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NANOMOTION

A Johnson Electric Company

AB5 and AB51 Drivers

User Manual



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- FCC 47 CFR: 2002 part 15, subpart B.
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List of Abbreviations

A	Ampere
AC	Alternating Current
DC	Direct Current
LED	Light Emitting Diode
mA	milli Ampere
mW	milli Watt
PWM	Pulse Width Modulation
TTL	Transistor-Transistor Logic
Vrms	Volts Root Mean Square
DIP	Dual-In-line Package

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1 Introduction

This manual is designed to help the reader to operate the AB5/AB51 driver. It assumes that the reader has a fundamental understanding of basic servo systems, as well as motion control concepts and applicable safety procedures.

1.1 General

The AB5 is a single axis amplifier box for driving Nanomotion Piezo-Ceramic motors. The AB5 amplifier box interfaces between the input command from a controller or joystick to the motor and drives the Piezo motor. It facilitates a linear response of the motor and eliminates the “dead zone”, previously associated with Piezo-Ceramic motor operation.

The AB5 amplifier box consists of three main cards. The Logic and driver cards are common to all AB5 configurations, while the Personality card is configuration specific and can be replaced by an authorized technician, to drive a different motor (in the HR family).



Figure 1: AB5 Driver Box

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An additional, related model is the AB51 driver, built identically to the above but carrying a different firmware. The AB51 is designed to have a minimal controlled Dead Zone, which is beneficial in Z applications or in repetitive Start/Stop mode of operation. The AB51 feeds less driving energy into the motor at low commands, thus facilitating the controlled Dead Zone, mentioned above, while maintaining the motor at a lower operating temperature. The AB51 driver should be chosen in general, unless a perfect Servo tracking or very low ripple Constant Velocity is needed, where AB5 is preferable.

1.2 Main Features

- High precision (11 bits) control of the output power stage.
- Zero Dead Band in AB5 and minimal Dead Band in AB51.
- Drives up to four HR8 motors.
- Four operation modes: Velocity, Step, and Brake On/Off.
- Interface to an analog command.
- Modular design, to allow replacement of configuration specific Personality cards.
- Discrete inputs enabling feedback from external sources, such as: limit switches, Emergency_Stop command, etc.
- Three color LED indicators.
- Over Current, Over Voltage, and motor interlock protections.
- Minimized sensitivity to cable length.
- User defined Enable input logic.
- Thermal Protection mechanism

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1.3 AB5 Operating Principle

The force transfer of the Nanomotion motor is based on friction of the motor's elements and the drive strip. This drive mechanism has many advantages, like high precision, zero backlash, inherent brake and more. Nevertheless, it poses a control challenge at low command due to non linearity, an effect known in Nanomotion User Manuals, as the "Dead Zone".

The AB5 driver is designed to eliminate the Dead Zone and to facilitate a linear response from 0 (zero) command level. This design allows easily controlling the driver by off-the-shelf servo controllers.

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

The linear feature is achieved by an effective higher excitation of the motor, causing a higher operating temperature. The higher temperature is permitted as long as the user adheres to the stiffness requirements and the EOP outlined in section 5.2 in this manual.



WARNING!

To prevent minor electric shock hazard, the ground screw, located on the bottom left of the front panel, must be connected to the infrastructure earth.

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2 Connecting the AB5/AB51 Driver

For connecting the driver to the system, refer to Figure 3: Differential Analog Input Connection or Figure 4: Single-ended (non-differential) Analog Input Connection..

2.1 Quick Instructions for Connecting the Driver

For connections refer to Figure 2, below.



Figure 2: AB5 Driver Front Panel

1. Connect motor's cable (for details refer to section 2.1.3) to driver's Motor connector (refer to Table 1).
2. Connect the 25 pins flat cable to driver's I/O port (for details refer to section 2.1.1) for analog or Joystick connection (for details refer to section 2.1.2).
3. Connect the power supply wires to driver's Terminal block (for details refer to section 2.1.1).
4. Plug in the terminal cable to the driver's mating connector.
5. Read the instructions in section 2.2 before operating the motor.
6. Switch the power on and continue to Chapter 3 for Driver Operation.

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2.1.1 Wires and Connectors

- **Power supply:** use 22 AWG (or lower AWG) wires for the power supply. 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.

Connector	Description
Control terminal	5 pin connector. Receives +24V from an external source and provides direct control over the motor ENABLE signal and the analog control signal (+Vin and/or -Vin). (Mating connector is by Wieland, P/N 25.621.0553.0). See Table 6 for connector pinout.
I/O Port	25 pins D-type female connector. Interfaces to the control source (joystick or controller). See Table 8 for connector pinout.
Motor Out	9 pins D-type male connector. Interfaces to the motor. See Table 7 for connector pinout.

Table 1: Front Panel Connectors

2.1.2 Motion Control Interfaces

The AB5/AB51 driver 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 AB5/AB51 driver are provided in following sections.

Note:

- *The motor may be operated from the Terminal block using the following signals: +24V,GND, +Vin, -Vin, Enable*

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2.1.2.1 Analog Controller Connection

There are two options of an analog connection of a motion controller to the AB5/AB51 driver:

- Differential connection (see Figure 3)
- Single-Ended (Non-differential) Connection (see Figure 4)

The differential connection enhances noise immunity.

