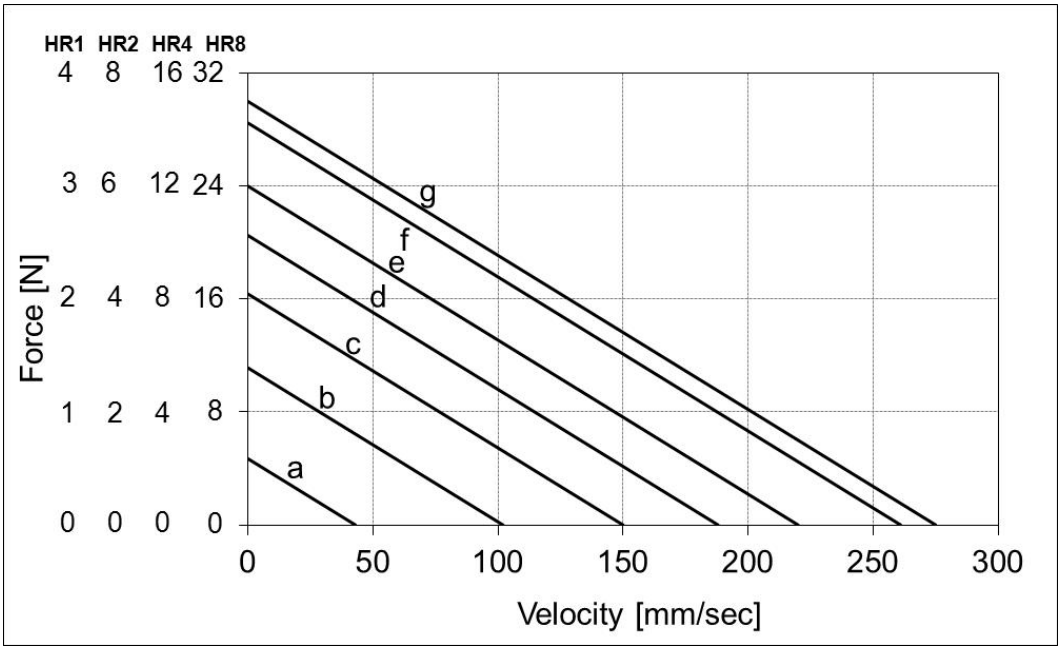


Figure 12: Motor Force vs. Velocity at the Various Work Regimes (a-g)

AB1A, AB2, AB4						
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

Table 1: EOP Table for HR Motors Driven by AB1A, AB2, AB4

3.4 EOP Protection with the MM

When the driver is configured to work with the MM, a built-in EOP mechanism is enabled, to protect the motor from over heating. It's algorithm is as follows:

For a command less than or equal to 3 Volts, the duty cycle is100%. For a higher command, the duty cycle is limited to 50% with maximum continuous opeartion time of 4 seconds.

4 Specifications

4.1 Parameters and Conditions

Table 2: AB4 Power Consumption

Power Input	+12VDC ±5% (stabilized)
Max Motor Output	280 (70 for MM)Vrms
Power Consumption without Load	+12VDC/300 mA
Power Consumption with Max load	+12VDC/3.5 A

Table 3: Electrical Specifications

Supply Voltage	**Current Consumption**	**Used When**
+12VDC ±5%	800 mA max	HR1 is connected.
	1400 mA max	HR2 is connected.
	2400 mA max	HR4 is connected.
	600 mA max	ST is connected.

The required power supply value should be calculated by adding the total power consumption of all the motors that are connected to the AB4 power consumption without motor (+12VDC/125 mA_{rms}) according to the following:

- I = 125mA + n*(current consumption of a single motor)
- n = Number of motors that are connected (n= 1/2/3/4).

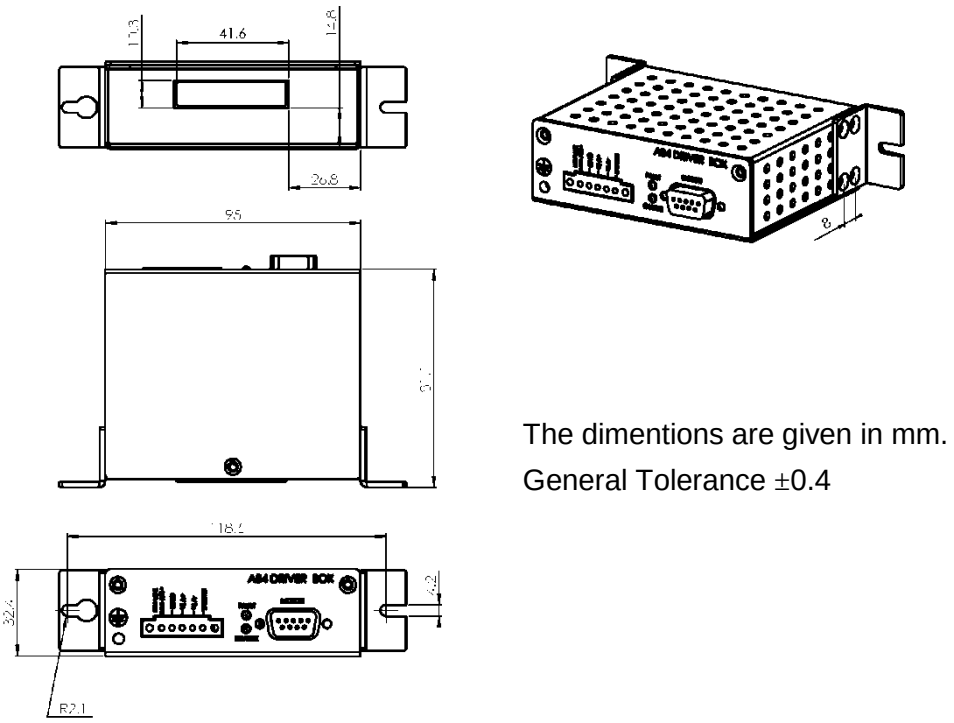
Table 4: Environmental Conditions

Operating Temperature	0°C to 50°C
Storage Temperature	-40°C to 70°C
Operating Humidity	Up to 80% Non-condensing