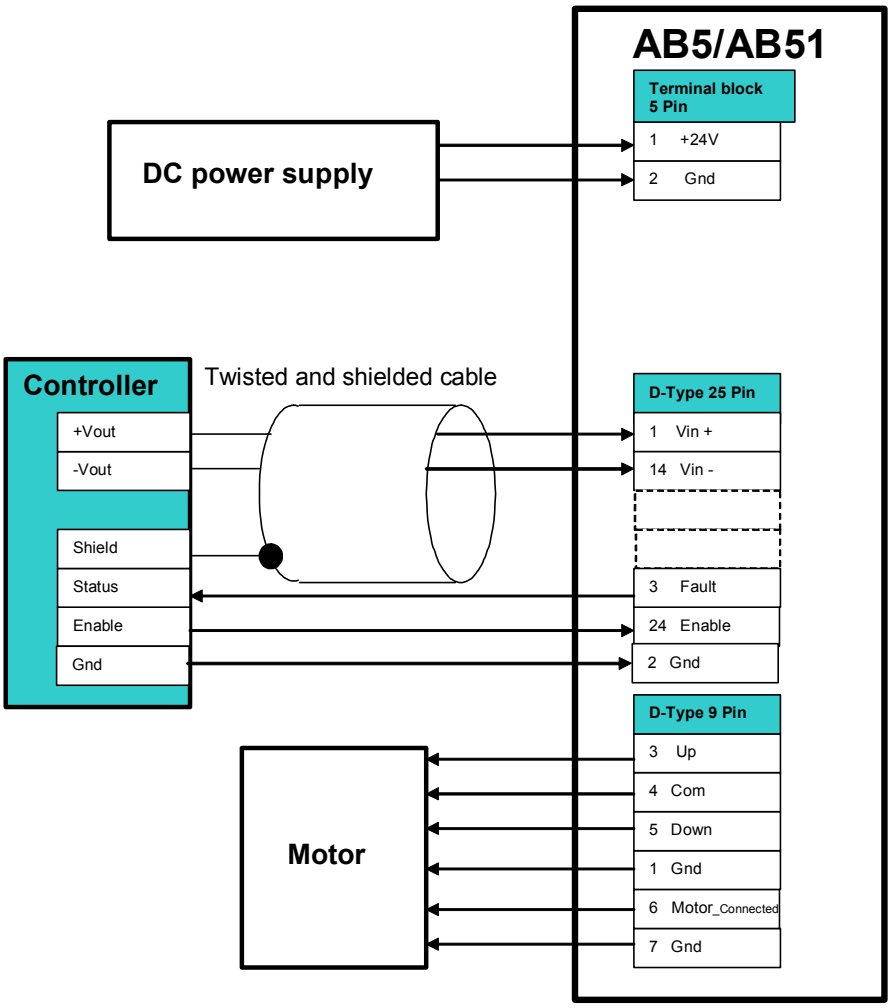


Figure 3: Differential Analog Input Connection

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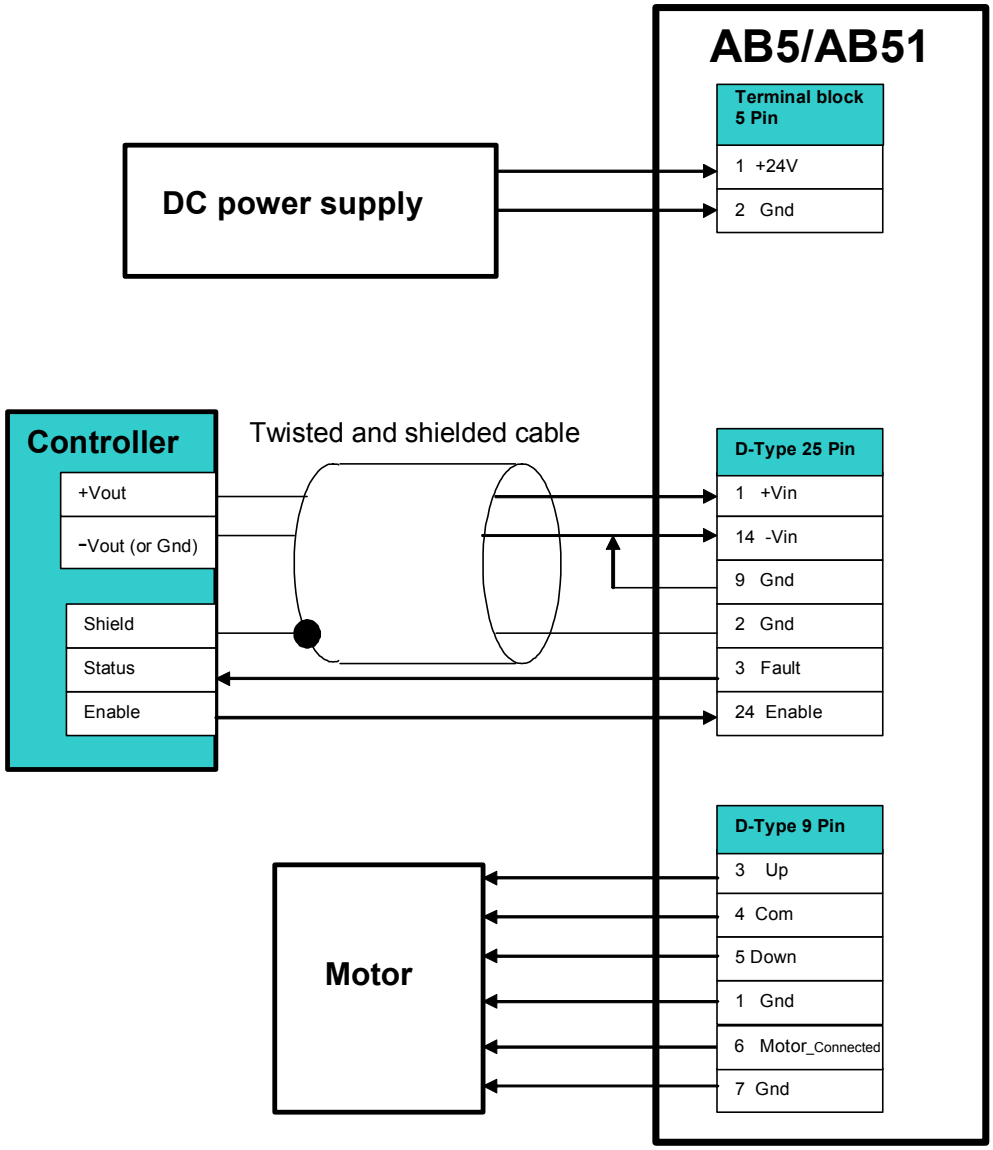


Figure 4: Single-ended (non-differential) Analog Input Connection.

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2.1.2.2 Joystick Connection

Using the joystick for supplying the command voltage to the AB5/AB51 driver allows the user to manually drive the motor without using a motion controller.

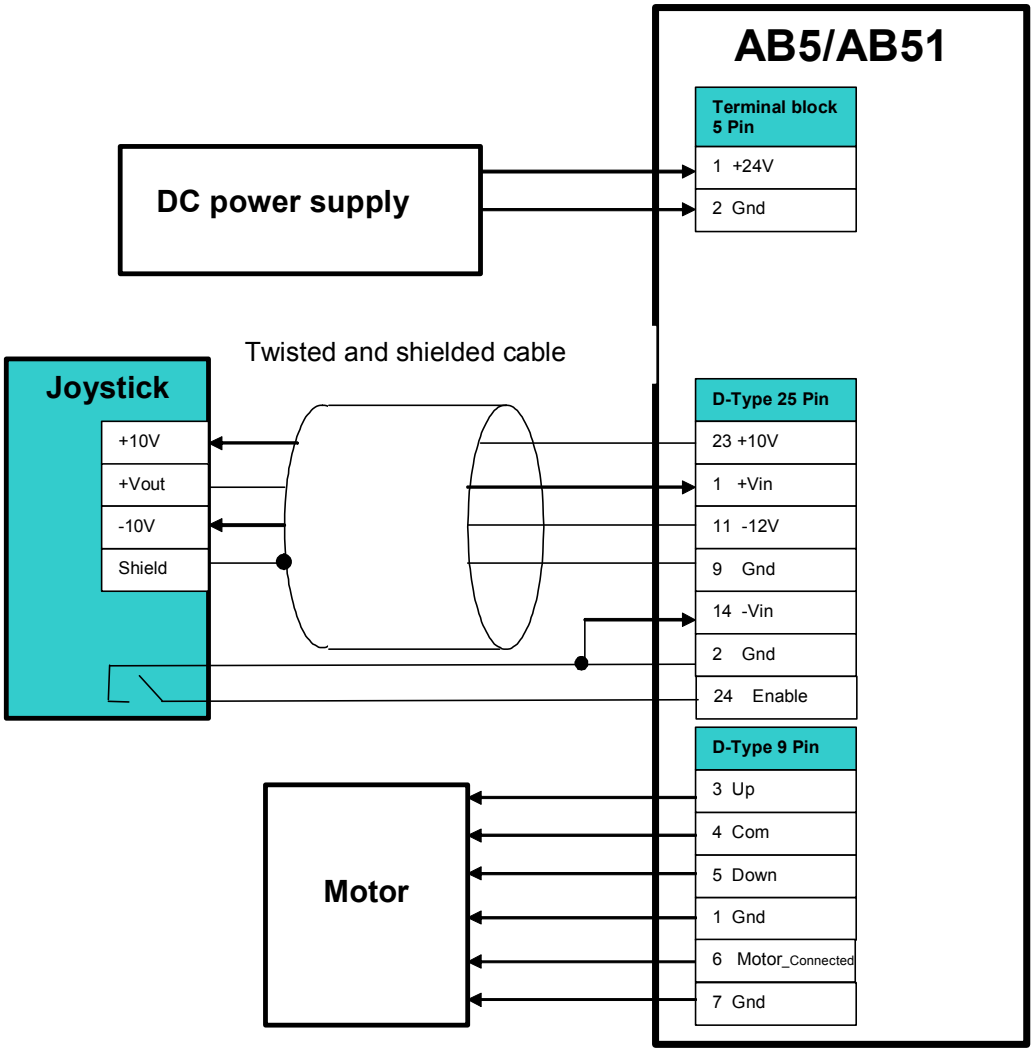


Figure 5: Joystick Connection

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2.1.3 Motor Cable Connections

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

- The Motor_Connected interlock is available at the motor connector, (see Table 7). It disables high voltage on the bare driver output connector, when the motor is not connected.
- If more than one motor is connected to the AB5/AB51, use a suitable branch cable. Branching is possible for two and four identical motors. Versions are available for motors operating either side by side or head to head.
- The allowed maximum total motor cable length (connecting the AB5/AB51 driver to the motor/s) is up to 10 meters for the HR or ST motor types and up to 20 meters for the vacuum motors. Branch cables must be of identical length. Their total length should not exceed the allowed total cable length.

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2.2 Before Operating the Motor

Before operating the AB5/AB51, verify the following:

- All motors are properly mounted and preloaded.
- Jumper JP2 is set to the required mode of operation (accessible only by an authorized service technician, see section 5.5.2 for more details).
- Mechanical screws lock all connectors.
- The external power supply is capable of supplying the required power consumption of the AB5/AB51 (see Table 7).
- There is no command when switching the power on.



WARNING !

The driver must be grounded to infrastructure earth before operating.

CAUTION:

The command should be limited according to the motor Envelope of Performance, refer to section 5.2.

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3 AB5/AB51 Operating

3.1 Set_Offset Procedure

3.1.1 Description

When working with AB5 driver in Brake_Off mode and the motor is enabled, the Offset procedure prevents motor's drifting due to system asymmetry. It generates an internal offset command at a "0 command" from the controller.

The Set_Offset procedure is executed to calibrate the “0 command” in the following cases:

- For a new motor / system – before first time operation.
- For motor which was dismounted from the system, and mounted again.

3.1.2 Setting the Offset

1. Disable and then Enable the driver before starting the adjustment.
2. Apply the "0 command" and observe if there the slide moves.
3. Adjust the command voltage level until the slide movement stops.
4. While still applying the command level, short pin 19 (of the I/O connector) to ground momentarily (refer to Table 8). The driver “remembers” this level of command as its 0 (zero) (max 2.5V).
5. Apply "0 command" level and verify that the slide is motionless.

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3.2 Operation Modes

Both Enable and Motor_Connected inputs must be active for operation, regardless of the operation mode.

The AB5/AB51 can be operated in one of the three operation modes listed below:

- **Velocity (AC) Mode:** the motor is driven continuously.
- **Step Mode:** the driver output is Hardware turned off and on, in predefined intervals of 1/16 sec every 1/2 sec, thus driving the motor in discrete steps.
- **Brake_On Mode:** while in Velocity Mode, enables the holding force to be turned on.

3.2.1 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).

This mode is driver's default operation mode.

3.2.2 Step Mode Operation

In this operation mode, the driver output to 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.

To enable the Step Mode: short pin 16 (of the I/O connector) to ground (refer to Table 8).

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3.2.3 Brake_On Mode

In break on mode the driver disconnects the power supply to the motor; however servo is still active. As the motor is turned off, it consumes no power and the EOP can be extended.

To enable the Brake_On Mode: short pin 17 (of the I/O connector) to ground (refer to Table 8). For the Brake_Off Mode, disconnect it from the ground.

Note:

- *The combination of Brake_On while the driver is Enabled poses a conflict and the user must consider the transient upon returning to the Brake_Off mode.*

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4 Motor Conditioning Using the AB5/AB51 Driver

4.1 Introduction

Conditioning of any Nanomotion motor prior to functional operation is an important action, as it stabilizes dynamic performance, reduces wear rate and increases the lifetime of the system.

The AB5/AB51 driver is unique in its mode of operation as compared to other Nanomotion drivers, as it allows a full linear response starting with very low commands. In order to do so, the AB5/AB51, when enabled, energizes the motor even at 0 (zero) command. Consequently, the AB5/AB51 may cause the motor to overheat, especially during the initial phase of conditioning. This chapter instructs the user on how to safely condition Nanomotion motors when using the AB5/AB51 driver.

4.2 The Conditioning Procedure

IMPORTANT:

The conditioning of all Nanomotion motors must be performed after initial assembly and before motor tuning. In addition, the conditioning should be performed any time a motor has been dismounted and remounted, or its pre-load released.

CAUTION:

Limit the command to 5V and use the "Abort on Position Error" option of the controller in order to protect the motor during initial integration and conditioning.

Do not perform the conditioning procedure in vacuum environment. This procedure must be performed in ambient air conditions only.