Table 5: Analog Input Specifications

Input voltage range:	±10V
Input impedance:	10kΩ
Input low pass filter:	2.7 kHz

4.2 AB4 Layout



The dimentions are given in mm.
General Tolerance ±0.4

Figure 13: AB4 Layout

4.3 AB4 Pin Arrangement

Table 6: Control Terminal Pin Out

Pin	Signal Name	Function	Description
1	+12V	Input	+12VDC Power Supply
2	GND	Ground	
3	VIN+	Input	Analog Command from controller
4	VIN-	Input	Analog Command from controller
5	ENABLE_IN	Input	Enable. See section 2.6

Table 7: Motor Output Port Pin Out

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_White	High voltage output	Connected to the white motor terminal.
4	Motor_Black	High voltage output	Connected to the black motor terminal.
5	Motor_Red	High voltage output	Connected to the red motor terminal.
6	Motor Connected	Input	Safety input; shorted to pin 1 in order to verify the motor connection and prevent the driver operation without the motor.
7	GND	Power supply ground	Shorted to the shield
8	N.C	Not used	
9	N.C	Not used	

Table 8: I/O Port Pin Out

Pin	Signal Name	Function	Description
1	+12V	Aux Output	Accessory voltage for powering a joystick (max 5 mA). Return is the GND pin.
2	CONVERT	Input	SPI (see Appendix 1)
3	SER_CLK	Input	SPI (see Appendix 1)
4	SER_DATA	Input	SPI (see Appendix 1)
5	N.C.	Not used	
6	N.C.	Not used	
7	MRN	Input	Reset. Activated by shorting to ground
8	Gate Enable	Input	Gate Mode enabling (see section 1.4.2.1 and 1.4.3.1)
9	EMERGENCY_STOP	Input	Protection Input (see section 2.6)
10	ENABLE_IN	Input	Enable signal (see section 2.6)
11	FAULT	Output	See section 2.7
12	-12V	Aux Output	Accessory voltage for powering a joystick (max 5 mA). Return is the GND pin.
13	RIGHT_SW	Input	Right Limit Switch (see section 2.6)
14	LEFT_SW	Input	Left Limit Switch (see section 2.6)
15	STEP_IN/GATE MODE	Input	Step/Gate modes selection (see section 1.4.2.1 and 1.4.3.1)
16	USER_VOLTAGE	Input	External power supply for opto-isolated inputs. (see section 0)
17	N.C	Not used	
18	N.C	Not used	
19	N.C	Not used	
20	N.C	Not used	
21	+12V_POWER_IN	Input	Power supply in
22	+12V_POWER_IN	Input	Power supply in
23	-VIN	Input	Negative analog command from controller.
24	+VIN	Input	Positive analog command from controller.
25 26	GND		Ground

Appendix 1: Serial Peripheral Interface (SPI)

Instructions

The SPI option is only available upon request, as it must be factory configured. Having this option cancels the standard, analog controller interface option (and vice versa).

As there is a linear dependence between the input command level and the output voltage, a higher input command is expected, as compared to the analog controller command. This would be most notable at the lower ranges of command voltages.

Maximum cable length between controller and driver should not exceed 50cm.

When in SPI mode, the intrinsic motor protection algorithm in the driver is overruled; thus, extra caution should be taken so as to operate the motor within its defined EOP.

SPI Protocol Logic

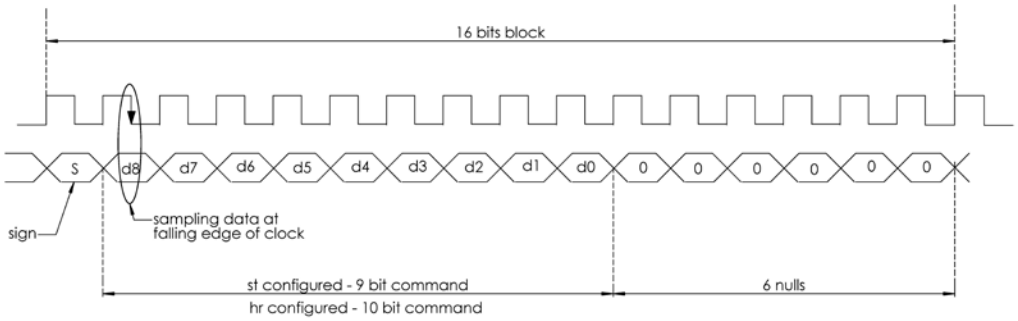


Figure 14: SPI protocol logic

The Controller updates the data on the clock-rise, while the AB4 samples the data on the clock negative derivative.