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To perform the conditioning procedure, follow the steps below:

1. Set the conditioning procedure to cover the whole expected operated travel of the ceramic drive strip.
2. Run the stage repetitively from end to end in closed-loop.
3. Profile: Velocity - 100 mm/sec; acceleration / Deceleration =0.1 to 1m/s$^{2.}$
4. The AB5/AB51 should be disabled during the dwell time.
5. Duty cycle - 25%. This means that the dwell time (AB5/AB51 disabled) should be three times longer than the move time (AB5/AB51 enabled).
6. Conditioning duration :
    - 8 hours for all HR and ST series motors.
    - 16 hours for all DuraMotor series motors.
    - 18 to 20 hours for applications which use Ceramic Coated Strips (CCS).
7. Wipe the ceramic drive strip surface with IPA (analytically pure grade isopropyl alcohol), without retracting the motor's fingers, approximately one hour into the conditioning process.
8. At the end of the conditioning procedure, wipe the drive strip with IPA without retracting the motor's fingers.
9. Run the motor for 10 min as IPA may leave some residual hydro carbons on the surface that affects performance.
10. The motor is now ready to operate.

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5 Technical Data

5.1 Specifications

Electrical Specifications		
Power Input	+24 Vdc ±5% (stabilized)	
Current Consumption w/o Load	100 mA @ 24 Vdc	
Power Consumption w/o Load	2.4W	
Recommended Power Supplies		
Supply Voltage	**Maximum Current Consumption**	**Applicable For**
+24 Vdc ±5%	1A	E1 to E4
	2A	E8
	4A	E16
	8A	E32
Physical Properties		
Weight	450g	
Environmental Conditions		
Operating Temperature	0°C to 50°C	
Storage Temperature	-40°C to 70°C	
Analog Input Specifications		
Input voltage range	±10V	
Input impedance	10kΩ	
Input low pass filter	2.7 kHz	

Table 2: AB5/AB51 Driver Specifications

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5.2 Thermal EOP (Envelope of Performance)

5.2.1 Description

Motor operating temperature depends on as the balance of heat generation and heat dissipation.

The heat generation depends on motor's work regime factor (driver command level). The heat dissipates through the following heat transfer mechanism: 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 achieve stable operation. EOP gives the reader the tools to assess the permitted operating regime that assures stable operation.

Considering the heat generation and the heat dissipation elements, when working in a specific work regime (see Figure 6), motor's operation must adhere to a specific duty cycle (see Table 3 and Table 4).

Note:

- *The duty cycle is the proportion between the operation time and the total work cycle (continued operation time + idle time).*

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When operating the motor with the AB5/AB51 driver continuously in Brake_Off mode (refer to section 3.2.3), the motor consumes power at all times, even when the control command voltage is 0 (zero) thus reducing the thermal EOP. Figure 6 describes motor's velocity-force curves with allowed operation Duty Cycle and continued operation.

IMPORTANT:

In Brake_Off mode, the motor operates in continuous mode and special attention must be given to maintain the work regime within the permitted "Duty Cycle" and "Maximal Continuous Operation Time" (refer to Table 3 and Table 4). Once the operation time has reached the "Maximal Continuous Operation Time", the motor must be disabled and allowed to cool down for at least 400 seconds.

Note:

- *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.*

Examples:

- *Curve C, when using the AB5, in vacuum, in the Brake_Off mode: after 150 seconds of operation (including time at command = 0), the motor must be disabled for at least 400 seconds to cool down. The corresponding Duty Cycle is 45%.*
- *When using the AB51 in the same conditions, the motor should be disabled after 280 seconds.*

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5.2.2 Thermal EOP for HR Motors Driven by AB5/AB51

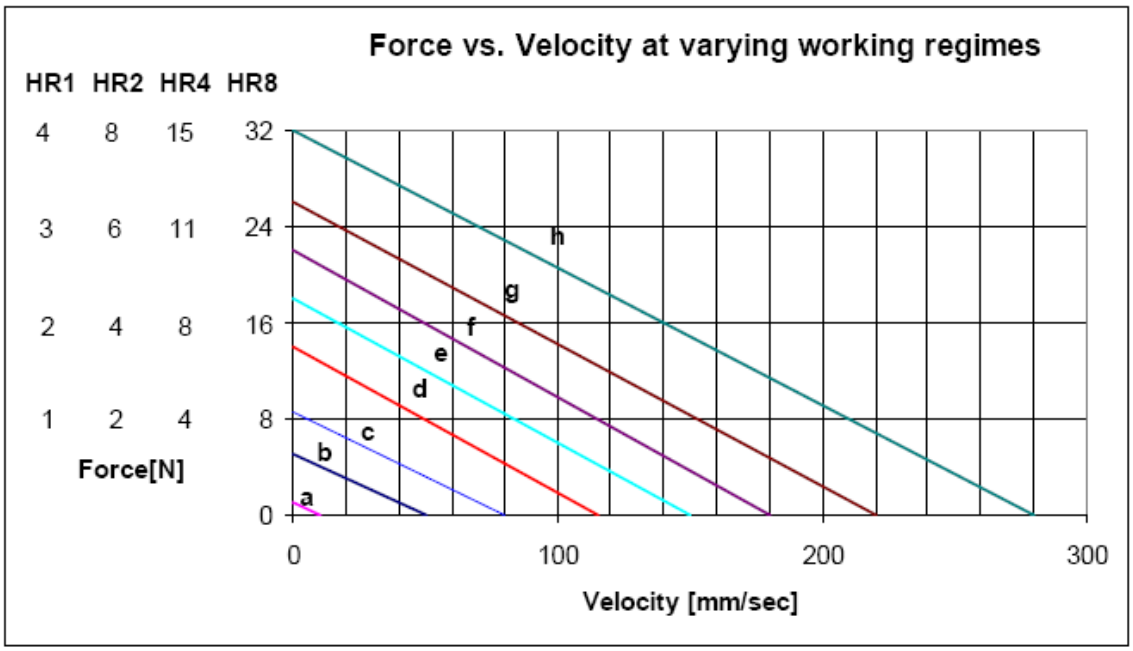


Figure 6: HR Motors – Force vs Velocity at Varying Work Regimes

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AB5					
Curve	**Duty Cycle [%]**			**Maximal Continuous Operation time [sec]**	
	Environment Ambient Temperature			**Environment Ambient Temperature**	
	Air 25°C Brake_ Off	**Air 25°C Brake_On**	**Vacuum Brake_On**	**Air 25°C**	**Vacuum**
a	100	100	28	∞	230
b	100	100	23	∞	210
c	100	100	19	∞	150
d	100	100	14	∞	110
e	50	80	13	280	90
f	33	58	12	170	66
g	24	45	10	77	44
h	11	28	6.5	32	25

Table 3: EOP Table for HR Motors Driven by AB5 (Standard LUT)

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AB51					
Curve	**Duty Cycle [%]**			**Maximal Continuous Operation time [sec]**	
	Environment Ambient Temperature			**Environment Ambient Temperature**	
	Air 25°C Brake_Off	**Air 25°C Brake_On**	**Vacuum Brake_On**	**Air 25°C**	**Vacuum**
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 4: EOP Table for HR Motors driven by AB51 (Reduced LUT).

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5.3 TP (Thermal Protection)

5.3.1 Description

Thermal Protections is a motor protection mechanism within the AB5 and the AB51 drivers, designed to minimize damage to the motor due to overheating. It is a unique feed-forward temperature protection feature (according to the EOP, see section 5.2), where accuracy is conditioned by the ambient temperature's input.

Based on an internal microcontroller, the TP option is an EOP computing algorithm that calculates the temperature of the motor by time integrating the command, corresponding to the input power and calculating the heating/cooling profile of the motor. This feed-forward algorithm is accurate, subject to the ambient temperature input, the proper installation of the motor, and ONLY AFTER motor's conditioning (refers to Chapter 4).

5.3.2 TP Configurations

The TP option is available in the following configurations:

- HR or ST motors
- 25°C or 50°C ambient temperature
- 25°C vacuum environment

The AB5/AB51 driver is factory preset to either HR or ST motors (a permanent DIP Switch #2 configuration), according to the motor type to be driven. In addition, each AB5/AB51 driver sent from Nanomotion, is preset to a standard 25°C ambient air environment, with the **TP** feature **turned on**.

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To provide application flexibility for the end user's technical requirements, an authorized service technician is able to open the driver box and change the temperature and environmental configurations or to disable the TP feature completely, using the DIP Switch Position Map. Every AB5 and AB51 driver, shipped from Nanomotion, is sent with a DIP Switch Position Map and the map is also available in this manual (see Figure 10).

The Thermal Protection feature has been implemented as a standard feature in every AB5 and AB51 drivers since March 30, 2007.

5.3.3 Benefits of Thermal Protection

The optional TP feature can be beneficial to the application, preventing the motor from overheating. A few examples are:

- A good precaution in first time integration and assembly of a system.
- Demanding applications that operate in high duty cycle.
- Joystick operation in open loop.

IMPORTANT:

To benefit from the Thermal Protection feature, the motor must be properly mounted, preloaded and conditioned.

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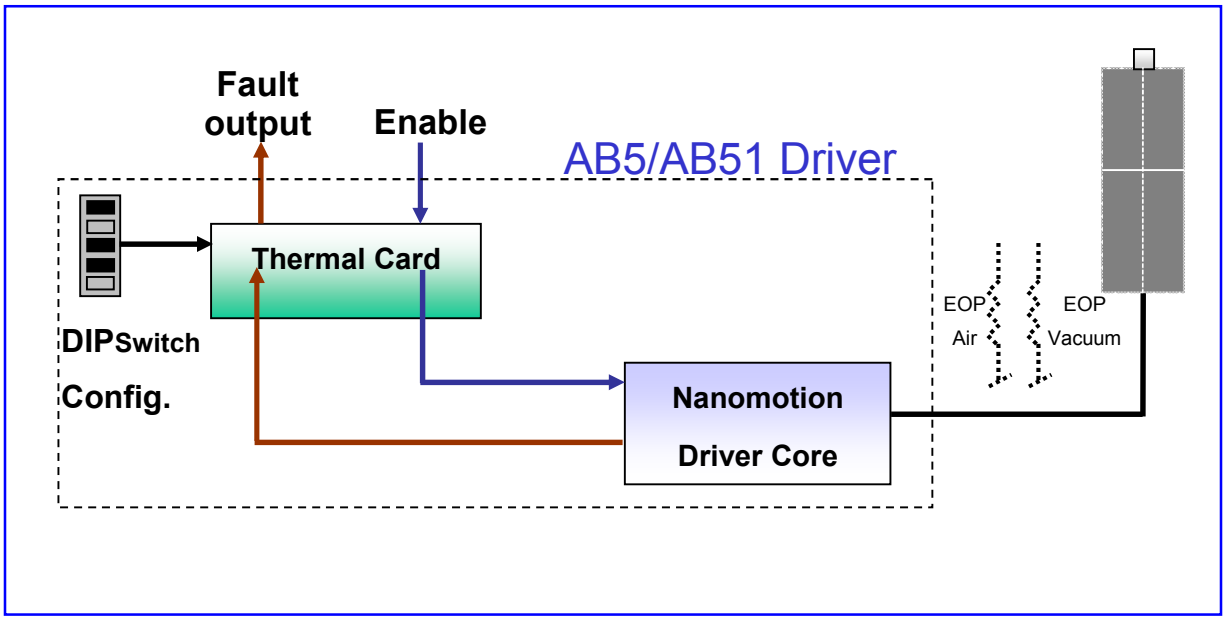


Figure 7: TP Mechanism Block Diagram

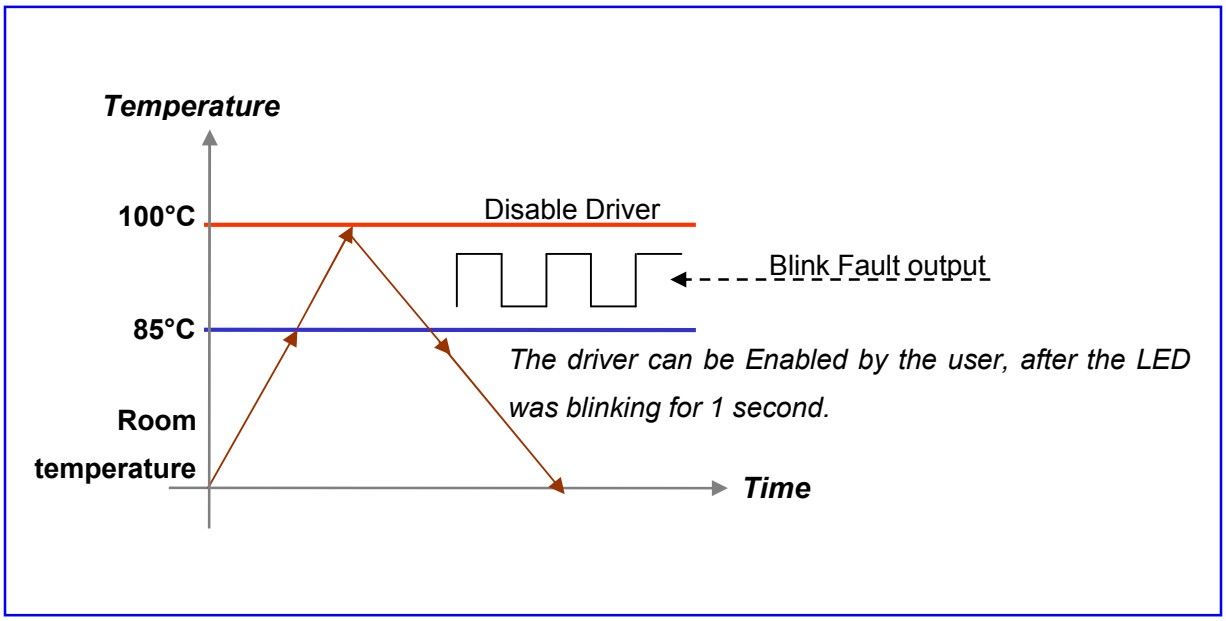


Figure 8: Operational Parameters

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5.3.4 How It Works

The TP feature is designed with the following motor calculated temperature settings:

- Motor temperature below 85°C - normal operation.
- Motor temperature between 85°C to 100°C - warning mode. Displayed by a blinking TP LED and an on\off Fault output signal (pin #3 in the 25 pin I/O connector).
- Motor temperature above 100°C - the motor is disabled. The TP LED is constantly on and so is the Fault output (pin #3). The driver remains disabled until motor temperature drops to 85°C (natural cooling).
- Motor temperature back under 85°C - once the driver computed the motor has cooled to just under 85°C, the TP LED will blink once and remain on and so will the Fault output signal. To resume operation, the driver will now need to be disabled and than Enabled again.

	Normal operation	**Warning zone**	**Shut down zone**
TP LED	Off	Blinking	On
Fault output (pin #3)	Off	Toggles on/off	On
Motor	Enabled	Enabled	Disabled

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IMPORTANT:

Once the motor is disabled and the Fault is turned on, leave the power on and wait for the driver to Enable. **DO NOT POWER OFF THE DRIVER AND THEN TURN IT BACK ON.** Turning off the driver when the motor is hot, and then immediately turning it on again will misalign the mechanisms' thermal calculations, as the accumulated temperature calculation was reset and the TP assumes the motor starts from the thermal equilibrium at the ambient temperature. Therefore, after the TP feature has turned the system off, it is not recommended to activate the system again until the motor is once again at the ambient temperature.

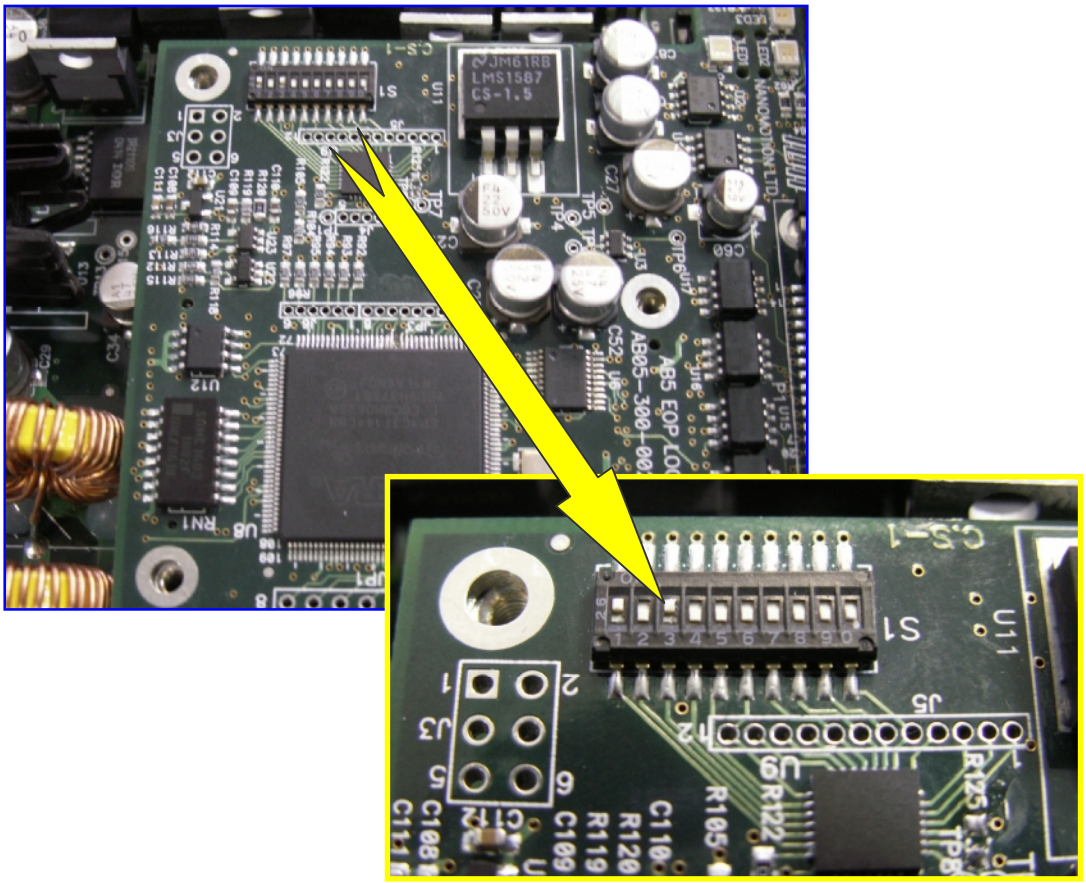


Figure 9: DIP Switch Location inside the AB5/AB51 Driver Box

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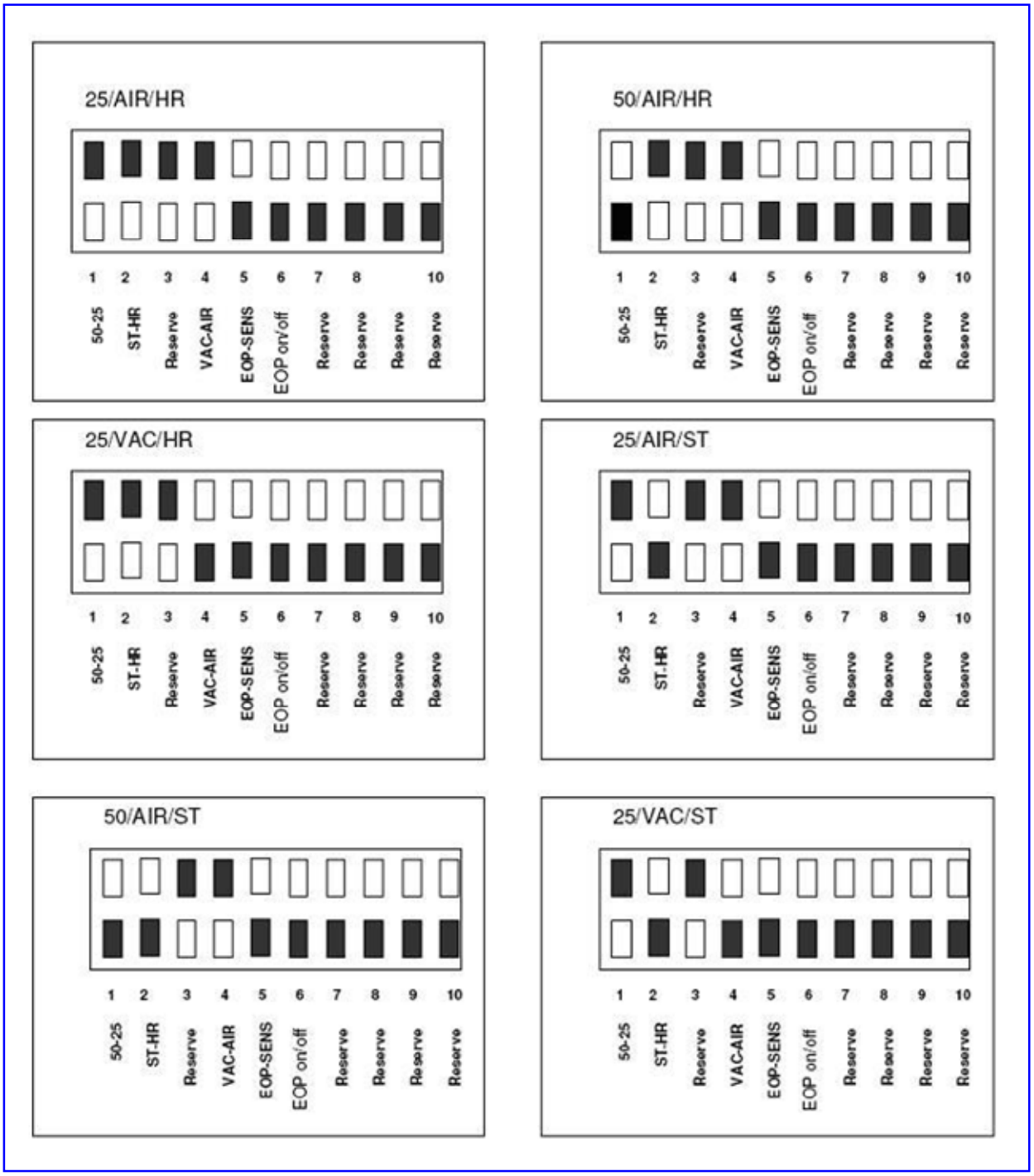


Figure 10: DIP Switch Position Map

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5.4 Front Panel Connectors and Indicators

5.4.1 Front Panel Description

The AB5/AB51 front panel (refer to Figure 13 for driver's layout) has the following connectors and indicators:

- Terminal block
- Motor Output port
- I/O Port
- Power/Enable/TP LED indicators
- Ground screw

5.4.2 LED Indicators

Condition	LED Indicator		
	Power	**Enable**	**TP**
24V power supply not connected	Off	Off	Off
24V power supply is connected	Green	Off	Off
Motor_Connected and Disabled	Green	Orange	Off
Motor Enabled	Green	Green	Off
Over voltage fault	Green	Red	Red
Warning zone temperature	Green	Green	Blink Red
Over temperature	Green	Orange	Red

Table 5 : Front Panel LED Indicators

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5.4.3 Control Terminal Block Pinout

Pin	Signal Name	Function	Description
1	+24V	Input	+24 Vdc power supply
2	Gnd	Ground	
3	+Vin	Input	Analog command from controller.
4	-Vin	Input	Analog command from controller.
5	Enable	Input	Enable. See section 5.5.1

Table 6: Control Terminal Block Pinout

5.4.4 Motor Output Port 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 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 7: Motor Output Port Pinout

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5.4.5 I/O Port Pinout

Pin	Name	Function	Description
1	V_In_Pos	Input	0 to 10Vdc Analog control
2	Gnd	Ground	
3	Fault	Output	See section 5.5.3.
4	Gnd	Ground	
5	SPI_Select	-	Disabled
6	Direction	-	Disabled
7	SPI_Data	-	Disabled
8	Acs_Int_Mode	-	Disabled
9	Gnd	Ground	Disabled
10	Set_Com_1	-	Disabled
11	-10V	Output	-10V supply for external device (Joystick)
12	Emergency_Stop	Input	Safety shut down, see section 5.5.1.
13	User_Voltage	Input	External power supply for the opto-isolated type inputs
14	V_In_Neg	Input	0 to -10Vdc Analog control
15	Gnd	Ground	
16	Step_Mode	Input	Step mode selection
17	Brake_On	Input	Disables driver operation
18	SPI_Clock	-	Disabled
19	Set_Offset	Input	Read command and remember as offset.
20	Enable_Sign_In	Input	When shorted to ground, the Enable input is active "high". Otherwise, Enable is active "low".
21	N.C.	Not used	
22	Set_Com_2	-	Disabled
23	+10V	Output	+10V supply for external device (Joystick)
24	Enable	Input	Must be activated to enable driver operation
25	N.C.	Not used	

Table 8: I/O Port Pinout

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5.5 I/Os

5.5.1 Opto-isolated Inputs

The following inputs are opto-isolated and are active “low”, i.e. by shorting them to ground (see Table 8 for more details):

- **Emergency_Stop:** disables driver’s output.
- **Enable_Sign_In:** changes Enable input logic to active “high”.
- **Enable:** enables driver operation; should be activated before operating the motor.
- **Step_Mode:** enables Step mode operation
- **Brake_On:** disables driver’s output.
- **Set_Offset:** adjust 0 (zero) command level.

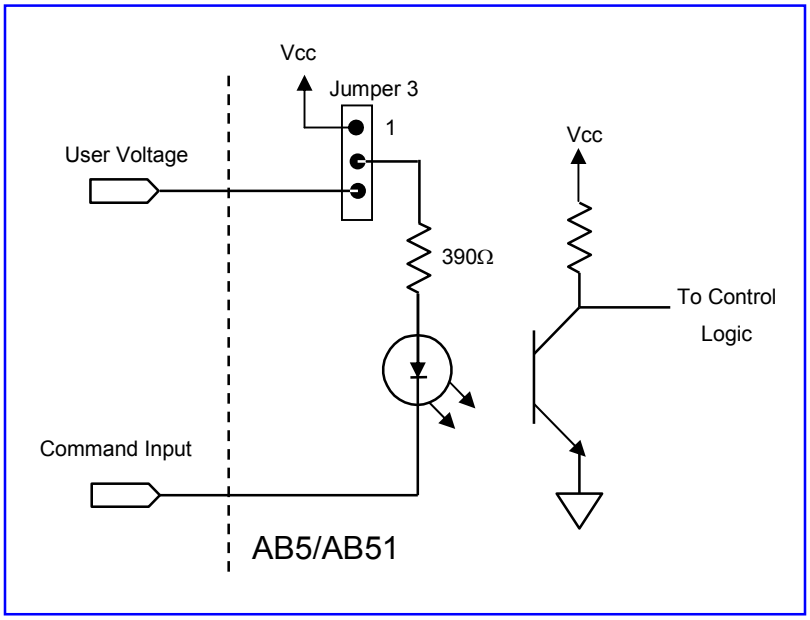


Figure 11: Opto-Isolated Input Interface

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5.5.2 Voltage Source Configuration

WARNING !

Only a qualified service technician is authorized to change jumpers' configuration.

Do not short other pins on JP2. Doing so, shorts the external power supply to +3.3V! The input circuit is limited to sink up to 10 mA, but not less than 3 mA.

The opto-isolated input signals (see section 5.5) are activated as short-to-ground. The voltage for the opto-isolated circuit (see Figure 11) is provided by either internal +3.3V supply (default state) or an external voltage supply via pin 13 of the I/O Port connector. The input to be activated should be shorted to the external voltage supply ground.

Configure jumper JP2 on the top AB5/AB51 card according to the voltage source:

- Pin 1 shorted to Pin 2, for an internal +3.3V source (default factory setting).
- Pin 3 shorted to Pin 4, for an external voltage source from +3.3V to +5V.

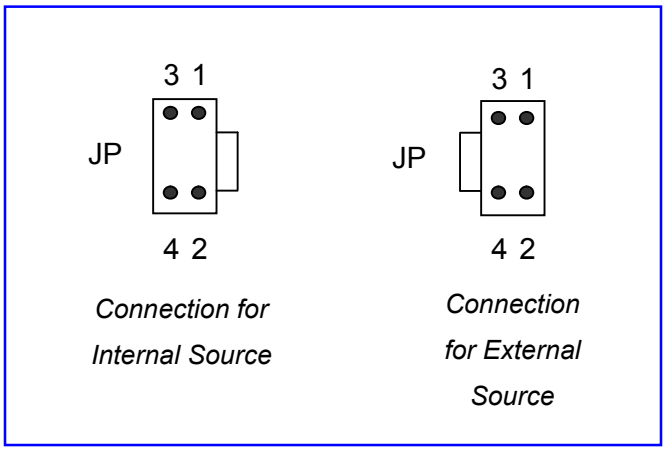


Figure 12: Jumper 2 Configuration

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5.5.3 Fault Output

The Fault output indicates either driver's over voltage or TP violation. When active “low”, it disables the driver due to this fault.

The fault output provides an open collector interface and needs to be pulled up by the user.

The maximum allowed current through the open collector transistor is **50mA**. The appropriate pull-up resistors should be used to avoid overloading this output.

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5.6 AB5/AB51 Layout

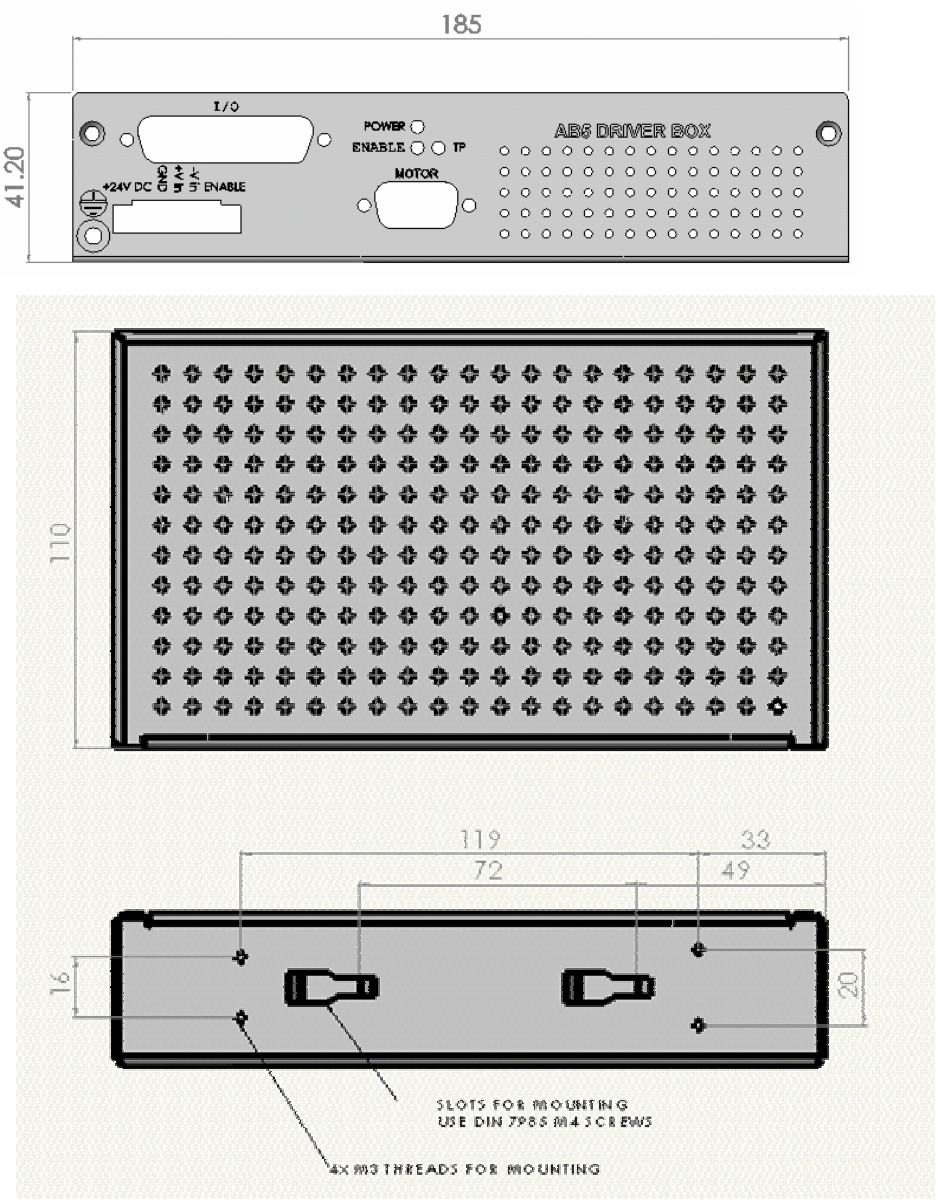


Figure 13: Layout and Mechanical Dimensions

Note:

- *All Dimensions are in mm*

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6 Part Numbering Methodology

The part numbers for the AB5/AB51 drivers with Thermal Protection follow this methodology:

Driver	Motor Type*	# of Elements	Temperature	Environment
AB5	HR	EXX**	25	V***
AB51	ST	EXX	50	A***

Notes:

- ** Motor type includes **DuraMotor** series.*
- *** "XX" represents number of motor elements, ranging from 1 to 32.*
- **** "V" = Vacuum environment; "A" = Ambient air environment.*

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